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FOUNDATIONS OF LIFE

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Enjoy & Master Advanced Biology

Topical Questions and Examinations: Form Five Topics

Ngaiza Series of Advanced Biology

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Every effort has been made to ensure the accuracy of the content in this book. The publisher welcomes corrections and suggestions for future editions.

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PREFACE

This book was written because you deserve better.

Advanced Level Biology rewards understanding, yet many students arrive in Form Five having learned to name parts they cannot explain and to recite processes they cannot reason through. Biology feels familiar, because we all breathe, eat, fall ill, and watch things grow, so it is easy to believe you understand it when you have only memorised it. Students memorise what happens, sit examinations that ask how and why, and leave believing Biology is a list of facts to be recalled under pressure. That is not Biology. That is memorisation dressed as understanding.

Biology is the study of life itself: how a single cell becomes a person, how a green leaf feeds a whole food chain, how a disease spreads and how the body fights back. It is the science in which you are the subject, with your own neurones, your own kidneys, your own blood on the page. It is powerful, deeply personal, and far more logical than its reputation suggests. But mastering it under examination conditions takes more than a textbook to read. It takes practice: attempting real questions, building real answers, and learning, answer by answer, how to turn what you know into marks. That is what this book sets out to give you.

Why a book of questions and answers?

You do not learn to swim by reading about water, and you do not learn Biology by reading model answers. You learn it by attempting a question, getting it wrong, finding out exactly why, and trying again. This book is built entirely around that truth. Every concept in the Form Five syllabus is turned into questions you must answer yourself, each followed by a full model answer that shows not only the correct biology but the exact, connected English that earns NECTA marks. Used honestly, with the answer covered until you have written your own, it trains the two things the examination really tests: understanding the mechanism, and explaining it clearly.

How this book is organised

The book covers the whole Form Five course in eight chapters: Cytology, Biochemistry, Principles of Classification, Comparative Studies of Natural Groups, Coordination and Irritability, Nutrition, Gas Exchange and Respiration, and Regulation.

The first part, Topical Questions and Answers, takes each chapter in turn. Every question is followed at once by its model answer, so you can attempt it and then check yourself immediately. Within each chapter the questions rise through three tiers.

BINDER questions anchor the core mechanism. Even here they ask you to explain how and why, never merely to state what. If you can answer these, you own the concept.

REAL questions carry the biology into real Tanzanian life, into health, farming, and the environment, where the subject actually lives.

HOT questions push you to examination standard and beyond, drawing several topics together and demanding genuine reasoning rather than recall.

The second part, the Examinations, brings together complete papers modelled on the NECTA format. Each paper is followed by full worked solutions, so that every question in this book, from the first to the last, has a complete, well-reasoned answer you can learn from, but only after you have attempted it with the book closed.

Before the questions begin, a short Student Survival Guide shows you how to study Biology, how to use this book, and how to beat the two traps, false confidence and weak scientific English, that quietly cost good students their marks. Read it first. It is the shortest and most important part of the book.

The team behind this book

Enjoy and Master Advanced Biology is the work of the Ngaiza Education Hub, built by a team of experienced biology educators who share one conviction: that Tanzanian students deserve world-class materials written for their context, their syllabus, and their aspirations.

Writers: Mr. Lameck Msangi, Mr. Godson Stephen, and Mr. Peter Marco.

Editors: Dr. Protase Reuben and Dr. Pius Magoyo.

Designer: Mr. Frank Mwita.

I am grateful to every member of this team for their dedication, their expertise, and their refusal to settle for "good enough." I thank too the students whose hard questions and honest struggles shaped every answer in this book. They reminded us, again and again, that a question a student cannot learn from has failed, no matter how correct its biology may be.

To every Form Five student opening this book for the first time: Biology is not as hard as its reputation, and it is not as easy as it first feels. It is as logical as any living thing is built to be, and as satisfying as a puzzle that finally clicks. Give it your honest effort, with the answer covered and your pen moving, and this book will give you its honest best in return.

Ngaiza, Lusima
Series Creator and Director

This book is dedicated to every Tanzanian student who was told that Biology is just memorisation. It is not, and this book will prove it to you.

STUDENT SURVIVAL GUIDE

How to turn what you know into marks.

Why Biology Feels Easy, Then Betrays You

You already know a great deal of Biology. You breathe, you eat, you fall ill and recover, you watch maize push out of the ground after the first rains. Biology is the one science you have been living since the day you were born, and that is exactly what makes it the most dangerous subject on your timetable.

The first trap is false confidence. Because the material feels familiar, it feels mastered, and that easy feeling fools thousands of students every year. The examination does not ask what happens; it asks how and why. You know green plants make food in sunlight, but explain how a single particle of light ends up locked inside a molecule of sugar and the easy feeling vanishes. The distance between knowing *what* and explaining *how* is where most marks are won or lost.

The second trap is the language barrier. Even when you understand the mechanism, you still have to put it on paper in clear, connected English, one cause leading into the next, in the order the examiner rewards. Scientific English is not built like everyday Swahili, and almost nobody is taught to cross that gap. So a student who truly understands respiration can lose half the marks because the sentences arrive broken, out of order, or missing the words that carry the logic.

On the answer sheet the two traps look identical. Both produce a weak, disjointed answer that bleeds marks, yet their cures are opposite. One student must understand the biology more deeply; the other understands it well and only needs to learn how to say it. This book is built to fix both at once, because every model answer shows you the mechanism and the exact English that earns the marks.

One example makes the difference clear.

> ***The same question, answered by two students.***
>
> **The question.** Most cells are no wider than a fraction of a millimetre. Explain why cells must stay so small.
>
> **The confident answer that fails.** Cells are small so that they can fit in the body and divide quickly. *(It sounds right, yet it explains nothing and scores almost nothing.)*
>
> **The answer that scores.** A cell absorbs the materials it needs across its surface but uses them throughout its volume. As it grows, its volume rises faster than its surface area, so the surface can no longer supply the inside fast enough. Staying small keeps the ratio of surface area to volume high enough for exchange to meet the cell's needs.

Both students *knew* the answer; only the second one explained it, and only the second one scores. That gap, repeated across a three-hour paper, separates a pass from a distinction. This guide, and every answer that follows it, exists to put you on the right side of it: from knowing to understanding.

How to Use This Book

This is not a book to read. It is a book to work. A model answer you have only read feels learned and is forgotten by morning; a model answer you have struggled toward, and then compared against your own, is learned for good. Work every question in four steps.

1. **Cover the model answer.** Read the question, then answer it in full on paper, in proper sentences, before you look at anything.
2. **Uncover and compare.** Read the model answer twice, once for the biology and once for the English. *Did you get the mechanism? Did you connect it the way the model does?*
3. **Mark yourself honestly.** Award yourself a point only where your answer truly made the same point. A near miss is a miss.
4. **Fix one thing, then move on.** Correct your single biggest error in your own words, and carry that lesson into the next question.

Climb the ladder, and do not skip the bottom rung. The questions rise through three tiers. BINDER builds the core mechanism, REAL applies it to real Tanzanian situations in health, farming and the environment, and HOT pushes into higher-order reasoning across topics. A student who jumps to HOT before owning BINDER is trying to enter a house through the top window. Work each chapter in order.

Treat the examination papers as real examinations. The papers at the end of this book are not extra questions. Sit each one in a quiet room, against the clock, with the book closed, then mark it against the solutions. That is the closest rehearsal for the real day you can get.

How to Write Biology for Marks

Marks in Biology are not awarded for knowing. They are awarded for showing that you know, in writing, in the right order. Two habits carry most of those marks.

Lead with the point, then explain it. State the thing the question asks for first, in a few words, then give the reasoning behind it. The examiner is trained to find the point, tick it, and read on for the explanation that earns the rest. Bury the point at the end of a long sentence and you force a tired examiner to hunt for it, and a point that cannot be found cannot be marked.

Join your ideas with the words that carry cause and effect. A NECTA answer is a chain in which one event causes the next. The words that build that chain are *because, so, as a result, which in turn, consequently*, and *whereby*. Use them on purpose. They are the whole difference between a list of true statements and an explanation.

One example shows both habits at work.

> ***The same biology, written two ways.***
>
> **The question.** Explain why the rate of an enzyme-controlled reaction falls at high temperature.
>
> **A list of true facts (low marks).** High temperature denatures the enzyme, the active site changes, and the substrate no longer fits. *(Every statement is true, yet nothing is joined, so it reads as memory, not understanding.)*
>
> **The same facts as a chain (full marks).** As the temperature rises above the optimum, heat energy breaks the bonds holding the enzyme's tertiary structure, so the active site changes shape. Because the substrate can no longer fit the altered active site, fewer enzyme-substrate complexes form, and as a result the rate of reaction falls.

Notice that the second answer adds no new facts. It only connects the ones already there. That connecting is the skill this whole book is teaching you, answer after answer.

How to Draw Biology for Marks

Diagrams carry marks that most students give away. A drawing is not decoration; it is an answer made of lines, and it is marked as strictly as a sentence.

Get the proportions right before anything else. A nucleus that fills half the cell, or a loop of Henle longer than the rest of the nephron, loses marks before a single label is read. Look first, then draw what is actually there.

Use single, clean lines. One firm line, not a furry sketch built from many short strokes. Keep a sharp pencil, and use a ruler wherever the structure is straight.

Rule your label lines, and never let them cross. Each label line is straight, drawn with a ruler, and touches the exact structure it names. Crossing or wandering label lines confuse the examiner and cost marks.

Label only the parts that carry marks. Do not decorate the drawing with every detail you know. Label the structures the question is about, using the correct biological term, and underline any scientific name, since underlining is the handwritten form of italics. Underline the two parts of the name separately, the genus and the species each on its own, for example <u>Zea</u> <u>mays</u>.

Show the scale or magnification when one is given. If a question provides a measurement or magnification, show it, and for cells and organelles add a labelled scale bar. A few diagrams return again and again in NECTA, among them the generalised cell, the neurone, the nephron and the heart. Practise each until you can draw it cleanly from memory in two minutes.

How to Fail Productively

You will get questions wrong. Every strong student does. What decides your grade is the five minutes after you get one wrong.

The unproductive response is to erase your attempt, read the model answer, nod, and move on. Your page looks complete and your memory has learned nothing, because you only watched someone else answer.

The productive response is to stop, and not erase. Set your answer beside the model and find the exact point where they part. Then name the cause: was it the biology, because you did not understand the mechanism; the English, because you understood it but could not connect it; or the question, because you answered what you expected instead of what was asked? Fix that one thing, cover the model again, and rewrite the answer from the start.

Those three causes need three different cures, and naming yours is half the cure. *A wrong answer you have diagnosed is worth more than a right answer you copied.*

How to Revise on Your Own

Most revision feels productive and is not. Be honest about which kind you are doing. Re-reading model answers, highlighting them, and copying them out neatly all feel like work, but your eyes move while your memory rests. A beautiful notebook is not understanding. These methods are.

Sit the examination papers under the clock. The papers at the back of this book are your single best revision tool. Do one in a quiet room, timed, with the book closed, then mark it against the solutions. Nothing else rehearses the real pressure.

Explain a mechanism out loud, as if to someone who knows nothing. Where you stumble is precisely what you have not understood yet. The silence is the lesson.

Teach a friend, and let them ask why. The moment you cannot answer their question is your revision target for the evening.

Redo the questions you got wrong, not the ones you got right. Return after a week to the answers you missed and do them again from a blank page.

Revise your weakest topic first, not your favourite. The topic you enjoy is the one you already know; the topic you avoid is the one the paper will ask.

How to Face NECTA

The examination does not test how clever you are. It tests whether you can show what you know, clearly, under pressure, in a fixed time. That is a skill, and skills can be practised.

Read every question twice before you write. Most lost marks come from answering the question you expected instead of the one on the paper. The second reading catches the word the first reading missed.

Obey the command word. Each command word asks for a particular kind of answer, and giving the wrong kind loses marks even when your biology is correct.

Command word	What it asks for
State, Name, List	Give the fact or item only, briefly, with no explanation.
Define, What is meant by	Give the exact, formal meaning of the term.
Outline	Give the main points or steps only, without the detail.
Describe	Give an orderly account of what is seen or what happens, step by step, with no reasons.
Explain	Give the reason why. Every explain answer needs a because.
Account for	Explain why an observation or result happens the way it does.
Suggest	Apply what you know to an unfamiliar case; a sensible, reasoned answer is rewarded even where more than one is possible.
Compare	Give similarities and differences together, point against point.
Distinguish, Differentiate	Give the differences directly, side by side, not two separate descriptions.
Discuss	Weigh more than one side: reasons for and against, advantages and disadvantages.
With the aid of a labelled diagram	A diagram is compulsory and carries marks; an answer without one is capped.
Calculate	Work out the number, showing each step and its unit, as in magnification, water potential and the respiratory quotient.

Show your reasoning, not just the conclusion. A bare conclusion scores little; the marks live in the steps between the question and the answer. Write the chain.

In data questions, read the axes, quote the figures, then explain. First state what the graph or table shows, using actual values with their units, then explain why it happens. Describing and explaining are two separate sets of marks.

Check that a calculated answer is sensible. A magnification has no units, and a respiratory quotient normally lies between 0.7 and 1.0. An answer far outside the expected range is a signal to recheck, and saying so earns credit for biological awareness.

Watch the clock, and leave nothing blank. Marks are easiest to win at the start of an answer and hardest at the end, so a question half answered is worth more than a question never reached. Spend your time by the marks, not by your interest.

The night before, do not cram. Your brain files what you have learned while you sleep. A calm student who rests well outperforms a tired one who revised until midnight. Rest is part of the preparation.

You now carry what the strongest students bring into the hall and most never receive: a way to use this book that turns reading into practice, the language to write biology that scores, the technique to draw it for full marks, an honest method of revision, and a clear plan for the examination itself. Turn the page, cover the first model answer, and begin. The biology is waiting, and it is better than its reputation.

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PART ONE
TOPICAL QUESTIONS AND ANSWERS

Chapter 1

CYTOLOGY

BINDER QUESTIONS

Work through each question in order: attempt it on paper, then check the model answer beneath and read the annotations before moving on. Every answer leads with the mark-bearing point in bold.

Question 1

An Amoeba is a single cell, yet on its own it feeds, respires, removes its wastes, responds to its surroundings and reproduces. Use this to explain why the cell is called the basic unit of life.

Model Answer

The cell is the smallest unit that can carry out all the activities of life on its own. The Amoeba is a single cell, yet by itself it feeds, respires, excretes, responds and reproduces, which shows that the processes of life are organised at the level of the cell. **Nothing smaller than the cell shows this independent living activity.** A single organelle removed from the cell cannot survive, because on its own it cannot maintain itself. In a many-celled body each cell is still the working unit, and the whole organism lives only because its cells do. The cell is therefore the basic unit of both the structure and the function of every living organism.

Examiner's Note

The mark is for the cell being the smallest unit that shows the full activity of life, both its structure and its function. Naming one process such as respiration is not enough on its own.

Language Clinic

The phrase "which shows that…" ties the observation to the conclusion in a single sentence, turning a fact into an argument. "because on its own it cannot maintain itself" supplies the reason the mark depends on.

Question 2

In 1665 Robert Hooke looked at a thin slice of cork and saw rows of empty boxes, which he named "cells". A few years later Antony van Leeuwenhoek looked at pond water and saw tiny living organisms swimming. Explain why the two men saw such different things.

Model Answer

Hooke saw only empty walls because cork is dead plant tissue. The living contents had long since disappeared, so what remained were the box-like cell walls, which is why he saw structure but no life. **Leeuwenhoek saw living organisms because he examined fresh pond water with a far better lens.** His single high-quality lens magnified close to three hundred times and gave a sharper image, so he could make out whole living cells in action. The difference came from both the material examined and the quality of the lens.

Examiner's Note

Two marks live here: dead walls for Hooke, and fresh living material plus a better lens for Leeuwenhoek. An answer that only says "Leeuwenhoek had a better microscope" misses why Hooke saw no life.

False Confidence Alert

Many write that Leeuwenhoek used a "compound microscope". He did not: his instrument used a single, very fine lens. The compound (many-lens) microscope came later, and naming it wrongly can cost the mark in a discovery-of-the-cell question.

Question 3

Most cells are no wider than a fraction of a millimetre. Explain why cells must stay so small, using the ideas of surface area and volume.

Model Answer

A cell takes in materials across its surface but uses them throughout its volume. As a cell grows, its volume increases faster than its surface area, so the surface becomes too small to serve the inside. **This falling surface-area-to-volume ratio is what keeps cells small.** A small cell has a large surface area for its volume, so oxygen and nutrients diffuse in, and wastes diffuse out, fast enough to supply every part. If the cell grew too large, its centre would be starved before diffusion could reach it.

False Confidence Alert

A common answer is that small cells are simply "lighter" or "simpler". Size by itself is not the point: it is the surface-area-to-volume ratio that matters, and a large cell fails because its surface cannot supply its volume.

Language Clinic

"so the surface becomes too small to serve the inside" and "before diffusion could reach it" carry the cause and its effect. The small word "so" does the mark-bearing work, linking the growth to its consequence.

Question 4

Cytology is the foundation of modern medicine, genetics and physiology. Choosing any two of these fields, explain how a knowledge of cells makes progress in them possible.

Model Answer

1) **In medicine, knowing the normal structure of cells lets doctors recognise diseased ones.** A cancer cell looks and behaves differently from a healthy cell, so examining cells under the microscope allows disease to be diagnosed early.
2) **In genetics, the cell holds the DNA that carries inherited information.** Because hereditary material is passed on when cells divide, understanding the cell explains how characteristics move from parents to offspring. Knowledge of the cell therefore underpins both how disease is detected and how inheritance is understood.

Examiner's Note

Each field must be tied to a specific cell fact: diseased cells differ in appearance (medicine), DNA is passed on at cell division (genetics). A general "cells are important" sentence does not score.

Question 6

A light microscope can be made to magnify a mitochondrion many hundreds of times, yet it can never show the cristae folded inside it. Explain why.

Model Answer

The limit is resolution, not magnification. Resolution is the ability to show two close points as separate, and a light microscope cannot resolve detail finer than about 200 nm because it uses light of a relatively long wavelength. **The cristae are folded far closer together than this limit.** Magnifying the image further only makes the blur larger, so the folds still merge into one. An electron microscope resolves them because its beam of electrons has a much shorter wavelength, which allows far finer detail to be seen.

Examiner's Note

The mark depends on resolution being limited by the wavelength used, not on magnification. Saying "the light microscope is too weak" misses the idea being tested.

False Confidence Alert

Students often answer "the magnification is not high enough". This scores nothing: the magnification could be raised endlessly. It is the resolving power, set by the wavelength of light, that fails.

Question 7

A student enlarges a blurred photograph on a screen until it fills the wall, but it only becomes a bigger blur. Use this to explain the difference between magnification and resolution.

Model Answer

Magnification is how many times larger the image is made; resolution is how much detail that image can show. Enlarging the photograph raises its magnification, but no new detail appears, because the detail was never captured in the first place. **Resolution sets the real limit on what can be seen.** Once magnification passes the point that resolution can support, the image only grows without becoming clearer. Useful magnification therefore depends on good resolution, which is why high magnification on its own is worthless.

Examiner's Note

The examiner wants the two ideas held apart and then linked: magnification enlarges, resolution reveals, and magnification without resolution is empty.

Language Clinic

"but no new detail appears, because the detail was never captured" pairs a contrast ("but") with a reason ("because") in one line. "which is why high magnification on its own is worthless" delivers the conclusion the mark rewards.

Question 8

A chloroplast is 5 µm wide. In a textbook diagram it is drawn 60 mm wide. Calculate the magnification of the diagram.

Model Answer

Magnification = image size ÷ actual size.

Both lengths must be in the same unit: 60 mm = 60000 µm.

Magnification = 60000 µm ÷ 5 µm = **×12 000.**

Magnification has no units, because it is a ratio of two lengths.

Examiner's Note

The marks are for converting to one unit before dividing, and for giving the answer as a pure number. A magnification written with a unit, such as "12 000 mm", is marked wrong.

Question 8

A bacterium is drawn 90 mm long at a magnification of ×30000. Calculate the real length of the bacterium, giving your answer in micrometres.

Model Answer

Actual size = image size ÷ magnification.

Actual size = 90 mm ÷ 30000 = 0.003 mm.

Converting: 0.003 mm × 1000 = **3 μm.**

False Confidence Alert

Forgetting to convert millimetres to micrometres is the common slip here, and it leaves the answer a thousand times too large. Always finish a magnification calculation by checking the unit the question asked for.

Question 9

Explain each of the main ideas of the cell theory, saying for each what it means for a living organism.

Model Answer

1) **All living organisms are made of one or more cells.** The body of every organism, from a bacterium to a person, is built only from cells and their products.
2) **The cell is the basic unit of structure and function.** All the activities of life are organised and carried out at the level of the cell.
3) **All cells arise from pre-existing cells.** New cells are produced only when existing cells divide, so life is continuous.
4) **Cells contain the hereditary material passed on during division.** This is what allows characteristics to be inherited from one generation to the next.

Examiner's Note

A question on the "main ideas" expects each statement followed by its meaning, not four bare lines. The fourth idea, the hereditary material, is the one most often left out.

False Confidence Alert

A frequent answer names only three ideas and stops, treating the cell theory as fixed in the nineteenth century. The idea that cells carry hereditary material is part of what the examiner counts.

Question 10

The classical cell theory was later given several "modern additions". Explain why these additions were needed, and what the original statements failed to account for.

Model Answer

The classical theory described cells but said nothing about how they work chemically or pass on information. It established that organisms are built from cells arising from other cells, yet it could not explain inheritance or metabolism. **The modern additions fill these gaps.** They state that:

1. Cells carry DNA that passes hereditary information between generations.
2. The energy changes and reactions of life occur within cells.
3. All cells share the same basic chemical make-up.

These additions were needed because later discoveries in genetics and biochemistry revealed activities the early theory could not describe.

Examiner's Note

The credit is for naming what the old theory could not explain (inheritance and metabolism) before giving the additions that supply it.

Language Clinic

"yet it could not explain…" marks the limit of the old theory, and "The modern additions fill these gaps" answers it directly. Stating the gap before the fix is what earns the explanation marks.

Question 11

Explain how Louis Pasteur's swan-necked flask experiment supported the idea that cells arise only from pre-existing cells.

Model Answer

Pasteur boiled broth to kill any cells already present, then left it in a flask with a long curved neck open to the air. The curve trapped dust and microorganisms, so none could reach the broth, and consequently it stayed clear with no new growth. **When the neck was broken off, microorganisms reached the broth and it quickly turned cloudy.** This showed that the new cells came from organisms entering from outside, not from the lifeless broth itself. The experiment therefore disproved spontaneous generation and supported the idea that cells come only from existing cells.

Examiner's Note

The credit is for the comparison: sealed by the curved neck means no growth, broken neck means growth. Describing only one half of the experiment does not prove where the cells came from.

False Confidence Alert

A common answer is that Pasteur "boiled the broth to keep it sterile", as if the boiling was the proof. The proof is the contrast between the intact and broken necks; boiling only set up the starting point.

Question 12

A bacterium has no nucleus, no mitochondria and no endoplasmic reticulum, yet it still respires, builds proteins and reproduces. Explain how it carries out these processes without those organelles.

Model Answer

A prokaryote carries out its life processes on its plasma membrane and free in its cytoplasm, not inside separate organelles. The reactions of respiration that release most of the energy take place on the cell-surface membrane, which does the work the mitochondrion does in other cells. **Protein synthesis happens on its 70S ribosomes, which lie free in the cytoplasm.** The instructions come from a single circular DNA molecule in the nucleoid, a region with no surrounding membrane. **The cell reproduces by binary fission, copying its DNA and splitting in two.** Because the membrane and the cytoplasm handle every process themselves, the cell needs no membrane-bound organelles.

Examiner's Note

The marks come from saying where each process is carried out, not merely that it happens. Linking respiration to the membrane and protein synthesis to the 70S ribosomes is what the examiner rewards.

False Confidence Alert

A common mistake is to assume that without mitochondria a cell cannot respire. A prokaryote respires perfectly well; the reactions simply take place on its plasma membrane instead of inside a mitochondrion.

Question 13

A disease-causing bacterium is often equipped with a capsule, pili and a plasmid. Explain how each of these helps it survive and spread.

Model Answer

Each of these structures gives the bacterium an advantage:

The capsule is a slimy outer coat that protects the cell. It guards against drying out and helps the bacterium resist being engulfed by the host's white blood cells.

The pili are fine appendages that let the bacterium attach and exchange genes. Some anchor it to a host's surface, while a sex pilus passes DNA from one cell to another during conjugation.

The plasmid is a small ring of extra DNA carrying useful genes. These often include genes for antibiotic resistance, which can be passed to other bacteria, so the whole population survives treatment.

Examiner's Note

Each mark depends on pairing the structure with what it does for the cell, such as the plasmid with antibiotic resistance. Naming the three parts without their roles does not score.

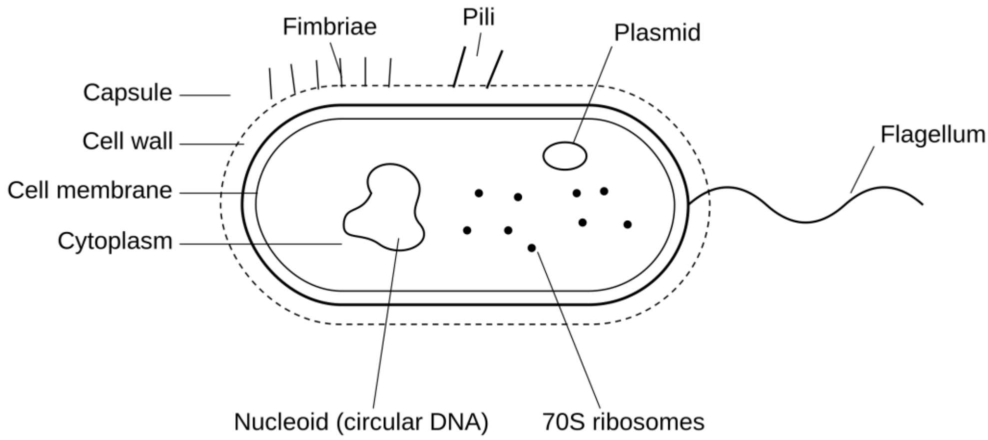
False Confidence Alert

Students often confuse the capsule with the cell wall. The wall lies beneath and stops the cell bursting; the capsule is an extra slimy layer outside it that resists drying and the host's defences.

Question 14

Draw and label a prokaryotic (bacterial) cell, showing at least seven structures.

Model Answer



Examiner's Note

The mark-bearing labels are the cell wall, plasma membrane, cytoplasm, nucleoid (circular DNA), 70S ribosomes, plasmid and flagellum; the capsule, pili and fimbriae earn further credit. A diagram that places the DNA inside a nuclear membrane loses marks, because a prokaryote has no true nucleus. Draw the DNA as a single free loop, keep the ribosomes as small dots, and let every label line touch the structure it names.

Question 15

A cell is examined and found to have a wall containing peptidoglycan and ribosomes of the 70S type. Explain why these two features show that the cell must be a prokaryote.

Model Answer

A peptidoglycan wall is found only in prokaryotes. Eukaryotic walls are made of cellulose or chitin, never peptidoglycan, so this wall alone places the cell among the prokaryotes. **The 70S ribosome is the smaller type a prokaryote uses for all its protein synthesis.** A eukaryote uses larger 80S ribosomes in its cytoplasm, so a cell whose only ribosomes are 70S cannot be eukaryotic. Taken together, the peptidoglycan wall and the 70S ribosomes show the cell must be a prokaryote, because no eukaryotic cell has either in this way.

Examiner's Note

Peptidoglycan in the wall is the most decisive feature, because no eukaryote ever has it. Tying each feature to what a eukaryote has instead, cellulose or chitin walls and 80S ribosomes, is what earns the marks.

False Confidence Alert

It is tempting to say 70S ribosomes are found only in prokaryotes. In fact a eukaryote also has 70S ribosomes inside its mitochondria and chloroplasts; what marks a prokaryote is that it uses 70S ribosomes everywhere and has no 80S ones.

Question 16

Explain how one bacterium can become millions within a few hours, and why this kind of reproduction does not involve mitosis.

Model Answer

A bacterium reproduces by binary fission, a simple splitting into two. Its single circular DNA molecule is copied, the cell grows longer, and the two copies move to opposite ends. **The cell then pinches inward and divides into two identical daughter cells.** Each daughter can repeat this in about twenty minutes, so the numbers double again and again, reaching millions within hours. **Binary fission needs no mitosis because a prokaryote has no nucleus and no chromosomes on a spindle.** The DNA is simply copied and shared out, without the spindle and stages that mitosis requires.

Examiner's Note

Two marks live here: the repeated doubling that explains the huge numbers, and the reason binary fission is not mitosis, namely the absence of a nucleus and spindle. Describing the splitting without the doubling misses the speed.

Language Clinic

The chain "is copied... grows longer... move to opposite ends... pinches inward and divides" carries the reader through the process in order. The linking words "then" and "so" keep each step leading into the next.

Question 17

Looking through an electron microscope, explain how you would tell a eukaryotic cell from a prokaryotic one.

Model Answer

A eukaryotic cell shows several features that a prokaryote lacks:

1) **It has a true nucleus bounded by a nuclear envelope.** A prokaryote shows only a nucleoid, a region of DNA with no surrounding membrane.
2) **It contains membrane-bound organelles such as mitochondria and an endoplasmic reticulum.** A prokaryote has none of these, so its cytoplasm looks comparatively empty.
3) **Its cytoplasmic ribosomes are the larger 80S type.** A prokaryote has only the smaller 70S ribosomes.
4) **It is much larger, often ten to a hundred times the diameter of a prokaryote.** Size alone is a strong first clue.

Examiner's Note

A true, membrane-bound nucleus is the single most decisive sign of a eukaryote. Each difference scores only when it is paired with what the prokaryote shows instead.

Question 18

A mitochondrion is sometimes called "a cell within a cell". Explain the evidence that it was once a free-living prokaryote.

Model Answer

Several features of the mitochondrion are those of a prokaryote:

1) **It has its own circular DNA, naked and not wound on histones, exactly like a bacterium's.**
2) **It has its own 70S ribosomes, the prokaryotic type, and makes some of its own proteins.**
3) **It is enclosed by a double membrane, the inner one thought to be the original prokaryote's own membrane.**
4) **It divides by binary fission, independently of the cell, just as bacteria do.**

5) **It is about the size of a bacterium, one to two micrometres across.**

Together these features suggest the mitochondrion descends from a prokaryote that was engulfed by an early cell and never digested.

Examiner's Note

The marks are for features that are specifically prokaryotic, with the circular DNA and 70S ribosomes carrying the most weight. A vague "it looks like a bacterium" does not score.

False Confidence Alert

Many answer only that the mitochondrion "has DNA", as if that alone were the evidence. The point is the kind of DNA, circular and naked like a bacterium's, together with 70S ribosomes and a double membrane.

Question 19

A chloroplast is often described as having a prokaryotic nature. Justify this description with four pieces of evidence.

Model Answer

A chloroplast shows four prokaryotic features:

1) **It has its own circular DNA, like that of a bacterium.**
2) **It has its own 70S ribosomes and makes some of its own proteins.**
3) **It is bounded by a double membrane.**
4) **It divides by binary fission, independently of the cell.**

These features support the idea that the chloroplast arose from a photosynthetic prokaryote engulfed by an early cell.

False Confidence Alert

Four pieces of evidence means four distinct features. Writing "it has DNA" and "it has its own genetic material" as two separate points is really one point twice, and the second earns nothing.

Question 20

Give three structural differences between a prokaryotic and a eukaryotic cell, and for each explain why the difference matters to the cell.

Model Answer

1) **A prokaryote has no true nucleus, only a nucleoid, while a eukaryote has a nucleus bounded by an envelope.** The envelope separates the DNA from the cytoplasm, so the cell can control its genes more precisely.
2) **A prokaryote has no membrane-bound organelles, while a eukaryote has many.** Organelles let the eukaryote keep different reactions in separate compartments, which makes its chemistry more efficient.
3) **A prokaryote has 70S ribosomes, while a eukaryote has larger 80S ribosomes in its cytoplasm.** Because the two kinds differ, antibiotics can be designed to block the bacterial 70S ribosome while leaving the host's 80S ribosomes unharmed.

Examiner's Note

Each mark needs the difference and its consequence, for example the nuclear envelope allowing closer control of the genes. A bare list of differences earns only half the credit.

Language Clinic

Phrases like "so the cell can control its genes more precisely" and "which makes its chemistry more efficient" turn each difference into a reason. The words "so" and "which" carry the consequence the mark rewards.

Question 21

Explain why the cell membrane lets oxygen and carbon dioxide pass through freely, yet stops ions such as sodium from crossing on their own.

Model Answer

The membrane is partially permeable because of its phospholipid bilayer. The centre of the bilayer is made of hydrophobic fatty-acid tails, which form an oily barrier. **Small, uncharged molecules such as oxygen and carbon dioxide dissolve in this oily centre and pass straight through.** Charged ions such as sodium cannot, because the hydrophobic core repels them, so they can only cross through a protein channel or carrier. In this way the membrane lets some substances through while holding others back.

Examiner's Note

The mark is for linking the hydrophobic core to what can and cannot cross: lipid-soluble molecules through, charged ions blocked. Saying only that the membrane 'is selective' without the bilayer reason does not score.

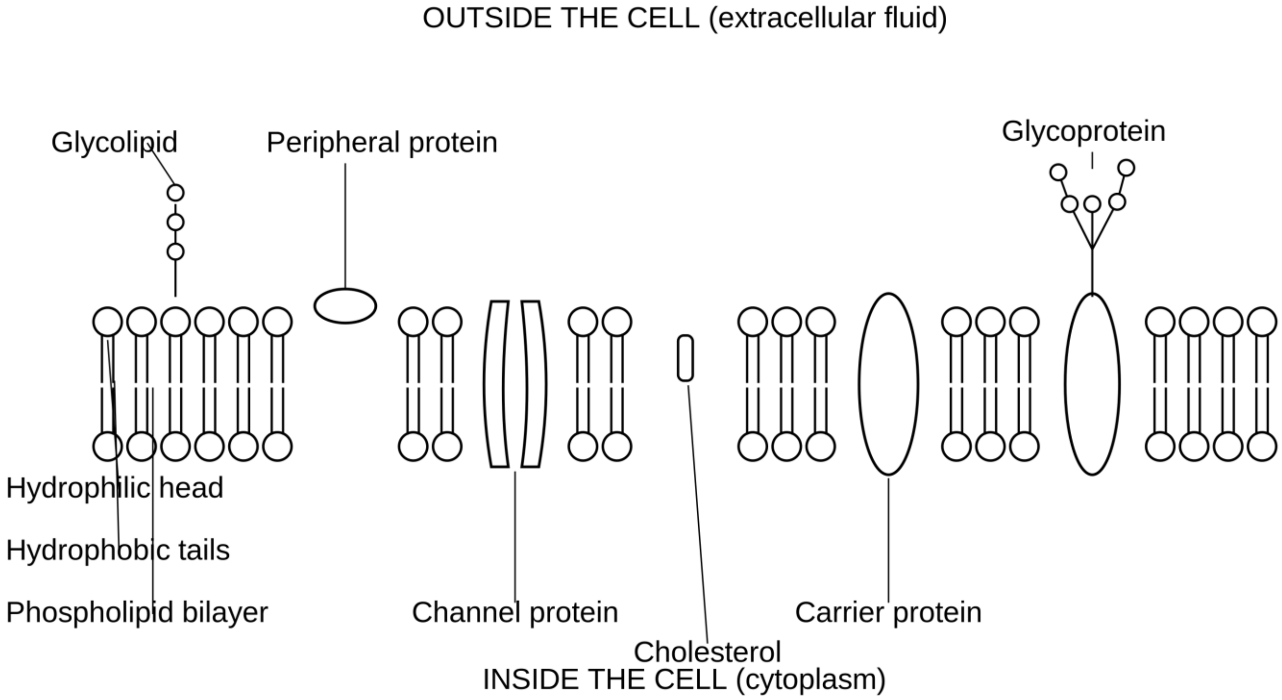
False Confidence Alert

Students often say ions cannot cross because they are 'too big'. A sodium ion is tiny; it is stopped because it is charged and the oily core of the bilayer repels it, not because of its size.

Question 22

Draw and label the fluid-mosaic model of the cell membrane, showing at least seven features.

Model Answer



Examiner's Note

The mark-bearing labels are the phospholipid bilayer with its hydrophilic head and hydrophobic tails, a channel protein, a carrier protein, a peripheral protein, cholesterol, and a glycoprotein or glycolipid. Draw the phospholipids as a double row, heads outward and tails meeting in the middle. The commonest error is to draw a single layer instead of a bilayer, or to bury the proteins among the tails rather than spanning the membrane.

Question 23

The cell membrane is described as a **'fluid mosaic'**. Explain what each part of this name tells you about the membrane.

Model Answer

The membrane is 'fluid' because its phospholipids and many of its proteins can move sideways within the layer. The bilayer is not solid; the molecules drift past one another, so the membrane behaves like a flexible, self-sealing sheet.

It is a 'mosaic' because the proteins are scattered through the bilayer like the tiles of a mosaic. They sit at different depths and positions rather than forming neat layers. Cholesterol fits between the phospholipids and steadies this fluidity, stopping the membrane from becoming too fluid when warm or too stiff when cool.

Examiner's Note

Both halves of the name must be explained: fluid means the molecules move, mosaic means the proteins are scattered through the bilayer. Naming the model without explaining either word earns little.

Language Clinic

The matched pair 'It is fluid because... It is a mosaic because...' answers the two parts of the name in turn. The word 'because' each time delivers the explanation the mark rewards.

Question 24

Explain why the fluid-mosaic model replaced the older Danielli-Davson model of the membrane.

Model Answer

The Danielli-Davson model pictured the membrane as a static sandwich, a phospholipid layer held between two continuous sheets of protein. It treated the membrane as fixed and the proteins as outer coats. **The fluid-mosaic model replaced it because the old model could not explain how substances cross the membrane or how cells recognise one another.** Later evidence showed that proteins are embedded within the bilayer and can move, not spread over its surface, and that some proteins span the membrane to form channels. Because the fluid-mosaic model fits this evidence, it is the one now accepted.

Examiner's Note

The credit is for naming what the old model could not explain, the movement of proteins, transport through the membrane, cell recognition, before giving the new model. A bare description of the fluid-mosaic model does not answer why it replaced the old one.

False Confidence Alert

A common answer is that the old model was 'simply wrong'. It was not wrong about the bilayer; what it got wrong was treating the proteins as static outer layers rather than embedded molecules that move.

Question 25

Explain how the nucleus controls the activities of the cell, tracing how it directs the making of a protein.

Model Answer

The nucleus controls the cell because it holds the DNA, which carries the instructions for making proteins. When a protein is needed, the gene for it is copied into messenger RNA inside the nucleus. **This messenger RNA passes out through the nuclear pores to the ribosomes, which build the protein.** By choosing which genes are copied, the nucleus decides which enzymes and proteins the cell makes, and so controls every activity the cell carries out. It also controls cell division by copying the DNA beforehand.

Examiner's Note

The mark depends on the chain from DNA to protein: the gene is copied into mRNA, which leaves through the nuclear pores to the ribosomes. Calling the nucleus the 'control centre' without this mechanism is only half an answer.

Language Clinic

The sequence 'copied into messenger RNA... passes out through the nuclear pores... build the protein' carries the reader step by step. Each clause leads into the next, which is what a mechanism answer needs.

Question 26

Explain how the rough and smooth endoplasmic reticulum differ, both in structure and in what they do.

Model Answer

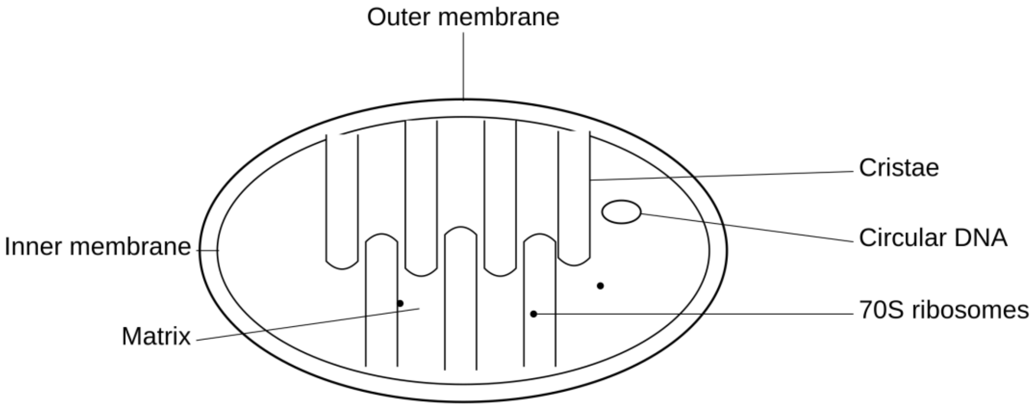
The rough endoplasmic reticulum is studded with ribosomes, which is why it looks rough. These ribosomes make proteins, and the rough ER then folds and carries those proteins to where they are needed. **The smooth endoplasmic reticulum has no ribosomes on its surface.** Instead it makes lipids and steroids, and in liver cells it helps to break down harmful substances. So the two differ in structure, by the presence or absence of ribosomes, and in their work, proteins against lipids.

> **False Confidence Alert**
>
> Students often say the smooth ER also makes proteins. It does not. Only the rough ER, through its ribosomes, makes proteins; the smooth ER handles lipids, steroids and detoxification.

Question 27

Draw and label a mitochondrion, showing six parts, and explain how the cristae suit its function.

Model Answer



The cristae are the folds of the inner membrane, and they greatly increase its surface area. This large surface holds many electron-carrier proteins and ATP synthase, so the mitochondrion can produce a great deal of ATP.

> **Examiner's Note**
>
> The six labels expected are the outer membrane, inner membrane, cristae, matrix, a 70S ribosome and the circular DNA. The cristae mark depends on linking the folds to a larger surface area for ATP production. The commonest error is to draw the cristae as full lines crossing the organelle rather than folds of the inner membrane.

> **False Confidence Alert**
>
> Many write that the cristae 'make energy'. They do not make energy; their folded surface provides the area on which the reactions that release energy and produce ATP take place.

Question 28

Explain why lysosomes are called 'suicide bags', and what would happen if a cell's lysosomes were to burst.

Model Answer

Lysosomes are called suicide bags because they contain powerful digestive enzymes. These hydrolytic enzymes break down worn-out organelles and material the cell has taken in. **If a cell's lysosomes were to burst, the enzymes would escape into the cytoplasm and digest the cell itself.** This self-digestion, called autolysis, would destroy the cell. The membrane around each lysosome normally keeps the enzymes shut safely away, so the cell is digested only when it is meant to die.

Examiner's Note

The name is earned by two points: the lysosome holds digestive enzymes, and if those enzymes are released they digest the cell's own contents. Saying only that 'they kill the cell' without naming the enzymes misses the mark.

False Confidence Alert

A common answer is that lysosomes 'kill germs only'. They do digest engulfed material, but the suicide-bag name comes from their power to digest the cell's own structures if the enzymes escape.

Question 29

A cell makes a protein that it will release to the outside. Explain how the protein is built, processed and exported, naming the organelles involved.

Model Answer

The protein is first built by ribosomes on the rough endoplasmic reticulum. The rough ER packs the new protein into a vesicle, which carries it to the Golgi apparatus. **The Golgi apparatus modifies the protein and packages it into a secretory vesicle.** This vesicle moves to the cell-surface membrane, fuses with it, and releases the protein outside by exocytosis. In this way the ribosomes, the endoplasmic reticulum and the Golgi work together as one production line.

Examiner's Note

The marks follow the order of the production line: ribosome on the rough ER, vesicle to the Golgi, Golgi packages, vesicle to the membrane, exocytosis. Naming the organelles out of order, or leaving out the Golgi's role, loses marks.

Language Clinic

Words such as 'first', 'which carries it to', and 'moves to the membrane, fuses with it, and releases' keep the steps in sequence. A process answer should read as one connected chain, not a set of separate facts.

Question 30

Explain how microtubules and microfilaments help an animal cell to keep its shape and to move materials about.

Model Answer

Microtubules are hollow tubes of protein that act as tracks and supports inside the cell. They give the cell its shape, pull the chromosomes apart during division, and form the core of cilia and flagella.

Microfilaments are much thinner threads of the protein actin. They support the cell surface, let the cell change shape and move, and pinch the cell in two at the end of division. Together they make up the cytoskeleton, the cell's internal framework.

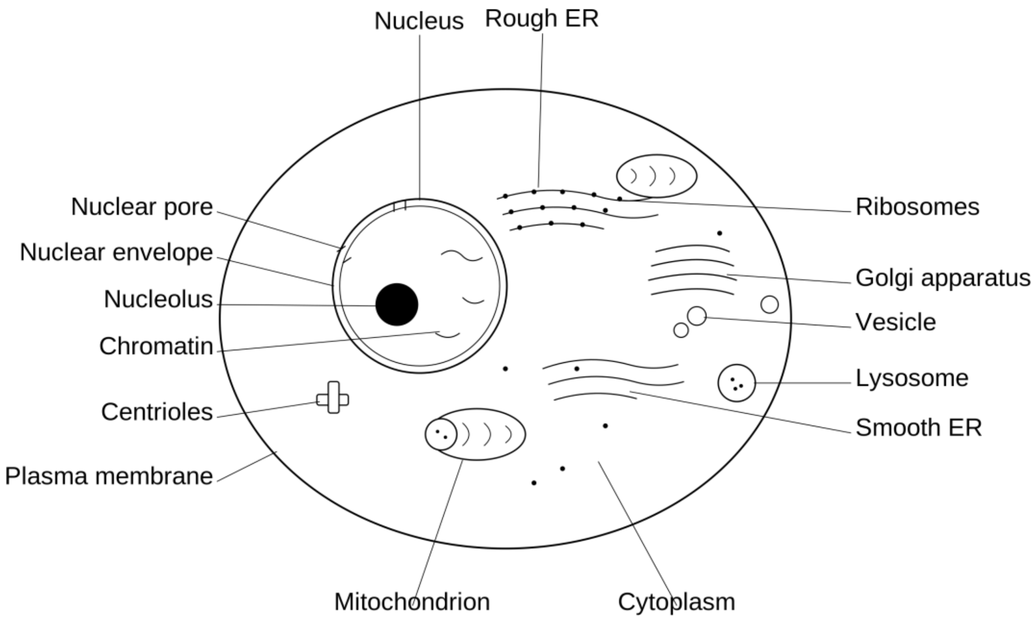
Language Clinic

The matched openings 'Microtubules are... Microfilaments are...' set the two side by side, and each is followed by what it does. Holding a comparison in parallel like this is what makes it easy to mark.

Question 31

Draw and label a generalised animal cell as it appears under the electron microscope, showing at least eight structures.

Model Answer



Examiner's Note

Eight labels expected from: the nucleus (with its envelope, pore and nucleolus), mitochondrion, rough and smooth endoplasmic reticulum, ribosomes, Golgi apparatus, lysosome, centrioles, and the cell-surface membrane. The commonest error is to draw a cell wall or chloroplasts; an animal cell has neither, and adding them loses marks.

Question 32

Distinguish between the cytoplasm and the cytosol, and explain why so many of the cell's reactions take place there.

Model Answer

The cytoplasm is everything inside the cell-surface membrane except the nucleus, including all the organelles. The cytosol is only the clear fluid part, without the organelles. **So the cytosol is one part of the cytoplasm, not another name for it.** Many of the cell's reactions, such as the first stage of respiration, take place in the cytosol because the enzymes and the substances they act on are dissolved there and can meet easily. The cytoplasm as a whole also holds the organelles in their places.

Examiner's Note

The mark is for the relationship: the cytosol is the fluid part, the cytoplasm is that fluid plus the organelles. Treating the two words as identical loses the mark.

Language Clinic

The line 'the cytosol is one part of the cytoplasm, not another name for it' fixes the relationship in a single sentence. Stating the distinction plainly is what the examiner rewards.

Question 33

Explain how the cell wall, the large vacuole and the chloroplast each suit a plant cell to its way of life: fixed in one place and making its own food.

Model Answer

A plant cell stays in one place and feeds itself, and three structures make this possible:

The cellulose cell wall gives the cell a firm, fixed shape and stops it bursting. It holds the plant up without a skeleton, which suits a life rooted in one spot.

The large central vacuole stores cell sap and presses outward to keep the cell firm. This turgor supports the soft parts of the plant, and the vacuole also stores food and pigments.

The chloroplast traps light and makes the plant's own food by photosynthesis. Because the plant cannot move to find food, it must manufacture its own where it stands.

Examiner's Note

Each mark depends on tying the structure to the plant's way of life: wall to support, vacuole to turgor, chloroplast to making food. Naming the three parts without that link does not score.

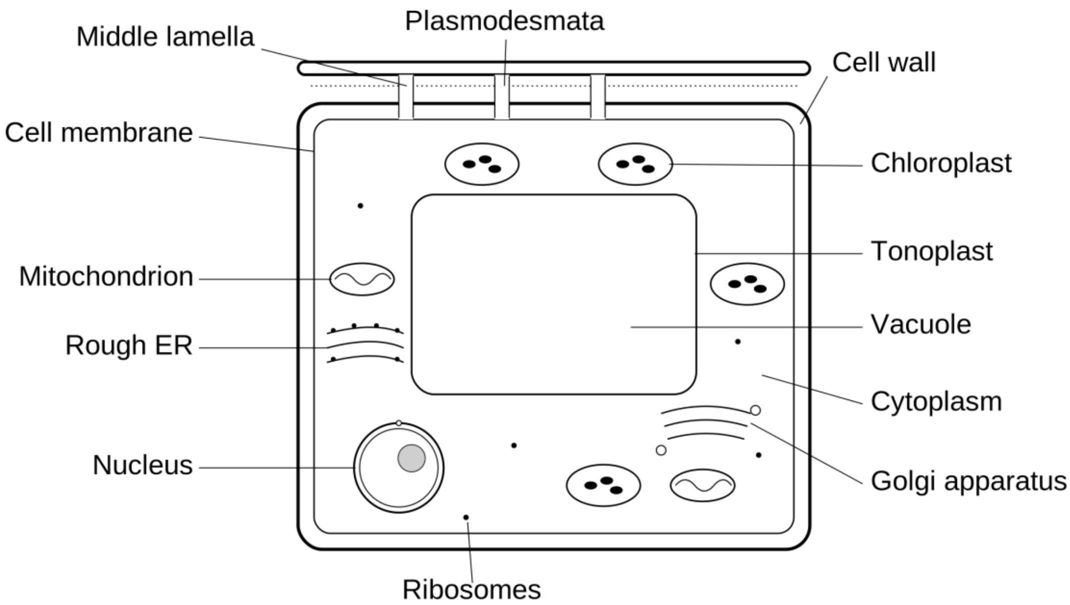
Language Clinic

The repeated shape 'The wall gives... The vacuole stores... The chloroplast traps...' opens each point with what the structure does. Leading with the function keeps a 'how does it suit' answer on target.

Question 34

Draw and label a generalised plant cell as it appears under the electron microscope, showing at least eight structures.

Model Answer



Examiner's Note

Eight labels expected from: the cellulose cell wall, middle lamella, plasmodesmata, cell-surface membrane, cytoplasm, nucleus, a large vacuole with its tonoplast, chloroplasts, mitochondria, endoplasmic reticulum, Golgi apparatus and ribosomes. The commonest error is to draw the cell rounded like an animal cell and to leave out the wall, the vacuole or the chloroplasts, which are exactly the features that mark it as a plant cell.

Question 35

Explain how the plant cell wall supports the cell without blocking materials from moving in and out, and how neighbouring plant cells stay connected.

Model Answer

The cell wall is made of cellulose fibres, which are strong yet leave spaces between them. These spaces make the wall fully permeable, so water and dissolved substances pass through freely while the wall still supports the cell. **The middle lamella is a layer of pectin that cements neighbouring walls together.** It holds the cells firmly side by side. **Plasmodesmata are fine channels of cytoplasm that pass through the walls,** linking the insides of neighbouring cells so that substances can move directly from one cell to the next.

Examiner's Note

Three points carry the marks: the wall is strong but freely permeable, the middle lamella cements cells together, and plasmodesmata connect their cytoplasm. Describing only strength misses why materials still pass through.

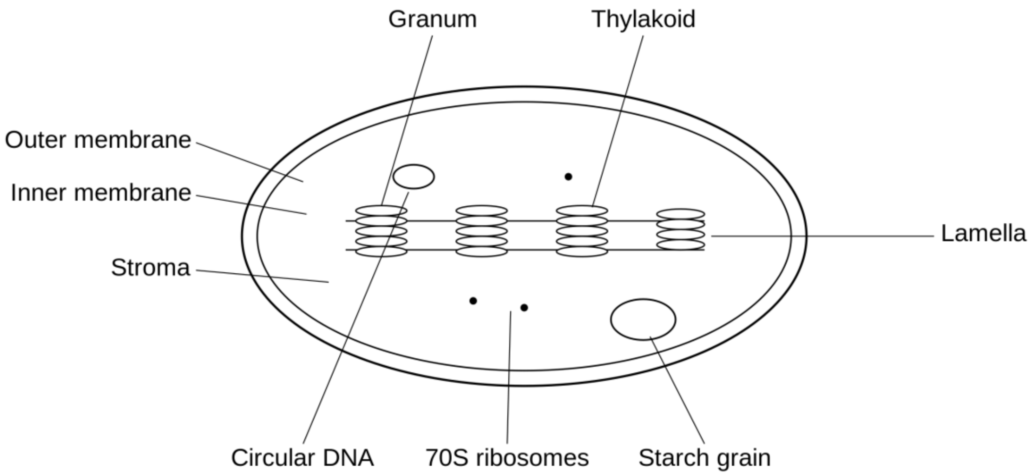
False Confidence Alert

Students often say the cell wall 'controls what enters the cell'. It does not. The wall is fully permeable; it is the plasma membrane just inside it that controls what enters and leaves.

Question 36

Draw and label a chloroplast, showing four parts, and explain how its structure suits photosynthesis.

Model Answer



The grana are stacks of thylakoid membranes that hold the chlorophyll. Their large surface area traps as much light as possible for the first stage of photosynthesis. **The stroma is the fluid around the grana,**

where the second stage takes place. It holds the enzymes that build sugars, so the two stages are kept in separate places inside one organelle.

Examiner's Note

The four labels expected are the double membrane (envelope), the stroma, a granum and a thylakoid; the lamella and a starch grain earn further credit. The explanation mark depends on linking the grana to light capture and the stroma to the sugar-building reactions. The commonest error is to draw the grana as solid blocks rather than stacks of flattened sacs.

False Confidence Alert

A common mistake is to swap the roles of grana and stroma. Light is captured on the grana, the thylakoid stacks; the sugar-building reactions happen in the stroma around them.

Question 37

Explain how a single fertilised egg can give rise to many different kinds of cell, even though every cell carries exactly the same DNA.

Model Answer

Every cell holds the same genes, but different cells switch on different genes. As the fertilised egg divides, each new cell uses only part of its DNA, so it makes only certain proteins. **The proteins a cell makes decide its structure and its job.** A cell that switches on the genes for haemoglobin becomes a red blood cell, while one that switches on muscle-protein genes becomes a muscle cell. This switching on of different genes is called differentiation, and it turns identical cells into many specialised types.

Examiner's Note

The mark is for the idea that all cells share the same genes but express different ones, so they make different proteins. An answer that says cells 'have different DNA' is wrong and scores nothing.

Language Clinic

The chain 'switch on different genes... makes only certain proteins... decide its structure and its job' carries cause into effect. The reader is led from gene to protein to cell type in one connected line.

Question 38

Explain how each of these specialised cells is built to suit the single job it does: a red blood cell, a sperm cell, and a root hair cell.

Model Answer

The red blood cell is a biconcave disc with no nucleus, packed with haemoglobin. The shape gives a large surface for taking up oxygen, and losing the nucleus leaves more room for the haemoglobin that carries it.

The sperm cell has a long tail and a middle piece full of mitochondria. The tail drives it forward to the egg, and the many mitochondria release the energy needed to swim.

The root hair cell has a long, narrow projection reaching into the soil. This greatly increases the surface area for absorbing water and mineral salts.

Examiner's Note

Each mark needs the feature joined to its purpose, for example the biconcave shape to a larger surface for oxygen. Listing the features without saying what they achieve earns only half.

Question 39

Explain how cells are organised into the levels that build a whole organism, and what is meant by saying each level can do more than the level below it.

Model Answer

Similar cells working together form a tissue, and different tissues together form an organ. Several organs that work together form an organ system, and the organ systems together make up the whole organism. **At each level the group can do something its separate parts cannot.** Muscle cells on their own only shorten, but built into a heart they pump blood, and joined with blood vessels as a circulatory system they carry materials around the body. So each level of organisation brings a new ability, from the single cell up to the whole organism.

Examiner's Note

The marks follow the ladder in order, cell to tissue to organ to system to organism, and reward the idea that each level gains an ability the one below lacks. Skipping a level or giving no example weakens the answer.

Language Clinic

The rising sequence 'cells... tissue... organ... organ system... organism' lays the hierarchy out in order, and 'but built into a heart... joined with blood vessels...' shows the new ability appearing at each step.

Question 40

Explain why it is an advantage for a large organism to have specialised cells, rather than every cell trying to do every job.

Model Answer

Specialised cells each do one job extremely well, which is far more efficient than every cell doing everything. A cell shaped and equipped for a single task carries it out better than a general-purpose cell ever could. **This division of labour lets the organism as a whole work efficiently,** because different groups of cells handle digestion, movement and transport at the same time. The cost is that the cells come to depend on one another, so the organism needs transport systems to supply them and coordination to keep them working together.

False Confidence Alert

It is tempting to treat specialisation as all gain. The trade-off is dependence: a specialised cell cannot survive alone, so the organism must transport materials to it and coordinate the whole body.

Question 41

A student is taught the rules of good biological drawing. Choosing three of these rules, explain how each one helps the drawing give a truer record of the specimen.

Model Answer

1) **Use clean, single, continuous lines, with no shading.** A single firm line records the real edge of a structure exactly, while shading or sketchy lines blur where one part ends and the next begins.
2) **Rule each label line straight, so that the lines do not cross and each ends on the part it names.** Crossing or wandering lines leave it unclear which label belongs to which structure, so the record becomes unreliable.
3) **Draw the parts in their correct proportions and state the magnification.** A drawing in true proportion, with the magnification given, shows the real sizes of the parts and how they relate, which a drawing out of proportion cannot.

Examiner's Note

Each mark depends on a rule joined to the reason it gives a truer record, not the rule alone. Naming rules without saying why each matters does not score.

Question 42

An electron micrograph of a chloroplast is printed at a magnification of ×15 000. On the print, a stack of grana measures 9 mm across. (a) Calculate the true width of the grana stack, in micrometres. (b) The whole chloroplast is 6 µm long in life. Calculate how long it would appear on the same print.

Model Answer

Magnification = image size ÷ actual size.

(a) Rearranging: actual size = image size ÷ magnification.

Converting: 9 mm = 9000 µm.

actual size = 9000 µm ÷ 15 000 = **0.6 µm.**

(b) Rearranging: image size = actual size × magnification.

image size = 6 µm × 15000 = 90 000 µm = **90 mm.**

Examiner's Note

The marks are for rearranging the formula each way, actual = image ÷ magnification and image = actual × magnification, and for converting between millimetres and micrometres. The final answers must carry the correct units.

Question 43

Give the three classical postulates of the cell theory, and support each with one piece of evidence.

Model Answer

Postulate 1: All living things are made of one or more cells.

Evidence: *Whenever living material is examined under the microscope, from plant tissue to blood, it is found to be built of cells.*

Postulate 2: The cell is the basic unit of structure and function in living things.

Evidence: *A single cell, such as an Amoeba, can carry out all the activities of life on its own, which no smaller part can do.*

Postulate 3: All cells arise from pre-existing cells.

Evidence: *Pasteur's swan-necked flask showed that broth kept free of airborne cells grows no new life, so cells come only from other cells.*

Examiner's Note

Each mark needs the postulate paired with evidence that supports it, not the postulate alone. The third postulate's evidence, that sterile broth stays lifeless, is the one most often left out.

Question 44

An electron micrograph shows three organelles. Organelle A has two membranes, the inner one folded into shelves. Organelle B is a stack of flattened, curved sacs with small vesicles at its edges. Organelle C is a network of membranes studded with many tiny dark granules. Identify A, B and C, and justify each identification from the feature given.

Model Answer

A is a mitochondrion. Its two membranes, with the inner one folded into shelves, the cristae, are the defining structure of a mitochondrion.

B is the Golgi apparatus. Its stack of flattened, curved sacs with vesicles budding from the edges is the structure of the Golgi.

C is the rough endoplasmic reticulum. The tiny dark granules studding its membranes are ribosomes, which mark the endoplasmic reticulum as rough.

Examiner's Note

Each mark depends on naming the organelle and tying it to the feature given, the folded inner membrane for the mitochondrion, the stacked sacs for the Golgi, the ribosomes for the rough ER. An identification without the matching feature does not score.

REAL QUESTIONS

These questions take the same ideas into real situations in health, farming and daily life. A few present a confident claim, from Kipanga or another student, for you to judge or to correct.

Question 45

At a clinic in Dar es Salaam, cells scraped from a patient are examined under the microscope to screen for cervical cancer. Explain how examining the cells can reveal the disease.

Model Answer

Cancer cells differ in structure from healthy cells, and these differences show under the microscope. A cancer cell often has a larger, darker nucleus and an irregular shape, because it is dividing in an uncontrolled way. **By comparing the patient's cells with normal ones, a trained eye can spot these changes early.** Catching them before the patient feels ill lets treatment begin when it is most likely to work. This is why the study of cells, cytology, is the foundation of such screening.

Examiner's Note

The mark is for linking a visible change in the cells, an enlarged or darker nucleus or an irregular shape, to the diagnosis. Saying only that 'the microscope finds cancer' without naming what is seen does not score.

Question 46

A cow is built from billions of tiny cells rather than a few enormous ones. Explain the advantage of being made of many small cells.

Model Answer

Many small cells give the body a far larger total surface area than a few large ones would. Each cell exchanges oxygen, food and wastes across its own surface, and a large surface for a small volume keeps this exchange fast. **A few giant cells would have too little surface for their volume, so their centres would be starved.** Small cells also allow different cells to specialise for different jobs. For both reasons, large organisms are built from many tiny cells.

Language Clinic

The contrast 'a large surface for a small volume keeps this exchange fast' against 'too little surface for their volume, so their centres would be starved' sets the advantage beside its opposite. The opposition is what makes the surface-area-to-volume point land.

Question 47

A student in a village school has only a light microscope. Explain what she can see when she examines a cheek cell, and what she cannot, giving a reason.

Model Answer

With a light microscope she can see the cell's outline, its cytoplasm and the nucleus. These are large enough to fall within the resolution of light. **She cannot see the small organelles, such as ribosomes, the endoplasmic reticulum, or the fine detail of mitochondria.** These lie closer together than about 200 nm, below what light can resolve, so they blur into one. To see them she would need an electron microscope, whose shorter wavelength resolves much finer detail.

Examiner's Note

The credit is for matching what is visible to the resolving power of light: the nucleus yes, the fine organelles no, because they fall below the 200 nm limit. Listing parts without the resolution reason misses the point.

False Confidence Alert

Students often think a light microscope can show everything inside a cell. It cannot: anything finer than about 200 nm, such as a ribosome, stays invisible because of the long wavelength of light.

Question 48

Kipanga draws an onion cell 60 mm wide. The real cell is 0.15 mm wide. He calculates the magnification as 0.15 ÷ 60 and announces that the cell is magnified about 0.0025 times. Identify his mistake and give the correct magnification.

Model Answer

Kipanga has divided the wrong way round. Magnification is the image size divided by the actual size, not the actual divided by the image, so he has turned the formula upside down. **The correct magnification is 60 mm ÷ 0.15 mm = ×400.** Both lengths are already in millimetres, so they divide directly. A magnification of ×400 means the drawing is four hundred times wider than the real cell, which fits a light-microscope view. His tiny figure of 0.0025 should itself have warned him, because a value far below one would mean the drawing was smaller than the cell.

Examiner's Note

The marks are for spotting the inverted formula and giving image ÷ actual = ×400. A magnification far below one for a clearly enlarged drawing is the clue that the formula was used upside down.

False Confidence Alert

Students often divide the larger number by the smaller out of habit. Always put the image size on top: a drawing bigger than the specimen must give a magnification greater than one.

Question 49

Kipanga leaves cooked *ugali* uncovered overnight and finds mould growing on it the next morning. He tells the class, *'This proves that living things can arise on their own from non-living food.'* Identify the errors in his reasoning and explain what really happened.

Model Answer

Living things do not arise from non-living matter; this idea, called spontaneous generation, was disproved long ago. Pasteur showed that broth kept free of airborne organisms never grows new life. **The mould did not come from the *ugali* itself; its spores landed on the food from the air and then grew.** Each mould cell came from a pre-existing cell, exactly as the cell theory states. That covered or sealed, boiled food does not grow mould shows the organisms come from outside, not from the food.

False Confidence Alert

It is tempting to accept what looks obvious: food left out 'grows' mould by itself. The mould grows from spores that settle on it from the air; the food only feeds them. Cells always come from pre-existing cells.

Language Clinic

The line 'its spores landed on the food from the air and then grew' replaces the false idea that life 'arose from the food' with its real source. Naming where the organisms came from is what corrects the error.

Question 50

When you cut your finger, the wound closes over and new skin forms. Use the cell theory to explain how the new skin is made.

Model Answer

New cells arise only from existing cells, by cell division. When the skin is cut, the healthy cells at the edge of the wound divide to produce more cells. **These new cells fill the gap and rebuild the skin.** No new cell appears from the blood or from nothing; each one comes from a cell that was already there. This is the cell theory's idea that all cells come from pre-existing cells, seen at work in healing.

Examiner's Note

The credit is for using the postulate that cells come from pre-existing cells: the cells at the edge divide to make the new ones. Describing healing without that link does not answer the question set.

Question 51

A doctor tells a patient that antibiotics will cure her bacterial throat infection but will do nothing for her child's common cold, which is viral. Explain why antibiotics act on bacteria but not on viruses.

Model Answer

Antibiotics work by attacking structures that bacteria have but human cells and viruses do not. Many target the peptidoglycan cell wall, or the 70S ribosomes, so the bacterium cannot grow or make its proteins. **A virus has neither a cell wall nor ribosomes of its own, so there is nothing for the antibiotic to attack.** A virus also multiplies inside the body's own cells, using their machinery. This is why the viral cold is unaffected, and why taking antibiotics needlessly only helps resistance to spread.

Examiner's Note

The marks are for naming the bacterial targets, the peptidoglycan wall and the 70S ribosomes, and for saying a virus lacks them. 'Antibiotics only kill bacteria' without the structural reason earns little.

False Confidence Alert

Many patients believe antibiotics cure any infection. They act only on bacterial structures; against a virus they do nothing, and taking them when they are not needed breeds resistance.

Question 52

In a Tanzanian hospital, a strain of bacteria stops responding to a common antibiotic, and within weeks other bacteria there are resistant too. Explain how the resistance can spread so quickly.

Model Answer

The genes for resistance are often carried on a plasmid, a small ring of DNA separate from the main chromosome. A resistant bacterium can pass a copy of this plasmid to another bacterium through a sex pilus, in conjugation. **Once a bacterium carries the plasmid, it divides by binary fission about every twenty minutes, and every daughter inherits the resistance.** In this way the gene spreads both sideways between cells and downward through the generations. The resistance can therefore sweep through the hospital's bacteria in a short time.

Examiner's Note

The marks are for the two routes: plasmid transfer by conjugation between cells, and rapid binary fission passing it to offspring. Naming only one route explains only half the speed.

Language Clinic

The phrase 'both sideways between cells and downward through the generations' captures the two directions of spread in a single line. Naming each route and how it works is what the answer needs.

Question 53

Kipanga says, *'Bacteria have no nucleus, so they have no DNA, and that is why they cannot pass on their features to their offspring.'* Identify his errors and correct them.

Model Answer

Having no nucleus does not mean having no DNA. A bacterium does have DNA; it lies free in the cytoplasm as a single circular molecule in a region called the nucleoid, simply without a membrane around it. **Because it has DNA, a bacterium certainly does pass on its features.** When it divides by binary fission it first copies this DNA, so each daughter cell receives a full set of the same genes. Kipanga has confused 'no nucleus' with 'no genetic material', which are not the same thing.

Examiner's Note

The marks are for separating the two ideas: a prokaryote lacks a nuclear membrane but still has DNA, in the nucleoid, and so does inherit features through binary fission. Correcting only one of his two errors loses marks.

False Confidence Alert

This is a classic trap: 'no nucleus' is read as 'no DNA'. The DNA is there; what the prokaryote lacks is the membrane around it. The genetic material and the nucleus are not the same thing.

Question 54

Bacteria are placed in a kingdom of their own, the Prokaryotae, while plants, animals, fungi and protoctists are grouped as eukaryotes. Explain what feature of their cells justifies this division.

Model Answer

The dividing line is whether the cell has a true, membrane-bound nucleus. Bacteria are prokaryotes: their DNA lies free in the cytoplasm with no nuclear membrane, and they have no membrane-bound organelles. **Plants, animals, fungi and protoctists are eukaryotes: their cells have a true nucleus and membrane-bound organelles such as mitochondria.** Prokaryotes also use the smaller 70S ribosomes, while eukaryotes use 80S. Because this difference in cell structure is so fundamental, it is used to set the prokaryotes apart from all the eukaryotic kingdoms.

Examiner's Note

The mark depends on the presence or absence of a true membrane-bound nucleus, and of membrane-bound organelles, as the basis of the split. A list of kingdoms without the cell-structure reason does not answer the question.

Question 55

Kipanga argues that a mitochondrion is just an organelle like any other. **Kipute** argues that it was once a free-living bacterium that came to live inside our cells. Decide whose position the evidence supports, and justify your answer.

Model Answer

Kipute is the better supported. A mitochondrion carries its own circular DNA and its own 70S ribosomes, both of the kind found in bacteria and not in the rest of the cell. **It is also wrapped in a double membrane and divides by binary fission, independently of the cell, just as a bacterium does.** These are exactly the features expected if a bacterium had been engulfed by an early cell and kept, the idea known as endosymbiosis. Kipanga is right that the mitochondrion now works as part of the cell, but its bacterial features show it did not begin that way.

Examiner's Note

The mark is for choosing Kipute and backing the choice with specifically bacterial features: circular DNA, 70S ribosomes, a double membrane and binary fission. Naming the winner without the evidence does not score.

Language Clinic

The closing 'Kipanga is right that... but its bacterial features show...' grants the small truth in the losing view before settling the question. A judgement answer reads as stronger when it weighs both sides.

Question 56

A muscle cell that works hard, such as one in the heart, contains very many mitochondria. Explain why.

Model Answer

Mitochondria are where most of the cell's ATP, its usable energy, is produced. A heart muscle cell contracts without rest, so it needs a large and constant supply of energy. **The more mitochondria it holds, the more ATP it can make at once to power that contraction.** A cell that did little work would need only a few. So the number of mitochondria in a cell matches how much energy the cell uses.

Language Clinic

The closing line 'the number of mitochondria in a cell matches how much energy the cell uses' states the rule the heart-cell example shows. Ending an application answer with the general principle ties it together.

Question 57

Explain how the glycoproteins on a cell's surface allow the body's immune system to tell its own cells apart from invading bacteria.

Model Answer

Each cell carries glycoproteins on its surface that act as identity markers. The body's own cells display a particular set of these markers, which the immune system learns to accept as 'self'. **An invading bacterium carries different surface molecules, so the immune system recognises it as foreign.** Once a cell is recognised as non-self, the immune system can attack it. In this way the surface markers let the body defend itself without harming its own cells.

Examiner's Note

The mark is for the markers acting as 'self' labels, so that cells with different markers are recognised as foreign. Saying the glycoproteins 'help recognition' without the self versus non-self idea is too vague.

Question 58

The cells lining the small intestine have their surface membrane folded into many tiny projections called microvilli. Explain how this suits the cells to their job.

Model Answer

The microvilli greatly increase the surface area of the cell membrane. The job of these cells is to absorb digested food from the gut. **A larger surface area means more food can be absorbed at the same time,** and the membrane can hold more carrier and channel proteins to take it in. So the folding makes absorption faster and more efficient than a flat surface would allow.

Language Clinic

The chain 'increase the surface area... more food can be absorbed... more carrier and channel proteins' carries the structure to its result. Leading with the surface-area point and following it to absorption is what the answer needs.

Question 59

Kipanga says, *'The cell wall is what controls which substances enter a plant cell.'* Identify his error and explain what really controls what enters.

Model Answer

The cell wall does not control entry, because it is fully permeable. Made of cellulose fibres with spaces between them, it lets water and dissolved substances pass straight through, so it cannot choose what enters. **It is the plasma membrane, just inside the wall, that controls what enters and leaves.** The membrane is partially permeable, letting some substances through while holding others back. Kipanga has confused the wall, which only supports and protects, with the membrane, which does the controlling.

Examiner's Note

The marks are for stating that the wall is fully permeable and that the partially permeable plasma membrane is the real gatekeeper. Correcting the claim without naming the membrane's role loses a mark.

False Confidence Alert

Because the wall is the outermost layer, students assume it must control entry. It does not: it is freely permeable and only supports the cell, while the membrane within it does the controlling.

Question 60

Three cells are examined under the electron microscope. Cell A, a sperm cell, has very many mitochondria; cell B, a gland cell in the pancreas, is packed with rough endoplasmic reticulum; cell C, a phagocyte, is full of lysosomes. For each cell, explain what its most abundant organelle tells you about its job.

Model Answer

Cell A's many mitochondria show it needs a great deal of energy. The sperm uses this ATP to drive its tail and swim to the egg.

Cell B's abundant rough endoplasmic reticulum shows it makes and exports a lot of protein. The pancreas cell secretes digestive enzymes, which are proteins built on the ribosomes of the rough ER.

Cell C's many lysosomes show it digests material it takes in. The phagocyte engulfs bacteria and uses the enzymes in its lysosomes to break them down.

Examiner's Note

Each mark needs the abundant organelle joined to the cell's specific job: mitochondria to energy for swimming, rough ER to enzyme secretion, lysosomes to digesting engulfed bacteria. A general 'it does its job' does not score.

Question 61

Kipanga says, *'The mitochondrion makes energy, so a cell with more mitochondria has more energy stored inside it.'* Identify his errors.

Model Answer

A mitochondrion does not make energy, because energy cannot be created. It transfers energy from glucose into ATP, the molecule the cell can actually use.

More mitochondria do not mean more energy is stored; they mean the cell can produce ATP faster. ATP is made as it is needed and used almost at once, not stockpiled in bulk. So a cell rich in mitochondria has a high rate of energy supply, not a large energy store.

Kipanga has confused making and storing energy with transferring it.

Examiner's Note

The marks are for two corrections: the mitochondrion transfers energy into ATP rather than 'making' it, and many mitochondria mean a faster ATP supply, not a larger store. Fixing only one error is half an answer.

False Confidence Alert

'Mitochondria make energy' is one of the most common phrasings, and it costs marks. Energy is transferred, not created: the mitochondrion moves it from glucose into ATP.

Question 62

Explain how each of these features suits its structure to its job: (a) the cristae of a mitochondrion; (b) the glycocalyx on the cell-surface membrane.

Model Answer

(a) **The cristae are folds of the inner membrane that increase its surface area.** This larger surface holds more of the proteins that produce ATP, so the mitochondrion can make ATP faster.
(b) **The glycocalyx is a layer of glycoproteins and glycolipids that act as surface markers.** These let cells recognise one another and let the immune system tell self from foreign. In each case the shape of the structure is matched to the task it carries out.

Examiner's Note

Each mark depends on tying the structure to its purpose: cristae to surface area for ATP, glycocalyx to cell recognition. Describing the structures without their roles does not score.

Question 63

In a rare inherited disease, a child's lysosomes lack a working enzyme, and a particular substance then builds up inside the cells. Explain why a fault in the lysosomes leads to this build-up.

Model Answer

Lysosomes normally break down and recycle substances inside the cell, using their digestive enzymes. If one of these enzymes is missing or faulty, the substance it would have broken down cannot be digested. **The undigested substance therefore collects inside the lysosomes and the cell, more and more over time.** As it builds up it crowds and damages the cell, which is why the disease appears. The fault is not in making the substance but in failing to clear it away.

Language Clinic

The closing 'The fault is not in making the substance but in failing to clear it away' pins down where the problem lies. Contrasting the real cause with the wrong one sharpens the explanation.

Question 64

Kipute says *a ribosome should not be called a true organelle because it has no membrane around it.* **Kipanga** says *it must be an organelle because it does a vital job.* Decide who has the stronger case, and justify your answer.

Model Answer

Kipute has the stronger case on the structural point. An organelle is usually defined as a membrane-bound compartment within the cell, and a ribosome has no membrane at all. **For this reason a ribosome is best described as a non-membranous structure rather than a membrane-bound organelle,** even though, as Kipanga rightly says, it does the vital job of building proteins. Importance alone does not make something a membrane-bound organelle. The fair conclusion is that the ribosome is an essential cell structure that falls outside the strict definition.

Examiner's Note

The mark is for judging by the definition, the lack of a membrane, rather than by importance, and for granting that the ribosome is still essential. A bare 'Kipute is right' without the membrane definition does not score.

Language Clinic

The move 'Kipute has the stronger case... even though, as Kipanga rightly says...' settles the question while crediting the true part of the other view. Weighing both sides is what a judgement answer rewards.

Question 65

A market trader sprinkles water over wilted *sukuma wiki*, and within minutes the limp leaves become firm and crisp again. Explain, in terms of the plant cells, why this happens.

Model Answer

Water moves into the plant cells and fills their vacuoles. As each vacuole swells, it presses the cytoplasm and the cell contents outward against the cell wall. **This outward pressure, called turgor, makes the cells firm, and firm cells make the leaf crisp.** When the leaves had wilted, the cells had lost water and gone limp; taking up water again restores the turgor. The detailed way the water moves in, by osmosis, is studied in the transport topic.

Examiner's Note

The credit is for water entering the vacuoles and the resulting turgor pressure stiffening the cells. Saying the leaves simply 'absorb water and become fresh' without the vacuole and turgor is too vague.

False Confidence Alert

Students often say the plant 'drinks' the water like an animal. The crispness comes from water filling the vacuoles and pressing on the cell walls (turgor), not from any drinking.

Question 66

Explain why green plants are described as the **'producers'** on which nearly all other life depends.

Model Answer

Green plants use their chloroplasts to make their own food by photosynthesis. Using light, they build glucose from carbon dioxide and water, and release oxygen. **Because animals cannot make their own food, they depend on plants,** either by eating them or by eating other animals that fed on plants. Plants therefore stand at the base of almost every food chain. They also release the oxygen that most living things need in order to respire, so life depends on them in two ways.

Examiner's Note

The mark is for plants making their own food by photosynthesis and so forming the base of the food chains that feed other organisms. Listing photosynthesis without the 'others depend on it' link misses the word 'producers'.

Question 67

Kipanga says, *'A plant cell does not need mitochondria, because its chloroplasts already make all the energy it needs.'* Identify his errors.

Model Answer

Chloroplasts do not make energy; they make food, namely glucose. Photosynthesis stores energy in glucose, but the cell cannot use glucose directly to do its work. **To release that energy as usable ATP, the plant cell must respire, and respiration needs mitochondria.** So a plant cell has both chloroplasts, to make glucose, and mitochondria, to release the energy from it. Plants respire all the time, day and night, just as animals do. Kipanga has confused making food with releasing energy from it.

False Confidence Alert

A widespread error is that plants 'only photosynthesise' while animals 'only respire'. Plants do both: they make glucose in their chloroplasts and release its energy in their mitochondria, day and night.

Language Clinic

The correction 'chloroplasts do not make energy; they make food' swaps the wrong idea for the right one in a stroke, and 'to release that energy... the plant cell must respire' supplies exactly what Kipanga left out.

Question 68

Doctors hope to use stem cells to treat conditions such as severe burns and leukaemia. Explain what makes stem cells suitable for this, and why embryonic stem cells are especially useful.

Model Answer

Stem cells are unspecialised cells that can keep dividing and can develop into different specialised cell types. This means they can replace cells that have been damaged or lost, such as skin cells after a burn or blood cells in leukaemia. **Embryonic stem cells are especially useful because they can form any type of cell in the body.** They are pluripotent, while most adult stem cells can form only a limited range of cells. This wider potential is what makes embryonic stem cells so valuable.

Examiner's Note

The marks are for the two properties: stem cells keep dividing and can differentiate into specialised cells, and embryonic ones can form any cell type. Saying stem cells 'cure disease' without these properties does not score.

Question 69

A farmer's maize plant takes up water and mineral salts through its root hair cells. Explain how a root hair cell is adapted for this, and how it differs from a palisade cell in the leaf.

Model Answer

The root hair cell has a long, narrow extension that reaches out among the soil particles. This gives a large surface area for absorbing water and mineral salts, and its thin wall lets them in easily. **A palisade cell is adapted for a different job, photosynthesis, not absorption.** It is packed with chloroplasts and sits near the top of the leaf to catch the light, whereas the root hair cell has no chloroplasts because it works underground in the dark. Each cell's shape and contents fit the one task it does.

Examiner's Note

The marks are for the root hair's large surface area for absorption and for the contrast with the chloroplast-packed, light-catching palisade cell. Describing one cell without the contrast only half answers the question.

Language Clinic

The pivot 'A palisade cell is adapted for a different job' turns the answer from one cell to the comparison the question asks for. Naming the different job before the differences keeps the contrast clear.

Question 70

The malaria parasite spends part of its life living inside a person's red blood cells. Explain why hiding inside a red blood cell makes the parasite hard for both the immune system and drugs to reach.

Model Answer

Inside the red blood cell, the parasite is shielded from the immune system by the cell's own membrane. The body's defences patrol the blood for foreign cells, but a parasite hidden within one of the body's own cells is largely hidden from them. **A drug, too, must first cross the red blood cell's membrane before it can reach the parasite inside.** Many drugs cannot cross easily, so the parasite is protected there. By living inside the host's own cell, the parasite uses it as a shelter from both attack and treatment.

Examiner's Note

The marks are for the red blood cell's membrane shielding the parasite from the immune system and standing as a barrier a drug must cross. Saying only that 'it hides' without the membrane barrier does not score.

Question 71

In sickle cell anaemia the red blood cell is pulled out of its disc shape into a stiff, curved sickle. Explain how this change harms the cell's ability to carry oxygen and to pass through narrow capillaries.

Model Answer

The sickle shape makes the red blood cells stiff and fragile, so they break apart more easily. When many are destroyed, too few red blood cells are left to carry enough oxygen, and this shortage is the anaemia. **The stiff, curved sickles also cannot bend to squeeze through the narrowest capillaries.** They jam and block these vessels, so blood cannot reach the tissues beyond. In both ways it is the change of shape, and the loss of whole cells, that does the harm.

Examiner's Note

The marks are for the fragile sickles breaking down to leave too few cells to carry oxygen, and for the stiff shape blocking narrow capillaries. The harm is the shape and the loss of whole cells.

False Confidence Alert

A common answer is that a sickle cell simply 'carries less haemoglobin'. The trouble is not the amount of haemoglobin in each cell; it is that the stiff sickles break down, leaving too few cells, and jam in the capillaries.

Question 72

A liver cell, whose work includes detoxifying the blood, is exceptionally rich in both mitochondria and smooth endoplasmic reticulum. Explain why a cell doing this work needs a great many of each.

Model Answer

The smooth endoplasmic reticulum is where harmful substances are broken down. A liver cell handles a constant stream of toxins, drugs and alcohol, so it needs a great deal of smooth ER to carry out all this detoxification. **The mitochondria supply the ATP that the work demands.** Breaking down and removing harmful substances uses energy, and the many mitochondria provide it. So the smooth ER does the detoxifying and the mitochondria power it, which is why a liver cell is rich in both.

Examiner's Note

Each mark needs the organelle joined to its part in the work: the smooth ER breaks down the harmful substances, the mitochondria supply the energy. Naming the organelles without their roles does not score.

Question 73

Many antibiotics kill bacteria without harming the human cells around them. Using the difference between 70S and 80S ribosomes, explain how this is possible.

Model Answer

Many antibiotics work by binding to the bacterium's 70S ribosomes and stopping them making proteins. A bacterium that cannot make proteins cannot grow or survive. **Human cells use the larger 80S ribosomes in their cytoplasm, which these antibiotics do not fit.** Because the drug acts only on the 70S type, it kills the bacteria while leaving the surrounding human cells unharmed. This difference between 70S and 80S ribosomes is what lets the antibiotic act on the bacteria alone.

> **Examiner's Note**
>
> The mark is for the antibiotic acting on the 70S ribosome that bacteria have but human cells, with their 80S ribosomes, do not. Saying 'antibiotics kill bacteria' without the ribosome difference does not score.

Question 74

A gene for antibiotic resistance is carried on a bacterium's plasmid. Using the structures of a prokaryotic cell, explain how the resistance can be passed from one bacterium to another.

Model Answer

The resistance gene sits on a plasmid, a small ring of DNA separate from the main chromosome. Because the plasmid is a separate, self-copying piece of DNA, it can be handed on by itself. **One bacterium joins to another through a sex pilus and passes a copy of the plasmid across, in conjugation.** The second bacterium now carries the resistance gene too. When either bacterium then divides by binary fission, the plasmid is copied into each daughter cell, so the resistance is inherited as well. In this way the plasmid, the pilus and binary fission together carry the gene from cell to cell.

> **Examiner's Note**
>
> The marks are for the plasmid as a separate ring of DNA, its transfer through the pilus in conjugation, and its inheritance at binary fission. Naming only one of these routes explains only part of the spread.

Question 75

Maize, rice and cassava are the energy staples of the Tanzanian table. Explain why these plant foods are so rich in stored food, in terms of how the plant cell stores it.

Model Answer

A plant cell stores its food as starch, laid down in grains inside the cell. When photosynthesis makes more sugar than the plant needs at once, the cell joins the sugar into starch and stores it as compact, insoluble grains. **The cells of maize grains, rice grains and cassava tubers are packed with these starch stores.** When we eat them, we take in that stored food, which is why the staples are so rich a source of it. The plant cell's part is to hold the food compactly as starch until it is needed.

> **Examiner's Note**
>
> The mark is for the plant cell storing its surplus food as starch grains, which the staples are rich in. The chemistry of why starch holds so much energy belongs to the next chapter; here the point is how and where the cell stores it.

Question 76

A man's fertility can depend on how strongly his sperm swim. Explain why the midpiece of a sperm cell is packed with mitochondria.

Model Answer

The midpiece is packed with mitochondria because swimming demands a great deal of energy. A sperm must propel itself a long way to reach the egg, beating its tail without rest. **The many mitochondria**

release this energy as ATP, supplying the tail's continuous movement. The more mitochondria the midpiece holds, the more ATP it can provide, and the more strongly the sperm can swim. This is why the energy-supplying organelles are gathered just where the tail begins.

> **Examiner's Note**
>
> The mark is for linking the many mitochondria to the ATP the tail needs to keep beating. Saying the midpiece 'has mitochondria for energy' without tying it to swimming is too vague.

Question 77

An electron micrograph of a cell from a maize leaf shows three structures: A, many bodies each holding stacks of disc-like membranes; B, several rod-shaped bodies with a folded inner membrane; and C, one large clear space that pushes the contents against the cell wall.

(a) Identify A, B and C.
(b) State what the large number of A tells you about the main job of this cell.

Model Answer

(a) **A is a chloroplast,** recognised by its stacks of disc-like membranes, the grana.
B is a mitochondrion, recognised by its rod shape and folded inner membrane.
C is the central vacuole, the single large space pushing the contents against the wall.
(b) **The large number of chloroplasts shows that the cell's main job is photosynthesis.** So many light-trapping organelles mean the cell is built mainly to make food.

> **Examiner's Note**
>
> Each identification must rest on the feature described, the grana for the chloroplast, the cristae for the mitochondrion, the large space for the vacuole; and part (b) must read the many chloroplasts as a sign of photosynthesis.

HOT QUESTIONS

These questions ask you to reason across topics, work out unfamiliar situations, and weigh evidence. The biology is the same as before; the demand is on your thinking, not on new facts.

Question 78

A student suggests that an organism could grow bigger simply by letting each of its cells swell to a larger size. Using surface area and volume, explain why this would not work, and what organisms do instead.

Model Answer

As a cell grows, its volume increases faster than its surface area, so its surface-area-to-volume ratio falls. A swollen cell would have a large volume to feed and to clear of waste, but too little surface to exchange materials fast enough. **Its centre would be starved of oxygen and nutrients before diffusion could reach it, and wastes would build up.** So a cell cannot grow without limit. Instead, organisms grow by making many more cells of the usual small size, each keeping a large surface for its volume. This is why a large animal is built from billions of tiny cells, not a few giant ones.

> **Examiner's Note**
>
> The mark is for the falling surface-area-to-volume ratio making exchange too slow in a giant cell, and for the alternative of adding more cells rather than bigger ones. Saying only that 'big cells are bad' without the ratio earns little.

Language Clinic

The contrast 'a large volume to feed... but too little surface to exchange' pits the two quantities against each other, and 'Instead, organisms grow by making many more cells' delivers the resolution. Setting the problem against its answer is what carries the reasoning.

Question 79

Two structures in a cell lie 150 nm apart. Explain why they appear as a single blur under a light microscope but as two separate structures under an electron microscope.

Model Answer

A microscope can show two points as separate only if they are farther apart than its limit of resolution. A light microscope uses light, whose wavelength is relatively long, and cannot resolve detail closer than about 200 nm. **Because the two structures are only 150 nm apart, which is below this limit, the light microscope merges them into one blur.** An electron microscope uses a beam of electrons of far shorter wavelength, so its limit of resolution is far smaller than 150 nm. The two structures then fall within what it can resolve, and appear separate. The difference is set by wavelength, not by magnification.

Examiner's Note

The marks depend on comparing the 150 nm gap with the ~200 nm light limit, and on crediting the electron microscope's finer resolution to the shorter wavelength of electrons. An answer about 'stronger magnification' misses the point.

Question 80

A virus is not made of cells, yet it can reproduce. Discuss whether the existence of viruses disproves the cell theory.

Model Answer

Viruses do not disprove the cell theory, because they cannot reproduce on their own. A virus is not a cell: it has no cytoplasm, no organelles and no machinery of its own. **It can multiply only by entering a living cell and using that cell's machinery to make copies of itself.** Outside a cell it is inert. The cell theory describes living, cellular organisms, all made of cells that arise from pre-existing cells; a virus, which depends entirely on a host cell and is often regarded as non-living, sits outside this. So viruses are an exception the theory does not cover, not evidence that it is wrong.

Examiner's Note

The credit is for the reasoning that a virus reproduces only inside a host cell, so it does not break the rule that cells come from cells. Simply saying 'viruses are different' without the host-dependence does not score.

False Confidence Alert

It is tempting to say viruses 'reproduce without cells, so the theory is wrong'. They reproduce only by hijacking a host cell's machinery; on their own they do nothing, which is why the cell theory still stands.

Question 81

Use the cell theory's statement that all cells come from pre-existing cells to explain why the endosymbiotic theory holds that mitochondria arose from bacteria, rather than appearing from nothing inside the early cell.

Model Answer

The cell theory states that cells come only from pre-existing cells, never from non-living matter. A mitochondrion has its own DNA, its own 70S ribosomes, and divides by binary fission, exactly like a bacterium. **Because a new mitochondrion forms only by the division of an existing one, it must descend from something that was already a living cell.** The endosymbiotic theory supplies that ancestor: a free-living bacterium engulfed by an early cell and kept rather than digested. This fits the cell theory, since the mitochondrion traces back to a pre-existing cell instead of appearing from nothing.

Examiner's Note

The mark is for linking 'cells from pre-existing cells' to the mitochondrion's own division, and so to a bacterial ancestor. Listing endosymbiosis evidence without using the cell-theory idea does not answer the question set.

Language Clinic

The chain 'a new mitochondrion forms only by the division of an existing one... so it must descend from a living cell' carries the cell-theory rule straight to the conclusion. The reasoning is in the link, not in the facts alone.

Question 82

Some bacteria live in hot springs at temperatures that would destroy human cells. Using what you know about prokaryotic cells, suggest why bacteria as a group survive in far more extreme places than complex animals do.

Model Answer

A prokaryotic cell is simple, with no delicate membrane-bound organelles to be destroyed. It has fewer fragile structures than a complex eukaryotic cell, so there is less to fail under extreme heat, cold or salt. **Bacteria also reproduce very rapidly by binary fission, so any chance variation that helps a cell survive a harsh condition is quickly passed on.** Over many fast generations, populations become adapted to conditions no animal could endure. Many also have protective features, such as a thick capsule or the ability to form resistant spores. Their simplicity, speed of reproduction and protection together let bacteria colonise places far beyond the reach of complex animals.

Examiner's Note

The marks are for reasoning from prokaryotic features, simple structure, rapid reproduction allowing fast adaptation, protective capsule or spores, to the wide range of habitats. A list of bacterial parts not linked to survival in extremes does not answer 'why'.

Question 83

Scientists treat a mitochondrion's own DNA and its 70S ribosomes as strong evidence that it was once a free-living bacterium. Explain why these particular features are such strong evidence, and not just coincidences.

Model Answer

These features are strong evidence because they are bacterial in type and unlike the rest of the cell. The cell's own DNA is held in the nucleus, is linear and wound on proteins, and its cytoplasmic ribosomes are the larger 80S kind. **The mitochondrion instead has a small circular DNA and smaller 70S ribosomes, exactly the kinds found in bacteria.** A compartment simply built by the cell would be expected to use the cell's own DNA and ribosomes, not a separate bacterial set. The simplest explanation for the mitochondrion keeping its own bacterial-type machinery is that it descends from a bacterium that once lived freely. That is why the features count as evidence, not coincidence.

Examiner's Note

The credit is for contrasting the mitochondrion's bacterial-type DNA and 70S ribosomes with the cell's own nuclear DNA and 80S ribosomes, and concluding that separate ancestry explains them best. Merely naming the features is recall, not evaluation.

Language Clinic

The contrast 'The cell's own DNA is... The mitochondrion instead has...' sets the two side by side so the difference itself makes the argument. Evaluation answers earn their marks from this kind of weighed comparison.

Question 84

A chloroplast and a mitochondrion are both said to have a prokaryotic nature, yet a chloroplast makes food in plant cells while a mitochondrion releases energy in nearly all eukaryotic cells. Explain how both can share a prokaryotic origin yet do such different jobs.

Model Answer

Both organelles arose by the same process, endosymbiosis, but from different kinds of prokaryote. The mitochondrion descends from an aerobic bacterium that was good at releasing energy, which is why it now carries out respiration. **The chloroplast descends from a photosynthetic prokaryote, a cyanobacterium, which is why it makes food using light.** Each kept the ability its free-living ancestor already had. So the shared prokaryotic nature, the circular DNA, 70S ribosomes and double membrane, comes from a common kind of origin, while the different jobs come from the different ancestors taken in. This is also why a plant cell, which both photosynthesises and respires, contains both organelles.

Examiner's Note

The mark is for one process, endosymbiosis, acting on two different prokaryotes, an aerobic bacterium and a photosynthetic one, giving organelles that kept their ancestors' different abilities. Saying only that both 'came from bacteria' does not explain the different jobs.

Question 85

Two unfamiliar cells are examined. Cell X has a wall containing peptidoglycan, no nucleus, 70S ribosomes and a single loop of DNA. Cell Y has a cellulose wall, a true nucleus, chloroplasts and a large central vacuole. Identify the type of each cell and justify your answer from the features given.

Model Answer

Cell X is a prokaryote, a bacterium. The peptidoglycan wall, the lack of a true nucleus, the 70S ribosomes and the single circular DNA loop are all defining prokaryotic features, and a peptidoglycan wall in particular is found in no other kind of cell.

Cell Y is a eukaryotic plant cell. Its true nucleus and membrane-bound organelles mark it as a eukaryote, and the cellulose wall, the chloroplasts and the large central vacuole are exactly the features that set a plant cell apart from an animal one.

Examiner's Note

Each identification must rest on the named features: peptidoglycan, no nucleus, 70S and circular DNA for the prokaryote; a nucleus plus a cellulose wall, chloroplasts and a vacuole for the plant cell. Naming the cell types without justifying from the evidence does not score.

Question 86

When a human cell and a mouse cell are fused together, their surface proteins, separate at first, become evenly mixed across the joined membrane within an hour. Explain how this experiment supports the fluid-mosaic model rather than the older static model.

Model Answer

The mixing shows that the membrane proteins can move freely within the membrane. If the membrane were a static sandwich, as the older model claimed, the proteins would stay fixed and the human and mouse proteins would remain on their own halves. **Instead they drift sideways and intermingle, which is exactly what the fluid-mosaic model predicts.** That model describes the membrane as a fluid bilayer in which proteins float and slide about like tiles that can move. The experiment therefore supports the fluid-mosaic model and contradicts the static one, because only a fluid membrane allows the mixing that is seen.

Language Clinic

The structure 'If the membrane were static... Instead they drift...' tests the old idea against the result and finds it wanting. Evaluating evidence means showing what each model predicts and which one the result fits.

Question 87

Predict what would happen to a cell membrane's function if all its cholesterol were removed and the cell were then placed in a hot environment, and explain your reasoning.

Model Answer

Without cholesterol the membrane would become too fluid in the heat and would lose control of what crosses it. Cholesterol normally sits between the phospholipids and steadies the membrane, holding it together when it is warm. **Removed, the phospholipids would move too freely as the temperature rose, so the membrane would grow leaky and weak.** Substances normally kept out would cross freely, and the cell could no longer hold its contents or keep the right internal conditions. In a hot environment the cell would therefore lose its partial permeability and could be damaged or die. This shows cholesterol's role as a stabiliser of membrane fluidity.

Examiner's Note

The marks are for predicting greater fluidity and a leaky, less selective membrane in the heat, and for tying this to cholesterol's normal role of steadying fluidity. A prediction with no reasoning from cholesterol's function does not score.

Question 88

A drug stops a cell's Golgi apparatus from working. Predict and explain what would happen to a protein that the cell normally secretes.

Model Answer

The protein would be built but could not be properly processed, packaged or secreted. Ribosomes on the rough endoplasmic reticulum would still make the protein and pass it in a vesicle toward the Golgi. **With the Golgi out of action, the protein could not be modified or packed into a secretory vesicle for**

export. It would therefore never reach the cell-surface membrane or be released, and would instead build up inside the cell. This shows that secretion depends on the whole production line, and that the Golgi's step cannot be skipped.

Examiner's Note

The mark is for tracing the production line and locating the block at the Golgi: made on the rough ER, but not modified, packaged or secreted, so it accumulates. Saying 'no protein is made' is wrong, because the ribosomes still work.

Question 89

A poison stops mitochondria from working. Explain why a nerve cell and a heart muscle cell would be harmed far more quickly than a mature red blood cell.

Model Answer

Nerve cells and heart muscle cells depend heavily on their mitochondria for energy. Both work constantly and need a large, steady supply of ATP, which their many mitochondria provide by aerobic respiration. **If the mitochondria are poisoned, these cells lose their main energy supply almost at once and quickly fail.** A mature red blood cell, by contrast, has no mitochondria at all; it meets its small energy needs by anaerobic respiration in the cytoplasm, so a poison aimed at mitochondria barely affects it. The harm therefore depends on how much each cell relies on its mitochondria.

Examiner's Note

The credit is for linking the harm to dependence on mitochondria: nerve and heart cells need much mitochondrial ATP, while a red blood cell has none and uses anaerobic respiration. Forgetting that the red blood cell lacks mitochondria loses the contrast.

False Confidence Alert

It is easy to assume every cell would be hit equally. A mature red blood cell has no mitochondria, so a mitochondrial poison scarcely touches it, while a nerve or heart cell, packed with mitochondria, fails fast.

Question 90

Kipanga says *the most important organelle is the nucleus, because it controls everything.* **Kipute** says it *is the mitochondrion, because nothing works without energy.* Evaluate both views and give a reasoned conclusion.

Model Answer

Both organelles are essential, and neither can fairly be called 'most important' on its own. Kipanga is right that the nucleus controls the cell, holding the DNA and directing which proteins are made. **Kipute is also right that the mitochondrion supplies the ATP without which no process, including the nucleus's own work, could continue.** Each depends on the other: the nucleus carries the instructions for building the mitochondrion's proteins, while the mitochondrion powers the nucleus. The question is therefore flawed, because the cell needs both working together. A fair conclusion is that the two organelles are interdependent, not ranked.

Language Clinic

Granting 'Kipanga is right that...' and 'Kipute is also right that...' before the verdict weighs each side fairly. The strongest judgement answers concede what is true in both views, then settle the matter.

Question 91

Explain how the structures found only in plant cells work together to keep a soft, non-woody plant such as a young maize seedling standing upright in the sunlight.

Model Answer

The large vacuole and the cellulose wall together give the plant its support. Water fills each vacuole and presses the cell contents against the strong cellulose wall, so the cell becomes firm and turgid. **Millions of firm, turgid cells packed together hold the soft stem and leaves upright, with no need for a skeleton.** At the same time the chloroplasts in those cells trap the sunlight that the upright plant is now well placed to receive, and make its food. So the wall, the vacuole and the chloroplast act as a set: the first two hold the plant up, and the third feeds it where it stands.

Examiner's Note

The marks are for the wall and the turgid vacuole together giving support, and for the chloroplasts using the light the upright plant gains. Treating the structures separately, without the combined outcome of an upright, feeding plant, weakens the answer.

Question 92

Trace how a single fertilised egg becomes a human being made of many specialised tissues and organs, using the ideas of cell division, differentiation and levels of organisation.

Model Answer

The fertilised egg first divides again and again to produce many identical cells. Each new cell comes from a pre-existing cell, as the cell theory states, so the whole body is built up from one starting cell. **The identical cells then differentiate: each switches on a different set of its genes and becomes a specialised cell, such as a nerve, muscle or blood cell.** Specialised cells of one kind group together as a tissue, different tissues form an organ, and organs that work together form an organ system. **Finally the organ systems together make up the whole organism.** At each level the group can do something its parts alone cannot, so one egg becomes a complex human being through division, differentiation and rising levels of organisation.

Examiner's Note

The marks follow the three ideas in order: division makes many cells, differentiation specialises them by switching on different genes, and the levels of organisation build tissues, organs, systems and the organism. Leaving out differentiation, the step that makes the cells different, breaks the account.

Language Clinic

The connectives 'first... then... Finally' carry the reader from one egg to the whole organism in sequence. A synthesis answer should read as one developing story, each stage leading into the next.

Question 93

From the set nucleus, mitochondrion, chloroplast and ribosome, identify the odd one out and state the rule that separates it from the other three. More than one answer can be defended, as long as you state the rule clearly.

Model Answer

One good answer is the ribosome, because it is the only one of the four with no membrane around it. The nucleus, the mitochondrion and the chloroplast are all bounded by membranes, while the ribosome is not. **Another defensible answer is the chloroplast, because it is the only one found only in plant cells.** The nucleus, mitochondrion and ribosome occur in animal cells too. A third is the nucleus, as the only one that does not itself handle energy or protein-building. Each answer is acceptable, provided the rule behind it is stated.

Examiner's Note

The mark is not for a particular choice but for a clear rule that truly separates one from the other three, such as 'the only one with no membrane'. An odd-one-out with no stated rule, or a rule that does not actually single one out, does not score.

Question 94

Rewrite each of these loose statements in precise biological English, naming the structure and following the cause through to its effect.

(a) The cell wall protects the cell.
(b) Mitochondria give the cell energy.
(c) The nucleus is the brain of the cell.

Model Answer

(a) The cellulose cell wall supports the plant cell and stops it bursting, because its rigid mesh resists the cell as it swells with water.
(b) The mitochondrion releases energy from glucose and transfers it to ATP, the molecule the rest of the cell spends.
(c) The nucleus stores the cell’s DNA and directs the cell’s activities, issuing its instructions as messenger RNA through the nuclear pores.

Examiner's Note

Each mark is for a precise statement that names the structure and carries the cause to its effect, replacing the loose word, 'protects', 'gives', 'brain', with the real mechanism. A reworded sentence that stays vague does not score.

Question 95

A student claims the double membrane is the single strongest piece of evidence that mitochondria evolved from free-living bacteria. Weighing it against the other lines of evidence, decide whether you agree, and justify your answer.

Model Answer

The double membrane is the strongest single line of evidence, because it is the hardest to explain in any other way. Its inner layer is the original membrane of the engulfed bacterium and its outer layer is the host's vesicle that wrapped around it, which is exactly what engulfing one cell inside another would produce. **The other lines, strong together, each leave a little room for doubt on their own.** The circular DNA and the 70S ribosomes point clearly to a bacterial past, but a sceptic could try to argue each away as a feature that arose within the cell. The double membrane is far harder to account for without endosymbiosis, so the claim is fair, though the case rests strongest on all the lines taken together.

Examiner's Note

The mark is for ranking the double membrane above the others with a reason, that its two layers are what engulfing would produce, and for noting the others are weaker alone. Listing the evidence without weighing it does not answer 'strongest'.

Language Clinic

The contrast 'the hardest to explain in any other way' against 'each leave a little room for doubt' does the weighing the question asks for. A 'which is strongest' answer needs this comparison, not just a list.

Question 96

Predict and explain what would happen to a cell if (a) its mitochondria stopped working, (b) its lysosomes ruptured, and (c) its ribosomes were destroyed.

Model Answer

(a) **The cell would run out of ATP, and its active processes would stop.** Without working mitochondria it cannot transfer energy from glucose to ATP, so active transport, movement and synthesis all cease.

(b) **The cell would digest itself.** The digestive enzymes released from the ruptured lysosomes break down the cell's own organelles and contents, killing it.

(c) **The cell could make no new proteins, and so no enzymes.** Ribosomes are the sites of protein synthesis, so without them no proteins are made, and because enzymes are proteins, the cell's reactions soon fail.

Examiner's Note

Each mark needs the predicted effect tied to the organelle's normal job: no ATP without mitochondria, self-digestion from ruptured lysosomes, no proteins without ribosomes. A consequence with no reason does not score.

Question 97

A researcher records, in three unlabelled cells, the relative number of mitochondria, the area of rough endoplasmic reticulum and the number of lysosomes.

- Cell X: very many mitochondria; little rough ER; few lysosomes.
- Cell Y: very extensive rough ER; many mitochondria; few lysosomes.
- Cell Z: very many lysosomes; a moderate number of mitochondria; little rough ER.

The three cells are a pancreas gland cell that secretes digestive enzymes, a sperm cell, and a phagocytic white blood cell. Match each of X, Y and Z to its identity, and justify every match from the cell's job.

Model Answer

Cell X is the sperm cell. Its very many mitochondria supply the ATP that powers the beating of its tail on the long swim to the egg, while it has little use for rough ER or for lysosomes.

Cell Y is the pancreas gland cell. Its very extensive rough ER builds the digestive enzymes it secretes, and its many mitochondria power that synthesis and secretion.

Cell Z is the phagocytic white blood cell. Its very many lysosomes digest the bacteria it engulfs.

Examiner's Note

Each match must be justified from the cell's job and its dominant organelle: mitochondria for the swimming sperm, rough ER for the enzyme-secreting pancreas cell, lysosomes for the engulfing phagocyte. A match with no reason does not score.

Chapter 2

BIOCHEMISTRY

BINDER QUESTIONS

Work through each question in order: attempt it on paper, then check the model answer beneath and read the annotations before moving on. Every answer leads with the mark-bearing point in bold.

Question 1

Almost every substance a cell uses, from glucose and mineral salts to the wastes it must remove, is carried dissolved in water, and the reactions of life take place in watery solution. Explain, beginning from the structure of the water molecule, why water is able to dissolve and carry so many of these substances.

Model Answer

Water dissolves so many substances because its molecule is polar, with a slightly negative oxygen and slightly positive hydrogen atoms. The oxygen pulls the shared electrons more strongly than the hydrogen atoms do, so the molecule has a negative end and a positive end. **These charged ends are attracted to ions and to other polar substances, surrounding their particles and drawing them into solution.** Glucose, mineral salts and wastes are therefore carried dissolved in the blood, the xylem sap and the cytoplasm, and because the reacting substances meet in this solution the reactions of the cell can take place.

Examiner's Note

The mark is earned by carrying the structure through to the job: the polar molecule, its attraction to ions and polar substances, and the carrying of those substances dissolved in the organism. Describing the polarity alone, with no transport, is only half the answer.

Language Clinic

Lead with the result, then the cause: water dissolves these substances because its molecule is polar. Putting the cause first turns a chemical fact into the reason the cell can move its materials.

Question 2

In a tall tree water is pulled up from the roots to the topmost leaves in unbroken columns, and on a pond a small insect can rest on the surface without sinking. Explain how the way water molecules hold together makes both of these possible.

Model Answer

Water molecules cling to one another by hydrogen bonds, an attraction between the slightly positive hydrogen of one molecule and the slightly negative oxygen of the next, and this clinging is called cohesion. A single hydrogen bond is weak, but each molecule bonds to several neighbours, so together they hold the water as one continuous body. **In a plant this cohesion keeps the water in the xylem as an unbroken column, so that water lost from the leaves draws more up behind it.** At the surface the same attraction pulls the molecules together into a thin skin, the surface tension that can support a light insect.

Examiner's Note

The answer must reach the biology: the unbroken column drawn up the plant, and the surface skin that holds up the insect. Stating only that water molecules cohere, with neither consequence, does not score.

Question 3

The enzymes inside a cell work properly only within a narrow range of temperature, yet the air around a lake can warm and cool sharply between day and night. Explain how a property of water keeps both the lake and the cells of the organisms living in it at a far steadier temperature.

Model Answer

Water has a high specific heat capacity, which means a large amount of heat must be taken in or given out to change its temperature. This is because much of the heat goes into weakening or re-forming its many hydrogen bonds rather than into making the molecules move faster. **A cell is mostly water, so it warms and cools only slowly, and its enzymes stay within the range in which they can work.** A large body of water such as a lake changes temperature slowly for the same reason, giving the organisms living in it a stable home.

Examiner's Note

Tie the property to the benefit. The high specific heat capacity earns the first mark; keeping enzymes, or the life in the lake, within a safe temperature earns the second.

False Confidence Alert

Do not confuse this property with latent heat of vapourisation. Specific heat capacity is about warming the liquid water itself; latent heat of vapourisation is about the heat taken in when water turns to vapour. They answer different questions.

Question 4

When a person works hard in the heat they sweat, and a plant in strong sunshine loses water vapour from its leaves. Explain how the loss of this water cools the body or the leaf, and why water is especially good at carrying heat away in this manner.

Model Answer

Water has a high latent heat of vapourisation, so a large amount of heat is absorbed whenever it evaporates. This is because many hydrogen bonds must be broken before a molecule can leave the liquid and escape as vapour, and the heat needed to do this is drawn from the surface left behind. **As sweat evaporates from the skin, or water evaporates from a leaf, it carries this heat away and so cools the body or the plant.** Because so much heat leaves with only a little water, evaporation is an efficient way for a living thing to avoid overheating.

Language Clinic

Name the property and its effect in one line: water has a high latent heat of vapourisation, so its evaporation removes much heat and cools the surface. The phrase removes much heat is what links the property to the cooling.

Question 5

In a cold region a lake may freeze over at the surface, yet fish and other organisms go on living in the water below. Explain how the behaviour of water as it cools allows life to survive there.

Model Answer

As water cools it grows denser and sinks, but below about 4 degrees Celsius it expands again, so the coldest water and the ice that forms float at the surface. Ice is therefore less dense than the liquid water beneath it. **This floating layer of ice insulates the water below, which stays liquid, so fish, plants and**

other organisms can go on living in it. If ice instead sank, the lake would freeze solid from the bottom upward and far less life would survive the cold season.

Examiner's Note

The benefit must be stated: the floating ice insulates the water below, which stays liquid so life survives. Saying only that ice floats leaves the biology unexplained.

Question 6

Besides being the medium of the cell, water takes part directly in its chemical reactions. Using digestion and photosynthesis as your examples, explain how living things use water as a raw material, and name one process in which water is instead produced.

Model Answer

In digestion, water is used up in hydrolysis, in which a water molecule is added to split a large molecule into smaller ones, as when starch is broken down into sugars the body can absorb. In photosynthesis, water is split to release oxygen, and the hydrogen it provides is used to reduce carbon dioxide to glucose. Water is therefore a raw material of life, not merely the background medium. It is produced again in condensation reactions, such as the joining of sugar units into starch, and during respiration, when hydrogen finally combines with oxygen. So living things both use and make water as they carry out their chemistry.

Examiner's Note

Name the type of reaction, hydrolysis or condensation, give a clear biological example, and make plain whether water is used up or made. A list of reactions without this does not score.

Language Clinic

Keep the direction explicit: in hydrolysis water is added to split a molecule, and in condensation water is removed as molecules join. The contrast, added against removed, is what makes the answer precise.

Question 7

A maize grain is packed with starch for energy, while the stalk that holds the maize plant upright is built largely of cellulose. Both are carbohydrates. Explain why carbohydrates are well suited both to supplying energy and to building supporting structures.

Model Answer

Carbohydrates are made of carbon, hydrogen and oxygen, and the bonds within their sugar units hold the energy a cell releases in respiration. A single sugar such as glucose is small and soluble, so it is easily moved about and quickly broken down to power the cell, and many such sugars can be joined into a compact store such as starch. **The very same sugar units can instead be joined into long, straight chains that lie side by side and bond together into tough fibres, as in cellulose.** These fibres are strong and not easily broken down, so they build the plant cell wall and hold the plant up. In this way one family of molecules both fuels life and gives it form.

Examiner's Note

The marks come from linking structure to job: the energy held in the sugar units and the small soluble sugar for fuel, set against the long bonded fibres for support. Naming starch and cellulose without this contrast does not score.

Question 8

Monosaccharides are grouped by the number of carbon atoms they contain. Explain the biological importance of a three-carbon, a five-carbon and a six-carbon sugar, giving an example of each.

Model Answer

A three-carbon sugar (triose), such as glyceraldehyde, is an intermediate formed as larger sugars are broken down in respiration and built up in photosynthesis. It is a stepping-stone in the cell's chemistry rather than a store.

A five-carbon sugar (pentose), such as ribose and deoxyribose, builds the backbone of the nucleic acids RNA and DNA, the molecules that carry the cell's genetic information.

A six-carbon sugar (hexose), such as glucose, fructose and galactose, is the cell's main energy sugar, broken down in respiration to release energy. So the size of a monosaccharide is tied closely to the job it does.

Examiner's Note

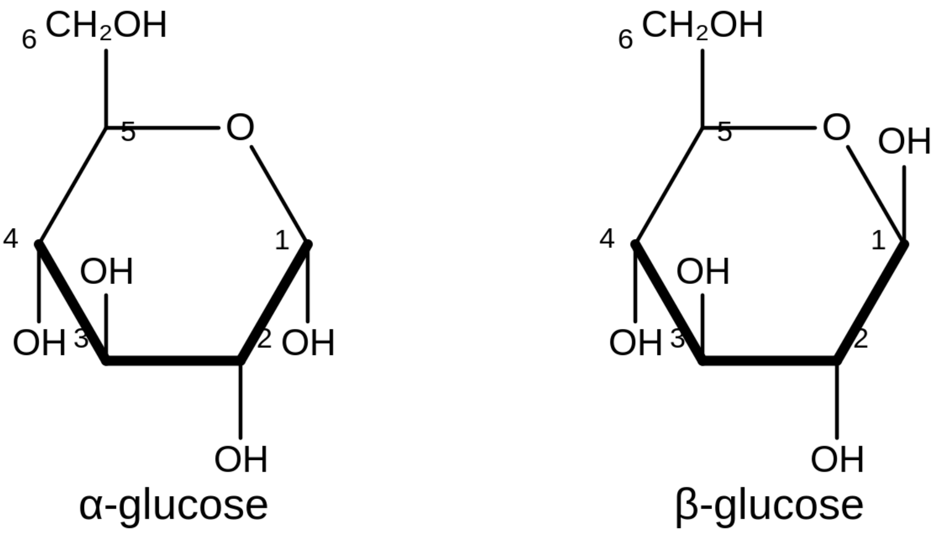
Each sugar must be tied to a use and an example: triose to respiration and photosynthesis, pentose to the nucleic acids, hexose to energy. A list of carbon numbers alone earns little.

Question 9

Living things build both their main food store and their main structural fibre from glucose, and which one they build turns on a tiny difference in the glucose ring. Draw the two ring forms of glucose, α and β, and show exactly where they differ.

Model Answer

Glucose closes into a six-sided ring, and that ring can form in two ways, called α-glucose and β-glucose.



The two are identical except at carbon 1, the carbon joined to the ring oxygen: its hydroxyl group points below the ring in α-glucose and above the ring in β-glucose. This single difference in the position of one hydroxyl group is all that separates them, yet it decides how the sugar units can be linked, and so whether they build a store or a structure.

Examiner's Note

The whole mark for the difference rests on carbon 1: show its hydroxyl group below the ring in α-glucose and above the ring in β-glucose. Drawing the two rings identically throws the mark away.

False Confidence Alert

It is easy to treat α and β glucose as two different sugars. They are the same sugar, glucose; only the position of the carbon-1 hydroxyl group differs.

Question 10

Starch and cellulose are both made only of glucose, yet a plant uses starch as its food store and cellulose to build its cell walls. Explain how the difference between α-glucose and β-glucose leads to this difference in job.

Model Answer

Starch is built from α-glucose, whose chains coil into a helix, as in amylose, or carry branches, as in amylopectin. This makes a compact store that is easily broken down to release glucose, and because starch is insoluble it neither dissolves away nor draws water into the cell by osmosis. **Cellulose is built from β-glucose, and for the units to join, every second glucose is turned over, so the chains come out straight rather than coiled.** Many straight chains then lie side by side and are held together by hydrogen bonds into strong fibres, which build the cell wall and resist digestion. So the same glucose gives a food store when it is α and a structural fibre when it is β.

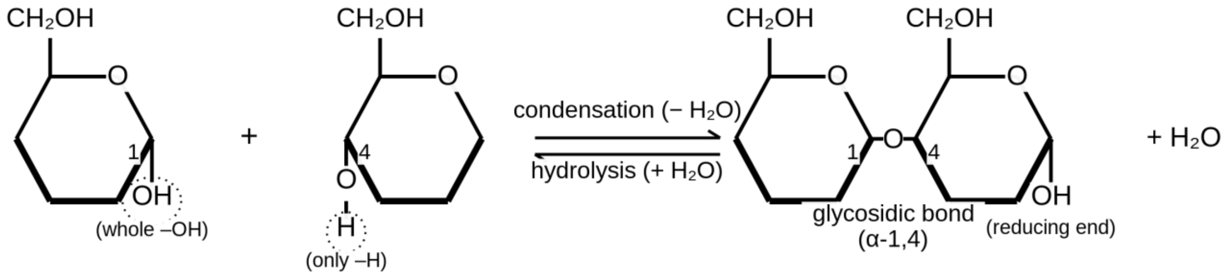
> **False Confidence Alert**
>
> A common claim is that starch and cellulose differ because one comes from plants and the other from animals. Both are made by plants. The real difference is α-glucose against β-glucose.

Question 11

When a maize plant breaks into its starch store, the first double sugar released is maltose, two glucose units joined together. Draw how two glucose molecules join to form maltose, name the bond formed and the molecule removed, and name the reverse reaction the body uses to digest it.

Model Answer

Two glucose molecules join by condensation: the hydroxyl group on carbon 1 of one glucose reacts with the hydroxyl group on carbon 4 of the next, a water molecule is removed, and a glycosidic bond forms between them.



The double sugar formed is maltose, and the link is an α-1,4 glycosidic bond because it joins carbon 1 to carbon 4. **The reverse reaction is hydrolysis, in which a water molecule is added back to break the glycosidic bond and free the two glucose units,** and this is exactly what happens when maltose is digested in the gut.

> **Examiner's Note**
>
> Credit depends on showing the reacting groups: the hydroxyl on carbon 1 of one glucose and on carbon 4 of the other, the water removed, and the new glycosidic bond. Leaving out the water loses the mark.

> **Language Clinic**
>
> State the reaction both ways in one breath: condensation joins the sugars and removes water; hydrolysis adds water and splits them. Naming the direction is what the examiner rewards.

Question 12

The starch in a plate of ugali is far too large to pass into the blood, yet after digestion the same meal supplies the body with glucose. Explain, in terms of hydrolysis, how digestion makes this possible.

Model Answer

Digestion breaks the large carbohydrate down by hydrolysis, adding a water molecule across each glycosidic bond to split the chain into its sugar units. Starch is a polymer of many glucose units joined by glycosidic bonds, and these bonds are broken as water is added, giving first smaller chains and maltose and finally single glucose molecules. **Glucose is small and soluble, so it can be absorbed through the gut wall into the blood and carried to the cells, where it is respired to release energy.** Hydrolysis therefore turns an insoluble store into a usable fuel.

Examiner's Note

The answer must name hydrolysis and say that water is added to break the bonds, then that the small, soluble glucose can be absorbed. Saying only that starch is broken down is not enough.

Language Clinic

Keep digestion in causal order: the bonds are hydrolysed, so glucose is freed, so it is absorbed, so it can be respired. Each step should lead into the next.

Question 13

Sugarcane juice is full of sucrose, yet a Benedict's test on it stays blue, while the same test on glucose turns brick-red. Explain why sucrose gives no positive result until it has been hydrolysed.

Model Answer

A sugar gives a positive Benedict's result only if it has a free reducing group, the reactive group that reduces the blue copper(II) in the reagent to a brick-red precipitate. In glucose and the other reducing sugars this group is free and available. **In sucrose, however, the reactive groups of its glucose and fructose units are both tied up in the glycosidic bond that joins them, so neither is free to react and the reagent stays blue.** If the sucrose is first hydrolysed with acid, the bond is broken and the glucose and fructose are released, freeing their reducing groups so that Benedict's then gives a brick-red result.

False Confidence Alert

Sucrose is often called a reducing sugar. It is not: the reactive groups of its two units are locked in the glycosidic bond, so it gives no result with Benedict's until it has been hydrolysed.

Question 14

Starch, glycogen and cellulose are all polymers of glucose, yet a plant stores starch, an animal stores glycogen, and a plant builds cellulose into its walls. Explain how the structure of each suits the job it does.

Model Answer

Starch is the store of glucose in plants, built from α-glucose as a coiled helix (amylose) and branched chains (amylopectin). It is compact and, being insoluble, neither dissolves away nor draws water in by osmosis, so it stores energy safely until the plant needs it.

Glycogen is the store of glucose in animals, built from α-glucose chains even more branched than starch. Its many branch ends can be broken off quickly, so glucose is released rapidly when a muscle or the liver needs energy.

Cellulose is a structural material in plants, built from straight chains of β-glucose held side by side by hydrogen bonds into strong fibres. These fibres give the cell wall great strength and resist being pulled apart, so they support the plant.

Examiner's Note

For each polysaccharide the structure must be turned into the job: coiled and insoluble for safe storage, highly branched for fast release, straight and hydrogen-bonded for strength. Describing the structure alone is half the answer.

Question 15

Fat stored in a cell, or carried in the blood, does not mix with the watery fluid around it but gathers into separate droplets. Explain, from the structure of a lipid, why it behaves in this way.

Model Answer

A lipid does not mix with water because its molecules are non-polar, carrying no charged regions for water to attract. Water molecules are polar and cling tightly to one another, so a non-polar lipid is shut out of this network and left undissolved. **As a result, the lipid molecules are driven together into separate droplets, which in turn keeps their contact with the surrounding water to a minimum.** A lipid does, however, dissolve readily in organic solvents such as ether and chloroform, because these are non-polar and therefore mix freely with it. This is why fat is stored and carried as droplets rather than in true solution.

Examiner's Note

The mark is for the cause and its result together: a non-polar molecule, shut out of the water, and therefore gathered into droplets. Stating that lipids do not dissolve, with no reason, does not score.

Language Clinic

Notice how each step pulls the next along: non-polar, so shut out of the water network, as a result driven into droplets. The small words so and as a result are the causal glue the examiner looks for.

Question 16

When a triglyceride is digested it yields glycerol and fatty acids, whereas starch yields a long string of identical glucose units. Explain why a lipid is not classed as a polymer, even though it is a large molecule.

Model Answer

A lipid is not a polymer because it is not built from many identical units repeated in a long chain. A polymer such as starch is made when the same monomer, glucose, is joined again and again, so its hydrolysis releases a long string of identical units. **A triglyceride, by contrast, is assembled from only two kinds of molecule, one glycerol and three fatty acids, held together by ester bonds.** Because there is no repeating monomer, the molecule does not grow as a chain, and consequently its hydrolysis yields just glycerol and fatty acids rather than a row of like units. Its large size comes from the length of its fatty-acid tails, not from repetition.

False Confidence Alert

A lipid is often called a polymer because it is large. It is not: a polymer is a chain of many repeating monomers, while a triglyceride is only one glycerol and three fatty acids.

Examiner's Note

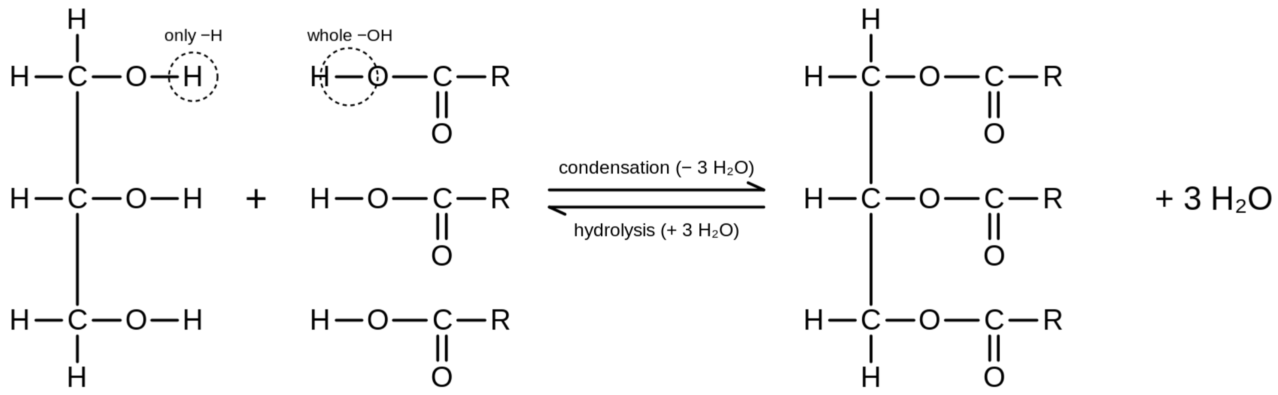
Earn the mark by naming what a polymer is, then showing the lipid lacks it: no repeating monomer and no chain. Size by itself does not make a polymer.

Question 17

Body fat and the oil stored in a seed are both triglycerides, formed when glycerol joins with fatty acids. Draw how a fatty acid joins to glycerol, name the bond formed and the molecule removed, and state how many such bonds make one triglyceride.

Model Answer

A fatty acid joins to glycerol by condensation: the hydroxyl group of the glycerol reacts with the carboxyl group of the fatty acid, a molecule of water is removed, and an ester bond forms between them.



Because glycerol carries three hydroxyl groups, three fatty acids can join to it in this way, so three ester bonds form and three molecules of water are removed, which in turn gives one triglyceride. The reaction is reversed by hydrolysis, whereby water is added back to break each ester bond, and this is exactly what happens when fat is digested.

Examiner's Note

Show the two reacting groups, the hydroxyl of glycerol and the carboxyl of the fatty acid, then the water removed and the ester bond formed. Leaving out the water, or the bond, loses the mark.

Language Clinic

Tie the bond to its direction in one breath: condensation forms the ester bond and removes water, whereas hydrolysis adds water and breaks it. Naming the direction is what earns the mark.

Question 18

Animals and plants store much of their long-term energy as fat rather than as carbohydrate. Explain why a triglyceride is well suited to be a long-term energy store.

Model Answer

A triglyceride suits long-term storage for three connected reasons:

1) **It is rich in energy, because its fatty-acid tails hold many carbon-hydrogen bonds and very little oxygen.** When these bonds are oxidised in respiration they release more than twice as much energy per gram as a carbohydrate does, so a small mass of fat stores a large amount of energy.
2) **It is insoluble in water, so it can be stored in bulk without dissolving in the cytoplasm.** Because it stays out of solution, it draws no water into the cell by osmosis, whereas the same mass of soluble sugar would.
3) **It is compact and light, which in turn matters most where weight is costly,** as in a seed that must be dispersed or an animal that must migrate.

False Confidence Alert

It is tempting to say fat gives energy faster than sugar. The opposite is true: fat stores more energy per gram, but the cell releases it more slowly, which is why glucose, not fat, is the body's quick fuel.

Examiner's Note

The high energy value must be explained, not merely stated: many carbon-hydrogen bonds and little oxygen, so oxidation releases more energy per gram than a carbohydrate.

Question 19

Unlike a triglyceride, a phospholipid has one end that mixes with water and one that does not. Explain why a phospholipid is described as amphipathic, and how this fits it to build the cell membrane.

Model Answer

A phospholipid is amphipathic because one end of it mixes with water while the other does not. In place of one of its three fatty acids, it carries a phosphate group. This phosphate is polar, so it mixes with water and forms a hydrophilic head. The two fatty-acid tails are non-polar, so they are hydrophobic and turn away from water. **When phospholipids are surrounded by water, they arrange themselves into a double layer.** The water-loving heads face outward into the water, while the water-hating tails tuck together inside, away from it. This bilayer forms the basic sheet of every cell membrane, which is why the phospholipid is the membrane's building block.

Examiner's Note

The marks lie in the two ends and what they build: a polar phosphate head that mixes with water, two non-polar tails that do not, and the bilayer that follows. Naming amphipathic without the bilayer is half the answer.

False Confidence Alert

A phospholipid is often drawn with three fatty-acid tails like a triglyceride. It has only two; a phosphate group takes the third place, and that is exactly what makes it amphipathic.

Question 20

Lipids are a varied group, and they can be sorted by what their molecules are made of. Classify lipids by composition into three groups, giving one example of each and where it is found in living things.

Model Answer

By composition, lipids fall into three groups:

1) ***Simple lipids* are esters of fatty acids with an alcohol.** They include the triglycerides stored in body fat and in seeds, and the waxes that waterproof a leaf surface or an insect's cuticle.

2) ***Compound lipids* contain a further group as well as fatty acids and alcohol.** The chief examples are the phospholipids that build cell membranes, in which an added phosphate group makes the molecule amphipathic.

3) ***Derived lipids* are formed from the others by breakdown or change.** The main examples are the steroids such as cholesterol, which the body uses to strengthen its membranes and to build certain hormones.

Examiner's Note

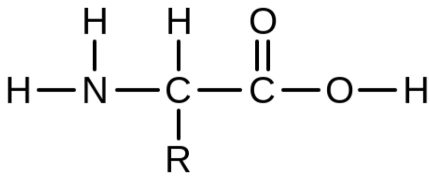
Sort by composition, not by use: simple, compound and derived, each with a named example. Listing fats, oils and waxes without the three-group framework does not answer the question.

Question 21

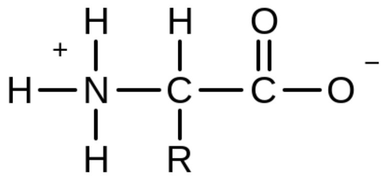
A cell builds thousands of different proteins, each with its own job, yet all are made from the same kind of building block. Explain how a single type of monomer can give rise to such variety.

Model Answer

Every amino acid is built on the same plan: a central carbon joined to an amino group, a carboxyl group, a hydrogen atom, and a variable side group called the R group.



amino acid



zwitterion

It is the R group that differs from one amino acid to the next, and because there are about twenty different R groups, there are twenty kinds of amino acid. These twenty can be joined in any order and in chains of any length, so the number of possible sequences is almost endless, and each sequence folds into its own protein with its own job. This is why one simple kind of building block can give rise to thousands of different proteins.

Examiner's Note

Name all four parts of the amino acid, then say that only the R group varies. The mark for diversity rests on the R group and on the order in which the amino acids are joined.

Question 22

The pH of blood and of the cell must be held steady for enzymes to work, and proteins help to do this. Explain how the structure of an amino acid lets it act as both an acid and a base.

Model Answer

An amino acid can act as both an acid and a base because it carries two groups of opposite character: an acidic carboxyl group and a basic amino group. The carboxyl group can give away a hydrogen ion, behaving as an acid, while the amino group can take up a hydrogen ion, behaving as a base; the form carrying both a positive and a negative charge at once is called a zwitterion. **Because it can both release and mop up hydrogen ions, an amino acid resists changes in pH, and so do the proteins built from many of them.** When acid is added the amino groups absorb the extra hydrogen ions, and when alkali is added the carboxyl groups release hydrogen ions to replace those lost, so the pH is held steady. This buffering keeps the blood and the cell at the steady pH that enzymes need.

Examiner's Note

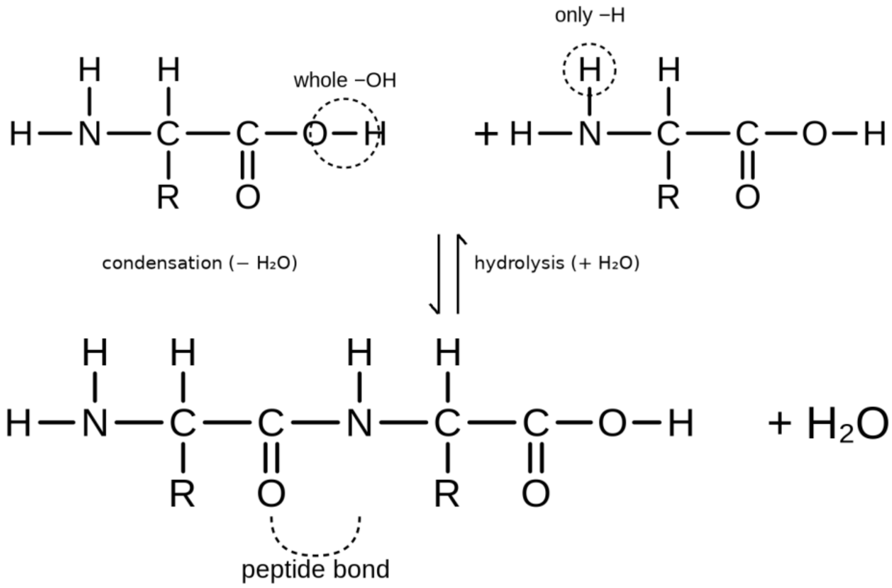
Credit needs both groups and what each does: the carboxyl releasing a hydrogen ion as an acid, the amino group accepting one as a base, and the steadying of pH that follows.

Question 23

Proteins are built by joining amino acids together in long chains. Draw how two amino acids join, name the bond formed and the molecule removed, and name the reverse reaction that digests a protein.

Model Answer

Two amino acids join by condensation: the carboxyl group of one reacts with the amino group of the next, a molecule of water is removed, and a peptide bond forms between them.



The two joined amino acids make a dipeptide, and as more are added in the same way a long polypeptide chain is built. **The reaction is reversed by hydrolysis, in which water is added back to break each peptide bond, which is exactly what happens when a protein is digested into its amino acids.**

Examiner's Note

Show the carboxyl of one amino acid and the amino group of the next reacting, then the water removed and the peptide bond formed. Leaving out the water loses the mark.

Language Clinic

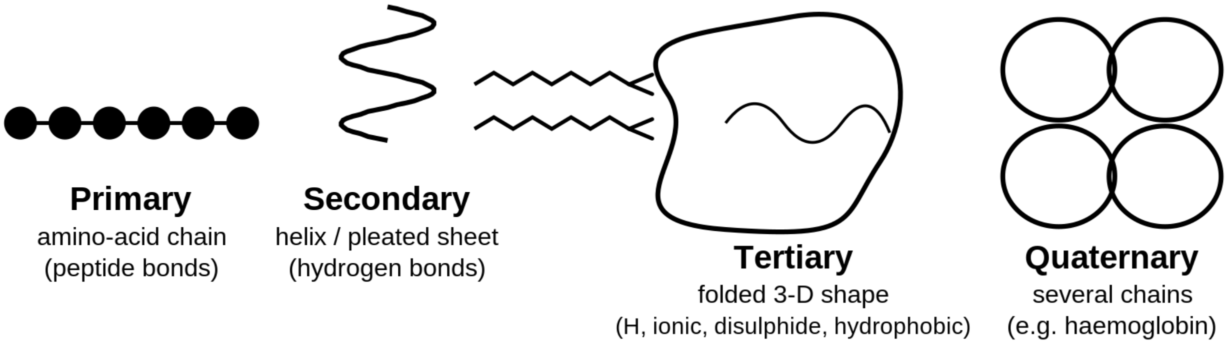
Tie the bond to its direction: condensation forms the peptide bond and removes water, whereas hydrolysis adds water and breaks it. Naming the direction earns the mark.

Question 24

A protein must fold into a precise shape to do its job. Name the four levels of protein structure and the main bond that holds each in place.

Model Answer

A protein is organised at four levels, each held by its own bonds:



1) ***The primary structure* is the sequence of amino acids, joined by peptide bonds.** This sequence is set by the gene, and it determines every level of folding that follows.
2) ***The secondary structure* is the coiling into an α-helix or folding into a β-pleated sheet, held by hydrogen bonds.** These bonds form between regularly spaced groups along the backbone of the chain.
3) ***The tertiary structure* is the further folding of the whole chain into a precise three-dimensional shape, held by hydrogen, ionic, disulphide and hydrophobic bonds.** This shape gives the protein its function, such as the active site of an enzyme.
4) ***The quaternary structure* is the joining of two or more folded chains into one protein, held by the same kinds of bond.** Haemoglobin, with its four chains, is the standard example.

Examiner's Note

Each level must be paired with its bond: peptide for primary, hydrogen for secondary, the four bonds for tertiary, and the same again for quaternary. Naming the levels without their bonds is half the answer.

False Confidence Alert

The primary structure is often confused with the gene. The gene carries the instructions; the primary structure is the chain of amino acids those instructions build.

Question 25

Within a protein, the chain often coils into a helix or folds into a sheet before it takes its final shape. Explain what holds these secondary structures in place, and why this bonding works even though each bond is weak.

Model Answer

The secondary structure is held in place by hydrogen bonds that form between the C=O group of one amino acid and the N-H group of another further along the chain. Because these groups are spaced regularly along the backbone, the bonds form at regular intervals, which pulls the chain into the orderly coil of an α-helix or the orderly folds of a β-pleated sheet. **Each hydrogen bond is weak on its own, but because so many form along the length of the chain, together they hold the shape firmly.** This is the same lesson as in water: many weak bonds, acting together, make a strong and stable structure.

Language Clinic

Notice the link back to water: many weak bonds, acting together, make a strong whole. Reusing because so many form... together they hold shows the examiner understanding, not memorising.

Question 26

Some proteins, like collagen, give strength and support, while others, like enzymes and haemoglobin, carry out reactions and transport. Contrast a fibrous protein with a globular protein, relating each to the job it does.

Model Answer

A fibrous protein is long, narrow and insoluble and serves a structural role, whereas a globular protein is rounded, soluble and serves a working role. A fibrous protein, such as collagen in skin and tendon or keratin in hair, is built from chains lying parallel and held side by side, which makes it tough and steady, so it gives strength and support. **A globular protein, such as an enzyme, an antibody or haemoglobin, is built from a single chain folded into a compact ball with a surface that dissolves in water,** so it can move about and take part in the chemistry of the cell. In short, the fibrous protein helps to build the body while the globular protein helps to run it.

> **Examiner's Note**
>
> Earn the marks by turning each structure into its job: parallel insoluble chains for support, a folded soluble ball for chemical work. A list of features without the roles does not score.

Question 27

Enzymes, antibodies and haemoglobin are all globular proteins. Give five features of a globular protein.

Model Answer

A globular protein has these features:

1) **It is roughly spherical, because its chain folds into a compact, rounded ball.**
2) **It is soluble in water, because its hydrophilic R groups face outward** while its hydrophobic R groups are tucked inside, away from the water.
3) **It has a precise three-dimensional shape, set by its tertiary folding,** which gives it a specific site such as the active site of an enzyme.
4) **It is chemically active rather than structural,** working as an enzyme, an antibody, a hormone or a carrier such as haemoglobin.
5) **It is sensitive to heat and pH, because the weak bonds holding its shape are easily broken,** so it denatures more readily than a fibrous protein.

> **Examiner's Note**
>
> Each feature should carry its reason: spherical because the chain folds compactly, soluble because the hydrophilic groups face outward. Bare adjectives earn less than features explained.

Question 28

When an egg is fried or a person runs a high fever, proteins are changed in a way that cannot be undone, yet their chains are not broken into pieces. Explain what happens to a protein during denaturation and why it loses its function.

Model Answer

During denaturation the weak bonds that hold a protein's shape are broken, so the chain unfolds and loses its precise three-dimensional structure. Heat and extremes of pH give the atoms enough energy to break the hydrogen and ionic bonds that hold the secondary and tertiary structure, whereupon the folded chain falls open. **Because the function depends on the exact shape, the protein can no longer do its job once that shape is lost,** which is why a boiled egg sets firm and an enzyme stops working at a high temperature. The peptide bonds and the order of the amino acids, however, are not broken, so the primary structure survives even though the shape is gone.

False Confidence Alert

It is a common error to say denaturation breaks the protein into its amino acids. It does not: only the weak bonds holding the shape break, while the peptide bonds and the sequence survive.

Examiner's Note

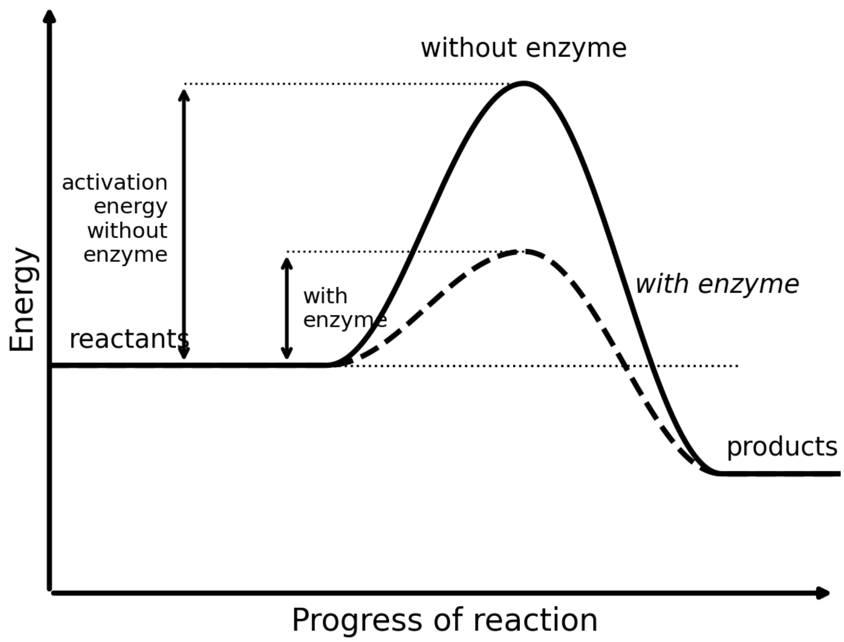
The answer must say the shape is lost, not the chain, and that the function goes with the shape. Saying only that the protein is destroyed does not score.

Question 29

Most reactions in a cell would happen far too slowly at body temperature to keep it alive, yet enzymes make them fast. Explain how an enzyme speeds up a reaction.

Model Answer

An enzyme speeds up a reaction by lowering its activation energy, the energy barrier that the reacting molecules must overcome before they can react.



It does this by bringing the reactants together on its active site and holding them so that reaction becomes easier, which provides an alternative route with a lower barrier. Because the barrier is lower, a far greater fraction of the molecules have enough energy to react at the cell's own temperature, and consequently the reaction proceeds many times faster than it would without the enzyme.

Examiner's Note

The mark is for lowering the activation energy and what follows: a lower barrier lets more molecules react at body temperature, so the rate rises. Saying only that the enzyme speeds the reaction earns little.

Question 30

A cell needs only a tiny amount of an enzyme to convert a large amount of substrate. Explain why so little enzyme is needed, and correct the idea that an enzyme supplies the energy for the reaction.

Model Answer

So little enzyme is needed because an enzyme is a catalyst: it is not used up in the reaction. After it has converted one substrate molecule into product, the enzyme is released unchanged and is free to bind another, so a single molecule can be used over and over and can deal with a great many substrate molecules. **An enzyme does not supply the energy for the reaction, either; it only lowers the activation energy.** The energy released or taken in belongs to the reaction itself, whereby the enzyme simply makes that reaction easier to start. This is why a trace of enzyme can keep a whole process running.

> **False Confidence Alert**
>
> Two errors are common: that the enzyme is used up, and that it gives the reaction its energy. Neither is true; the enzyme is released unchanged and only lowers the activation energy.

Question 31

Amylase breaks down starch but has no effect on protein, while pepsin does the opposite. Explain why each enzyme acts only on its own substrate.

Model Answer

Each enzyme acts only on its own substrate because it has an active site with a particular shape, formed by the way its protein chain folds in its tertiary structure. Only a substrate whose shape is complementary to the active site can fit into it and form an enzyme-substrate complex, so only that substrate is converted to product. **A molecule of a different shape cannot fit the active site, and consequently the enzyme has no effect on it.** This is why amylase, whose active site fits starch, breaks down starch but leaves protein untouched, while pepsin, with a different active site, does the reverse.

Examiner's Note

Credit depends on the active site's shape and where it comes from, the tertiary fold, and on the complementary substrate fitting it. Saying the enzyme is specific, without the shape, does not score.

Question 32

When an enzyme acts on its substrate, the two come together, react, and part again. Describe, in order, the steps by which an enzyme converts its substrate into product.

Model Answer

The substrate first binds to the active site of the enzyme, forming an enzyme-substrate complex. Held in the active site, the substrate is strained or brought together in a way that lowers the activation energy, so it is readily converted into product. **The product, having a different shape, no longer fits the active site and leaves it, whereupon the enzyme is free to bind another substrate molecule.** The whole sequence is written $E + S \rightarrow ES \rightarrow E + P$.

Examiner's Note

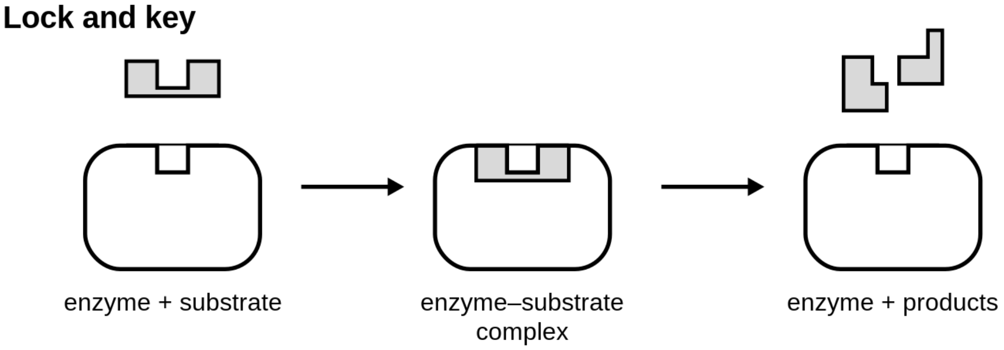
Set out the steps in order: substrate binds, complex forms, product forms, product leaves, enzyme is reused. The line $E + S \rightarrow ES \rightarrow E + P$ captures it.

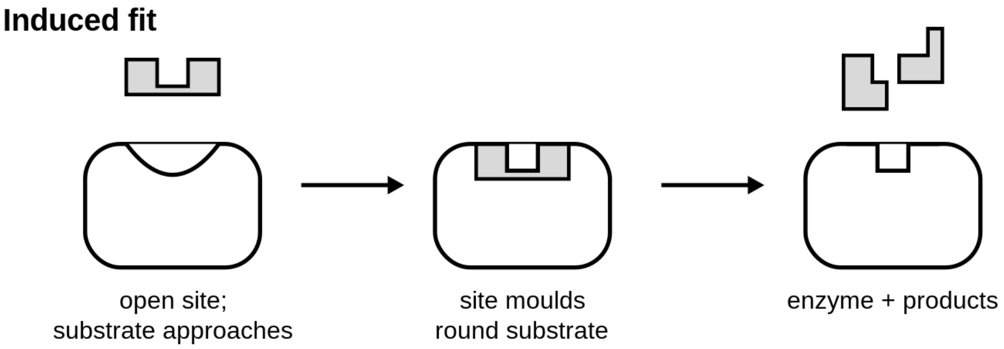
Question 33

Two models have been used to picture how a substrate fits an enzyme's active site. Compare the lock-and-key model with the induced-fit model, and say which better explains an enzyme that acts on several similar substrates.

Model Answer

Both models picture how a substrate fits the active site, but they differ in whether that site is rigid or flexible.





In the lock-and-key model the active site is a fixed, exactly complementary shape, so the substrate fits it as a key fits a lock. In the induced-fit model the active site is not rigid; as the substrate binds, the site moulds slightly to fit closely around it. Induced fit better explains an enzyme that acts on several similar substrates, because a flexible site can adjust to each of them, whereas a rigid site could not.

Examiner's Note

The marks lie in the contrast: a rigid complementary site for lock-and-key, a flexible moulding site for induced fit, and induced fit explaining enzymes that take several substrates.

Language Clinic

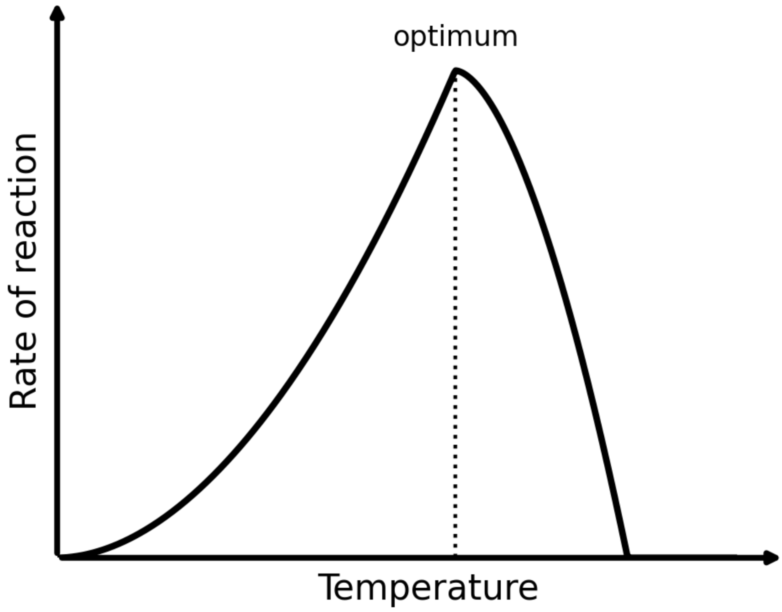
Build the comparison with a turning word: the site is rigid in lock-and-key, whereas in induced fit it moulds round the substrate. The word whereas signals the contrast the examiner wants.

Question 34

An enzyme works fastest at a particular temperature, and a high fever can be dangerous because of what heat does to enzymes. Sketch and explain how temperature affects the rate of an enzyme-controlled reaction.

Model Answer

As temperature rises, the enzyme and substrate molecules gain kinetic energy and collide more often, so the rate increases up to an optimum, which for many human enzymes is near body temperature.



Above the optimum the rate falls sharply, because the heat now breaks the weak bonds that hold the enzyme's shape, so the enzyme denatures and its active site is lost. Once the active site is destroyed the substrate can no longer bind, and consequently the reaction stops. This is why a high fever, which overheats the body's enzymes, is dangerous.

Examiner's Note

Two halves earn the marks: the rate rising with kinetic energy to the optimum, then falling sharply as the enzyme denatures and the active site is lost. Draw the fall steeper than the rise.

False Confidence Alert

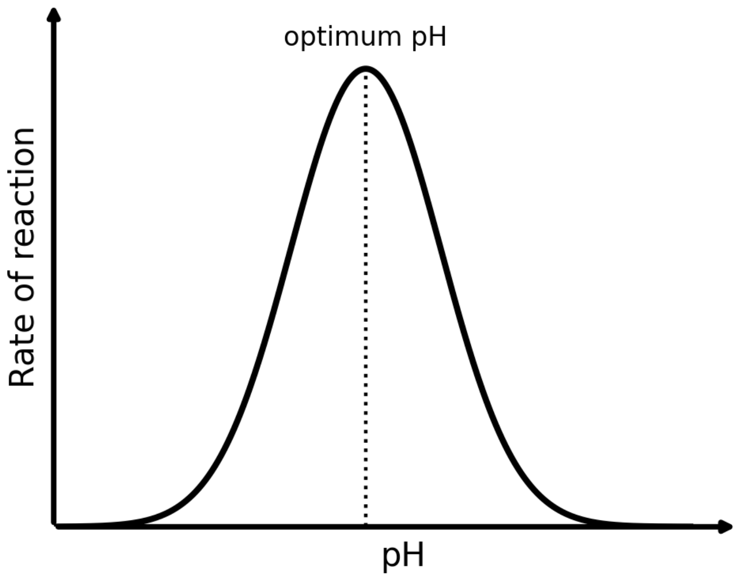
The temperature curve is not a symmetrical bell like the pH curve. It rises to the optimum and then drops sharply, because denaturation, once it begins, destroys the enzyme's shape quickly.

Question 35

Pepsin works best in the acidic stomach, while the enzymes of the small intestine work best in alkaline conditions. Sketch and explain how pH affects the rate of an enzyme-controlled reaction.

Model Answer

Each enzyme works fastest at a particular optimum pH, at which its active site has exactly the right shape and charge to bind the substrate.



As the pH moves away from the optimum on either side, the rate falls, because the change in hydrogen-ion concentration begins to alter the charges and bonds that hold the active site in shape. At an extreme pH these bonds are broken, so the enzyme denatures and the active site is lost. This is why pepsin works in the acid of the stomach while the enzymes of the small intestine need alkaline conditions.

Examiner's Note

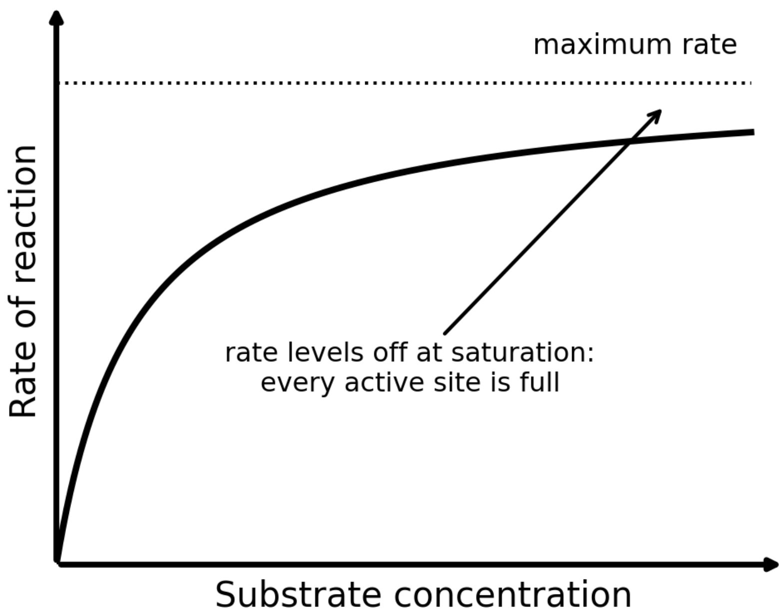
Name the optimum pH and the loss of shape at the extremes. The marks are for the active site's shape and charge changing, then denaturing, not merely for the enzyme slowing down.

Question 36

As more substrate is supplied to a fixed amount of enzyme, the reaction speeds up at first but then levels off. Sketch and explain how substrate concentration affects the rate.

Model Answer

At low substrate concentration many active sites are empty, so adding more substrate gives more collisions and the rate rises in proportion.



As the substrate concentration goes on rising, more and more active sites become occupied, until at saturation every active site is working as fast as it can. **Beyond this point adding more substrate makes no difference, so the rate levels off, because the fixed number of enzyme molecules has now become the limiting factor.**

Examiner's Note
Explain both parts: the rise while active sites are free, and the plateau at saturation when every active site is full and the number of enzyme molecules limits the rate.

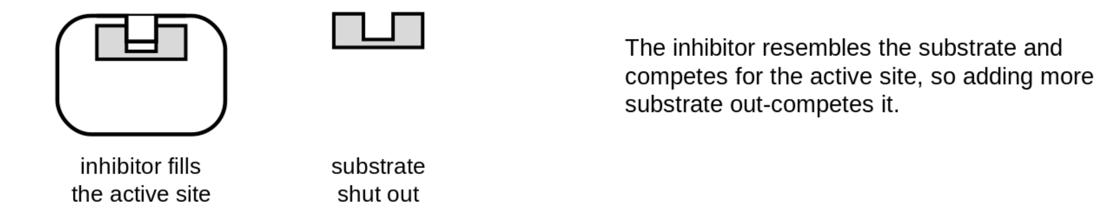
Question 37

Some substances slow an enzyme by blocking its active site, others by changing the site's shape from elsewhere. Explain the difference between competitive and non-competitive inhibition, and why adding more substrate overcomes one but not the other.

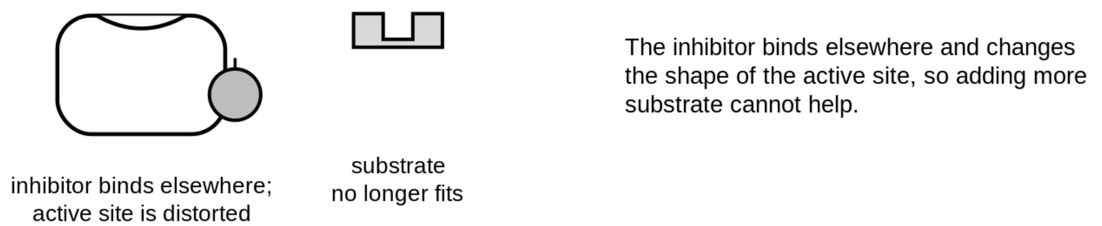
Model Answer

A competitive inhibitor has a shape similar to the substrate, so it competes with the substrate for the active site and blocks it.

Competitive



Non-competitive



Because the inhibitor and the substrate compete for the same site, adding more substrate tips the competition back in the substrate's favour and the rate is restored. A non-competitive inhibitor instead binds at a different site and changes the shape of the active site, so the substrate can no longer fit. Here adding more substrate cannot help, because the active site itself has been altered, and no amount of substrate will fit a changed site.

False Confidence Alert
Only competitive inhibition is overcome by more substrate. Non-competitive is not, because the active site itself has changed shape, so flooding it with substrate cannot restore the fit.

Examiner's Note
Tie each inhibitor to its site and its effect: the competitor in the active site, beaten by more substrate; the non-competitor at another site, distorting the active site, not beaten by more substrate.

Question 38

Many enzymes cannot work alone but need a non-protein helper, some of which come from the vitamins in our diet. Distinguish a cofactor, a coenzyme and a prosthetic group, giving one example of each.

Model Answer

These non-protein helpers are of three kinds:

A cofactor is any non-protein substance that an enzyme needs in order to work, often a metal ion such as zinc or magnesium.

A coenzyme is an organic cofactor that binds only loosely and is often made from a vitamin, such as NAD, which is derived from a B vitamin.

A prosthetic group is a cofactor that is bound permanently and tightly to the enzyme, such as the haem group of some enzymes, or FAD.

Examiner's Note

The definitions must separate the three: any non-protein helper (cofactor), an organic loosely-bound one often from a vitamin (coenzyme), and a permanently bound one (prosthetic group), each with an example.

Question 39

Enzymes are grouped into six classes by the type of reaction they catalyse. Name the six classes and the reaction each carries out, giving an example where appropriate.

Model Answer

The six classes are:

1) **Oxidoreductases catalyse oxidation and reduction, transferring hydrogen or electrons,** as the dehydrogenases do in respiration.
2) **Transferases transfer a chemical group from one molecule to another,** as a transaminase moves an amino group.
3) **Hydrolases break a molecule by adding water,** as the digestive enzymes amylase, lipase and the proteases do.
4) **Lyases add or remove a group to form or break a double bond without using water,** as a decarboxylase removes carbon dioxide.
5) **Isomerases rearrange the atoms within a single molecule,** changing it into its isomer.
6) **Ligases join two molecules together using energy from ATP,** as DNA ligase joins lengths of DNA.

Examiner's Note

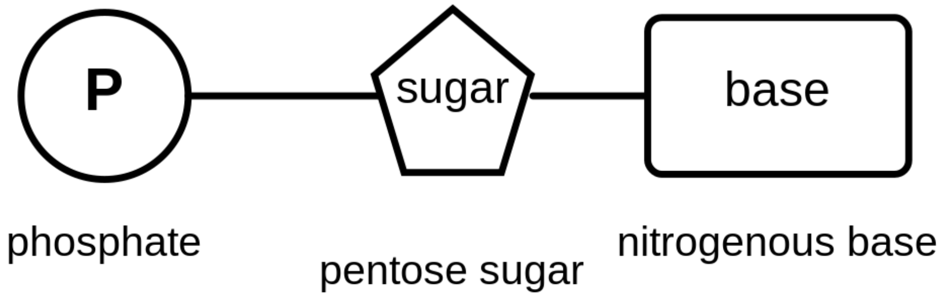
Each class needs its reaction type and, where you can, an example. Naming the six without saying what each does earns little.

Question 40

The cell uses the same kind of building block both to store its genetic information and to carry its energy. Explain how a single type of unit, the nucleotide, can serve such different purposes.

Model Answer

Every nucleotide is built from three parts: a pentose sugar, a phosphate group and a nitrogenous base.



Because the same three-part unit can be varied, it serves very different purposes: in DNA and RNA, many nucleotides are joined into long chains whose order of bases carries the cell's genetic information, while in ATP a single nucleotide carrying three phosphates acts as the cell's energy carrier. So one kind of building block underlies both the storage of information and the carrying of energy.

Examiner's Note

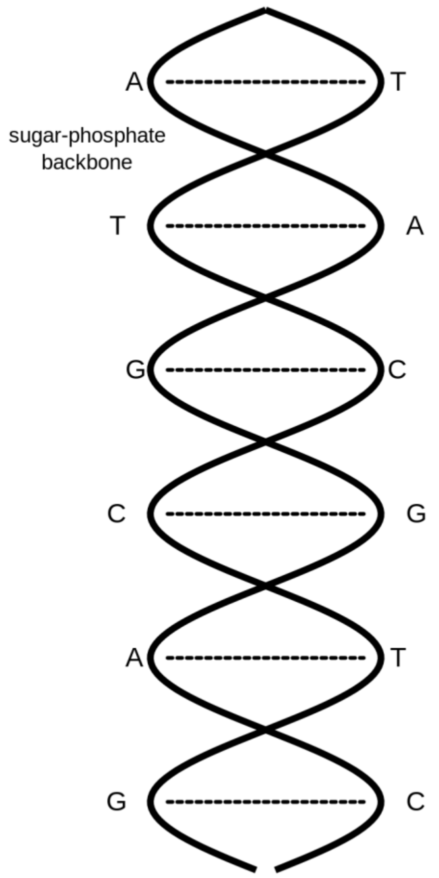
Name the three parts of a nucleotide, then show the same unit serving two jobs: many joined in a chain for information, one carrying three phosphates for energy.

Question 41

DNA must store the cell's information and be able to copy it exactly. Describe the structure of DNA and state the base-pairing rule.

Model Answer

DNA is made of two nucleotide strands wound around each other into a double helix.



two strands wound into a double helix

A pairs with T, G pairs with C (hydrogen bonds)

The sugar and phosphate groups form the two backbones on the outside, while the bases project inwards and pair up across the middle, held together by hydrogen bonds. The base-pairing rule is that adenine always pairs with thymine and guanine always pairs with cytosine, so the two strands are complementary, which is what allows the molecule to be copied exactly.

Examiner's Note

The marks lie in the double helix, the backbones outside and the paired bases inside, and the exact rule, A with T and G with C. Drawing a helix without the pairing rule is half the answer.

False Confidence Alert

A common slip is to pair the bases wrongly, such as adenine with guanine. The rule is fixed: adenine with thymine and guanine with cytosine, never across the wrong pair.

Question 42

One strand of a DNA molecule reads A-T-G-C-C-A. Write the sequence of the strand that pairs with it, and explain how the base-pairing rule makes the exact copying of DNA possible.

Model Answer

The strand that pairs with A-T-G-C-C-A is T-A-C-G-G-T. This follows from the base-pairing rule: adenine pairs with thymine, thymine with adenine, guanine with cytosine and cytosine with guanine, so each base on one strand fixes the base opposite it. **Because every base has only one partner, each strand carries all the information needed to rebuild the other, and consequently DNA can be copied exactly each time a cell divides.**

Examiner's Note

Write the partner of each base in turn, then explain why having one partner each makes exact copying possible. The complementary strand alone, without the reason, earns less.

Language Clinic

Chain the reasoning with the same link word: each base has one partner, so each strand fixes the other, so the molecule copies exactly. The repeated so is the causal thread.

Question 43

Both DNA and RNA are nucleic acids built from nucleotides, yet they differ in structure. Set out three ways in which RNA differs from DNA.

Model Answer

RNA differs from DNA in three main ways:

1) **RNA is a single strand,** whereas DNA is a double strand.

2) **RNA contains the sugar ribose,** whereas DNA contains deoxyribose.

3) **RNA has the base uracil** in place of the thymine found in DNA.

RNA also comes in three forms, messenger, transfer and ribosomal RNA, each with its own task in building proteins.

Examiner's Note

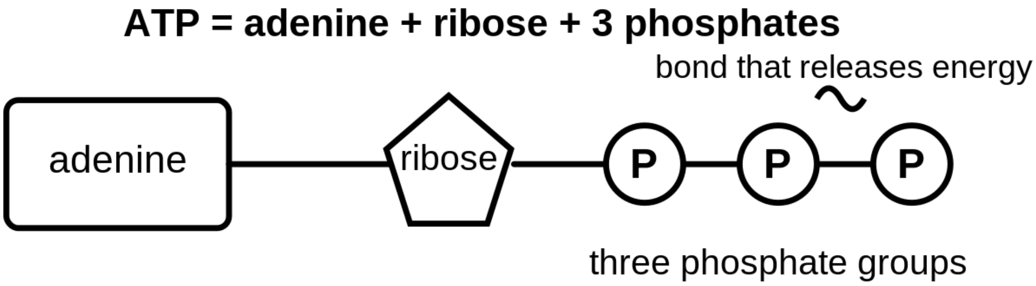
Three clear differences earn the marks: the number of strands, the sugar, and the base that replaces thymine. Vague answers such as 'they look different' do not score.

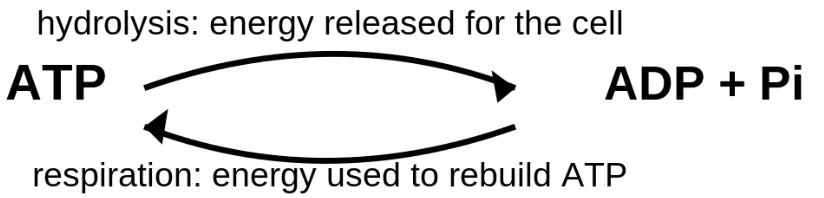
Question 44

ATP is the molecule that powers almost every energy-needing process in the cell. Draw the structure of ATP and explain how it releases and stores energy.

Model Answer

ATP, adenosine triphosphate, is a nucleotide made of the base adenine, the sugar ribose and three phosphate groups joined in a row.





Energy is released when the bond holding the third, outermost phosphate is broken by hydrolysis, leaving ADP (adenosine diphosphate) and a free phosphate (Pi). This released energy is used to drive the cell's work, and respiration then rejoins the phosphate to ADP to rebuild ATP, so the molecule is recharged and used over and over.

Examiner's Note

Credit needs the three parts (adenine, ribose, three phosphates), the energy released when the terminal phosphate bond is hydrolysed to ADP + Pi, and the rebuilding of ATP by respiration.

False Confidence Alert

ATP is not a long-term energy store like fat. It holds only a little energy and is spent and remade constantly; it is a currency that carries energy, not a battery that hoards it.

Question 45

Having made ATP in respiration, the cell spends it on many tasks. Give three processes in the body that are powered by ATP, and explain why ATP is described as the cell's energy currency.

Model Answer

ATP powers a wide range of work in the body, for example:

1) **active transport,** such as the sodium-potassium pump that moves ions against their concentration gradient;
2) **muscle contraction,** in which ATP drives the sliding of the muscle filaments;
3) **the synthesis of large molecules,** such as the joining of amino acids to build proteins.

ATP is called the cell's energy currency because it is the common, ready form in which energy is passed from respiration to wherever work is done, and because it releases that energy in small, usable amounts.

Examiner's Note

Name real processes, not just 'it gives energy': active transport, muscle contraction, synthesis. The phrase energy currency should be explained, not merely stated.

REAL QUESTIONS

These questions take the same biology into real life in Tanzania, and test whether you can spot and correct the mistakes students often make. Attempt each on paper, then check the model answer beneath. Every answer leads with the mark-bearing point in bold.

Question 46

Water makes up about two-thirds of the human body and takes part in nearly everything it does. Give four ways in which water is important to the human body, explaining each.

Model Answer

1) **Transport.** The blood plasma is mostly water, and it carries dissolved glucose, mineral salts, hormones and other substances to the cells, because they must be in solution to be moved.
2) **Removal of wastes.** Wastes such as urea dissolve in water and are carried out of the body in the urine and the sweat, so that they do not build up to harmful levels.
3) **Secretion.** Watery fluids such as saliva, mucus and the digestive juices are largely water, so they moisten the food and allow the enzymes to act on it.
4) **Hearing and balance.** The fluid that fills the inner ear is watery, and the movement of this fluid is what lets us hear sounds and keep our balance.

Examiner's Note

Each way must carry a reason, not just a name: what the water does and why it matters. Listing 'transport, secretion' without saying what water does there earns little.

Question 47

In what ways is water important to a green plant such as a maize plant in a Tanzanian farm? Give four ways, explaining each.

Model Answer

1) **A raw material for photosynthesis.** Water is split in the light stage to provide the hydrogen used to build glucose, so without water the plant cannot make its own food.
2) **Transport.** Water in the xylem carries mineral salts up from the roots, while water in the phloem carries dissolved sugars to where they are needed.
3) **Support.** Water entering the cells by osmosis makes them turgid, and this turgor keeps the soft tissues firm, holding a non-woody plant upright.
4) **Cooling.** Water evaporating from the leaves during transpiration carries heat away, so the plant does not overheat in the strong sun.

Examiner's Note

Tie each role to the plant's life: food-making, transport, support, cooling. A bare list of words, with no explanation, does not reach the marks.

Question 48

In a tall tree such as a mango, water is carried from the roots all the way to the topmost leaves with no pump of any kind. Explain, using the ideas of cohesion and adhesion, how water rises through the plant.

Model Answer

Water rises because it is pulled up from the top, not pushed up from below. As water evaporates from the leaves in transpiration, it draws up the water behind it in the xylem. **Cohesion, the sticking of water molecules to one another by hydrogen bonds, holds the water in the xylem as one unbroken column, so the pull at the top is passed all the way down to the roots. Adhesion, the sticking of water to the walls of the narrow xylem vessels, helps to hold the column up and draws water upward by capillary action.** Together, cohesion and adhesion let an unbroken thread of water be lifted to the top of even a very tall tree.

Examiner's Note

The marks lie in the chain: transpiration pulls, cohesion keeps the column unbroken so the pull reaches the roots, and adhesion helps hold and raise the column. Saying only that water 'travels up the xylem' does not score.

False Confidence Alert

It is a common error to think the roots push water up. They do not; the water is pulled from the top by evaporation at the leaves, and cohesion carries that pull down the unbroken column.

Question 49

Kipanga is revising the thermal properties of water and writes: *"Water has a high latent heat of vapourisation, which is why Lake Victoria stays at a steady temperature through the day. Water cools the body when we sweat because of its high specific heat capacity."* Identify the mistakes in what Kipanga has written, and rewrite the statement correctly.

Model Answer

Kipanga has swapped the two properties over.

Lake Victoria stays at a steady temperature because of water's high specific heat capacity, not its latent heat of vapourisation, since a large amount of heat must be taken in or given out before the temperature of so much water changes.

Sweat cools the body because of water's high latent heat of vapourisation, not its specific heat capacity, since a great deal of heat is absorbed when the sweat evaporates from the skin.

Rewritten correctly: water has a high specific heat capacity, which is why Lake Victoria stays at a steady temperature through the day; and water cools the body when we sweat because of its high latent heat of vapourisation.

False Confidence Alert

These two properties are the most-confused pair in the topic. High specific heat capacity steadies the temperature of a mass of water; high latent heat of vapourisation cools a surface as water evaporates from it.

Language Clinic

When you correct a mistake, name the right property and give its reason in the same breath: 'high specific heat capacity, because much heat is needed to change the temperature.' Naming without the reason leaves the correction half-made.

Question 50

A student wants to find out which of three Tanzanian foods contains starch, which contains a reducing sugar, and which contains a non-reducing sugar: *ugali*, honey and table sugar. Describe the test used for each and the result expected.

Model Answer

Ugali, the test for starch. Add a few drops of iodine solution to the ugali; it turns blue-black, which shows that starch is present. No heating is needed.

Honey, the test for a reducing sugar. Add Benedict's solution and heat in a water bath; a brick-red precipitate forms, showing that the honey contains a reducing sugar.

Table sugar (sucrose), the test for a non-reducing sugar. Benedict's added to the sugar solution and heated stays blue, so it is not a reducing sugar; the sucrose is then boiled with dilute hydrochloric acid to hydrolyse it, neutralised with sodium hydrogencarbonate, and tested again with Benedict's, which now gives a brick-red precipitate. This shows a non-reducing sugar that had to be hydrolysed first.

Examiner's Note

Each test needs its reagent, what is done, the result and the conclusion. The non-reducing test scores only if you hydrolyse, neutralise, then re-test; leaving out the neutralising step loses the mark.

Question 51

Many Tanzanian adults feel bloated and uncomfortable after drinking fresh milk, although they could drink it freely as children. Explain, in terms of the enzyme lactase and the glycosidic bond, why this happens.

Model Answer

Fresh milk contains lactose, a double sugar of glucose and galactose joined by a glycosidic bond, and this bond must be broken by the enzyme lactase before the sugar can be absorbed. In childhood the small intestine makes plenty of lactase, so the lactose is hydrolysed into glucose and galactose, which are then absorbed into the blood. **In many adults the making of lactase falls away, so the lactose is no longer hydrolysed and passes undigested into the large intestine.** There the gut bacteria ferment it, producing gas and drawing in water, and this is what causes the bloating and discomfort. Because the glycosidic bond cannot be broken without lactase, the lactose stays a sugar the body cannot take up.

Examiner's Note

The marks are for the chain: lactose held by a glycosidic bond, lactase needed to break it, too little lactase in the adult, so undigested lactose is fermented in the large intestine.

Question 52

A runner takes honey for a quick lift of energy, while sugarcane must be digested before its sugar can be used. Both taste sweet, yet honey gives a brick-red colour with Benedict's at once and sugarcane juice does not. Explain the difference, and what it tells us about how quickly each gives energy.

Model Answer

Honey gives an immediate result because it is rich in reducing sugars, mainly glucose and fructose, which have a free reactive group that reduces the blue copper(II) in Benedict's to a brick-red precipitate. Being already free, these sugars can be absorbed and respired quickly, which is why honey gives a fast lift of energy.

Sugarcane juice, by contrast, is rich in sucrose, a non-reducing sugar in which the reactive groups of its glucose and fructose units are both locked in the glycosidic bond that joins them, so neither is free to reduce the Benedict's and the solution stays blue. Only when the sucrose is hydrolysed, freeing the glucose and fructose, does sugarcane juice give a brick-red result, and only then can its sugar be absorbed; so its energy is released more slowly.

Sweetness on the tongue and a positive Benedict's test are therefore not the same thing.

Examiner's Note

Tie the test result to the sugar: free reactive groups in honey give an immediate red and quick energy; the locked groups of sucrose give no red, and no energy, until the bond is hydrolysed.

Question 53

In bright sunlight a green plant takes in carbon dioxide and builds it into a carbohydrate that it stores. Name this storage carbohydrate, and explain how its structure suits it to the job of a store.

Model Answer

The plant stores the carbohydrate as *starch*, built by joining many α-glucose molecules made from the carbon dioxide taken in during photosynthesis. Starch is insoluble, so it does not dissolve in the cytoplasm, it does not draw water into the cell by osmosis, and it does not leak away. It is also compact, because its chains coil and branch, so a great deal of glucose is packed into a small space. When the plant needs energy, the starch is hydrolysed back into glucose, which is then respired. This is why crops such as cassava (muhogo) and maize store so much starch in their tubers and grains.

Examiner's Note

Name starch, then turn each structural point into a storage advantage: insoluble so osmotically inactive and not lost, compact so it holds much energy, and hydrolysed back to glucose when needed.

Question 54

Kipanga claims that *a person could live on grass like a cow if only they ate enough of it, since grass is made of glucose.* Kipute disagrees, saying *a human cannot live on grass at all.* Judge whose case is the stronger, and explain the biology.

Model Answer

Kipute is right: a human cannot live on grass, however much of it they eat. Grass is built largely of cellulose, which is a polymer of β-glucose, and its β-glucose units are joined by β-glycosidic bonds. **Breaking these bonds needs the enzyme cellulase, which a human, like most animals, cannot make, so a human cannot hydrolyse the cellulose and the glucose stays locked in the grass and passes through the gut undigested. A cow can live on grass not because it makes cellulase itself, but because it keeps microbes in its rumen that produce cellulase and break the cellulose down for it.** So although

Kipanga is right that grass contains glucose, he is wrong that eating more would help, because a human has no way to release that glucose.

> **False Confidence Alert**
>
> Containing glucose is not the same as providing glucose. The glucose in grass is real, but locked in cellulose; without cellulase a human cannot reach it, so grass passes through as roughage.

Examiner's Note

A Biology Judge answer must pick a side and defend it with the mechanism: cellulose is β-glucose, humans lack cellulase, the cow borrows cellulase from its rumen microbes.

Question 55

Sunflower oil stays liquid at room temperature, while the cooking fat sold in blocks is solid. Explain this difference in terms of the fatty acids they contain, and say which is the healthier choice for the heart.

Model Answer

The difference lies in whether the fatty acids are saturated or unsaturated. Sunflower oil is rich in unsaturated fatty acids, whose chains carry carbon-to-carbon double bonds that put kinks in them, and the kinked chains cannot pack closely together, so the oil stays liquid at room temperature. **Cooking fat is rich in saturated fatty acids, whose chains have no double bonds and so lie straight, pack tightly together, and set into a solid.** The unsaturated oil is the healthier choice, because a diet heavy in saturated fat raises the level of cholesterol in the blood and the risk of fatty deposits forming in the arteries, which can lead to heart disease. So one kink in the chain separates a liquid oil from a solid fat, and the healthier choice from the less healthy one.

Examiner's Note

The mark depends on the double bond doing the work: it kinks the chain, so the chains cannot pack, so the lipid is liquid. Saying only that oils are unsaturated, with no packing, does not score.

Question 56

A student suspects that groundnuts are rich in fat. Describe the test the student would use to show that the groundnuts contain a lipid, and the result expected.

Model Answer

The student would use the emulsion test. The crushed groundnuts are first shaken with ethanol, in which any lipid dissolves, and the ethanol is then poured into a tube of water. **If a lipid is present, a milky-white emulsion forms in the water, because the dissolved lipid comes out of solution as tiny droplets that scatter the light.** If no lipid were present, the mixture would stay clear, so the white emulsion shows that the groundnuts contain a lipid. The ethanol must be added before the water, because the lipid has to dissolve in the ethanol first; lipid does not dissolve in water, so adding water directly would not work.

Examiner's Note

The result and the reason both earn marks: a white emulsion, formed because the lipid leaves the ethanol as droplets in the water. The order, ethanol before water, must be right.

Language Clinic

State the result and what it means together: a white emulsion forms, which shows a lipid is present. A colour or cloudiness named without its meaning leaves the answer unfinished.

Question 57

Besides being an energy store, fat does other jobs in animals. Explain how fat helps a person keep warm, and how the fat in a camel's hump helps it survive in the dry lands of northern Tanzania.

Model Answer

A layer of fat stored under the skin, the subcutaneous fat, acts as insulation, because fat is a poor conductor of heat and so slows the loss of heat from the body and helps a person stay warm. The fat in a camel's hump is mainly a store of energy, but it brings a second benefit: when the fat is respired it yields not only energy but also water, called metabolic water. This metabolic water helps the camel survive long periods in dry country where there is little to drink. Fat yields a large amount of both energy and water per gram because it holds many carbon-hydrogen bonds and very little oxygen, which is why it serves so well as a store in animals that must go without food or water.

Examiner's Note

Two distinct points carry the marks: fat as a poor heat conductor insulating the body, and respired fat releasing metabolic water as well as energy. Do not confuse insulation with the energy store.

Question 58

Kipanga argues that *an athlete should eat fat rather than sugar just before a race, because a gram of fat holds more than twice the energy of a gram of sugar, so it must give energy faster.* Identify what is wrong with Kipanga's reasoning, and explain the correct biology.

Model Answer

Kipanga is right that fat holds more energy per gram, but wrong that this makes it a faster source of energy. Fat does store more than twice the energy of a carbohydrate per gram, because it has many carbon-hydrogen bonds and little oxygen. **The cell, however, releases that energy slowly, because the fat must first be broken down and then oxidised through a longer pathway than glucose.** Glucose, by contrast, is small, soluble and quickly respired, so it is the body's quick fuel and the better choice just before a race. More energy stored is not the same as energy released faster: fat is the long-term store, while glucose is the ready, fast-release fuel.

False Confidence Alert

The most-confused point in this topic: storing more energy is not the same as releasing it faster. Fat is the larger store; glucose is the quicker fuel.

Examiner's Note

Spot the flaw and name the correct fuel: fat does hold more energy, but it is released slowly, so glucose, being quickly respired, is the better choice for a sudden effort.

Question 59

A child suffering from kwashiorkor, a disease of severe protein shortage, often has a swollen belly and swollen legs even while the child is starving. Explain, in terms of the plasma proteins and water, why this swelling (oedema) develops.

Model Answer

The swelling develops because, without enough protein in the diet, the blood plasma loses the proteins that normally help to hold water inside the blood vessels. Plasma proteins such as albumin raise the water-attracting (osmotic) pull of the blood, so water is drawn back into the capillaries from the tissues by osmosis. **When the diet lacks protein, the level of plasma protein falls, so less water is drawn back from the tissues and fluid collects in the tissue spaces.** This build-up of fluid in the tissues is the swelling, or oedema, seen in the belly and the legs. So the swelling is a sign not of too much food but of too little protein, because the blood can no longer hold its water where it belongs.

Examiner's Note

The marks are for the osmosis chain: plasma proteins hold water in the vessels, too little protein lowers that pull, so fluid stays in the tissues as oedema.

Question 60

A protein loses its shape and its function when it is denatured. Give five ways in which the denaturation of a protein, such as an enzyme being kept in storage, could be prevented.

Model Answer

1) **Keep it cool.** Store it at a low temperature, because heat gives the atoms energy to break the weak bonds that hold the protein's shape.
2) **Keep the pH steady and moderate.** Avoid strong acids and alkalis, which disturb the charges and bonds that hold the shape.
3) **Keep heavy-metal ions away.** Ions such as those of lead or mercury break the bonds holding the protein and denature it.
4) **Avoid strong alcohol and other organic solvents,** which also break the weak bonds that maintain the shape.
5) **Avoid violent shaking or frothing,** which can unfold a protein at the surface where air and liquid meet.

Examiner's Note

Five distinct ways, each with its reason: cool, steady pH, no heavy metals, no strong solvents, no violent agitation. A list without reasons earns fewer marks.

Question 61

Describe the Biuret test used to show that a food contains protein, and explain why a purple colour appears when protein is present.

Model Answer

To carry out the Biuret test, an equal volume of sodium hydroxide solution is added to the food sample, followed by a few drops of dilute copper(II) sulphate solution, and the mixture is shaken; no heating is needed. If protein is present the solution turns from blue to purple, while if no protein is present it stays blue. The purple colour appears because the copper(II) ions form a coloured complex with the peptide bonds of the protein. So it is the peptide bonds, the links between the amino acids, that the Biuret test detects, which is why it shows a protein but not a solution of single amino acids.

Examiner's Note

The procedure (sodium hydroxide then dilute copper sulphate, no heat) and the result (blue to purple) both earn marks, and the purple must be tied to the peptide bonds.

False Confidence Alert

Biuret detects the peptide bond, not the amino acid. A solution of free amino acids, having no peptide bonds, gives no purple colour, which is a point examiners like to test.

Question 62

Proteins carry out a great many different jobs in the body. Name four proteins and state one function of each.

Model Answer

1) **Haemoglobin** carries oxygen from the lungs to the tissues, held inside the red blood cells.
2) **An enzyme such as amylase** speeds up a reaction in the body, here the breakdown of starch into sugars.
3) **An antibody** binds to a pathogen and helps to destroy it, as part of the body's defence.
4) **Collagen** gives strength and support to the skin, the tendons and the bones.

Examiner's Note

Each protein must be paired with a real, specific job. Naming 'protein' or giving a vague 'helps the body' does not score; name the protein and what it actually does.

Question 63

When an egg is fried it sets firm, and when milk turns sour to make mtindi it curdles. Explain what is happening to the proteins in each case, using the idea of denaturation.

Model Answer

In both cases the proteins are being denatured, that is, losing their natural three-dimensional shape. When an egg is heated, the heat gives the atoms enough energy to break the weak bonds that hold the egg-white protein in its folded shape, so the chains unfold and tangle together and the runny white sets into a firm solid. **When milk turns sour, acid made by bacteria lowers the pH, and this change in pH breaks the bonds that hold the milk protein in shape, so the protein unfolds and clumps together and the milk curdles.** In neither case are the chains broken into amino acids; only the shape is lost, which is why the change cannot be undone, just as a boiled egg cannot be un-boiled.

Examiner's Note

Name the cause in each case (heat for the egg, low pH for the milk) and the effect (the weak bonds break, the shape is lost). The note that the chains are not broken into amino acids guards the mark.

False Confidence Alert

Denaturation is not the same as digestion. Frying or souring changes the protein's shape but does not break it into amino acids; only the shape, and so the function, is lost.

Question 64

In many Tanzanian kitchens, tough meat is rubbed with pawpaw or wrapped in its leaves to make it tender before cooking. Explain how the pawpaw softens the meat.

Model Answer

Pawpaw contains an enzyme called papain, which is a protease, an enzyme that breaks down protein. Tough meat is tough because of its strong protein fibres, mainly the connective-tissue protein and the muscle protein. **The papain hydrolyses the peptide bonds in these proteins, breaking the long protein fibres into shorter pieces, so the meat becomes softer and easier to chew.** This is the same kind of reaction as the digestion of protein, but happening outside the body, so the meat is partly broken down and tenderised even before it is cooked.

Examiner's Note

The marks are for naming papain as a protease and saying it hydrolyses the peptide bonds of the meat proteins, breaking the fibres so the meat softens.

Language Clinic

Lead with the cause: pawpaw softens meat because it contains a protease that hydrolyses the protein. Beginning with the enzyme, then its action, then the result, makes the explanation flow.

Question 65

In a Tanzanian home, yeast is used both to brew local drinks and to make bread rise. Explain the part the enzymes of yeast play in fermentation, and why this both makes the bread rise and produces the alcohol in the brew.

Model Answer

Yeast carries out fermentation using its enzymes, which break down sugar in the absence of oxygen into ethanol, the alcohol, and carbon dioxide gas. In brewing, the enzymes of the yeast act on the sugars from grain or fruit, and the ethanol they produce is the alcohol of the drink. **In bread-making, the same fermentation produces carbon dioxide, and the bubbles of this gas, trapped in the dough, are what make the bread rise.** The heat of the oven then drives off the gas and the small amount of alcohol, leaving the light, risen loaf. So one process, fermentation by the yeast's enzymes, gives both the alcohol in the brew and the rise in the bread.

Examiner's Note

The marks are for fermentation giving two products: ethanol, which is the alcohol of the brew, and carbon dioxide, whose bubbles raise the bread. Name both and where each matters.

Question 66

Food kept in a refrigerator stays fresh far longer than food left out in the warm. Explain, in terms of enzymes, why cooling slows the spoiling of food.

Model Answer

Food spoils largely because enzymes, both the food's own enzymes and those of the microbes growing on it, break it down, and the rate of enzyme action falls as the temperature falls. In the cold of a refrigerator the enzyme and substrate molecules have less kinetic energy and collide far less often, so the reactions that spoil the food go very slowly. The cold also slows the growth of the bacteria and moulds whose enzymes rot the food. **Because the enzymes are only slowed and not destroyed, the food begins to spoil again once it is taken back into the warmth. So refrigeration preserves food by slowing enzyme action, not by stopping it for good.**

> **False Confidence Alert**
>
> Cold does not kill or destroy enzymes; it only slows them down. That is why food spoils again once it warms up, the enzymes simply speed back up.

Question 67

A very high fever can be dangerous, and a body temperature above about 42 degrees Celsius can be fatal. Explain, in terms of the body's enzymes, why a high fever is so dangerous.

Model Answer

A high fever is dangerous because the heat begins to denature the body's own enzymes. The body's enzymes work best at about 37 degrees Celsius, and as the temperature rises above this optimum the heat breaks the weak bonds that hold each enzyme in its precise shape. **Once an enzyme's shape is lost, its active site no longer fits the substrate, so the reaction it controls slows down or stops altogether.** Because almost every process in the body depends on enzymes, the failure of many at once can halt vital reactions, which is why a very high fever can be fatal; and unlike a change in pH, this damage from heat cannot be undone by cooling.

Examiner's Note

Credit needs the optimum and the denaturation: above about 37 degrees the heat breaks the enzymes' shape, the active sites are lost, and the reactions they control fail.

Question 68

Biological washing powders remove stains of blood, egg and grease that ordinary soap leaves behind. Explain how these powders work, and why they are often advised to be used in warm rather than very hot water.

Model Answer

Biological washing powders contain enzymes, mainly proteases that digest protein stains and lipases that digest fat and grease stains. A stain such as blood or egg is largely protein, and the protease hydrolyses it into small, soluble pieces that wash away, while a greasy stain is broken down by the lipase in the same way. **Warm water is advised because it speeds the enzymes up to a good working rate, but very hot water would denature them and destroy their action.** So the enzymes do their best work in warm water, where they are fast but not yet denatured, which is why the instructions warn against using boiling water.

Examiner's Note

Name the enzymes and their stains, protease for protein, lipase for fat, then explain the warm-not-hot point by the optimum and the risk of denaturation.

Question 69

All the main digestive enzymes, such as amylase, the proteases and lipase, belong to the same class, the hydrolases. Explain why digestion is carried out by hydrolases.

Model Answer

Digestion is the breaking down of large food molecules into small ones, and a hydrolase is an enzyme that breaks a bond by adding water, which is exactly what digestion needs. The large food molecules, starch, proteins and fats, are built from smaller units joined by bonds that were made in condensation, with a water removed. **To break these molecules apart, a water molecule is added back across each bond, and this reaction, hydrolysis, is the one the hydrolases catalyse.** Amylase hydrolyses the glycosidic bonds of starch, the proteases hydrolyse the peptide bonds of proteins, and lipase hydrolyses the ester bonds of fats. So every digestive enzyme is a hydrolase because digestion is, in every case, hydrolysis.

Examiner's Note

The mark is for tying digestion to hydrolysis: large molecules are split by adding water across each bond, which is precisely what a hydrolase does.

Question 70

A student put 2 cm^3 of starch solution in a test tube and added 2 cm^3 of saliva that had first been boiled and then cooled. After leaving the mixture, the student tested for starch and found the starch was still present. Explain this result.

Model Answer

The starch was still present because boiling the saliva had denatured the amylase, the enzyme in saliva that digests starch. Fresh saliva contains amylase, which would normally hydrolyse the starch into maltose, so that a starch test would then be negative. **But boiling the saliva broke the weak bonds holding the amylase in shape and destroyed its active site, so the denatured enzyme could no longer act on the starch.** Cooling the saliva afterwards did not bring the enzyme back, because denaturation cannot be reversed, so the starch remained undigested and the starch test stayed positive.

False Confidence Alert

Cooling a boiled enzyme does not restore it. Denaturation by heat is permanent, so the boiled saliva stays unable to digest starch however long it is left.

Question 71

Kipanga says *an enzyme must be alive, because it speeds up reactions and stops working when it is boiled, just as a living thing dies when it is overheated.* **Kipute** says *an enzyme is not alive; it is only a protein.* Judge whose case is the stronger, using the idea of denaturation and what it means to be alive.

Model Answer

Kipute is right: an enzyme is not alive; it is a protein molecule made by living cells. Kipanga has taken two true observations and given them the wrong explanation. **An enzyme speeds up reactions not because it is alive but because, as a catalyst, it lowers the activation energy; and it stops working when boiled not because it dies but because the heat denatures it, breaking the bonds that hold its shape.** A living thing shows features such as respiration, growth, reproduction and response to stimuli, none of which a single enzyme molecule does. So although an enzyme is made by living cells and is destroyed by heat, neither of these makes it alive, any more than a wooden spoon is alive because it came from a tree and burns in a fire.

Examiner's Note

A Biology Judge answer must choose a side and defend it with the mechanism: the enzyme speeds reactions by lowering activation energy, is denatured rather than killed by heat, and lacks the features of a living thing.

Question 72

Because every person's DNA is unique, DNA testing has many uses. Give three ways in which DNA testing is useful in Tanzania, explaining each briefly.

Model Answer

1) **Paternity testing.** Comparing a child's DNA with that of a possible father can settle who the true parent is, because a child's DNA is inherited half from each parent.

2) **Forensic identification.** DNA left at the scene of a crime, in blood, hair or saliva, can be matched to a suspect, because no two people, apart from identical twins, share the same DNA.

3) **Improving livestock and crops.** DNA testing lets breeders pick the animals or plants that carry useful genes, such as cattle that give more milk or cassava that resists disease, so that the best can be bred from.

Examiner's Note

Each use needs its reason: paternity rests on inheritance from both parents, forensics on every person's DNA being unique, breeding on choosing useful genes. A bare list of uses earns less.

Question 73

Kipanga suggests that *the body would do better to build up a large store of ATP, kept ready like a store of fat, so that energy is always available*. Identify what is wrong with Kipanga's idea, and explain how the body really manages its ATP.

Model Answer

Kipanga is wrong because ATP is not a store of energy; it is the cell's energy currency, made and spent moment by moment. A molecule of ATP holds only a small amount of energy, released when its terminal phosphate bond is hydrolysed to give ADP and a free phosphate. **The cell keeps only a little ATP at any one time, and respiration continually rebuilds it from ADP and phosphate as fast as it is used, so the supply is renewed rather than stored up.** The body's true energy stores are fat and glycogen, which hold far more energy, and ATP is the ready cash that these stores are turned into when work must be done. So a large store of ATP would be neither practical nor useful, because ATP is meant to be spent at once, not hoarded.

False Confidence Alert

ATP is a currency, not a battery. It carries energy in small, ready amounts and is remade constantly; the long-term stores are fat and glycogen, not ATP.

Examiner's Note

Spot the error, then give the right picture: little ATP is held at a time, respiration recharges it from ADP and phosphate, and the real energy stores are fat and glycogen.

Question 74

RNA comes in three main forms, all taking part in the making of proteins. Name the three types of RNA and state the role of each in one line.

Model Answer

1) **Messenger RNA (mRNA)** carries the coded instructions for a protein from the DNA in the nucleus to the ribosomes.

2) **Transfer RNA (tRNA)** brings the correct amino acids to the ribosome, one by one, to be joined in the right order.

3) **Ribosomal RNA (rRNA)** forms part of the ribosome itself, the structure on which the protein is built.

Examiner's Note

Name each type in full and give its one job: mRNA carries the message, tRNA carries the amino acids, rRNA builds the ribosome. The full names and the matching roles earn the marks.

Question 75

The sugar in a nucleotide is one you have already met among the carbohydrates. Name the sugars found in DNA and in RNA, say what kind of sugar they are, and explain how this links the nucleic acids back to the carbohydrates.

Model Answer

The sugar in RNA is ribose and the sugar in DNA is deoxyribose, and both are pentoses, that is, five-carbon sugars. Pentoses are one of the groups of monosaccharides met among the carbohydrates, alongside the trioses with three carbons and the hexoses with six carbons such as glucose. **So the backbone of every nucleic acid is built on a carbohydrate, the pentose sugar, joined to a phosphate and a base to make each nucleotide.** This shows that the same simple sugars studied as carbohydrates also build the molecules of heredity, deoxyribose in DNA and ribose in RNA, so the carbohydrates and the nucleic acids are not separate worlds but are linked by the pentose sugar.

Examiner's Note

Name both sugars, call them pentoses (five-carbon sugars), and make the link explicit: the pentose is a carbohydrate, and it forms the backbone of every nucleotide.

Language Clinic

Carry the link in one sentence: ribose and deoxyribose are pentoses, and a pentose is a carbohydrate, so the nucleic acids are built on a sugar. Naming the class, pentose, is what ties the two topics together.

HOT QUESTIONS

These questions ask you to reason, not merely to recall: to compare, to predict, to judge, and to put loose statements right. Attempt each on paper, then check the model answer beneath. Every answer leads with the mark-bearing point in bold.

Question 76

A cook notices two things about water: a large pot of water on the fire takes a long time to come to the boil, and a wet cloth hung in the breeze cools the room. State which property of water each observation shows, and explain why the two properties are not the same.

Model Answer

The pot being slow to heat shows water's high specific heat capacity, while the cooling wet cloth shows its high latent heat of vapourisation. The high specific heat capacity means a large amount of heat must be taken in before the temperature of the water rises, because much of the heat goes into weakening its many hydrogen bonds rather than into making the molecules move faster, which is why the pot heats slowly. The high latent heat of vapourisation means a large amount of heat is absorbed when water evaporates, because many hydrogen bonds must be broken for a molecule to escape as vapour, and so the evaporating cloth draws this heat from its surroundings and cools the room. So one property is about warming the liquid and the other about turning it into vapour, which is why the two must not be confused.

Examiner's Note

Each observation must be matched to the right property and then explained: slow heating to specific heat capacity, evaporative cooling to latent heat of vapourisation. Swapping them, the commonest error here, loses both marks.

Question 77

Water is unusual in being densest a few degrees above freezing, so the ice that forms floats. Predict what would happen to life in a deep lake through a long cold season if water instead behaved like most substances, so that its ice sank. Explain your prediction.

Model Answer

If ice sank, a deep lake would freeze solid from the bottom upward, and most of the life in it would die. As water really behaves, the ice that forms floats and makes an insulating layer at the surface, under which the water stays liquid, so fish, plants and other organisms live on in the water below. **If instead the ice sank, each piece of ice would fall to the bottom and fresh ice would form on top, so the freezing would spread downward until the whole lake became a block of ice.** Organisms cannot survive being frozen solid, so the lake would lose almost all of its life. The floating of ice, which depends on water's density anomaly, is therefore what lets deep waters carry life through a cold season.

Examiner's Note

A prediction earns marks only when it is explained: ice sinking lets the lake freeze solid from the bottom up, so the life is killed, unlike the real case where floating ice insulates the water below.

Question 78

Starch and cellulose are both polymers of glucose, yet starch serves as a food store and cellulose as a structural fibre. Argue which of the two is better suited to its own job, giving the structural reason in each case.

Model Answer

Each is better suited to its own job than the other would be, and in both cases the reason is the kind of glucose and the way the chains are arranged. Starch is built from α-glucose, whose chains coil and branch, so it is compact and, being easily reached by enzymes, can be broken down quickly to release glucose when it is needed; this makes it a far better store than cellulose, whose chains could not be unpacked for energy. Cellulose is built from β-glucose, whose straight chains lie side by side and are held together by many hydrogen bonds into strong fibres, so it gives the cell wall great strength; starch, with its loose coils, could never give such support. So neither could do the other's job: the coiled α-glucose of starch suits a store, while the straight, hydrogen-bonded β-glucose of cellulose suits a structure.

Examiner's Note

A Compare-and-Justify answer must defend both sides with structure: coiled, branched α-glucose for a quick-release store, and straight, hydrogen-bonded β-glucose for strength. Praising one without the structural reason does not score.

Question 79

Amylase readily breaks down starch, but it has no effect at all on cellulose, even though both are made only of glucose. Explain why.

Model Answer

Amylase cannot break down cellulose because the two polymers are joined by different bonds, and the active site of amylase fits only the bond found in starch. Starch is made of α-glucose joined by α-glycosidic bonds, while cellulose is made of β-glucose joined by β-glycosidic bonds. **Amylase has an active site shaped to fit and hydrolyse the α-glycosidic bond, so it acts on starch, but the β-glycosidic bond of cellulose has a different shape that does not fit the active site, so amylase cannot act on it.** This is enzyme specificity: an enzyme acts only on a substrate whose shape matches its active site. To digest cellulose a different enzyme, cellulase, is needed, which most animals cannot make. So it is the single difference between α-glucose and β-glucose that decides what amylase can and cannot digest.

> **Examiner's Note**
>
> The marks lie in joining two ideas: the α versus β glycosidic bond, and the active site that fits only one shape. Saying merely that amylase is specific, with no mention of the bond, is half the answer.

Question 80

From glucose, sucrose, maltose and lactose, choose the odd one out and state the rule that separates it from the other three. More than one answer can be correct, provided the rule behind it is clear.

Model Answer

The clearest odd one out is glucose, because it is the only monosaccharide, a single sugar unit, while sucrose, maltose and lactose are all disaccharides made of two units joined by a glycosidic bond. That is the simplest rule: glucose has one sugar unit, the others have two. **A second answer can be defended: sucrose is the odd one out, because it is the only non-reducing sugar of the four, while glucose, maltose and lactose are all reducing sugars.** By this rule sucrose differs because the reactive groups of its two units are locked in the glycosidic bond that joins them. So either glucose, by the number of units, or sucrose, by reducing power, can be the odd one out, as long as the rule is stated.

> **Examiner's Note**
>
> In an Odd-One-Out the mark is for the rule, not the choice: state clearly what separates your odd one, whether it is being a single sugar or being the only non-reducing one.

Question 81

When they are completely oxidised, one gram of fat releases more than twice as much energy as one gram of carbohydrate. Explain why fat is so much richer in energy.

Model Answer

Fat is richer in energy because its molecules hold many more carbon-to-hydrogen bonds and far less oxygen than carbohydrate molecules do. The energy of a food is released when it is oxidised in respiration, and it is the carbon-to-hydrogen bonds that are oxidised to release that energy. **A fat is made largely of long hydrocarbon chains, which are packed with carbon-to-hydrogen bonds and carry very little oxygen, so there is a great deal to oxidise in each gram.** A carbohydrate, by contrast, already carries much oxygen within it, its formula being close to CH_2O, so it is already partly oxidised and has less left to give. This is why a gram of fat yields more than twice the energy of a gram of carbohydrate.

> **Examiner's Note**
>
> The mark depends on the chemistry of the molecule: many carbon-to-hydrogen bonds and little oxygen in fat, against the already part-oxidised carbohydrate. 'Fat has more energy' without this reason earns little.

Question 82

A bird preparing for a long migration must build up an energy store to carry on its journey. Predict whether it should store this energy as fat or as glycogen, and justify your answer.

Model Answer

The bird should store its energy as fat rather than as glycogen, because fat holds far more energy for far less weight. Fat releases more than twice as much energy per gram as carbohydrate, so a given amount of energy can be carried in a much smaller and lighter mass of fat than of glycogen. **For a flying bird,**

weight is the deciding factor, because every extra gram carried costs energy to lift, so the lightest possible store is the best one. Glycogen has a further drawback: it is stored with a good deal of water bound to it, which adds still more weight, while fat is stored almost dry. So fat is the better store for migration, giving the most energy for the least weight to carry.

> **Examiner's Note**
>
> A prediction must be justified, not just stated: fat gives more energy per gram, and weight matters most to a flier, so fat is the lighter store; the water held with glycogen is a further, telling point.

Question 83

Sickle-cell anaemia, found in parts of Tanzania, is caused by a change in a single base of the gene for haemoglobin, which alters just one amino acid in the protein. Explain how so small a change can affect the shape and the working of the whole red blood cell.

Model Answer

A single base change matters because the primary structure, the exact order of amino acids, decides the final folded shape of the whole protein. The order of amino acids is set by the order of bases in the gene, so changing one base can place the wrong amino acid at one point in the haemoglobin chain. **Although only one amino acid out of many is changed, it lies on the surface of the molecule and makes the haemoglobin less soluble, so that in low oxygen the molecules stick together into long fibres.** These fibres pull the red blood cell out of its normal disc shape into a stiff, curved sickle shape, which cannot pass easily through the smallest blood vessels. So a change of one base, acting through one amino acid, reshapes the whole cell, because in a protein the sequence decides the shape and the shape decides the function.

> **Examiner's Note**
>
> Follow the chain of cause and effect: one base changes one amino acid, which lowers solubility, which lets the haemoglobin form fibres, which bend the cell. An answer that stops at 'one amino acid changes' without reaching the cell earns little.

Question 84

Kipanga writes: *'When an egg is boiled, the heat breaks the peptide bonds of the protein and splits it into its amino acids, and that is why the egg turns solid.'* Identify what is wrong with this and rewrite the explanation correctly.

Model Answer

Kipanga is wrong on two counts:

Boiling does not break the peptide bonds, and it does not split the protein into its amino acids. Heat breaks the weaker bonds, the hydrogen bonds and other links, that hold the protein's three-dimensional shape, so the protein unfolds and loses its specific shape, and this unfolding is called denaturation.

The peptide bonds of the primary structure are strong and are not broken by boiling, so the chain of amino acids stays joined; the protein is unfolded, not taken apart. The egg white turns solid because the unfolded chains tangle and join loosely with one another into a firm mass, a change called coagulation, not because amino acids are set free.

So the correct statement is that boiling denatures the egg protein by breaking the bonds that hold its shape, while the peptide bonds, and so the amino acid sequence, stay intact.

Examiner's Note

Name the error and give the right term: boiling denatures the protein, breaking the bonds that hold its shape, but the peptide bonds remain. Denaturation is a change of shape, not a breaking of the chain.

Question 85

Some enzymes are held in their precise shape partly by disulphide bonds between cysteine amino acids in the chain. Predict what would happen to such an enzyme if a mutation removed one of these cysteines, and explain your prediction.

Model Answer

If a cysteine were removed, the enzyme would lose one of its disulphide bonds, so its tertiary shape would be held less firmly and the enzyme would work less well or not at all. A disulphide bond is one of the strongest links holding the folded tertiary structure in place, so losing one weakens the hold on that shape. **Without the bond the chain may fold a little differently or unfold more readily, so the active site may be altered or made less stable, and the substrate may no longer fit as well.** The enzyme would then act more slowly or stop working altogether, and it would be denatured more easily by heat or by a change in pH than the normal enzyme. So removing a single cysteine can weaken the whole structure, because the disulphide bond it formed helped to lock the active site in its working shape.

Examiner's Note

A prediction must be reasoned from the structure: the disulphide bond steadies the tertiary shape, so losing it makes the active site less stable and the enzyme easier to denature. Link the missing bond to the active site, not just to 'the shape'.

Question 86

The table shows how the rate of an enzyme-controlled reaction changed with temperature. Study it, then answer the questions that follow.

Temperature (°C)	Rate (arbitrary units)
10	5
20	10
30	21
40	44
50	15
60	0

(a) State the optimum temperature for this enzyme. (b) Describe and explain the change in rate from 10 °C to 40 °C. (c) Explain why the rate falls between 40 °C and 60 °C. (d) Predict the rate if the sample at 60 °C is cooled back to 40 °C, and explain your prediction.

Model Answer

(a) The optimum temperature is 40 °C, the temperature at which the rate is highest, at 44 units.

(b) From 10 °C to 40 °C the rate rises steadily, from 5 to 44 units. This is because heating gives the enzyme and substrate molecules more kinetic energy, so they move faster and collide more often and with more energy, forming enzyme-substrate complexes more frequently and speeding the reaction.

(c) From 40 °C to 60 °C the rate falls sharply, reaching zero at 60 °C. This is because the heat now breaks the bonds that hold the enzyme's tertiary shape, so the active site loses its shape and the substrate can no longer fit; the enzyme has been denatured.

(d) Cooling the 60 °C sample back to 40 °C would not restore the rate; it would stay at or near zero. This is because denaturation is permanent: once the active site has lost its shape it does not reform on cooling, so the enzyme cannot work again.

Examiner's Note

In a data-response answer, quote the figures from the table (rate 5 up to 44, then to 0) and tie each trend to its cause: more collisions on warming, denaturation on overheating, and no recovery on cooling.

Question 87

An enzyme-controlled reaction is slowed by adding a non-competitive inhibitor. A student then adds a large amount of extra substrate, expecting the rate to recover. Predict whether the rate recovers, and explain each step from the way the inhibitor works.

Model Answer

The rate does not recover when extra substrate is added, because a non-competitive inhibitor does not compete with the substrate for the active site. A non-competitive inhibitor binds to the enzyme at a different site, away from the active site, and in doing so it changes the shape of the active site so that the substrate can no longer fit or be acted upon. **Because the inhibitor is not sitting in the active site, adding more substrate cannot crowd it out, so the extra substrate makes no real difference and the rate stays low.** This is the key difference from a competitive inhibitor, which does sit in the active site and can be outnumbered by adding more substrate. So the student's expectation is wrong: with a non-competitive inhibitor, more substrate does not restore the rate, because the trouble is a changed active site, not a blocked one.

False Confidence Alert

Adding more substrate cures competitive inhibition, not non-competitive. A non-competitive inhibitor changes the active site from elsewhere, so flooding with substrate cannot displace it.

Question 88

In a chain of reactions, substance A is changed to B, then B to C, then C to D, each step needing its own enzyme. An irreversible inhibitor permanently blocks the first enzyme, the one that changes A to B. Predict what happens to the amounts of B, C and D, and explain.

Model Answer

If the first enzyme is permanently blocked, then B, C and D all stop being made, because the whole chain depends on the first step. The first enzyme is needed to change A into B, so if it is blocked no B can be formed; with no B the second enzyme has nothing to act on, so no C is made; and with no C the third enzyme has nothing to act on, so no D is made either. **The block at the start therefore halts every step that follows, like a stream that runs dry below a dam.** Because the inhibitor is irreversible, this is permanent: the enzyme cannot recover, so the pathway stays shut until the cell makes new enzyme. So blocking the first enzyme stops the final product D, even though the enzymes for the later steps are themselves unharmed.

Examiner's Note

Trace the pathway step by step: no B means no substrate for the next enzyme, so no C, so no D. The point is that the later enzymes are fine but are left with nothing to act on.

Question 89

A student writes: *'Enzymes are living catalysts that are used up in the reactions they speed up, and they work by giving the reaction the energy it needs.'* Identify every error in this sentence and rewrite it correctly.

Model Answer

There are three errors: enzymes are not living, they are not used up, and they do not give the reaction energy.

First, enzymes are not alive; they are protein molecules, made by living cells but not themselves living, so 'living catalysts' is wrong.

Second, enzymes are not used up; being catalysts, each enzyme molecule takes part in a reaction and is then free to act again and again, unchanged.

Third, enzymes do not supply energy; they speed a reaction by lowering its activation energy, the energy barrier that must be crossed, so that the reaction happens more easily, not by adding energy to it.

So the **corrected sentence** is: enzymes are biological catalysts, made by cells, that are not used up and that work by lowering the activation energy of a reaction.

Examiner's Note

Three faults, each to be named and corrected: not living but protein; not used up but reusable; and lowering the activation energy rather than supplying energy. Miss any one and the answer is incomplete.

Question 90

DNA is a double-stranded molecule using the sugar deoxyribose, while RNA is single-stranded and uses ribose. Suggest why DNA's structure makes it better suited to storing the genetic information for a long time, while RNA's structure suits it to a short-lived working role in the making of proteins.

Model Answer

DNA's double strand and deoxyribose make it stable enough to store the information safely for a long time, while RNA's single strand and ribose suit it to a temporary working copy. In DNA the two strands hold the bases paired and tucked safely inside the double helix, and the deoxyribose sugar, which lacks one oxygen, makes the molecule chemically more stable, so the information is protected and can be kept and copied faithfully for the life of the cell. **RNA, being a single strand made with the more reactive ribose, is less stable and more easily broken down, which is exactly what a short-lived messenger needs to be.** A working copy should be made when it is needed and then destroyed, so that the cell makes only the protein it needs at the time. So the very features that make DNA durable, two strands and deoxyribose, would be wasteful in RNA, whose single strand and ribose suit a molecule meant to be used and then replaced.

Examiner's Note

Match each structural feature to its role for both molecules: two strands and deoxyribose for safe, lasting storage; one strand and ribose for a copy that is meant to be made, used and broken down. Comparing only one side leaves half the marks.

Language Clinic

Hold the comparison together with 'while' and 'whereas': DNA is double-stranded and stable, whereas RNA is single-stranded and short-lived. A Compare-and-Justify answer must keep both molecules in view at once.

Chapter 3

PRINCIPLES OF CLASSIFICATION

BINDER QUESTIONS

Work through each question in order: attempt it on paper, then check the model answer beneath and read the annotations before moving on. Every answer leads with the mark-bearing point in bold.

Question 1

A single patch of forest on the Uluguru Mountains may hold thousands of kinds of plants, insects, birds and microbes, far more than any one scientist could ever study one at a time. Explain what classification is, and why sorting this great variety of living things is the first task a biologist must carry out before it can be understood.

Model Answer

Classification is the arrangement of living things into groups whose members share important features in common. A biologist compares organisms by their structure, their way of feeding and their way of reproducing, and places those that agree into the same group. **Sorting the variety in this way turns an unmanageable number of separate organisms into a few groups that can be studied.** Instead of examining thousands of individuals, the scientist examines a handful of groups, because the members of one group are alike enough that one of them can stand for the rest. As a result the diversity becomes an ordered picture that can be named, compared and understood, rather than a confusing list.

Examiner's Note

The marks are earned by two moves: defining classification as grouping by shared characteristics, and giving a reason the sorting is needed, that the variety is far too large to study one organism at a time. Giving only the definition leaves most of the available marks unclaimed.

False Confidence Alert

A common slip is to think classification is simply giving organisms names. Naming is only the last step; classification first gathers organisms into groups by their shared features, and the name then follows from the group.

Question 2

The earliest biologists, following Aristotle, sorted every living thing into just two groups, animals and plants, and placed a bat and a bird together simply because both can fly. Explain why grouping organisms on so few features eventually proved misleading, and what this shows about how a sound classification must be built.

Model Answer

Grouping by a single easily seen feature puts unrelated organisms together and hides their real differences. A bat and a bird both fly, but a bat has hair and feeds its young on milk like other mammals, whereas a bird has feathers; flight is only a surface resemblance, not a sign of close kinship. **A reliable classification must therefore rest on many shared features, not one.** When organisms are compared across structure, feeding and reproduction, the weight of the evidence places the bat among the mammals and the bird in its own group, the birds. **This is also why classification keeps changing.** As better tools reveal more features, early groupings are corrected, so the system grows steadily more natural over time.

Examiner's Note

Credit comes from naming the fault, that too few features group unrelated organisms, and then stating the cure, that a reliable classification uses many features. The bat-and-bird contrast is the evidence that earns the explanation mark, so it must be used, not merely mentioned.

Language Clinic

Carry the difference with a contrast word: a bat has hair and feeds its young on milk, whereas a bird has feathers. The word 'whereas' shows the reader you are comparing the two, not just listing facts about each.

Question 3

In their work biologists use three closely related terms, taxonomy, taxonomist and taxon, which students often confuse. Explain what each one means, and how the three are connected.

Model Answer

Taxonomy is the science of classifying living things. It is the whole study of how organisms are identified, named and arranged into groups according to agreed principles and rules.

A taxonomist is the scientist who carries out that work. This is the person who examines organisms, decides which group each belongs to, and gives it its correct name.

A taxon, plural taxa, is any one named group the work produces. A kingdom, a phylum, a genus or a species is each a taxon, that is, a group standing at one level of the arrangement.

So a taxonomist practises taxonomy, and every group the work yields is a taxon.

Examiner's Note

Three terms are asked for, so each must be given its own meaning; defining taxonomy alone and leaving the other two implied loses two of the three marks.

Language Clinic

Hold the three apart by their roles: taxonomy is the subject, a taxonomist is the worker, and a taxon is the product. A clean sentence says the taxonomist practises taxonomy and produces taxa.

Question 4

Placing a lion (Panthera leo) and a leopard (Panthera pardus) in the same genus, Panthera, says far more than that the two cats look alike. Explain how classifying organisms in this way reveals the evolutionary relationship between them.

Model Answer

Organisms are grouped together because they share many inherited features, and a depth of shared features points to shared ancestry. The lion and the leopard have the same big-cat body plan, hair, mammary glands and the same skull and tooth pattern, so they are placed together in the genus Panthera. **Because these shared features are not single and superficial but many, inherited and detailed, the simplest explanation is that both cats inherited them from a common ancestor rather than evolving them separately.** The close grouping therefore says the two cats branched from one ancestral cat comparatively recently. **Classification therefore doubles as a map of evolution.** In a natural classification the closer two organisms sit, the more recently their lines separated, which is why such a grouping means much more than a list of look-alikes.

> **Examiner's Note**
>
> The mark hinges on the link from shared features to common ancestry. Saying the cats 'look similar' is not enough; the answer must state that their shared inherited features point to descent from a recent common ancestor.

Question 5

A grasshopper carries dozens of different local names across Tanzania and the world, yet a scientist anywhere can refer to it without confusion. Using this, and the case of a newly discovered organism, explain two practical benefits a single agreed system of classification gives to biologists.

Model Answer

1) Classification gives every organism one agreed name that means the same thing everywhere

Because all biologists place the organism in the same group and attach the same scientific name, a worker in Dodoma and a worker abroad can be sure they mean the same creature, so the confusion of many local names disappears.

2) Classification lets the features of a newly found organism be predicted before it is fully studied

When a new species is slotted into a group on its few known features, it can be expected to share the other features of that group, so a new plant with flowers, berries and stipules like the coffee plant can at once be placed near the coffee family and many of its likely features foretold.

> **Examiner's Note**
>
> Two distinct benefits are asked for, so two must be given: one uniform name, and prediction from the group. Offering two versions of the naming benefit scores only once.

> **False Confidence Alert**
>
> It is easy to think any second sentence counts as a second benefit. Saying 'it names organisms' and then 'it avoids confusion' is one benefit stated twice; the second benefit must be genuinely different, such as predicting a new organism's features from its group.

Question 6

There are far more kinds of living things on Earth than any biologist could ever examine one at a time. Explain how classifying them makes this vast number possible to study, and why examining one member of a group can teach you about the rest.

Model Answer

Classification collapses a huge number of separate organisms into a small number of groups. Millions of kinds are sorted, by their shared features, into a manageable few groups and sub-groups, so the biologist faces a short, ordered set instead of an endless list. **Examining one member then teaches you about the whole group, because the members were placed together precisely for being alike.** The organisms in one genus share most of their important features, so for those shared features, in structure, feeding or reproduction, what is true of one is largely true of the others. **A well-chosen representative is therefore the key to studying life efficiently.** By examining one organism from a group the scientist learns the shared features of all its members, and the impossible task of studying every organism becomes the practical task of studying a few representatives.

Examiner's Note

The answer must close the loop: grouping cuts the numbers down, and a representative works because the members of a group share most of their features. State why one member can stand for the rest, rather than only asserting that it can.

Language Clinic

Name the cause before the convenience: because the members of a group share most of their features, one representative can describe them all. The small word 'because' is what turns a claim into an explanation.

Question 7

A market trader sorts her produce into fruits, vegetables and grains, and a child may sort animals simply into those that fly and those that do not. Explain what the artificial system of classification is, and why grouping organisms on just a few easily seen features is described as artificial.

Model Answer

The artificial system of classification groups organisms using only a few easily observed features, chosen for convenience rather than for kinship. It picks one or two obvious characters, such as the ability to fly, the place where an organism lives, or its size, and sorts every organism by that character alone, so that all fliers, or all water-dwellers, fall into one group.

It is called artificial because the groups it makes are human conveniences, not natural relationships. Organisms are placed together simply because they happen to share the chosen feature, even when they are otherwise unrelated, so the grouping reflects the sorter's choice of character rather than the true affinities of the organisms. Grouping all plants as flora and all animals as fauna, or all small organisms as microorganisms, are everyday examples.

Examiner's Note

The definition needs two parts: that the system uses a few, easily seen features, and that the grouping is made for convenience, not for natural relationship. Giving examples alone, without the idea of a few features chosen for convenience, leaves the definition mark unearned.

False Confidence Alert

Artificial does not mean wrong or useless. The artificial system gives real, workable groups; it is called artificial only because those groups are convenient human inventions rather than natural relationships.

Question 8

Modern taxonomists place organisms together only after comparing them in fine detail, from their internal anatomy to their DNA. Explain what the natural system of classification is, and how the features it uses differ from those of the artificial system.

Model Answer

The natural system of classification groups organisms by the many features they truly share, especially those that reflect their evolutionary relationship. Instead of relying on one or two obvious characters, it compares organisms across a wide range of features, including their internal anatomy, the way their embryos develop, their physiology and, most powerfully, their molecular make-up such as DNA sequences.

Because it weighs so many inherited features, the natural system reflects real kinship, whereas the artificial system reflects only surface convenience. Organisms placed together by the natural system are genuinely related, having inherited their shared features from a common ancestor, which is why it gives a far truer picture of the living world than grouping by a single convenient character.

Language Clinic

Separate the two systems with a contrast word: the natural system groups by many inherited features, whereas the artificial system groups by a few convenient ones. The word 'whereas' shows you are comparing the basis of each, which is exactly what the question asks.

Question 9

As classification has developed, biologists have used five approaches in turn: artificial, natural, phyletic, phenetic and phylogenetic. Explain what chiefly separates these approaches, and which of them do, and do not, group organisms by their evolutionary relationship.

Model Answer

What chiefly separates the approaches is whether they group organisms by true evolutionary relationship or merely by convenience and overall likeness. The artificial approach uses a few convenient features, and the phenetic approach uses very many features, yet both sort organisms by surface similarity without asking how they are related by descent. **The natural, phyletic and phylogenetic approaches all set out to reflect real relationship.** The natural approach groups organisms by the many features they genuinely share; the phyletic approach arranges them along their lines of descent, broadly from simpler to more complex; and the phylogenetic approach, the most modern, groups them strictly by shared ancestry. **So three of the five reflect evolutionary relationship and two do not.** The natural, phyletic and phylogenetic approaches each aim at descent, whereas the artificial and phenetic approaches group on convenience or overall similarity alone.

Examiner's Note

The mark is earned by sorting the five on one clear principle, evolutionary relationship, rather than describing each in isolation. State plainly which approaches use descent (natural, phyletic, phylogenetic) and which do not (artificial, phenetic).

Question 10

The phylogenetic approach, also called cladistics, is the most modern way of classifying organisms. Explain how it groups organisms, and why the use of DNA has made it so powerful.

Model Answer

The phylogenetic approach groups organisms strictly by shared ancestry, placing together those that descend from a recent common ancestor. It sorts organisms by shared derived characters, that is, inherited features that arose in a common ancestor and were passed to all its descendants, and the groups formed in this way are called clades.

The use of DNA has made this approach especially powerful. Comparing DNA sequences shows how closely organisms are related far more precisely than outward features can, because the more alike the DNA, the more recently the organisms shared an ancestor, so relationships once hidden can now be read directly from the molecules themselves.

Language Clinic

Define a clade in one clean clause: a clade is a group of organisms that share a recent common ancestor. Naming the term and then giving its meaning, rather than describing it loosely, is what reads as a precise answer.

Question 11

Although the artificial system is no longer the scientists' first choice, it has real strengths that explain why it served for so long and is still convenient today. Explain three merits of the artificial system of classification.

Model Answer

1) **It is simple and quick to use.** Because it relies on only a few easily seen features, an organism can be sorted into its group rapidly, without long or detailed study.
2) **It is stable and does not change as new knowledge appears.** The few chosen features are fixed, so the groups stay the same even as science advances, which makes the system dependable to use.
3) **It is cheap and needs no special skill or equipment.** Sorting by obvious features such as size or habitat calls for no laboratory techniques or trained taxonomists, so almost anyone can apply it.

Examiner's Note

Each merit must be tied to the reason it follows from using a few obvious features. 'It is simple' is only a statement; 'it is simple because it uses a few easily seen features' is the explanation that earns the mark.

Question 12

The very thing that makes the artificial system convenient, its reliance on a few characters, is also the source of its weaknesses. Explain three demerits of the artificial system of classification.

Model Answer

1) **It ignores the natural and evolutionary relationship between organisms.** Because it groups on a single convenient feature, it says nothing about how organisms are truly related, so its groups carry no biological meaning beyond the chosen character.
2) **It places quite unrelated organisms in the same group.** Sorting by one feature throws very different organisms together, as when viruses, bacteria and fungi are lumped together as microorganisms merely for being small, even though they are fundamentally different, since viruses are non-cellular, bacteria are prokaryotic and fungi are eukaryotic.
3) **It cannot predict an organism's other features, nor take in new discoveries.** Since the groups hold no real relationship, knowing an organism's group tells you little else about it, and the system does not improve as fresh knowledge appears.

Examiner's Note

A demerit scores only when its cause is given. The grouping is weak because it rests on one convenient feature; name that cause, then its effect, rather than only listing faults.

False Confidence Alert

Do not assume that organisms sharing one obvious feature must be related. Whales and fish both swim, and bats and birds both fly, yet each pair belongs to a very different group; one shared feature is no proof of kinship.

Question 13

The natural system is the one taxonomists prefer today. Explain three merits that make it more useful than the artificial system.

Model Answer

1) **It groups organisms that are genuinely related, reflecting their evolutionary relationship.** Because it weighs many shared features, the organisms in a group share a common ancestry, and that relatedness grows closer further down the hierarchy.
2) **It allows an organism's features to be predicted and missing links to be filled.** Since the members of a group share most of their features, much about one can be inferred from the group, even where fossil evidence for the relationship is lacking.
3) **It is accurate and gives a true picture of the living world.** Because placement rests on the wide and careful study of many features, the groups it forms stand up to new evidence instead of being arbitrary.

Examiner's Note

The strength of the natural system is that its groups mean something, namely common ancestry. Tie each merit back to that, rather than praising the system in general terms.

Language Clinic

Lead with the result, then the cause: the natural system can predict an organism's features because the members of a group share most of their features. The word 'because' is what turns the merit into an explanation.

Question 14

For all its strengths, the natural system carries costs that the artificial system avoids. Explain three demerits of the natural system of classification.

Model Answer

1) **It is tedious, expensive and time-consuming.** Placing an organism correctly demands a great deal of information about many features, so much study and resources are needed before a decision can be reached.
2) **It is unstable, changing as knowledge and technology grow.** New tools keep revealing new features, so groupings must be revised; the microscope first brought single-celled life into view as the Protista, and later the comparison of the organisms' genetic material, their ribosomal RNA, split the prokaryotes into the archaea and the true bacteria, which look alike under any microscope.
3) **It can be applied only by trained experts.** The wealth of information and technique it demands means the work is limited to specialist taxonomists, and cannot be done quickly by an untrained person.

Examiner's Note
Each demerit is the price of using many features. Show the link, that the demand for so much detailed evidence is what makes the system slow, costly and expert-only.

False Confidence Alert
The instability of the natural system is not a sign that it is wrong. Its groupings change because knowledge is growing and the classification is being improved, not because the system is unreliable.

Question 15

To classify the maize plant, a biologist places it in a series of groups, each one narrower than the last, from the broadest group down to the single kind. Name the seven ranks of this hierarchy in order from the broadest to the narrowest, and explain why the second rank is called a phylum for animals but a division for plants.

Model Answer

The seven ranks, from the broadest to the narrowest, are Kingdom, Phylum or Division, Class, Order, Family, Genus and Species. Each rank is held within the one above it, so a kingdom contains several phyla, a phylum several classes, and so on down to the species, the narrowest group of all.

The second rank carries two names only because of long-standing custom in the two fields. Zoologists, who classify animals, call this rank a phylum, while botanists, who classify plants, call the very same level a division, so the two words name one step in the hierarchy, one used for animals and one for plants.

Examiner's Note

Marks are lost when the ranks are given out of order or one is left out. Learn them as a fixed ladder from Kingdom down to Species, and remember that Phylum (animals) and Division (plants) name the same rank.

False Confidence Alert

A common error is to treat phylum and division as two different ranks. They are the very same level of the hierarchy; only the field differs, phylum for animals and division for plants.

Question 16

A lion, a leopard and a tiger are placed in three different species, yet all three share the genus Panthera. Explain what makes them three separate species rather than one, and what the rank of species means in terms of breeding.

Model Answer

A species is the narrowest rank, a group of organisms so alike that they can interbreed and produce fertile offspring. Its members share the largest number of features of any taxon, because they are the most closely related of all organisms.

The lion, leopard and tiger are separate species because in the wild they do not interbreed to produce fertile offspring. Although all three are big cats of the genus Panthera and share many features, in nature they stay reproductively isolated by separate ranges and mating behaviour, so Panthera leo, Panthera pardus and Panthera tigris remain three species. A lion and a tiger can be crossed in captivity to give a liger, but this does not happen in the wild and such hybrids are not reliably fertile, which is why the three are still counted as separate.

Examiner's Note

The species mark turns on one test: the members interbreed and produce fertile offspring. Sharing many features is not enough; it is breeding fertile young together that marks a single species.

Language Clinic

State the test as one condition: a species is a group whose members can interbreed and produce fertile offspring. Both halves matter, that they breed, and that the young are themselves fertile.

Question 17

The taxonomic hierarchy is more than a list of seven names; each rank is built from the rank below it. Explain how a genus, a family and an order are each formed, and what this nesting shows about the way organisms are grouped.

Model Answer

Each higher rank is formed by gathering together the related groups of the rank just below it. A group of related species makes up a genus; a group of related genera makes up a family; and a group of related families makes up an order, the same nesting continuing up through class, phylum and kingdom.

This nesting shows that classification works by collecting the related into ever larger groups. Because each rank gathers the related members of the rank beneath it, organisms that share a genus also share its family, order and every rank above, so the hierarchy sorts life into groups within groups, each wider one holding the narrower ones inside it.

Examiner's Note
The answer must show the building-up: related species to a genus, related genera to a family, related families to an order. Naming the ranks without saying that each gathers the related members of the one below misses the question.

Language Clinic
Use the repeating frame to keep it clear: a group of related species forms a genus, a group of related genera forms a family, a group of related families forms an order. The same sentence shape carries the whole idea.

Question 18

Biologists describe a kingdom or a genus as a taxon, and the level it occupies as a taxonomic rank. Explain what each of these two terms means, and why the organisms placed in any one taxon can be described by a shared set of features.

Model Answer

A taxon is any named group of organisms in the classification, while a taxonomic rank is the level at which that group sits in the hierarchy. A kingdom, a phylum, a genus and a species are all taxa; the rank tells you how broad each one is, from the wide kingdom down to the narrow species.

The organisms in any one taxon can be described together because they share a set of features characteristic of that group. Each taxon is marked out by features that its members have and that members of other groups at the same level lack, so describing those shared features describes the whole taxon, and one member can largely stand for the rest.

Examiner's Note
Two terms need two definitions: a taxon is a named group, a rank is the level it occupies. The second part of the answer must say why a taxon can be described as a unit, that its members share features characteristic of the group.

False Confidence Alert
Do not use taxon and rank as if they were the same word. A taxon is an actual group of organisms, such as the genus Panthera; a rank is the level, such as genus, at which many different taxa can sit.

Question 19

Two organisms that share only a kingdom have little in common, while two that share a genus are remarkably alike. Explain why the number of features organisms share increases as you move down the taxonomic hierarchy from kingdom to species.

Model Answer

Shared features increase down the hierarchy because each step down gathers organisms that are more closely related. At the rank of kingdom organisms are grouped on only a few very broad features, so they share little else; but each narrower rank adds further shared features, until at the rank of species the members are alike in almost everything. This follows from how the groups are built: because every lower taxon collects only the more closely related members of the taxon above, organisms grouped together at genus level branched from a common ancestor far more recently than those grouped only at kingdom level, and the more recent the shared ancestor, the more features they have inherited in common.

Examiner's Note

The mark is the link between rank and relatedness: lower taxa share more features because their members are more closely related, through a more recent common ancestor. State that link rather than only asserting that lower groups are more alike.

False Confidence Alert

It is easy to get the direction wrong. Shared features are fewest at the top, the kingdom, and most at the bottom, the species; organisms grow more alike as you move down the hierarchy, not up.

Question 20

Arranging organisms in a ranked hierarchy, rather than in one long list, brings real advantages to biologists. Explain three reasons why the taxonomic hierarchy is important in classification.

Model Answer

1) **It provides a standard, orderly method for naming and placing organisms.** Every taxonomist follows the same ranks in the same order, so a newly discovered species can be slotted in and named in a way that others will at once recognise.
2) **It reveals the relationships between organisms.** Because each rank gathers more closely related members, an organism's position in the hierarchy shows which groups it lies near and how closely it is related to them.
3) **It makes communication and the finding of information simple.** Naming the rank an organism belongs to tells other biologists a great deal about it at once, which avoids confusion and saves repeating long descriptions.

Examiner's Note

Each reason must be paired with what it achieves, an orderly naming method, a picture of relationships, or easier communication. Three bare phrases will not earn the explanation marks.

Language Clinic

Tie each reason to its payoff with a linking word: the hierarchy eases communication because naming an organism's rank tells another biologist a great deal at once. The word 'because' joins the reason to the benefit the question asks for.

Question 21

Within the kingdoms, the next rank down already shows how varied life is. Name the four divisions into which the kingdom Plantae is sorted, and four of the phyla into which the kingdom Animalia is sorted, and state what this rank represents.

Model Answer

The kingdom Plantae is sorted into four divisions: Bryophyta, the mosses; Pteridophyta, also called Filicinophyta, the ferns; Coniferophyta, the cone-bearing gymnosperms; and Angiospermophyta, the flowering plants. Each division gathers plants built to one general plan, as the flowering plants all reproduce through flowers and seeds.

The kingdom Animalia is sorted into several phyla, among them Platyhelminthes, Annelida, Arthropoda and Chordata. Each phylum, like each plant division, stands for a major shared body plan, so this rank marks the broadest divisions of structure within a kingdom.

Examiner's Note

Name the taxa exactly and keep each in its own kingdom; slipping a plant division into the animal list, or the reverse, loses marks. Saying that the rank stands for a shared body plan earns the understanding mark.

Question 22

Every organism studied by biologists is given a formal scientific name. Explain what the terms nomenclature and binomial nomenclature mean, and name the two parts that make up a scientific name such as *Homo sapiens*.

Model Answer

Nomenclature is the process of giving organisms agreed names, and binomial nomenclature is the system of giving each organism a two-part scientific name. The system was established and applied consistently by the Swedish taxonomist Carolus Linnaeus in the eighteenth century, and the word binomial comes from Latin, bi meaning two and nomen meaning name, so it means two names.

A scientific name is made of two parts, the generic name followed by the specific epithet. In *Homo sapiens* the first part, *Homo*, is the genus to which human beings belong, while the second part, *sapiens*, is the specific epithet that picks out our particular species within that genus.

Examiner's Note

Define both terms and name both parts. Nomenclature is naming in general; binomial nomenclature is the two-part system; and the two parts are the generic name and the specific epithet. Dropping either definition or either part loses marks.

False Confidence Alert

The specific epithet on its own does not name an organism. *sapiens* by itself is meaningless; a species is named only by both parts together, the genus and the epithet, as in *Homo sapiens*.

Question 23

A student writes the leopard's name in four ways: *panthera pardus*, *Panthera Pardus*, *Panthera pardus*, and Panthera pardus in ordinary upright type. Using the correct form, explain the rules that govern how a scientific name must be written.

Model Answer

1) **The name has two parts, the genus first and the specific epithet second.** Together they name one kind of organism, as in *Panthera pardus* for the leopard.
2) **The genus begins with a capital letter and the specific epithet is written in small letters.** So it is *Panthera pardus*, never *panthera pardus* and never *Panthera Pardus*.
3) **The whole name is written in Latin.** Latin is a fixed, unchanging language, so the name means the same everywhere and does not drift as living languages do.
4) **In print the name is set in italics, and when handwritten the two parts are underlined separately.** This sets the scientific name apart from the ordinary words around it.

Examiner's Note

Most marks here are thrown away on the small things: a lower-case genus, a capital on the epithet, or a name left in ordinary type. Show the correct form, *Panthera pardus*, and state each rule plainly.

Language Clinic

Write the form into your answer, do not just describe it: the genus takes a capital and the epithet stays in small letters, as in *Panthera pardus*, set in italics. Showing the correct name proves the rule.

Question 24

Over the years, an organism may be given several different scientific names by different scientists. Explain how taxonomists decide which one of these names is the single correct name to use.

Model Answer

The single correct name is the earliest one that was validly published, under the rule known as priority. When the same organism has been named more than once, the name that was properly published first is kept and the later names are set aside as synonyms. This rule leaves every organism with exactly one accepted name, which prevents the confusion that would arise if several names competed for the same creature.

False Confidence Alert

Priority does not mean the most popular or the most recent name. It is the earliest name that was validly published that stands, even when a later name has become more familiar.

Question 25

The naming of plants is governed by one set of rules and the naming of animals by another. Explain what these nomenclatural codes are, and why animals and plants are governed by separate codes.

Model Answer

A nomenclatural code is the agreed rule-book that lays down how the organisms in a group must be named. Plants are named under the International Code of Botanical Nomenclature, while animals are named under the International Code of Zoological Nomenclature, and each code sets out the rules its workers must follow.

Animals and plants have separate codes because the two codes were drawn up separately and independently, one by zoologists and one by botanists. Because the codes are independent, the very same name may even be used once for an animal and once for a plant, as *Pieris* names both a butterfly and a garden shrub; yet the shared principles, such as the two-part name and priority, still run through both codes.

Language Clinic

Pair each code with its group in one clean sentence: plants are named under the botanical code, animals under the zoological code. Naming which code governs which group is what the answer needs.

Question 26

In a long report, the bacterium *Escherichia coli* is written in full the first time and as *E. coli* afterwards, and a botanist may write *Hyparrhenia* spp. or *Hyparrhenia* sp. Explain how a scientific name may be shortened, and what the forms spp. and sp. mean.

Model Answer

Once a scientific name has been written in full, the genus may be shortened to its first letter, a capital followed by a full stop, when the name appears again. So *Escherichia coli* is written out the first time and as *E. coli* thereafter, which saves space without losing the meaning, since the reader already knows which genus the letter stands for.

The forms spp. and sp. stand in place of the species name when it is not given. *Hyparrhenia* spp. means several species of the genus *Hyparrhenia* taken together, while *Hyparrhenia* sp. means a single, unidentified species of that genus; in both, the genus stays in italics but the abbreviation does not.

Examiner's Note

Keep the two ideas separate: shortening the genus to a capital letter and a full stop (*E. coli*), and the use of spp. and sp. for the species. The genus stays italicised or underlined; the abbreviations spp. and sp. do not.

False Confidence Alert

Do not confuse spp. with sp. The plural spp. means several species of the genus together, while the singular sp. means one species that has not yet been identified.

Question 27

The frog's scientific name is sometimes written *Rana temporaria* L., with a letter added at the end, and a new name counts only once it has been published with a description. Explain what the added letter means, and why a scientific name must be published with a description before it is accepted.

Model Answer

The letter added at the end names the author, the person who first published the name. In *Rana temporaria* L. the L stands for Linnaeus, showing that he was the first to publish this name effectively, so the citation credits the namer and records who established the name.

A scientific name is accepted only once it has been published together with a description of the organism. The description sets out the features that mark the species off from all others, so that other scientists can recognise exactly which organism the name belongs to, and a name given without one cannot be checked or trusted.

Examiner's Note
Answer both parts: the trailing letter is the author who first published the name, and the description is what makes the name usable, since it fixes which organism the name belongs to.

Language Clinic
Read the citation in plain words: *Rana temporaria* L. means the frog named by Linnaeus. The author's initial is not part of the two-word name; it simply credits who published it.

Question 28

A single insect may be called by a dozen different common names across Tanzania and the wider world, yet its scientific name never changes. Explain three reasons why scientific names are so important to biologists.

Model Answer

1) **They give every organism one uniform name used worldwide.** Because all biologists attach the same scientific name to the organism, everyone knows exactly which creature is meant, wherever they work.
2) **They remove the confusion and ambiguity of common names.** One common name may be used for several organisms, and one organism may carry many common names, but a single scientific name clears away that muddle.
3) **They are tied to no single language or region.** A scientific name stays the same in every country and is not changed by the local language, so it crosses the language barriers that common names cannot.

Language Clinic
Lead each reason with the benefit, then the cause: scientific names remove confusion because one common name may label several different organisms. The connector 'because' is what earns the explanation mark.

Question 29

A student is handed an unfamiliar insect and a printed taxonomic key, and within minutes is able to name it. Explain what a taxonomic key is, and the kind of features it relies on to identify an organism.

Model Answer

A taxonomic key is a tool that identifies an unknown organism by leading the user through a series of choices about its features. At each step the user compares the organism with the key and follows the choice that fits, narrowing the possibilities until a single name is reached, which makes naming an unfamiliar organism both quick and reliable.

A key works on diagnostic features, the contrasting and easily observed characters that set one group apart from another. These are features such as the presence of hair or feathers, the number of legs, or the shape of a leaf, chosen because they are easy to see and because each clearly separates one group of organisms from the rest.

Examiner's Note
Two things earn the marks: that a key identifies an unknown organism through a series of choices, and that it uses diagnostic features, the contrasting observable characters. A key that is called a 'tool for naming' without the idea of stepwise choices is only half-defined.

Language Clinic
Name what a key does in one line: a taxonomic key identifies an unknown organism through a series of either-or choices about its features. The phrase 'a series of choices' captures how it works.

Question 30

The commonest and simplest taxonomic key is the dichotomous key. Explain what is meant by a dichotomous key, and how its pairs of statements lead the user to a name.

Model Answer

A dichotomous key is a key that divides a group in two at every step, the word dichotomous coming from a Greek word meaning cut in two. It is built from pairs of contrasting statements, called leads or couplets, and the two statements of each pair offer mutually exclusive choices, so an organism can fit only one of them. Choosing the statement that fits sends the user on to the next pair, and each split reduces a large, mixed group to a smaller one until a single organism is named.

Examiner's Note

The marks rest on three ideas: two branches at each step (dichotomous), the pair of contrasting statements (the couplet or leads), and the mutually exclusive choice. Naming the key without the two-way contrasting choice misses its defining feature.

False Confidence Alert

A dichotomous key never offers three or more options at a step. Dichotomous means two: at every branching there are exactly two contrasting statements, and the organism must fit one of them.

Question 31

Two kinds of dichotomous key are in common use: the indented key and the bracketed or numbered key. Explain how each of these two kinds is laid out.

Model Answer

In an indented key, the two contrasting statements of each pair are written one above the other and set in from the margin, each pair indented a little further than the last. The paired statements describe the same character and often begin with the same word, and the growing indentation shows at a glance how the groups branch and nest within one another.

In a bracketed or numbered key, the two statements of each pair are kept together and numbered, and they all begin at the same distance from the margin. The user reads a numbered pair, chooses the statement that fits, and is then directed by a number to the next pair to read, working through the numbers until a statement gives the organism's name.

Examiner's Note

Describe the layout of each, not just the names: the indented key steps further in at each pair and nests the groups visually, while the bracketed key keeps each numbered pair together and sends the user on by number.

Question 32

Suppose you are given five different leaves and asked to build a key that anyone could use to tell them apart. Explain the main steps you would follow to construct a simple numbered dichotomous key.

Model Answer

1) **Collect and display the specimens to be identified.** Lay the five leaves out together so that all of them can be examined side by side.

2) **Observe and record the features of each specimen.** Examine every leaf carefully and write its observable features, such as shape, margin and texture, in a table.
3) **Choose one contrasting feature that divides the whole group into two.** Pick a single character that some leaves show and the others lack, and use it to split the collection into two groups.
4) **Subdivide each group in two, again and again, using further features.** Within each group choose another contrasting feature that separates its members, and keep dividing each smaller group into two.
5) **Number the pairs of statements and write them out as the key.** Give each pair of contrasting leads a number, arrange them in order, and direct the user from one numbered pair to the next until each leaf is named.

Examiner's Note

The heart of the method is dividing the group into two, again and again, on a single contrasting feature each time. An answer that lists 'observe and record' but never reaches the repeated splitting into two has not described how a key is built.

Question 33

The features used in a key may be either quantitative or qualitative. Explain the difference between these two kinds of feature, giving an example of each from a plant.

Model Answer

Quantitative features are those that can be counted or measured, giving a definite number. The number of petals on a flower, the length of a leaf or the length of a petiole are quantitative features, because each can be expressed as a figure.

Qualitative features are those that are described rather than counted. The shape of a leaf, the texture of a stem or the colour of a flower are qualitative features, because they are matters of kind and appearance, not of number.

Language Clinic

Mark the divide with one word: quantitative features are counted or measured, whereas qualitative features are described. Setting 'counted' against 'described' shows the difference at once.

Question 34

When choosing features for a key, a biologist avoids characters such as the presence of flowers, which a plant shows only in one season, or body size, which changes as an organism grows. Explain why the features used in a taxonomic key must be permanent ones.

Model Answer

The features used in a key must be permanent because the key has to work whenever, and on whichever specimen, it is used. A feature that comes and goes, such as flowers that appear only in one season, or one that changes as the organism grows, such as overall size, would mislead the user whenever it happened to be absent or different. Only stable, always-present features give an identification that can be trusted at any time of year and at any stage of growth.

Examiner's Note

Tie the rule to its reason: permanent features are required because a key must give the same answer at any season and any stage of growth. State why a changing feature fails, that it misleads when it is absent or altered.

False Confidence Alert

A striking feature is not always a good one for a key. Bright flower colour or large size may catch the eye, but if they appear only in one season or change as the organism grows, they make the key unreliable.

Question 35

For a long time every living thing was placed in just one of two kingdoms, plants or animals. Explain why this two-kingdom system was eventually abandoned, and what evidence led scientists to recognise five kingdoms instead.

Model Answer

The two-kingdom system was abandoned because many organisms fit neither plants nor animals. Bacteria, fungi and the many single-celled organisms are neither true plants nor true animals, so forcing them into one of only two kingdoms hid their real differences and threw together organisms that are built and live in quite different ways.

The change to five kingdoms came as new tools revealed differences the naked eye had missed. The microscope uncovered a whole world of single-celled organisms and showed that bacteria have no nucleus, while later study of cell structure and of molecules made the deep differences between bacteria, protists, fungi, plants and animals clear, so these five groups were recognised as separate kingdoms.

Examiner's Note

Two points carry the marks: that the two kingdoms could not hold organisms such as bacteria and fungi, and that new evidence, from the microscope and from cell and molecular study, revealed the five groups. Naming five kingdoms without saying why two were not enough leaves the explanation unearned.

False Confidence Alert

A common error is to count fungi, or even bacteria, as plants because many do not move and some grow in soil. Fungi do not photosynthesise but absorb their food, and bacteria have no nucleus at all, so each belongs in a kingdom of its own.

Question 36

A bacterium, an amoeba, a mushroom, a mango tree and a tilapia each belong to a different kingdom. Name the five kingdoms of the modern classification, and the kind of organism each one contains.

Model Answer

1) **Monera, also called Prokaryotae, contains the bacteria.** These are the prokaryotes, the single-celled organisms whose cells have no true nucleus.
2) **Protoctista contains the simple, mostly single-celled organisms such as the amoeba.** These are eukaryotes that are neither fungi, plants nor animals, including the protozoa and many algae.
3) **Fungi contains the moulds, yeasts and mushrooms.** These are eukaryotes that absorb their food from their surroundings rather than making it or taking it in.
4) **Plantae contains the plants, such as the mango tree.** These are multicellular eukaryotes that make their own food by photosynthesis.
5) **Animalia contains the animals, such as the tilapia.** These are multicellular eukaryotes that feed by taking in other organisms.

Examiner's Note

Name all five and add the feature that fixes each: prokaryotic Monera, the simple eukaryotic Protoctista, the absorbing Fungi, the photosynthesising Plantae and the ingesting Animalia. A bare list of five names earns less than a list that shows what each kingdom is.

Language Clinic

Tie each kingdom to its hallmark in one breath: Fungi absorb their food, whereas Plantae make it and Animalia take it in. The three verbs, absorb, make and take in, carry the difference between the kingdoms.

Question 37

When a newly studied organism must be placed in one of the five kingdoms, a taxonomist looks at a small number of basic features. Explain the main features used to decide which kingdom an organism belongs to.

Model Answer

Organisms are placed into kingdoms chiefly on three basic features: their cell type, whether their body is one cell or many, and the way they feed. Cell type asks whether the cells are prokaryotic, without a true nucleus, or eukaryotic, with one; cellularity asks whether the organism is single-celled or multicellular; and mode of nutrition asks whether it makes its own food, absorbs it, or takes in other organisms. These few features are together enough to assign almost any organism to its kingdom.

Examiner's Note

Three features must appear: cell type (prokaryotic or eukaryotic), cellularity (one cell or many), and mode of nutrition (make, absorb or take in food). Giving only one or two of the three is a part-answer.

Question 38

Four of the five kingdoms, Protoctista, Fungi, Plantae and Animalia, are grouped as eukaryotes, while the bacteria are set apart in their own kingdom. Explain the difference that separates them, and why it is treated as the deepest division in the living world.

Model Answer

The bacteria are prokaryotes, whose cells have no true nucleus and no membrane-bound organelles, while the other four kingdoms are eukaryotes, whose cells have both a nucleus and such organelles. In a bacterium the genetic material lies free in the cytoplasm, whereas in a plant, animal, fungus or protist it is enclosed within a nuclear membrane, and the cell is far more complex inside.

This difference is treated as the deepest division because it separates two fundamentally different kinds of cell. The presence or absence of a nucleus marks the most basic split in the structure of life, a far greater difference than any among the four eukaryotic kingdoms, so the bacteria are kept in a kingdom of their own, the Monera or Prokaryotae.

Examiner's Note

The marks rest on the nucleus: prokaryotic bacteria have none and no membrane-bound organelles, while eukaryotes have both. Say why this is the deepest split, that it divides two fundamentally different kinds of cell, not merely large cells from small ones.

Language Clinic

Lead with the dividing feature: bacteria are prokaryotic, having no true nucleus, whereas the other four kingdoms are eukaryotic. The single word 'whereas' draws the line the question asks for.

Question 39

Viruses, such as the one that causes measles, are not placed in any of the five kingdoms. Explain why viruses are left outside the five-kingdom system, and what this shows about whether they are living.

Model Answer

Viruses are left outside the five kingdoms because they are not made of cells. Every one of the five kingdoms holds organisms built from cells, but a virus is only a piece of genetic material wrapped in a protein coat, with none of the cell structure on which the kingdoms are based, so it has no place among them.

Their exclusion reflects the fact that viruses show only a few of the features of living things. On its own a virus cannot feed, grow or respire, and it can reproduce only by entering a living cell and using that cell's machinery; outside a host it shows none of these activities and behaves like non-living matter, which is why it sits at the very edge of what we call life.

False Confidence Alert

Whether a virus is alive has no simple yes or no. It carries genes and can multiply, which seem alive, yet it has no cell and can do nothing on its own outside a host, which seem non-living; this is exactly why it is left outside the five kingdoms.

REAL QUESTIONS

These questions take the same biology into real life in Tanzania, and test whether you can apply it, spot a mistake and judge an argument. Attempt each on paper, then check the model answer beneath. Every answer leads with the mark-bearing point in bold.

Question 40

A Form Five student on a trip to the Serengeti meets thousands of different kinds of plants, insects, birds and mammals, and wonders why scientists bother to classify them all. Use five points to show the importance of classifying organisms.

Model Answer

1) **It reduces a vast number of organisms to a few manageable groups.** The millions of kinds are sorted into a small number of groups, so they can be studied through a few representatives instead of one at a time.
2) **It reveals the relationships between organisms.** Grouping by shared features shows which organisms are closely related and which are distant, giving an ordered picture of how life is connected.
3) **It gives every organism one uniform name used worldwide.** A single agreed scientific name lets scientists everywhere know exactly which organism is meant, free of the confusion of many local names.
4) **It allows the features of a newly found organism to be predicted.** Once a new organism is placed in a group on its few known features, the other features of that group can be expected of it.
5) **It aids other fields such as agriculture, medicine and ecology.** Knowing an organism's group guides the farmer, the doctor and the ecologist, since related organisms often share the same uses, needs or roles.

Examiner's Note
Five separate points are asked for, so five different reasons must be given. Repeating one reason in two forms, such as 'it reduces numbers' and 'it makes study easier', counts only once.

Question 41

A student collects six organisms from the school grounds: an earthworm, a grasshopper, a fern, a maize seedling, a housefly and a tilapia. Explain how the student could sort these six into groups, and state the criteria used.

Model Answer

The first and broadest criterion is the mode of nutrition, the way each organism feeds, which separates the plants from the animals. The fern and the maize seedling make their own food by photosynthesis and are placed together as plants, whereas the earthworm, grasshopper, housefly and tilapia feed on other organisms and are placed together as animals.

Each group is then split further on more detailed features. Among the animals, the presence of a backbone sets the tilapia apart from the rest, and among the animals without a backbone the presence of jointed legs groups the grasshopper and the housefly together and leaves out the earthworm; among the plants, the maize is separated from the fern because it reproduces by seeds while the fern reproduces by spores.

Language Clinic
Name the criterion each time you split: the first division is by mode of nutrition, the next by the presence of a backbone, then by jointed legs. Stating the feature used at each step is exactly what 'state the criteria' asks for.

Question 42

When biology relied on the naked eye, only two kingdoms were recognised, but a Tanzanian student today learns five. Explain how advances in scientific tools changed classification from a two-kingdom to a five-kingdom system.

Model Answer

The first great change came with the microscope, which revealed living things the naked eye could never see. Once microscopes uncovered a whole world of single-celled organisms, and showed that bacteria have no nucleus while other tiny organisms do, it became clear that these did not belong among the plants or the animals, and groups such as the Protoctista were recognised.

Later tools went deeper still, into the structure of cells and their molecules. The electron microscope laid bare the fine structure of cells, and the study of molecules such as DNA measured how closely organisms are truly related, so the differences between bacteria, protists, fungi, plants and animals were confirmed and the five-kingdom system took shape.

Examiner's Note
The marks go to the tools and what each revealed: the microscope uncovered single-celled life and the absent nucleus of bacteria, while the study of cell structure and molecules measured true relationship. Saying only that 'science improved' is too vague.

False Confidence Alert
A common error is to think the new kingdoms were newly discovered organisms. Bacteria, fungi and protists were already known; what changed was the realisation, through better tools, that they belong among neither the plants nor the animals.

Question 43

Kipanga is revising the basic words of the topic and writes: *"Classification, taxonomy and identification are three names for the same thing. When I look at a bird and recognise it as a weaver, I am classifying it."* Identify the mistakes in what Kipanga has written and correct them.

Model Answer

Kipanga is wrong that classification, taxonomy and identification mean the same thing; each names a different idea. Classification is the arrangement of organisms into groups by their shared features; taxonomy is the whole science of classifying, naming and identifying organisms; and identification is the naming of a single organism by matching it to an existing classification.

He is also wrong that recognising the bird as a weaver is classifying it. Matching one organism to a name that already exists is identification, not classification; he would be classifying only if he were working out the groups into which weavers and other birds should be placed in the first place.

Examiner's Note

A mistake-spotting answer must do two things: name each mistake and give the correction. Writing only 'he is wrong' earns nothing; the marks are in the corrected statement.

Language Clinic

Keep the three apart in a single line: classification builds the groups, identification names one organism using them, and taxonomy is the whole science that covers both. Three clean clauses settle the confusion.

Question 44

Modern taxonomists almost always choose the natural system of classification over the artificial one. Give four reasons why scientists prefer the natural system.

Model Answer

1) **It reflects the true evolutionary relationships between organisms.** Because it groups by many shared inherited features, the organisms placed together really are related, so the classification mirrors how life actually evolved.
2) **It allows the features of an organism to be predicted.** Since the members of a natural group share most of their features, much about one organism can be inferred from the group it belongs to.
3) **It is accurate and stands up to new evidence.** Placement rests on the wide and careful study of many features, so the groups it forms are not arbitrary and rarely need to be overturned.
4) **It can absorb new discoveries and even suggest missing links.** As fresh evidence appears it fits into the natural scheme, and the relationships it shows help work out where undiscovered or extinct organisms belong.

Examiner's Note

Four distinct reasons are asked for, each a separate strength of the natural system. Giving the same idea twice, such as 'it shows relationships' and 'it shows evolution', scores only once.

Question 45

Use five points to support the statement that the artificial system of classification is not preferred by scientists.

Model Answer

1) **It ignores the evolutionary relationships between organisms.** Grouping on a single convenient feature says nothing about how the organisms are truly related.
2) **It places quite unrelated organisms in the same group.** Sorting by one feature throws very different organisms together, as when bacteria, fungi and protists are lumped as microorganisms merely for being small.
3) **It cannot predict an organism's other features.** The members of an artificial group share only the one feature used to sort them, so knowing the group tells you nothing else about an organism's biology.
4) **It does not take in new discoveries.** Its fixed, convenient features cannot absorb new knowledge, so the system fails to improve as science advances.
5) **It can be positively misleading.** By placing unrelated organisms together it suggests relationships that do not exist, which works against the very aim of classification.

Examiner's Note

Each point must be a real weakness paired with its effect, for example that grouping on one feature lumps unrelated organisms together. Naming a fault without its consequence is a half-point.

False Confidence Alert

The question asks why the artificial system is not preferred, so every point must be a weakness. Slipping in a merit, such as 'it is simple and quick', answers the opposite question and earns nothing.

Question 46

In a Tanzanian market and kitchen, plants are often grouped as food crops and weeds, or as medicinal and non-medicinal, and animals as edible and non-edible. Explain why these everyday groupings are examples of artificial classification, and what they fail to show.

Model Answer

These everyday groupings are artificial because they sort organisms by a single convenient feature, their use to people, whereas a natural classification sorts by the organisms' true relationships. Plants are placed together simply because they are all eaten, or all used as medicine, and animals because they are all edible, regardless of how the organisms are actually related.

Such groupings fail to show the true relationships between the organisms. Two plants grouped as food crops, such as maize and beans, may belong to quite different families, while a food crop and a weed may be close relatives, so grouping by use hides the real kinship that a natural classification would reveal.

Examiner's Note

Two things earn the marks: that the grouping is artificial because it uses one convenient feature, use to people, and that it therefore hides the organisms' true relationships. Stopping at 'it is artificial' leaves the second half unearned.

Language Clinic

Carry the contrast with one word: these everyday groupings sort by use, whereas a natural classification sorts by kinship. The word 'whereas' makes the comparison the question is really about.

Question 47

Explain the scientific and technological advances that made it possible for classification to shift from the artificial system towards the natural system.

Model Answer

The shift became possible as new techniques let scientists look beyond a few surface features to the deeper, shared features that reveal relationship. The microscope and the study of internal anatomy, of how embryos develop and of body chemistry gave taxonomists far more features to compare than the naked eye alone, and these deeper features reflect how organisms are related.

The greatest advance came with the study of molecules, above all DNA. Comparing the DNA of organisms shows directly how closely they are related, far more reliably than outward appearance, so taxonomists could at last group organisms by true evolutionary kinship, which is the aim of the natural system.

Language Clinic

Tie each tool to what it reveals: comparing DNA shows how closely organisms are related, which is why it let classification become natural. Naming the technique and then what it shows is what reads as understanding.

Question 48

Kipanga says that *grouping birds, bats and butterflies together as 'flying animals' is a good natural classification, because they all share the important feature of flight.* **Kipute** disagrees, saying *it is only an artificial grouping.* Who is right, and why?

Model Answer

Kipute is right: grouping birds, bats and butterflies as 'flying animals' is an artificial grouping, not a natural one. Flight is a single convenient feature, and the three are otherwise very different: a bird has feathers, a bat has hair and feeds its young on milk like other mammals, and a butterfly is an insect with six legs and a quite different body plan.

A natural classification would group them by their many shared inherited features, which places them far apart. Because the three reached flight separately rather than inheriting it from a common flying ancestor, the natural system puts the bird among the birds, the bat among the mammals and the butterfly among the insects, so Kipanga's grouping rests on one surface feature and is therefore artificial.

Examiner's Note

A Biology Judge answer must give a clear verdict and then justify it. Say plainly who is right, Kipute, and support it with the natural-versus-artificial distinction; sitting on the fence earns little.

False Confidence Alert

Shared flight does not mean shared ancestry. Birds, bats and insects each came to fly on their own, so flight is a feature reached separately, not a sign that the three belong together in one natural group.

Question 49

Illustrate the taxonomic hierarchy of a human being, from the broadest rank down to the narrowest.

Model Answer

A human being is classified through seven ranks, narrowing from the kingdom Animalia at the broadest down to the species Homo sapiens at the narrowest, as illustrated below.

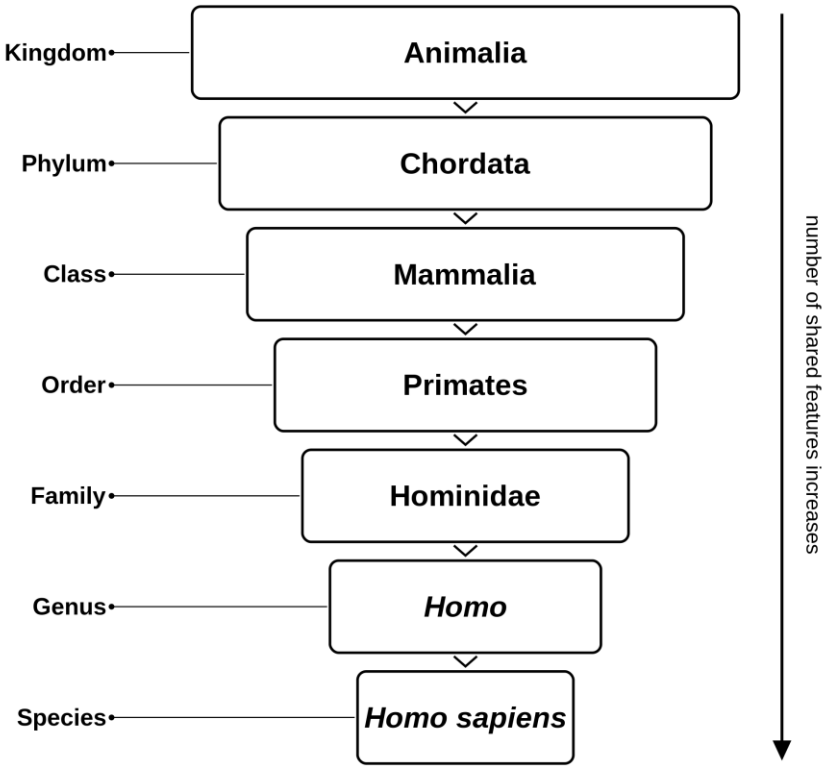


Figure 3.1: *The taxonomic hierarchy of a human being.*

Examiner's Note

The marks go to the seven ranks in the correct order, from kingdom down to species, with none left out and the species name written in its two-part form. A jumbled order or a missing rank loses marks even when the taxa themselves are right.

Question 50

Illustrate the taxonomic hierarchy of the lion (Panthera leo), and use it to show the rank at which the lion and a human being part company.

Model Answer

The lion is classified through the same seven ranks, and placing it beside a human being shows clearly where the two part company.

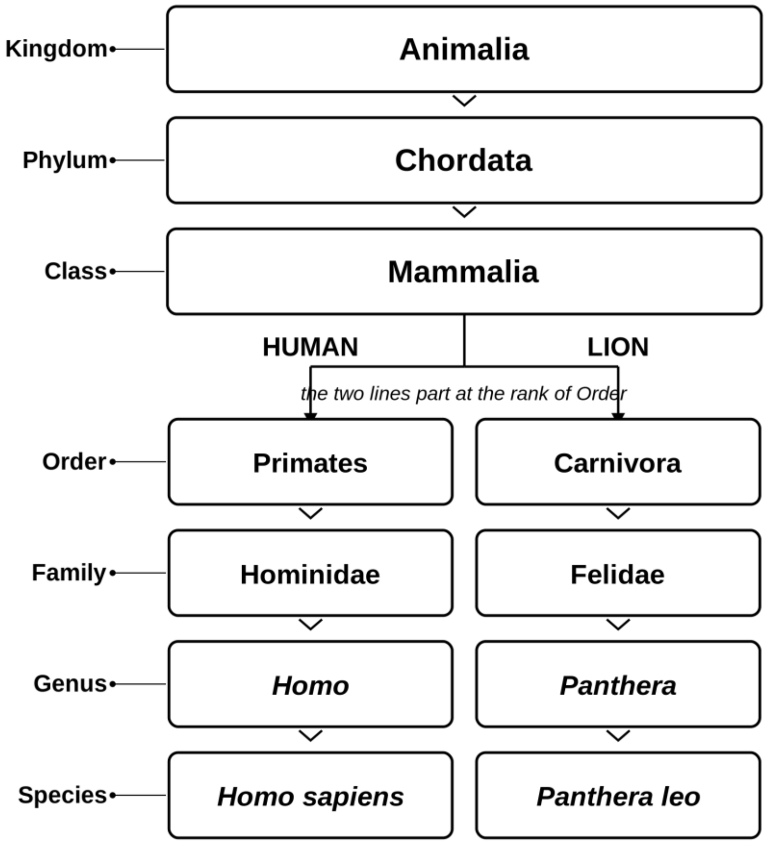


Figure 3.2: *The hierarchies of a human being and a lion compared.*

The lion and the human share their first three ranks, both being animals, both chordates and both mammals. Down to the level of class they are grouped together, which is why both are warm-blooded, hairy animals that suckle their young.

They part company at the rank of order, and grow steadily more different below it. The human is placed in the order Primates and the lion in the order Carnivora, and from there their lines run separately through different families and genera to their own species, Homo sapiens and Panthera leo.

Language Clinic

Say plainly where the two part: the human and the lion share the kingdom, phylum and class, but separate at the rank of order. Naming the exact rank of divergence is what the question wants.

Question 51

The lion (Panthera leo) and the leopard (Panthera pardus) are placed in the same genus, Panthera, yet a lion and a leopard cannot breed together to give fertile young. Explain how both of these statements can be true at the same time.

Model Answer

The lion and the leopard share the genus Panthera because they have a great many features in common. Both are big cats with the same body plan, hair, teeth and claws, so they are closely related and are grouped together at the level of genus.

They remain separate species because they cannot naturally breed together to produce fertile offspring. Belonging to one genus makes them close relatives, not the same kind; the test of a single species is the ability to interbreed and give fertile young, and since the lion and the leopard cannot do this, they are kept as two species, Panthera leo and Panthera pardus, within the one genus.

Examiner's Note

Two ideas must both appear: that a shared genus means many shared features and close relationship, and that separate species means they cannot interbreed to give fertile young. Answering only one half earns half the marks.

False Confidence Alert

Sharing a genus does not make two organisms one species. The lion and the leopard are close relatives within Panthera, yet they remain two species because they cannot breed together to give fertile offspring.

Question 52

Kipanga is revising the taxonomic ranks and writes: *"The broadest group is the species, which then splits into smaller and smaller groups down to the kingdom, the narrowest of all. Members of a kingdom are therefore the most alike."* Identify the mistakes in what Kipanga has written and correct them.

Model Answer

Kipanga has the hierarchy upside down: the broadest group is the kingdom, not the species. The ranks run from the kingdom, the widest group, down through phylum, class, order, family and genus to the species, the narrowest group of all, so it is the kingdom that splits into smaller groups, ending at the species.

He is also wrong that the members of a kingdom are the most alike. Shared features increase as the ranks narrow, so the members of a kingdom share only a few broad features and are the least alike, whereas the members of a single species are the most alike of all.

Examiner's Note

A mistake-spotting answer must name each error and correct it. Here both the order of the ranks and the direction of likeness are reversed, so both must be put right.

Language Clinic

Fix the direction in one line: the kingdom is broadest and its members least alike, whereas the species is narrowest and its members most alike. The word 'whereas' carries the contrast.

Question 53

A Tanzanian fruit seller calls her fruit embe, an English buyer calls it mango, and a botanist calls it *Mangifera indica*. Give five reasons why the scientific name *Mangifera indica* is more useful to a taxonomist than the common name mango.

Model Answer

1) **It names one definite species, the same the world over.** *Mangifera indica* refers to exactly one kind of plant everywhere, while the word mango may be applied loosely to several different fruits.
2) **It is free of any language barrier.** The scientific name stays the same in Kiswahili, English or any other tongue, whereas the common name shifts from embe to mango and beyond.
3) **It removes the confusion of many local names.** One organism may carry a dozen common names across regions, but it has only one scientific name, so no one is left guessing which plant is meant.

4) **It places the organism in its group.** The first part, *Mangifera*, names the genus, so the name itself tells a taxonomist the wider group the mango belongs to, which a common name cannot do.
5) **It is fixed and recognised by international rules.** The scientific name is governed by an agreed code, so it is stable and accepted by scientists everywhere, unlike a casual common name.

Examiner's Note

Five distinct reasons are asked for. Each should name something the scientific name does that the common name cannot, such as naming one definite species or crossing language barriers. Repeating one idea in two forms scores once.

Question 54

In different parts of Tanzania and the world the same animal may be known by several names, while the same name may be given to different animals. Using three points, explain why common names are unreliable for naming organisms in science.

Model Answer

1) **One organism may carry many different common names.** The same animal is called by different names in different languages and regions, so a single common name cannot be relied on to identify it everywhere.
2) **One common name may be used for several different organisms.** A name such as robin is given to quite different birds in different countries, so the name does not point to one definite organism.
3) **Common names are tied to a particular language.** Because they belong to one language, common names mean nothing to a scientist who speaks another, whereas science needs a name everyone can use.

Examiner's Note

Three separate points are needed, each a reason common names fail science: one organism with many names; one name for many organisms; and being tied to a single language. A general 'they are confusing' is not three points.

False Confidence Alert

A common name may serve well in one village or country, but science needs a name that works everywhere. Familiarity is not the same as reliability, which is why common names cannot replace scientific ones.

Question 55

A student writes four scientific names as follows: mangifera indica, Zea Mays, solanum Tuberosum and homo sapiens, all in ordinary upright type. Rewrite each name correctly, and state the rule the student has broken.

Model Answer

mangifera indica should be *Mangifera indica*. The generic name must begin with a capital letter.

Zea Mays should be *Zea mays*. The specific epithet must be written in small letters, never with a capital.

solanum Tuberosum should be *Solanum tuberosum*. Here both parts are wrong: the genus needs a capital and the specific epithet must be in small letters.

homo sapiens should be *Homo sapiens*. The generic name must start with a capital letter.

In addition, every one of the four, written here in ordinary type, must be set in italics, or underlined separately if it is handwritten.

Examiner's Note

Each name must be both rewritten correctly and matched to the rule it breaks. Correcting a name without naming the rule, or naming a rule without the correction, earns only half the marks.

Language Clinic

State the fix and the rule together: Zea Mays should be *Zea mays*, because the specific epithet is written in small letters. Pairing each correction with its reason is what the question wants.

Question 56

Two of the operative principles that govern scientific naming are priority and publication. Explain how each of these two principles works.

Model Answer

Priority is the rule that, when an organism has been given more than one name, the earliest validly published name is the one that stands. Later names for the same organism are set aside as synonyms, so priority keeps a single, settled name for each organism and stops rival names from competing.

Publication is the rule that a new name counts only once it has been properly published, together with a description of the organism. Until a name appears in print with a description that others can read and check, it has no standing; publication is what makes a name official and available for everyone to use.

Language Clinic

Keep the two principles apart in plain words: priority decides which name wins, the earliest validly published one, and publication decides when a name counts, once it appears with a description. One clean sentence for each is enough.

Question 57

Kipanga writes the maize plant as "Zea Mays" and the human as "Homo Sapiens", both in ordinary upright letters, and says: *"I have given both parts of each name a capital letter to show that the organisms are important, and there is no need to underline or italicise a scientific name."* Identify the mistakes in what Kipanga has done and said, and correct them.

Model Answer

Kipanga is wrong to put a capital on the second part of each name: they should be *Zea mays* and *Homo sapiens*, with the specific epithet in small letters. Only the generic name takes a capital, and that capital is a fixed rule of naming, not a way of showing that an organism is important, so his reason is mistaken as well as his spelling.

He is also wrong that a scientific name need not be underlined or italicised. A scientific name must be set in italics when printed, or underlined when handwritten, so that it stands out as a formal name; leaving it in ordinary upright type breaks the rule.

Examiner's Note

Both mistakes must be named and corrected: the capital on the specific epithet, and the missing italics or underlining. The student's reason, that capitals show importance, should be put right too.

False Confidence Alert

Capital letters in a scientific name follow a fixed rule, not importance. The genus always begins with a capital and the specific epithet never does, however important the organism may be.

Question 58

Using the features hair, feathers, scales, fins and the type of skeleton, construct a simple numbered key that could be used to identify the six classes of the phylum Chordata: Mammalia, Aves, Reptilia, Amphibia, Chondrichthyes and Osteichthyes.

Model Answer

The six classes can be separated by the following numbered key:

1a. Has fins and lives in water (a fish)..**2**
1b. Has limbs and lives on land..**3**
2a. Skeleton made of cartilage.. **Chondrichthyes**
2b. Skeleton made of bone..**Osteichthyes**
3a. Body covered with hair; young fed on milk ....**Mammalia**
3b. Body without hair **4**
4a. Body covered with feathers.. **Aves**
4b. Body without feathers..**5**
5a. Skin dry and covered with scales..**Reptilia**
5b. Skin moist and without scales.. **Amphibia**

Examiner's Note

A key earns marks for working, not for length: each couplet must split the group into two, the two statements must be true opposites, and every path must end at one of the six classes. Check that each class can actually be reached.

False Confidence Alert

A dichotomous key must offer exactly two choices at each step, and they must be genuine opposites. A step with three options, or a vague pair such as 'large or small', is not a working key.

Question 59

You are provided with the following specimens: a frog, a lizard, a bird, a bony fish and a guinea pig. Construct a simple numbered key that could be used to identify each of them.

Model Answer

The five animals can be separated by the following numbered key:

1a. Has fins and lives in water .... **bony fish**

1b. Has limbs and lives on land **2**

2a. Body covered with hair .... **guinea pig**

2b. Body without hair **3**

3a. Body covered with feathers .... **bird**

3b. Body without feathers **4**

4a. Skin dry and covered with scales .... **lizard**

4b. Skin moist and without scales .... **frog**

Examiner's Note

Each of the five animals must be reachable by following the leads, and no two may end at the same point. Run every animal through the key before writing it down to be sure it works.

Question 60

Construct a simple numbered key that could be used to identify these four arthropods: a housefly, a spider, a crab and a millipede.

Model Answer

The four arthropods can be separated by the following numbered key:

1a. Three pairs of legs (six legs in all) .... **housefly**

1b. More than three pairs of legs **2**

2a. Four pairs of legs; antennae absent .... **spider**

2b. Five or more pairs of legs; antennae present **3**

3a. Five pairs of legs and a hard shell; lives in water .... **crab**

3b. Very many legs along a long, segmented body .... **millipede**

Examiner's Note

The key must separate the arthropods on clear, countable features such as the number of pairs of legs. Each couplet splits the group in two, and every animal ends at its own name.

Language Clinic

Write each lead as a definite, checkable statement: 'three pairs of legs' rather than 'few legs'. A reader must be able to answer yes or no to it at a glance.

Question 61

A biologist working in the field carries a taxonomic key. Explain why a biologist needs such a key, and how a key, once it has been made, is used to identify an unknown organism.

Model Answer

A biologist needs a key because it makes the naming of an unfamiliar organism quick, certain and repeatable. Without one, an unknown organism would have to be compared with countless described kinds; a key instead narrows the search to a single name through a short series of definite choices, and anyone using the same key reaches the same answer.

A key is used by working through its paired statements, choosing at each step the one that fits the organism. The user reads the first couplet, picks the lead that matches the unknown, and follows it to the couplet it points to; this is repeated, each choice ruling out one branch, until a lead ends not in another number but in the organism's name.

Language Clinic

Answer the two parts in turn: a key is needed because it makes identification quick and certain, and it is used by following the matching lead from one couplet to the next until a name is reached. The words 'because' and 'until' carry the two halves.

Question 62

You are provided with three plant species: *Solanum incanum* (which bears prickles), *Solanum tuberosum* (the Irish potato) and *Solanum nigrum* (black nightshade). Construct a bracketed key and an indented key that could be used to identify them.

Model Answer

The three species can be told apart by their prickles, tubers and berries. Set out as a bracketed (numbered) key:

1a. Stem and leaves bearing sharp prickles .... ***Solanum incanum***

1b. Stem and leaves without prickles... **2**

2a. Plant forming underground tubers .... ***Solanum tuberosum***

2b. Plant without tubers; ripe berries black .... ***Solanum nigrum***

A bracketed key keeps its numbered couplets together and sends the reader on by number, whereas an indented key sets out the same couplets stepped further in from the margin:

1a. Stem and leaves bearing sharp prickles .... ***Solanum incanum***

1b. Stem and leaves without prickles

> **2a.** Plant forming underground tubers .... ***Solanum tuberosum***
>
> **2b.** Plant without tubers; ripe berries black .... ***Solanum nigrum***

Examiner's Note

Both forms must appear and both must work. The bracketed key numbers its couplets and sends the reader on by number; the indented key steps each pair further in. The same three species must come out of each.

Language Clinic

Name the difference in layout plainly: in a bracketed key the couplets are numbered and kept together, whereas in an indented key each pair is stepped further in from the margin. The word 'whereas' draws the contrast.

Question 63

In the five-kingdom system the bacteria are placed in a kingdom of their own, while Animalia, Plantae, Protoctista and Fungi are grouped as eukaryote kingdoms. Explain why classification draws this line between the bacteria and the other four kingdoms.

Model Answer

The line is drawn because the bacteria have a fundamentally different kind of cell from the members of the other four kingdoms. The cells of animals, plants, protoctists and fungi are eukaryotic, each with a true nucleus and membrane-bound organelles, whereas a bacterial cell is prokaryotic, with its genetic material lying free and no such organelles.

This difference in cell structure is treated as the deepest of all, so it sets the bacteria apart. Because the presence or absence of a nucleus is a more basic difference than any among the eukaryotes, the bacteria are kept in their own kingdom, the Prokaryotae or Monera, while the four kingdoms that share the eukaryotic cell fall on the other side of the line.

Examiner's Note

The mark rests on the cell: bacteria are prokaryotic, with no true nucleus, while the four other kingdoms are eukaryotic, with one. Name that difference and say it is the deepest, rather than only listing the kingdoms.

Question 64

In cytology you learned that some cells have chloroplasts and make their own food while others do not. Using a plant and a fungus as examples, explain how features seen at the level of the cell decide which kingdom a eukaryote is placed in.

Model Answer

A plant is placed in the kingdom Plantae partly because of a cell feature, the chloroplast, that lets it make its own food. The chloroplasts in a plant cell carry out photosynthesis, so the plant feeds by making its own food, and this way of feeding, together with its cellulose cell wall, marks it as a member of Plantae.

A fungus, though also a eukaryote, is placed in a kingdom of its own because its cells tell a different story. A fungal cell has no chloroplast and cannot photosynthesise; whereas a plant makes its own food, a fungus absorbs ready-made food from its surroundings, and this absorptive feeding, together with a cell wall made of chitin rather than cellulose, places it in the kingdom Fungi rather than among the plants.

Examiner's Note

Tie each kingdom to a cell feature: the chloroplast and photosynthesis place an organism in Plantae, while the lack of one and absorptive feeding place it in Fungi. A kingdom named without the cell feature that decides it is only half an answer.

Language Clinic

Connect cell to kingdom in one line: a plant cell has chloroplasts and makes its own food, whereas a fungal cell has none and absorbs it. The contrast word 'whereas' carries the two cases.

Question 65

Kipanga collects a mushroom from a rotting log and writes: *"This is a plant. It grows in one place and does not move about, just like other plants, so it belongs to the kingdom Plantae."* Identify the mistakes in what Kipanga has written and correct them.

Model Answer

Kipanga is wrong that the mushroom is a plant: it is a fungus, and belongs to the kingdom Fungi, not Plantae. A mushroom has no chloroplasts and cannot make its own food; instead it absorbs ready-made food from the rotting log, which is the way fungi feed and not the way of plants.

He is also wrong to group it with plants merely because it grows in one place and does not move. Being rooted and still is not what makes an organism a plant; the kingdom is decided by mode of nutrition, and because the mushroom absorbs its food rather than making it by photosynthesis, it is placed among the fungi.

Examiner's Note

Two things must be put right: that the mushroom is a fungus, not a plant, and that the kingdom is decided by mode of nutrition, not by whether the organism moves. Naming the right kingdom without the right reason earns only part of the marks.

False Confidence Alert

Staying in one place and not moving does not make an organism a plant. Fungi are rooted and still too, yet they absorb their food instead of making it, which is why they form a kingdom of their own.

HOT QUESTIONS

These questions ask you to reason, not merely to recall: to compare, to predict, to judge, and to put loose statements right. Attempt each on paper, then check the model answer beneath. Every answer leads with the mark-bearing point in bold.

Question 66

Tanzania is one of the most biologically rich countries on Earth, with thousands of species in its forests, parks and waters. Evaluate whether such biodiversity could be managed and conserved without a system of classification.

Model Answer

Without a system of classification, Tanzania's biodiversity could not be managed or conserved in any reliable way. Conservation depends first on knowing what exists: a species cannot be counted, protected, or its decline noticed, unless it can be identified and named, and classification is what gives each kind a fixed identity that everyone recognises.

Classification also makes it possible to act on relationships and to share information. Because related organisms often share habitats and needs, grouping them guides which areas and resources to protect; and because a scientific name means the same to a ranger in the Serengeti and a scientist abroad, classification lets the many people in conservation work from one shared record rather than a confusion of local names.

Examiner's Note

An evaluate question needs a clear position and reasons for it. Take a stand, that conservation could not work without classification, and support it: you cannot protect what you cannot identify, name and communicate about.

Question 67

A botanist on Mount Kilimanjaro finds a flowering plant that has never been described before. Predict how the existing system of classification would let her place and begin naming this new plant, even before it has been fully studied.

Model Answer

Even from a few features, the botanist could at once place the new plant in the higher ranks of the system. Because it bears flowers, it can be put straight away among the flowering plants of the kingdom Plantae, and as more features are seen, such as the form of its leaves and flowers, it can often be narrowed toward a class and an order without waiting for a full study.

Its place in the system would then let her predict much about it and give it a provisional name. By matching it to the family and genus it most resembles, she can expect it to share the other features of that group, and she can give it a two-part scientific name, the genus it belongs to followed by a new specific epithet, to be confirmed once the plant is fully described and published.

Examiner's Note

A predict answer should use the system, not guess: place the plant by an obvious feature (flowers leads to Plantae), narrow it as more features appear, predict its other features from the group, and give it a provisional two-part name.

False Confidence Alert

A new organism does not have to be fully studied before it can be classified. A few clear features are enough to place it in the broad groups at once; the finer ranks and the settled name come later.

Question 68

The artificial system of classification is praised as stable and yet condemned as misleading. Explain how both of these descriptions can be true of the same system.

Model Answer

The artificial system is stable because it rests on a few fixed, easily seen features that do not change. Since it sorts organisms by something simple, such as whether they fly or where they live, its groups stay the same over time and are not upset by new discoveries, which makes it dependable and easy to use.

It is misleading for the very same reason: those few convenient features take no account of how organisms are really related. By grouping on one surface character it throws unrelated organisms together and suggests kinships that do not exist, so the stability it offers is the stability of a grouping that does not reflect the truth, which is how one system can be steady and misleading at once.

Language Clinic

Show that one cause gives both effects: because the artificial system uses a few fixed features, it is stable; and because those same features ignore real relationship, it misleads. Pointing to the one cause behind both is what resolves the paradox.

Question 69

It is often said that a complete natural system of classification has never been achieved in the fullest sense. Explain why a perfect natural classification is so hard to reach.

Model Answer

A perfect natural classification is hard to reach because it would need complete knowledge of every organism and of how all of them are related, which science does not yet have. Many organisms are still undiscovered, the fossil record of extinct ancestors is full of gaps, and the true relationships between groups can be worked out only as far as the available evidence allows.

It is also a moving target, because each new tool and discovery can change what is known. As fresh evidence arrives, from anatomy to molecules, groupings have to be revised, so the natural system keeps improving towards the truth without ever quite reaching a final, complete form.

Examiner's Note

The marks lie in two ideas: the knowledge needed is incomplete (undiscovered species, gaps in the fossil record), and it keeps changing as new evidence appears. A single reason is only half the answer.

Language Clinic

Give the two halves plainly: a complete natural system is out of reach because much is still unknown, and because what is known keeps being revised. 'Still unknown' and 'always revised' together carry the point.

Question 70

A Form Five student groups a chicken and a grasshopper together, on the grounds that both lay eggs. (a) Name the system of classification the student has used. (b) Give two demerits of classifying organisms in this way.

Model Answer

The student has used the artificial system of classification. Grouping the chicken and the grasshopper on the single, easily seen feature of laying eggs, for convenience rather than for any real relationship, is exactly what the artificial system does.

This way of classifying carries serious demerits. First, it throws together quite unrelated organisms, for a chicken is a bird and a grasshopper is an insect; and second, it ignores their evolutionary relationship, since laying eggs is shared by many different groups and says nothing about true kinship, so the grouping cannot be relied on or used to predict anything further.

Examiner's Note

Answer both parts: name the artificial system, then give two separate demerits, that it groups unrelated organisms and that it ignores their real relationship. One demerit given twice in different words counts once.

False Confidence Alert

A shared feature such as laying eggs does not make two organisms related. Birds, insects, fish and reptiles all lay eggs, yet they belong to completely different groups.

Question 71

Imagine that biologists had names for organisms but did not arrange them in ranks at all, keeping only one enormous list of every kind of living thing. Predict the problems this would cause.

Model Answer

Without ranks, the sheer number of organisms would become unmanageable, and finding or studying any one of them would be very difficult. A single flat list of millions of kinds could not be searched or learned the way a ranked system can, where an organism is found by narrowing from a broad group down to a small one, so the order that makes the living world studiable would be lost.

The relationships between organisms, and the power to predict, would also be lost. Ranks show how closely organisms are related, each level grouping more closely related kinds, so without them there would be no way to see which organisms are near relatives, and nothing about an unknown organism could be predicted from the company it keeps.

Examiner's Note

A predict answer should name concrete problems, not just say it would be 'hard'. Two earn the marks: the organisms could not be managed or searched, and their relationships, and any prediction from them, would be lost.

Question 72

Of all the ranks in the hierarchy, the species is said to carry the most information about its members. Explain why this is so, using the test that defines a species.

Model Answer

The species carries the most information because its members share more features than the members of any wider rank. Each step down the hierarchy gathers more closely related organisms, so at the narrowest rank, the species, the members are alike in most of their features, and to name an organism's species is therefore to say a great deal about it at once.

This richness follows from the test that defines a species: that its members can interbreed and produce fertile offspring. Only organisms alike in their whole make-up, down to the level that allows successful breeding, can pass this test, so membership of one species implies the closest similarity of any rank, which is why the species tells you more than any rank above it.

Examiner's Note

The mark is the link between the rank and the information it carries: the species is the narrowest rank, so its members share the most features, and the interbreeding-and-fertile-offspring test guarantees that depth of similarity. Name the test, do not just say 'they are alike'.

Language Clinic

Build the answer from the test outward: because members of a species can interbreed to give fertile young, they must be alike in their whole make-up, which is why the species carries the most information. The word 'because' ties the test to the conclusion.

Question 73

A scientific name is made of the genus and the specific epithet, yet the higher ranks, such as the family and the order, are left out of the name. Evaluate why it is the genus, rather than any other rank, that is carried into the scientific name alongside the species.

Model Answer

The genus is carried into the name because it is the nearest broader group above the species, close enough to be highly informative yet small enough to be practical. Naming the genus places the organism among its closest relatives at once, so the two-part name already shows the wider group it belongs to, while the specific epithet still points to one kind.

The higher ranks are left out because they would lengthen the name without adding the same value. A family or an order holds very many kinds and would say far less about the particular organism, and stringing several ranks together would make names clumsy, so the genus alone, the closest grouping, is chosen to travel with the species in a short, two-word name.

Examiner's Note

An evaluate answer should justify the choice and rule out the alternatives. Say why the genus is included (the nearest, most informative broader group) and why the higher ranks are not (too broad, and they would make the name long).

False Confidence Alert

It is a mistake to think a fuller name, with the family or order added, would be better. The extra ranks would lengthen the name and say less about the particular organism; the genus alone is the most useful broader group to carry.

Question 74

A scientist proposes to name a newly found Tanzanian beetle Bigblack beetlei, written in ordinary letters. State the qualities of a good scientific name, and judge the proposed name against them.

Model Answer

A good scientific name is short, written in Latin or a latinised form, and made of two parts: a validly published generic name and a distinct specific epithet. It should belong to one organism only and follow the writing rules, with the genus capitalised, the epithet in small letters and the whole italicised, and ideally it should be easy to say and to remember.

The proposed name Bigblack beetlei meets almost none of these. Bigblack is a plain English word, not the Latin or latinised form a generic name must take; beetlei merely adds a Latin-looking ending to the English word beetle and tells nothing useful about the animal; and the whole name is written in ordinary letters instead of being italicised, so it breaks the basic rules and could not stand as a proper scientific name.

Examiner's Note

Two things are wanted: the qualities of a good name, and a judgement of the example against them. List the qualities, then test the proposed name point by point, rather than only saying it is wrong.

False Confidence Alert

Two words do not make a scientific name. The first must be a proper generic name in Latin or latinised form, not just a descriptive English word, and the whole name must follow the writing rules of capital, lower case and italics.

Question 75

When a taxonomist discovers an organism that has never been named before, giving it its scientific name is not a simple matter. Explain the challenges the taxonomist faces in naming a newly discovered organism.

Model Answer

The first challenge is being sure the organism is truly new and deciding which group it belongs to. The taxonomist must compare it carefully with all similar known organisms to be certain it has not already been named, and must study enough of its features to place it in the correct genus, which is hard when the organism is unusual or little known.

The second challenge is meeting the rules and making the name official. A new name must obey the code of nomenclature, must not repeat a name already in use, and must be published together with a proper description before it counts, so the taxonomist has careful work to do and must have the name accepted by others before it is settled.

Language Clinic

Set out the challenges in two stages: first being sure the organism is new and finding its group, then naming it under the rules and publishing it with a description. The order, confirm then name, keeps the answer clear.

Question 76

You are given five unfamiliar seeds that differ in size, colour, shape and surface texture, but you do not know their names. Explain how you would set about building a dichotomous key to tell them apart, and how you would choose the feature for the very first division.

Model Answer

I would begin by examining all five seeds carefully and recording the features of each, then look for a feature that divides the whole set into two. Working from a table of their size, colour, shape and texture, I would split the five into two groups on one clear feature, then keep dividing each group in two until every seed stood alone at the end of its own path.

For the very first division I would choose the feature that splits the whole set most clearly and evenly into two. A good first feature is one that every seed plainly either has or has not, such as a smooth against a rough surface, and that divides the five into two real groups rather than singling out one seed, because a clean, even first cut makes the rest of the key simpler and surer.

Examiner's Note

A build-a-key answer must give the method, observe and tabulate, then divide in two and keep subdividing, and justify the first division. The first feature is chosen because it splits the whole set cleanly into two, not because it is the most eye-catching.

Language Clinic

Justify the first cut, do not just name it: choose the feature because it divides the whole set cleanly and evenly into two. 'Because it splits them evenly' is the reasoning the question is asking for.

Question 77

A student asks why a dichotomous key must offer exactly two choices at each step, rather than three or four, and what makes one couplet better than another. Evaluate the reasons behind the two-way rule, and explain what makes a good couplet.

Model Answer

A key branches in twos because a choice between just two clear alternatives is the simplest and surest decision a user can make. With only two options the user can always decide, since an organism either has a feature or does not, whereas three or four choices invite hesitation and overlap, where an organism seems to fit more than one; the two-way rule keeps every step a clean yes-or-no and so makes the key reliable.

A good couplet is built from a single, clear feature whose two statements are true opposites. Each lead should describe one definite character the user can check at a glance, such as 'leaves with a smooth edge' against 'leaves with a toothed edge', so that exactly one of the two always fits; vague or double-barrelled statements, or features that come and go, make a couplet weak.

Examiner's Note

Two things are wanted: why the key uses two choices, that a yes-or-no decision is the simplest and surest, and what makes a good couplet, one clear feature whose two leads are true opposites.

False Confidence Alert

Offering three or four choices at a step does not make a key more precise; it makes it harder to use. The strength of a key is that each step is a single clear choice between two opposites.

Question 78

A student constructs the following key for three small animals, a sparrow, a housefly and an earthworm:

1a. Has wings...**2**

1b. Has no wings.. **earthworm**

2a. Body covered with feathers.. **sparrow**

2b. Body covered with feathers .... **housefly**

(a) Try to use the key to identify a housefly, which has wings and a body covered with fine bristles, not feathers.
(b) Identify the flaw in the key, and correct it.

Model Answer

(a) **The key cannot identify the housefly, because neither statement of the second couplet fits it.** Following the key, the housefly has wings and so goes to couplet 2, but both leads there describe an animal covered with feathers, which the housefly is not, so it reaches a dead end and cannot be named.
(b) **The flaw is that the two statements of the second couplet are not opposites: both of them say 'covered with feathers'.** A couplet must offer two contrasting choices, so it should read '2a. Body covered with feathers ... sparrow' and '2b. Body without feathers, with bristles ... housefly', which makes the two leads true opposites and lets the housefly be reached.

Examiner's Note

A faulty-key answer must show why the key fails and then mend it. Point out that the housefly hits a dead end because both leads are the same, then rewrite the couplet as two genuine opposites.

Question 79

Viruses are sometimes called living and sometimes called non-living, and biologists place them outside the five kingdoms. Weighing their characteristics, judge whether a virus should be counted as a living thing.

Model Answer

On balance a virus is best counted as non-living, because on its own it shows almost none of the features of life. Outside a host it does not feed, grow, respire or respond, it is not built from a cell, and it can even be stored like an ordinary chemical, all of which point away from life.

The one feature that points the other way is that a virus carries genetic material and can multiply, though only inside a living cell. Because it can reproduce solely by taking over a host's machinery and can do nothing by itself, it sits on the very border of life, and this mixture of one living-like trait with so many non-living ones is exactly why classification leaves the virus outside the five kingdoms.

Examiner's Note

A judge question needs a verdict with the evidence weighed on both sides. Come down on one side, that a virus is on balance non-living, after setting its one living-like trait, host-dependent reproduction, against the many features of life it lacks. The fuller study of viruses comes in the next chapter.

False Confidence Alert

A virus reproducing is not proof that it is alive. It cannot reproduce on its own; it only directs a living cell to make copies of it, so even this one living-like activity depends entirely on a host.

Question 80

The five-kingdom system was built largely from what the microscope revealed about cells. Predict how a powerful new technique, such as the comparison of organisms' DNA, might change the number of kingdoms that scientists recognise.

Model Answer

A powerful new technique could reveal deep differences hidden from earlier methods, and so split an existing kingdom into more than one. If the DNA of organisms now grouped together showed that some are in fact only distantly related, scientists would separate them, raising the number of kingdoms, just as closer study once split the prokaryotes into the archaea and the true bacteria.

Equally, new evidence could show that groups once thought separate are closely related, and join them, or simply confirm the present kingdoms. Because classification follows the best current evidence, the number of kingdoms is not fixed but provisional, and a tool as powerful as DNA comparison could raise it, lower it, or leave it unchanged, depending on what the molecules reveal.

Examiner's Note

A predict answer should reason from how classification works: because it follows the evidence, a powerful new tool could split a kingdom and raise the number, merge kingdoms and lower it, or confirm the present five. Say that the number is provisional, not fixed.

Chapter 4

COMPARATIVE STUDIES OF NATURAL GROUPS OF ORGANISMS

BINDER QUESTIONS

Work through each question in order: attempt it on paper, then check the model answer beneath and read the annotations before moving on. Every answer leads with the mark-bearing point in bold.

Question 1

A bat flies on wings of skin and feeds its young on milk, while a swift flies on feathered wings and lays eggs. Seeing only that both can fly, an early naturalist placed the two together in one group. Explain why a single shared feature such as flight is a weak basis for grouping organisms, and what comparative classification uses in its place to group them soundly.

Model Answer

A single shared feature can mislead, because unrelated organisms often develop the same feature separately to meet the same need. Flight is found in a bat, a bird and even an insect, yet each wing is built to a completely different plan, so grouping by flight alone would tie a mammal, a bird and an insect into one unnatural group. The wing of a bat is a sheet of skin stretched over long finger bones, whereas the wing of a bird is a feathered forelimb, which shows that the likeness is only on the surface and hides a deep difference in build.

Comparative classification instead groups organisms on many shared characteristics together with their common ancestry. When two organisms agree in a whole set of detailed features, the simplest explanation is that they inherited those features from a shared ancestor, so the more features they share, the more closely related they are taken to be. These features are drawn from internal structure, from physiology and from embryonic development, and today from the sequence of the DNA itself, which together give a far surer guide than any single character.

> **Examiner's Note**
>
> The marks are earned by two moves: showing that one feature can be shared by unrelated organisms, with a clear example such as the wing of a bat against the wing of a bird, and then naming what classification uses instead, that is many shared features together with common ancestry.

> **False Confidence Alert**
>
> It feels safe to assume that any feature shared by two organisms shows they are related. Yet a feature can be shared because each organism evolved it separately for the same task, as wings were; only a large set of agreeing features, pointing back to a common ancestor, is firm evidence of a real relationship.

Question 2

For a long time every living thing was filed as either a plant or an animal. As biologists looked closer, this two-way scheme broke down and was replaced, step by step, by a system of five kingdoms. Explain what forced biologists to abandon the two kingdoms, and how the count grew to five.

Model Answer

The two-kingdom scheme broke down because many organisms fit neither a plant nor an animal. Bacteria, the single-celled organisms of ponds and soil, the moulds and the mushrooms could not be forced into either group without ignoring how they were built or how they fed, and the microscope made this plain by revealing a whole world of tiny organisms unlike both plants and animals. As long as only two kingdoms were allowed, these misfits were filed by force rather than by their true nature.

The count grew to five as each misfit was given a kingdom that matched its real features. The single-celled organisms were gathered into a kingdom of their own; the bacteria were then set apart once the electron microscope confirmed that their cells have no true nucleus, marking them as prokaryotes; and the fungi were separated because they feed by absorbing food rather than by making it as plants do. These steps left five kingdoms, namely Monera, Protoctista, Fungi, Plantae and Animalia, each defined by features the two-kingdom scheme had been ignoring.

Examiner's Note

A strong answer ties every change to the evidence that drove it: the microscope revealing single-celled life, the electron microscope revealing the absence of a nucleus in bacteria, and the difference in feeding that sets the fungi apart. Naming the five kingdoms without these reasons earns far less.

Language Clinic

Notice how the answer moves with words that carry the cause: because, once and rather than. The phrase once the electron microscope showed does the real work, because it links the new tool to the new kingdom and makes clear that the change was forced by evidence, not chosen at will.

Question 3

A biologist sorting the living world into five kingdoms leans on just a few features of the cell and on how each organism feeds. Name the five kingdoms, and explain the criteria that decide which kingdom an organism is placed in.

Model Answer

The five kingdoms are Monera, Protoctista, Fungi, Plantae and Animalia, and an organism is placed in one of them by weighing a small set of cell features against its mode of nutrition.

1) ***Cell type,* that is whether the cell is prokaryotic or eukaryotic.** This is the first and deepest cut, because a cell with no true nucleus places the organism in Monera, while a true nucleus places it among the other four kingdoms.

2) ***Cellularity,* that is whether the organism is single-celled or many-celled.** This mainly separates the largely single-celled Protoctista from the Fungi, Plantae and Animalia, which are mostly many-celled, although a few fungi such as yeasts remain single-celled.

3) ***Mode of nutrition,* that is how the organism obtains its food.** Plants make their own food by photosynthesis, animals take in food by ingestion, and fungi absorb food after digesting it outside the body, which is what sets these three eukaryote kingdoms apart.

Examiner's Note

Credit goes to naming the five kingdoms correctly and then giving the three criteria, cell type, cellularity and mode of nutrition, each with what it decides. The strongest answers point out that cell type is the first division, because it sets the prokaryotic Monera against all of the eukaryotes.

Language Clinic

Set each criterion out as its own point and say what it decides, not merely that it exists. A phrase such as this places the organism or this separates the two turns a bare list of features into an explanation of how the sorting is actually done.

Question 4

Of the five kingdoms, four are gathered loosely together while Monera is kept firmly apart as the Prokaryotae. Explain what sets Monera apart from the rest, and why this difference is treated as the deepest division in the living world.

Model Answer

Monera is set apart because its members are prokaryotes, cells that have no true nucleus and no membrane-bound organelles. Their genetic material lies coiled free in the cytoplasm rather than sealed inside a nuclear membrane, and they lack the mitochondria, chloroplasts and other compartments found in other cells, so their whole cell plan is simpler and fundamentally different.

This difference is treated as the deepest division because the presence or absence of a true nucleus is the single greatest difference between cells. Every member of the other four kingdoms is a eukaryote, keeping its DNA inside a nucleus, so the first and widest split in the living world lies between the prokaryotic Monera and all the eukaryotes, whereas the lines that separate Protoctista, Fungi, Plantae and Animalia from one another are smaller matters of cellularity and nutrition built upon the same eukaryotic cell.

Examiner's Note

The answer must name the prokaryotic cell, with no true nucleus and no membrane-bound organelles, as the feature that isolates Monera, and then state that this prokaryote-eukaryote difference is the deepest divide, because it separates two whole grades of cell rather than two ways of life.

False Confidence Alert

It is tempting to think Monera is kept apart because bacteria are small, or simple, or primitive. The real reason is the kind of cell, not its size or rank: a prokaryotic cell has no nucleus, and that single fact, not any idea of being lower, is what places Monera on its own.

Question 5

When the five kingdoms are drawn up, viruses are left out of every one of them and placed in a group of their own. Explain why a virus cannot be fitted into any of the five kingdoms.

Model Answer

Viruses are left out first because they are not made of cells. Every one of the five kingdoms is built from cells, the basic unit of life, but a virus is only a strand of nucleic acid wrapped in a protein coat, with no cytoplasm, no organelles and no cell membrane of its own, so it fails the very first condition for a place in any kingdom.

They are left out also because they cannot carry out the processes of life by themselves. A virus cannot feed, grow or respire, and it can reproduce only by entering a living cell and using that cell's machinery, so outside a host it is as inert as a lifeless chemical; since the five-kingdom system is a way of sorting living, cellular organisms, a particle that is neither cellular nor independently alive belongs to none of them.

Examiner's Note

Two points carry the marks: that a virus is acellular, only nucleic acid in a protein coat, and that it cannot perform the processes of life on its own, reproducing only inside a host. Together these explain why a system built for living cells has no room for it.

False Confidence Alert
Because viruses cause so many familiar diseases, it is easy to treat them as a sixth kingdom, or as very small bacteria. They are neither: a bacterium is a complete living cell, whereas a virus is a non-cellular particle that does nothing at all until it is inside a host, which is exactly why it sits outside the kingdoms altogether.

Question 6

Tobacco plants struck by mosaic disease yield a sap that can pass through the finest filter, one that holds back every bacterium, and yet still infect healthy plants. From what is now known of a virus, explain what a virus is made of, and why it can multiply only after it has entered a living cell.

Model Answer

A virus is an extremely small infectious particle made of a core of nucleic acid enclosed in a protein coat called a capsid. The nucleic acid, which may be DNA or RNA, carries the few genes the virus needs, while the capsid protects that genetic material and helps the virus attach to a host cell; in some viruses the capsid is further wrapped in an outer envelope of lipid and protein.

It can multiply only inside a living cell because it has no machinery of its own. A virus has no cytoplasm, no ribosomes and no enzymes for respiration or for building proteins, so by itself it can neither release energy nor make new parts; only by entering a host cell and taking over that cell's ribosomes, enzymes and raw materials can it have copies of itself made. This is why the sap passes through a filter like a lifeless chemical, yet behaves like a parasite once it is inside a cell.

Examiner's Note
The marks are earned by naming the two parts of a virus, a nucleic-acid core and a protein capsid, and then giving the reason it needs a host: it has no ribosomes or enzymes of its own, so it cannot make proteins or release energy without the host's machinery.

Language Clinic
Let the answer turn on the words because and only: it multiplies only inside a living cell because it has no machinery of its own. That small word only marks the very point the question is testing, that the virus cannot reproduce by itself.

Question 7

A bacteriophage is a virus that attacks bacteria, and its parts are easy to identify. Draw a large, clearly labelled diagram of a bacteriophage, then explain briefly what each labelled part does.

Model Answer

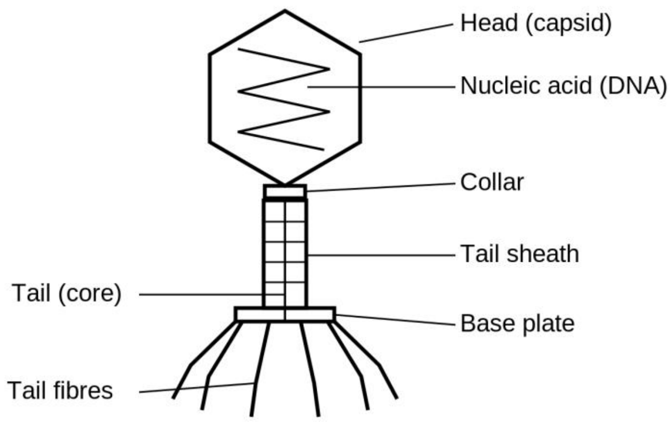


Figure 4.1: *The structure of a bacteriophage.*

A bacteriophage has a polyhedral head joined by a tail to a set of tail fibres, and each part does a particular job.

1) **Head (capsid):** a protein coat that encloses and protects the nucleic acid.
2) **Nucleic acid (DNA):** the genetic material, injected into the bacterium to direct the making of new phages.
3) **Collar:** the short neck that joins the head to the tail.
4) **Tail sheath:** a hollow sleeve that contracts to drive the DNA through the bacterial wall.
5) **Base plate and tail fibres:** these grip the surface of the bacterium and hold the phage firmly in place.

Examiner's Note

Most of the marks are for the labelled diagram itself: the head with the nucleic acid shown inside it, the tail or tail sheath, and the tail fibres, each named correctly. The brief note on what each part does then earns the rest.

False Confidence Alert

It is a common slip to draw a virus as a simple round blob. A bacteriophage is not round, and leaving out the tail, the base plate and the tail fibres throws away the easiest marks, because those parts are exactly what the question is testing.

Question 8

Although all viruses share the same basic plan of nucleic acid within a protein coat, they are built in a few distinct shapes. Using a named example of each, describe the main shapes that viruses take.

Model Answer

Viruses are grouped, by the shape of the capsid, into three main forms.

1) **Helical:** the capsomeres are arranged in a spiral around the nucleic acid, giving a rod or thread, as in the tobacco mosaic virus.
2) **Polyhedral:** the capsomeres form a many-sided geometric shell, most often a twenty-sided icosahedron, as in the adenovirus that causes colds.
3) **Complex:** the capsid is built of more than one shape joined together, as in a bacteriophage, which has a polyhedral head joined to a tail.

Besides these, many animal viruses, such as the viruses of HIV and of influenza, carry an outer envelope wrapped around the capsid.

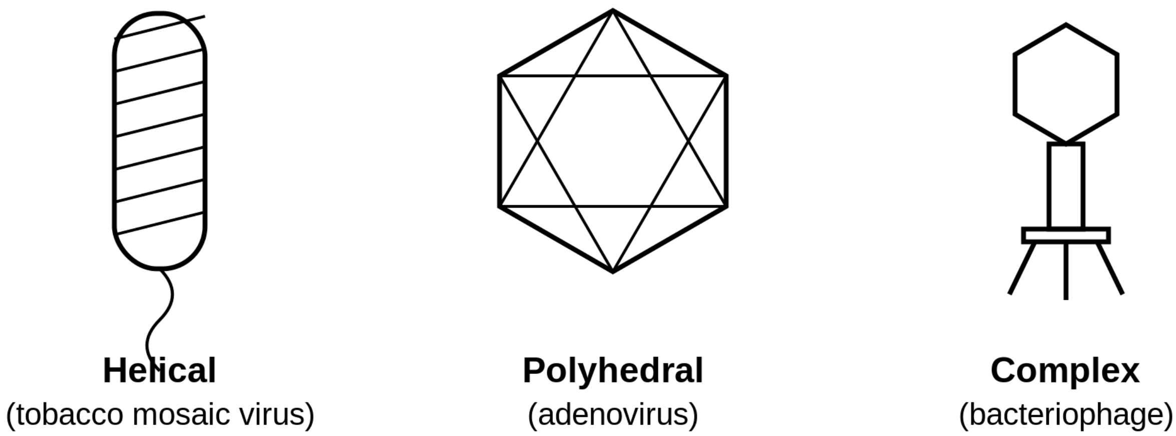


Figure 4.2: *The three main shapes of viruses.*

Examiner's Note

Each shape must be named and tied to an example: helical with the tobacco mosaic virus, polyhedral with a virus such as the adenovirus, and complex with the bacteriophage. A shape without its example, or an example without its shape, earns only half the mark.

Question 9

When scientists draw up groups of viruses, they look past the outward shape to the genetic material inside. Explain how viruses are classified using the nature of their genome together with the form of their capsid.

Model Answer

Viruses are classified first by the nature of their nucleic acid. The genome may be either DNA or RNA, and either kind may be single-stranded or double-stranded, so a virus is described as, for example, a double-stranded DNA virus or a single-stranded RNA virus; this division matters because the type of nucleic acid decides how the virus copies its genes once it is inside the host.

They are classified further by the form of the capsid, that is its morphology. According to how the capsomeres are arranged, a virus is placed as helical, polyhedral or complex, and a note is added of whether the capsid is naked or enclosed in an envelope, so that the genome type and the capsid form together fix the group to which a virus belongs.

Examiner's Note

The answer must use both bases of classification: the genome, named as DNA or RNA and as single-stranded or double-stranded, and the capsid morphology, named as helical, polyhedral or complex. Giving only one of the two is a half answer.

Question 10

A bacteriophage, the tobacco mosaic virus and the measles virus are all viruses, yet a biologist can tell them apart. Explain how a bacteriophage differs from a plant virus and an animal virus, both in the host it attacks and in its structure.

Model Answer

The clearest difference lies in the host that each virus attacks. A bacteriophage infects only bacteria, a plant virus such as the tobacco mosaic virus infects plant cells, and an animal virus such as the measles virus infects animal cells, so each kind of virus is confined to its own host, because it can recognise and enter only the particular kind of cell it is adapted to.

They differ also in structure. A bacteriophage has a complex form, with a polyhedral head and a tail whose fibres grip the bacterium and inject the DNA, whereas a plant or an animal virus is usually simpler, being helical or polyhedral with no tail at all; many animal viruses are, in addition, enclosed in an outer envelope, which bacteriophages and most plant viruses lack.

Examiner's Note
Credit is for the two lines of difference: the host, that is bacteria against plant or animal cells, and the structure, that is the phage's tail and tail fibres against the tail-less, often enveloped, plant and animal viruses.

False Confidence Alert
Because the bacteriophage is the virus most often drawn, it is tempting to imagine that every virus has a tail. Only complex viruses such as phages do; the plant and animal viruses behind most familiar diseases have no tail at all.

Question 11

When a bacteriophage multiplies by the lytic cycle, the host bacterium is destroyed within minutes. Describe, in their correct order, the steps of the lytic cycle.

Model Answer

The lytic cycle runs through five steps, ending in the death of the host cell.

1) **Attachment:** the phage settles on the bacterium and grips the cell wall by its tail fibres.
2) **Penetration:** the tail sheath contracts and injects the phage DNA into the bacterium, while the empty capsid stays outside.
3) **Replication:** the phage DNA takes command, halts the cell's own activities, and directs the cell to make many copies of phage DNA and phage proteins.
4) **Assembly:** the new DNA and protein coats are put together into many complete new phages.
5) **Release:** the cell bursts open, or lyses, setting free the new phages to infect further bacteria.

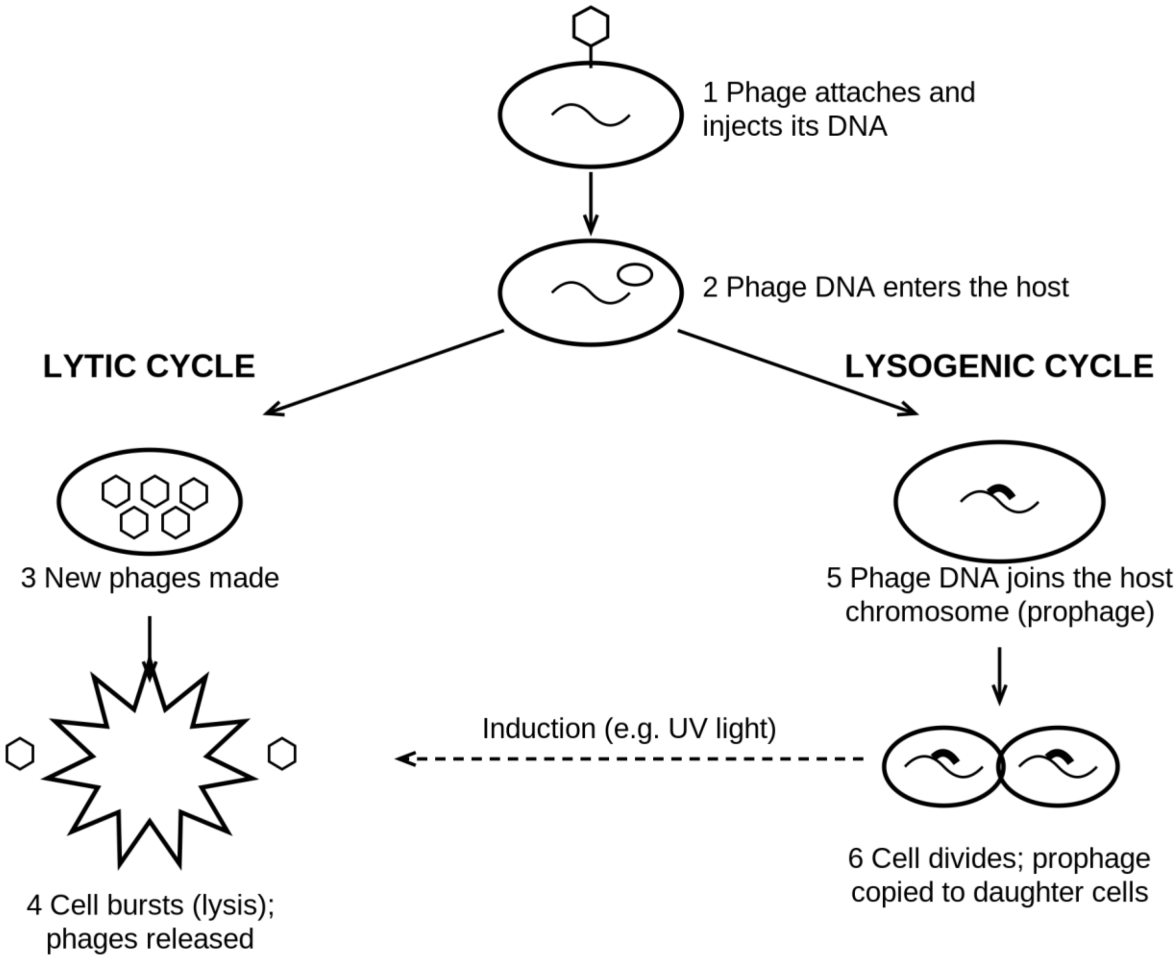


Figure 4.3: *The lytic and lysogenic cycles of a bacteriophage.*

Examiner's Note

Full marks need the steps named and kept in order: attachment, penetration, replication, assembly and release by lysis. Reversing the order, or leaving out the bursting of the cell, loses marks.

Language Clinic

Name each step and hold them in their true order, because a cycle is defined by its sequence: penetration cannot come before attachment, nor release before assembly. The order itself is part of the answer, which is why the steps are best set out as a numbered list.

Question 12

Not every infection ends in the swift destruction of the host. In the lysogenic cycle the phage DNA may lie hidden within the bacterium for many generations. Explain what happens in the lysogenic cycle, and how it differs from the lytic cycle.

Model Answer

In the lysogenic cycle the phage does not destroy the host at once, but hides its DNA within the host's own chromosome. After the DNA is injected, it becomes inserted into the bacterial chromosome, where it is called a prophage; the prophage is then copied and passed on every time the bacterium divides, so it spreads quietly to all the daughter cells without any new phages being made. Later a trigger, such as ultraviolet light, can rouse the prophage, which leaves the chromosome and enters the lytic cycle.

It differs from the lytic cycle chiefly in the speed of attack and in the fate of the host. The lytic cycle quickly takes over the cell, builds new phages and bursts the cell open, whereas the lysogenic cycle leaves the host alive and the phage DNA dormant for many generations; in the lytic cycle the phage genes act at once, whereas in the lysogenic cycle they stay silent as a prophage until some trigger switches them to the lytic path.

Examiner's Note

The marks are for the prophage: the phage DNA joins the host chromosome, is copied at every cell division, and can later switch to the lytic cycle. The difference to state is that the host survives in the lysogenic cycle but is killed in the lytic.

False Confidence Alert

It is easy to think a virus in the lysogenic cycle has been beaten or has gone away. It has not: its DNA sits hidden in the chromosome as a prophage, copied at every division, ready to turn destructive when conditions change.

Question 13

Every organism in Kingdom Monera, from the bacteria in a spoonful of soil to those that sour milk, shares one feature that sets the whole kingdom apart from the other four. Explain what that feature is, and how it makes a moneran cell fundamentally different from the cell of a plant or an animal.

Model Answer

The feature that defines Monera is the prokaryotic cell, a cell that has no true nucleus. In a moneran the genetic material is a single circular strand of DNA lying coiled free in the cytoplasm, not sealed inside a nuclear membrane, so the cell has no true nucleus of the kind found in plants and animals.

This makes a moneran cell fundamentally different because it also lacks the membrane-bound organelles that fill a plant or an animal cell. A prokaryotic cell has no mitochondria, no chloroplasts, no endoplasmic reticulum and no Golgi body; its ribosomes are of the smaller 70S type, and all its activities go on in one open compartment, which makes its whole organisation far simpler than that of a eukaryotic cell.

Examiner's Note

The defining mark to name is the prokaryotic cell with no true nucleus, its DNA lying free in the cytoplasm. The fuller answer adds that it also lacks membrane-bound organelles and carries the smaller 70S ribosomes.

False Confidence Alert

It is tempting to call a moneran a primitive or lower form of life because its cell is simple. Simple does not mean inferior: the bacteria are among the most successful organisms on Earth, and what defines them is the absence of a nucleus, not any rank.

Question 14

A bacterium is built to a plan all of its own. Draw a labelled diagram of a generalised bacterial cell, then describe the part that each labelled structure plays.

Model Answer

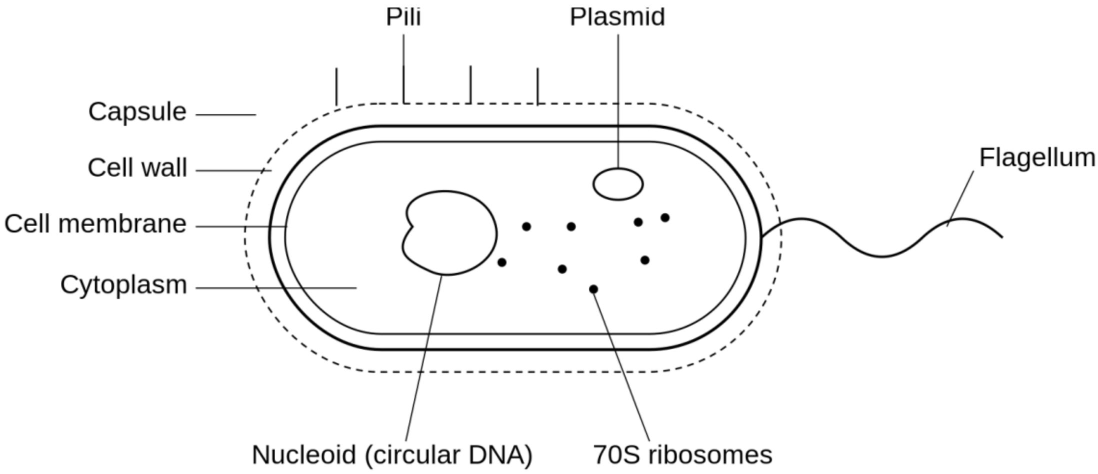


Figure 4.4: *The structure of a generalised bacterial cell.*

A bacterial cell is bounded by a wall and a membrane, and holds its genetic material and ribosomes in the cytoplasm, with structures on the surface for protection and movement.

1) **Cell wall:** a rigid wall of peptidoglycan that gives the cell its shape and stops it bursting.
2) **Cell membrane:** the boundary that controls what enters and leaves the cell.
3) **Cytoplasm:** the fluid in which the reactions of the cell take place; it holds no membrane-bound organelles.
4) **Nucleoid (circular DNA):** the single circular chromosome that carries the genes, lying free in the cytoplasm.
5) **Plasmid:** a small extra ring of DNA that can be passed from one bacterium to another.
6) **Ribosomes (70S):** the sites where proteins are built.
7) **Capsule, flagellum and pili:** an outer slime capsule for protection, a flagellum for movement, and pili for attachment.

Examiner's Note

The marks are for a clear diagram with the key parts labelled, the cell wall, cell membrane, cytoplasm, circular DNA, plasmid and ribosomes, and above all for showing the DNA free in the cytoplasm rather than shut inside a nucleus.

Question 15

The wall of a bacterium is made of a material found nowhere else in the living world, and the amount of it decides how the cell behaves towards certain stains. Explain what the bacterial cell wall is made of and what it does, and how it forms the basis of the Gram stain.

Model Answer

The bacterial cell wall is made of peptidoglycan, a mesh of sugar chains cross-linked by short peptides. This tough, netted material lies outside the cell membrane, where it gives the cell its fixed shape and, above all, stops it from bursting when water enters by osmosis.

It forms the basis of the Gram stain because bacteria differ in how much peptidoglycan their walls contain. A wall with a thick layer of peptidoglycan holds the violet stain, and the bacterium is called Gram-positive, whereas a wall with only a thin layer of peptidoglycan beneath an outer membrane loses the violet stain and is called Gram-negative, so the single feature of wall thickness sorts the bacteria into two great groups.

Examiner's Note
Two things earn the marks: naming the wall material as peptidoglycan and its job of preventing bursting, and then linking the Gram result to the thickness of that peptidoglycan, thick in Gram-positive and thin in Gram-negative cells.

Language Clinic
Tie the two halves together with because and whereas: the stain works because the walls differ in peptidoglycan, thick in one group whereas thin in the other. Those connectors show that you are explaining the cause, not merely naming two groups.

Question 16

Seen under the microscope, bacteria fall into a few basic shapes, and naming the shape is the first step in identifying one. Using a named example of each, describe the main shapes of bacteria.

Model Answer

Bacteria are grouped, by the shape of the cell, into four main forms.

1) **Cocci:** spherical cells, as in *Streptococcus*, which causes a sore throat.
2) **Bacilli:** rod-shaped cells, as in *Lactobacillus*, which sours milk into mtindi.
3) **Spirilla:** rigid spiral or corkscrew cells, as in *Spirillum*.
4) **Vibrio:** short curved, comma-shaped cells, as in *Vibrio cholerae*, which causes cholera.

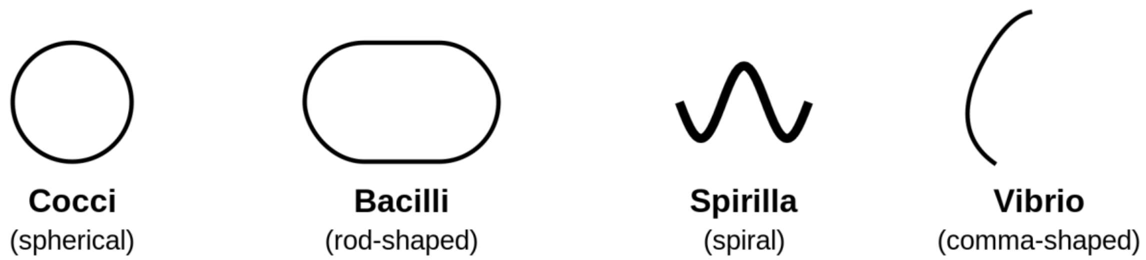


Figure 4.5: *The four main shapes of bacteria.*

Examiner's Note
Each shape must be named and tied to an example bacterium: cocci as spheres, bacilli as rods, spirilla as spirals and vibrio as comma shapes. A shape given without an example earns only part of the mark.

Question 17

When a biologist sets out to identify an unknown bacterium, the Gram stain is usually the first test applied. Explain what the Gram stain separates bacteria into, and the difference in the cells that explains the two results.

Model Answer

The Gram stain separates bacteria into two groups, the Gram-positive and the Gram-negative. After the cells are stained with a violet dye, treated with iodine that fixes the dye as a large complex, and then washed with alcohol, the Gram-positive bacteria keep the violet colour and appear purple, while the Gram-negative bacteria lose it, take up a red counterstain and appear pink.

The difference lies in the wall of the cell. A Gram-positive bacterium has a thick layer of peptidoglycan that traps the violet dye-iodine complex, whereas a Gram-negative bacterium has only a thin layer of peptidoglycan covered by an outer membrane, so the alcohol washes the complex out and the cell takes the red counterstain instead.

Examiner's Note
Credit goes to naming the two groups and giving the reason: the thick peptidoglycan of Gram-positive cells holds the violet dye-iodine complex, while the thin peptidoglycan and outer membrane of Gram-negative cells let the alcohol wash it away.

False Confidence Alert
It is easy to think the Gram stain is only about colour, purple against pink. The colour merely reports a real difference in the wall; what the test truly reveals is the thickness of the peptidoglycan.

Question 18

Monerans live in almost every habitat on Earth, and one reason is the great variety of ways in which they obtain food. Explain the main modes of nutrition found among the bacteria.

Model Answer

Some bacteria are autotrophic, making their own food from simple inorganic materials. Photosynthetic bacteria use light energy to build their food, much as green plants do, while chemosynthetic bacteria use energy released by chemical reactions, such as the oxidation of sulphur or of ammonia, to build food without any light.

Other bacteria are heterotrophic, taking their food ready-made from other organisms. Saprophytic bacteria feed on dead organic matter, which they digest and absorb, so returning nutrients to the soil, whereas parasitic bacteria live in or on a living host and take their food from it, often causing disease in the process.

Examiner's Note
The answer should set out the two great divisions, autotrophic and heterotrophic, and then name their kinds: photosynthetic and chemosynthetic among the autotrophs, saprophytic and parasitic among the heterotrophs.

Language Clinic
Group the modes under their two headings and mark the contrast with whereas: autotrophs make their own food, whereas heterotrophs take it ready-made. Naming the two headings first keeps a long answer in order.

Question 19

A single bacterium left in warm, well-fed conditions can give rise to millions within hours. Explain how bacteria reproduce, and how they are still able to exchange genes even without ordinary sexual reproduction.

Model Answer

Bacteria reproduce asexually by binary fission, a simple splitting of one cell into two. The single circular chromosome is first copied, the cell then grows and divides across the middle, giving two identical daughter cells; because each division can take as little as twenty minutes in good conditions, the numbers climb extremely fast.

They exchange genes by conjugation, which brings variation without being true reproduction. In conjugation two bacteria join by a fine tube and one passes a copy of some of its DNA, often a plasmid, to the other, so new combinations of genes spread through the population; this is how a feature such as resistance to a drug can pass quickly from one bacterium to another.

Examiner's Note

The marks are for naming binary fission as the asexual method, with the copying of the DNA and the splitting into two identical cells, and then for conjugation as the means by which genes are exchanged.

False Confidence Alert

Conjugation is easily mistaken for reproduction, but it makes no new individuals. It only transfers genes between two bacteria that already exist; the making of new cells is done by binary fission alone.

Question 20

When conditions turn deadly, with great heat, drought or a lack of food, many bacteria are not killed but simply wait. Explain how the formation of an endospore allows a bacterium to survive such harsh conditions.

Model Answer

A bacterium survives by forming an endospore, a tough resting body built around a copy of its DNA. As conditions become hostile, the cell copies its chromosome and seals it, with a little cytoplasm, inside a thick resistant coat; the rest of the cell then breaks down, leaving the dormant endospore behind.

The endospore can withstand extremes that would kill the active cell, and it revives when conditions improve. Its thick coat and very low water content let it survive boiling, drying and many chemicals for long periods, so the bacterium passes the bad times in a dormant state; when warmth, moisture and food return, the endospore germinates into an active bacterium once more.

Examiner's Note

Full marks need the endospore named as a dormant, thick-coated resting stage formed around a copy of the DNA, its resistance to heat, drought and chemicals, and its germination back into an active cell when good conditions return.

Question 21

Kingdom Protoctista is often called a dustbin kingdom, holding the eukaryotes that fit nowhere else. Explain the general characteristics that the members of Protoctista share, and why the kingdom is such a varied collection.

Model Answer

The members of Protoctista are all eukaryotes that are mostly single-celled and live in water or in damp places. Each has a true nucleus and membrane-bound organelles, which marks it as a eukaryote; most are made of a single cell, though some algae are simple many-celled forms, and none builds the true tissues and organs found in plants and animals.

The kingdom is so varied because it is defined by what its members are not, rather than by one shared way of life. It gathers every eukaryote that is neither a plant, an animal nor a fungus, so it holds plant-like algae that make their food by photosynthesis, animal-like protozoa that take in their food, and even fungus-like forms, which is why its members differ so widely.

Examiner's Note

Marks come from the shared characteristics, eukaryotic, mostly unicellular and aquatic, and from the point that the kingdom is defined by exclusion: it holds the eukaryotes that are not plants, animals or fungi.

False Confidence Alert

It is wrong to picture every protist as a tiny animal. The kingdom also holds the algae, which feed like plants, so calling all of its members protozoa misses half the kingdom.

Question 22

The animal-like protists, the protozoa, are commonly grouped by the way they move. Explain the four groups of protozoa based on their means of movement, naming an example of each.

Model Answer

The protozoa are placed in four groups according to how they move.

1) **Flagellates:** move by one or more long, whip-like flagella, as in *Euglena* and the sleeping-sickness parasite *Trypanosoma*.
2) **Ciliates:** move by many short, beating cilia, as in *Paramecium*.
3) **Sarcodines:** move by pseudopodia, or false feet, formed by flowing cytoplasm, as in *Amoeba*.
4) **Sporozoans:** lack specialised organs of movement, having no flagella, cilia or pseudopodia, and are all parasites, as in *Plasmodium*, which causes malaria.

Examiner's Note

Each group must be tied to its means of movement and an example: flagella in the flagellates, cilia in the ciliates, pseudopodia in the sarcodines, and none at all in the parasitic sporozoans.

Language Clinic

Give the three parts in the same order for every group: name the group, then its moving structure, then the example, as in the flagellates move by flagella, for example Euglena. A fixed order keeps a long answer easy to follow.

Question 23

Euglena puzzles biologists because it behaves partly like a plant and partly like an animal. Explain the features that make Euglena plant-like and the features that make it animal-like.

Model Answer

***Euglena* is plant-like chiefly because it contains chloroplasts and can make its own food by photosynthesis.** Its green chloroplasts trap light energy to build sugars from carbon dioxide and water, so in sunlight it feeds as a green plant does, and it keeps its food reserve as paramylon.

***Euglena* is animal-like because it moves and senses its surroundings as an animal does.** It swims actively by lashing a flagellum, turns towards light with the help of an eyespot, has no rigid cellulose wall but only a flexible pellicle, controls its water with a contractile vacuole, and in darkness it can take in ready-made food from outside, all of which are animal features.

Examiner's Note

A full answer gives both sets in balance: the plant features, that is the chloroplasts and photosynthesis, and the animal features, that is the flagellum, eyespot, contractile vacuole, flexible pellicle and the ability to feed in the dark.

Language Clinic

Give the plant features together and the animal features together, each as its own group rather than mixed. Setting the two natures side by side, one group and then the other, is what shows you understand why Euglena is so hard to place.

Question 24

Draw a large, labelled diagram of Euglena, then state the function of the flagellum, the eyespot and the contractile vacuole.

Model Answer

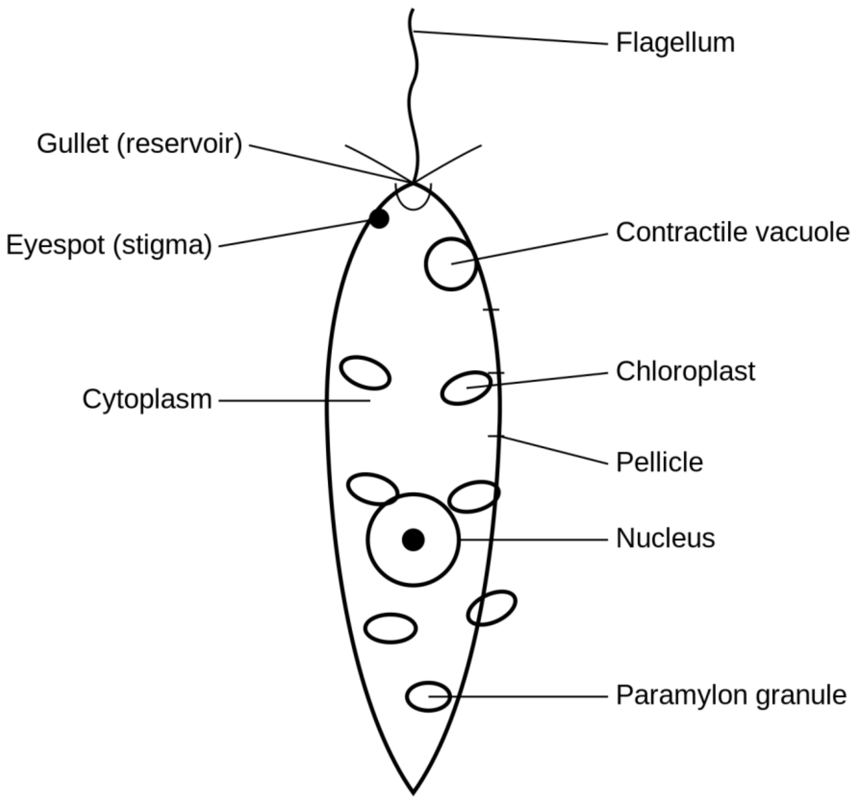


Figure 4.6: *The structure of Euglena.*

***Euglena* is a spindle-shaped cell with a flagellum at its front end, and three of its parts have clear and separate roles.**

Flagellum: it lashes from side to side to drive the cell through the water.

Eyespot (stigma): it shades the light-sensitive swelling at the base of the flagellum, so the cell can steer towards the light it needs for photosynthesis.

Contractile vacuole: it collects the excess water that constantly enters the cell and expels it, stopping the cell from swelling and bursting.

Examiner's Note
The diagram earns most of the marks: a spindle-shaped cell with the flagellum, eyespot, chloroplasts, nucleus and contractile vacuole all labelled. The three stated functions then complete the answer.

Question 25

Euglena lives in still ponds and ditches, often in sunlit but crowded water that may grow dark or dry up. Explain how Euglena is adapted to this mode of life.

Model Answer

***Euglena* is fitted to life in a changeable pond in several ways.**

Chloroplasts: they let it make its own food whenever there is light, so it needs no other source by day.

Eyespot and flagellum: together they let it swim towards the light, keeping it where photosynthesis works best.

Feeding in the dark: if the water turns dark, it can take in ready-made food instead, so it survives when light fails.

Flexible pellicle: it lets the cell change shape and squeeze through crowded water, where a rigid wall would hold it back.

Contractile vacuole: it bails out the water that steadily enters, keeping the cell from bursting in the fresh water of the pond.

Paramylon store: it holds a food reserve the cell can draw on when conditions are poor.

Examiner's Note
Tie each adaptation to a survival value rather than just naming it: the chloroplasts for making food in light, the eyespot and flagellum for reaching light, the contractile vacuole for removing water, and feeding in the dark for surviving when light fails.

Question 26

Amoeba is a shapeless protist that creeps over the mud of ponds, engulfing its food as it goes. Explain how Amoeba moves and how it feeds.

Model Answer

***Amoeba* moves by pushing out pseudopodia, temporary false feet formed by the flowing of its cytoplasm.** The granular inner endoplasm streams forward into a bulge in the cell surface, and the rest of the cell flows after it, so the whole organism creeps slowly along; this kind of movement is called amoeboid movement.

***Amoeba* feeds by phagocytosis, flowing its pseudopodia around a food particle until the particle is wholly enclosed.** The trapped food is taken into a food vacuole, where enzymes digest it and the useful products are absorbed into the cytoplasm, while any indigestible remains are left behind as the cell moves on.

Examiner's Note
Marks are for the pseudopodia doing two jobs, both moving the cell and surrounding the food, and for naming phagocytosis and the food vacuole in which the food is digested.

False Confidence Alert
Pseudopodia are not fixed legs. They are temporary, pushed out and drawn back in as the cytoplasm flows, which is why the shape of an Amoeba is always changing.

Question 27

Draw a large, labelled diagram of Amoeba, showing the structures it uses to move and to feed.

Model Answer

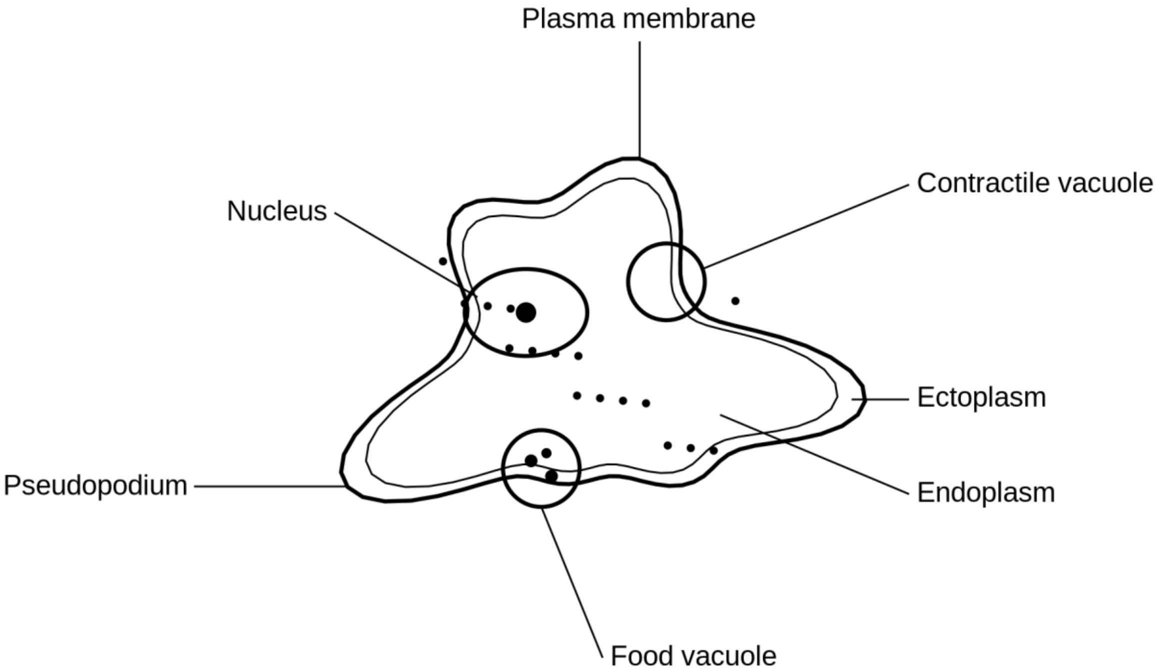


Figure 4.7: *The structure of Amoeba.*

***Amoeba* is drawn as an irregular cell pushing out blunt pseudopodia, with its main contents shown inside.**

1) **Pseudopodium:** the false foot that both moves the cell and engulfs its food.
2) **Food vacuole:** the space in which engulfed food is digested.
3) **Contractile vacuole:** it expels the excess water that enters the cell.
4) **Nucleus:** it controls the activities of the cell.
5) **Ectoplasm and endoplasm:** the clear outer layer and the granular inner cytoplasm whose flow drives the movement.

Examiner's Note
The diagram must show an irregular cell with blunt pseudopodia, and label the nucleus, the contractile vacuole and a food vacuole; the pseudopodia are the parts the question is really testing.

Question 28

Paramecium is a slipper-shaped protist that swims swiftly through pond water, sweeping in its food as it goes. Explain how Paramecium moves and how it feeds.

Model Answer

***Paramecium* moves by the beating of the many tiny cilia that cover its whole surface.** The cilia beat in coordinated waves, like rows of oars pulling together, driving the cell forward along a spiral path; by reversing the beat of its cilia the cell can also back away from an obstacle.

***Paramecium* feeds by using the cilia of its oral groove to sweep food into the cell.** The beating cilia draw bacteria and other small particles, in a current of water, down the oral groove to the cytostome, or cell mouth, where the food is closed off in a food vacuole; enzymes then digest it, the useful products are absorbed, and the indigestible remains are pushed out through the anal pore, or cytoproct.

Examiner's Note

Marks come from the cilia doing two jobs, swimming and feeding, and from the feeding pathway: the oral groove sweeps food to the cytostome, where it is enclosed in a food vacuole and digested.

Language Clinic

Trace the food along one clear route: cilia, oral groove, cytostome, food vacuole. Naming the path in order shows how the parts work together, which a bare list of parts on its own does not.

Question 29

Draw a large, labelled diagram of Paramecium, and point out the structures that carry out its feeding.

Model Answer

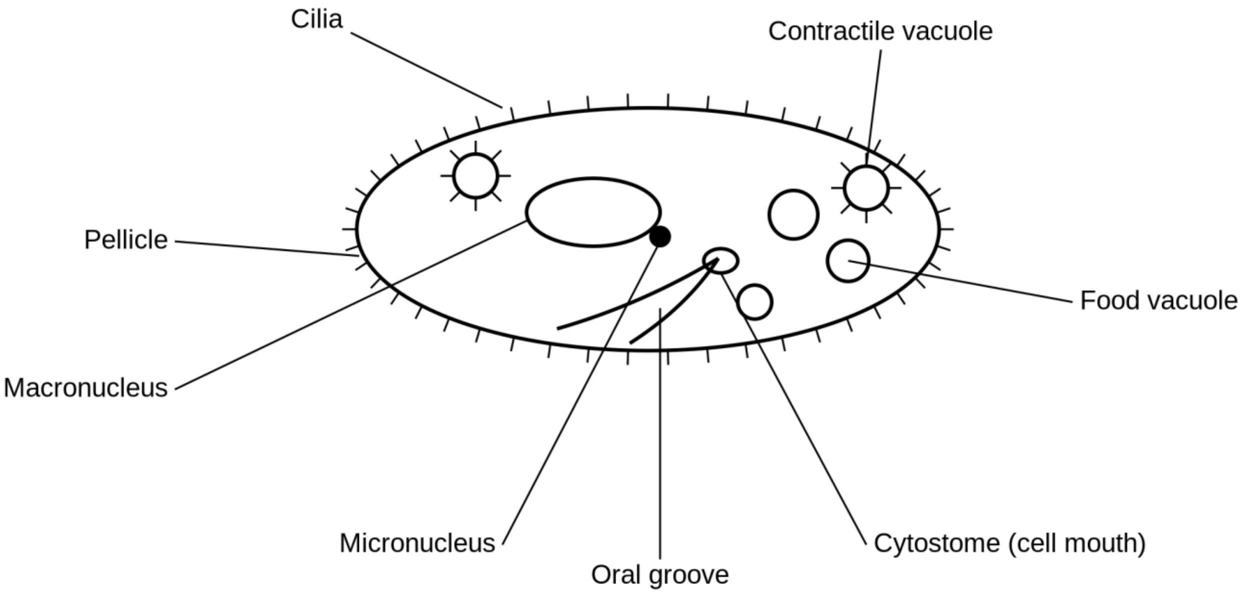


Figure 4.8: *The structure of Paramecium.*

***Paramecium* is a slipper-shaped cell covered with cilia, and a set of its structures works together in feeding.**

1) **Cilia of the oral groove:** they sweep a current of water carrying food into the cell.
2) **Oral groove:** the channel along which the food is driven towards the cell mouth.
3) **Cytostome (cell mouth):** the opening where the food enters and is packed into a food vacuole.
4) **Food vacuole:** the space in which the food is digested before the useful products are absorbed.

Examiner's Note

The diagram earns most of the marks: a slipper shape covered in cilia, with the oral groove, cytostome, food vacuoles, two contractile vacuoles and the large and small nuclei all labelled.

Question 30

A freshwater protist such as Amoeba or Paramecium would swell and burst if it could not deal with the water that constantly enters it. Explain how the contractile vacuole solves this problem.

Model Answer

Water enters a freshwater protist all the time by osmosis, because the cytoplasm is a more concentrated solution than the fresh water around it. The water passes in across the cell membrane down the concentration gradient, and if it were left to build up, the cell would swell and finally burst.

The contractile vacuole removes this excess water and so keeps the cell from bursting. It slowly fills with the water gathered from the cytoplasm, then contracts and drives the water out through the cell surface; this is repeated over and over, balancing the steady inflow, and the control of water in this way is called osmoregulation.

Examiner's Note
The marks are for the cause and the cure: water enters by osmosis because the cytoplasm is more concentrated than fresh water, and the contractile vacuole collects this water and expels it, a process named osmoregulation.

False Confidence Alert
It is a mistake to think every protist must work its contractile vacuole hard. A protist living in the sea, where the water is not dilute, gains little water by osmosis and so has little need of one; the busy contractile vacuole belongs to freshwater life.

Question 31

Plasmodium, the protist that causes malaria, belongs to the phylum Apicomplexa, a group whose members have no means of movement of their own. Explain the distinctive features of the phylum Apicomplexa, using Plasmodium as your example.

Model Answer

The phylum Apicomplexa has a set of distinctive features, all shown by *Plasmodium*.

1) **All are parasites:** they live inside the cells or body of a host, as *Plasmodium* lives in human liver cells and red blood cells.
2) **No organs of movement:** the feeding stages have no cilia, flagella or pseudopodia, although some infective stages glide and the male gamete bears a flagellum.
3) **An apical complex:** a cluster of organelles at one end of the cell, used to break into the host cell.
4) **Reproduction by many spores:** they multiply by repeated division, producing large numbers of small infective stages.
5) **A complex life cycle:** it often passes between two hosts, as *Plasmodium* passes between a human being and a female *Anopheles* mosquito.

Examiner's Note
Credit is for the features that mark the phylum: parasitic, no organs of movement, an apical complex for entering the host, reproduction by many spores, and a complex life cycle that often needs two hosts.

False Confidence Alert
Because it causes a disease, Plasmodium is loosely called a germ. It is not a bacterium and not a virus; it is a protist, a single eukaryotic cell, which is why anti-bacterial drugs do not cure malaria.

Question 32

The green algae, such as Spirogyra found in the green scum of ponds, are grouped in the phylum Chlorophyta and are often mistaken for simple plants. Explain the characteristics of the green algae, and why Spirogyra in particular so resembles a plant.

Model Answer

The green algae are eukaryotic, photosynthetic protists that live mostly in water. They contain the same chlorophyll, chlorophyll a and chlorophyll b, that gives green plants their colour, they have a cellulose cell wall, and they store their food as starch; some are single cells, while others, like *Spirogyra*, grow as simple unbranched filaments.

***Spirogyra* resembles a plant because it shares the very features that define the plant kingdom.** It makes its own food by photosynthesis using chlorophyll held in chloroplasts, it has a cellulose wall around each cell, and it stores starch, exactly as a green plant does; it is kept among the protists only because it is a simple filament with no true roots, stems, leaves or tissues.

Examiner's Note

The answer needs the characteristics of the green algae, that is photosynthetic, chlorophyll a and b, a cellulose wall and starch storage, and then the reason Spirogyra looks plant-like: it does all a plant does but has no true roots, stems, leaves or tissues.

Language Clinic

Mark the comparison with because: Spirogyra resembles a plant because it photosynthesises, has a cellulose wall and stores starch. The connector turns a list of shared features into the reason it looks like a plant.

Question 33

Many protists make their own food in the same organelle that green plants use. Draw a large, labelled diagram of this food-making organelle, the chloroplast, and explain how its structure suits it for photosynthesis.

Model Answer

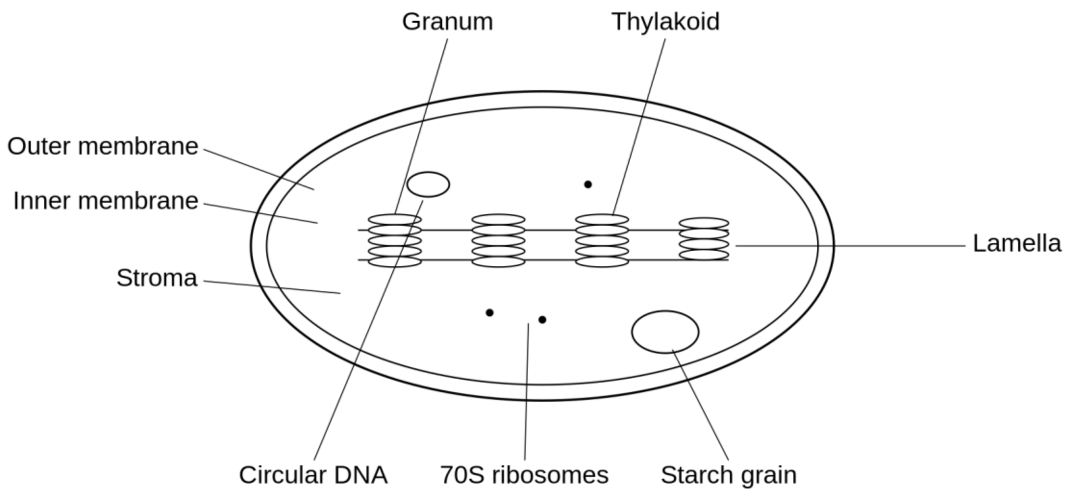


Figure 4.9: *The structure of a chloroplast.*

The food-making organelle is the chloroplast, and its structure is well suited to capturing light and building food.

1) **Stacked thylakoids (grana):** the many disc-like thylakoids, stacked into grana, give a large surface area for the chlorophyll.
2) **Chlorophyll in the thylakoids:** it absorbs the light energy that drives the making of food.
3) **Stroma:** the fluid around the grana holds the enzymes that build sugars from carbon dioxide.
4) **Double membrane:** it encloses the organelle and keeps the reactions of photosynthesis together.
5) **Starch grains:** the food that is made is stored inside the chloroplast as grains of starch.

Examiner's Note

The diagram should show the double membrane, the grana of stacked thylakoids, and the stroma. The explanation then links structure to function: the stacked thylakoids give a large surface for chlorophyll to trap light, and the stroma holds the enzymes that build the sugars.

Question 34

Bread left in a warm, damp place soon grows a fuzzy mould, one of the fungi. Explain the general characteristics that place an organism in Kingdom Fungi.

Model Answer

An organism is placed in Kingdom Fungi by a set of shared characteristics.

1) **Eukaryotic:** the cells have a true nucleus and membrane-bound organelles.
2) **Chitin cell wall:** the wall is made of chitin in most fungi, not the cellulose of plants.
3) **A body of hyphae:** most fungi are built of thread-like hyphae forming a mycelium, though some, such as yeast, are single cells.
4) **Heterotrophic by absorption:** having no chlorophyll, a fungus cannot make its own food, so it digests food outside the body and absorbs it.
5) **Food stored as glycogen:** the food reserve is glycogen, not the starch of plants.
6) **Reproduction by spores:** fungi spread by producing large numbers of spores.

Examiner's Note

The marks reward the defining set: eukaryotic, a chitin wall, a body of hyphae, feeding by absorption with no chlorophyll, and reproduction by spores. The chitin wall and feeding by absorption are the features that most clearly separate fungi from plants.

False Confidence Alert

Because a mould is fixed in place and fuzzy like a small plant, it is tempting to file the fungi with the plants. They do not belong there: a fungus has no chlorophyll and cannot photosynthesise, its wall is chitin and not cellulose, and it feeds by absorbing food.

Question 35

The body of a typical fungus is not made of ordinary cells but of fine threads. Explain how the body of a fungus is built, and the difference between septate and aseptate hyphae.

Model Answer

The body of a fungus, the mycelium, is a tangled mass of fine, branching threads called hyphae. Each hypha is a tube bounded by a chitin wall and filled with cytoplasm and nuclei, and the spreading mycelium gives a very large surface area for absorbing food.

Hyphae are of two kinds, septate and aseptate. A septate hypha is divided by cross-walls, the septa, into many compartments, each usually holding its own nucleus, whereas an aseptate hypha has no cross-walls and is one long continuous tube, described as coenocytic, with many nuclei in a shared cytoplasm, as in *Rhizopus*.

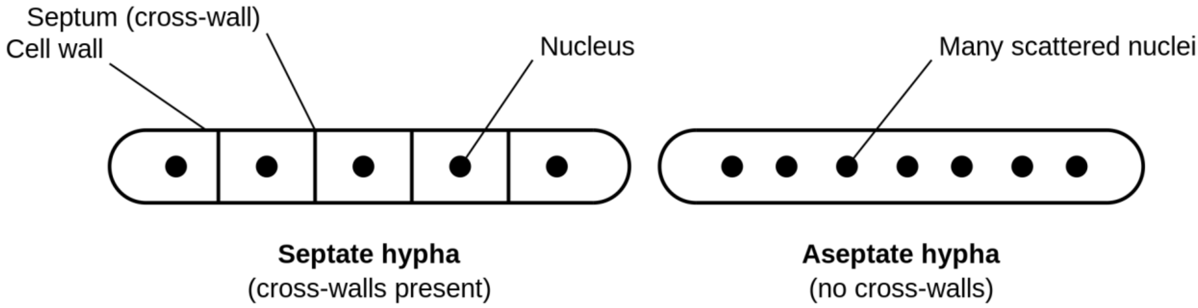


Figure 4.10: *Septate and aseptate hyphae.*

Examiner's Note

Two points carry the marks: the body is a mycelium of hyphae giving a large surface area for absorption, and the difference between the two hyphae, that is cross-walls present in a septate hypha and absent in an aseptate one.

Language Clinic

Mark the contrast with whereas: a septate hypha has cross-walls, whereas an aseptate hypha has none. The connector makes the single real difference between the two kinds stand out.

Question 36

Yeast, used to raise bread and to brew beer, is a fungus quite unlike the moulds. Explain how yeast differs in structure from a mould, and how it reproduces by budding.

Model Answer

Yeast differs from a mould in being a single-celled fungus rather than a mycelium of hyphae. It is a small oval cell with a chitin wall, a nucleus, cytoplasm and a vacuole, and it lives and feeds as one cell instead of as spreading threads.

Yeast reproduces asexually by budding. A small bulge, the bud, grows out from the parent cell; the nucleus divides and one daughter nucleus passes into the bud, which enlarges and then either breaks away as a new cell or stays joined, so that a short chain of cells may form.

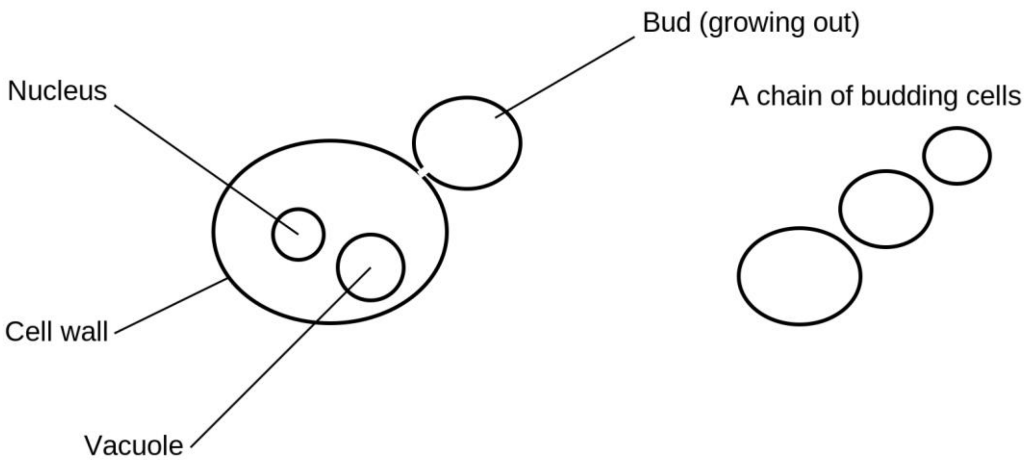


Figure 4.11: *A yeast cell reproducing by budding.*

Examiner's Note

The marks are for yeast being a single-celled fungus, and for the steps of budding: a bud grows from the parent, the nucleus divides, one nucleus enters the bud, and the bud grows and separates.

False Confidence Alert

A single yeast cell looks nothing like a fuzzy mould, so it is easy to doubt that it is a fungus. It is one: it has a chitin wall, feeds by absorption and buds off new cells; being single-celled does not place it outside the kingdom.

Question 37

Rhizopus, commonly known as bread mould, is a representative fungus often used to illustrate fungal structure. Draw a large, labelled diagram of Rhizopus, and state the function of the rhizoids, the sporangiophore and the sporangium.

Model Answer

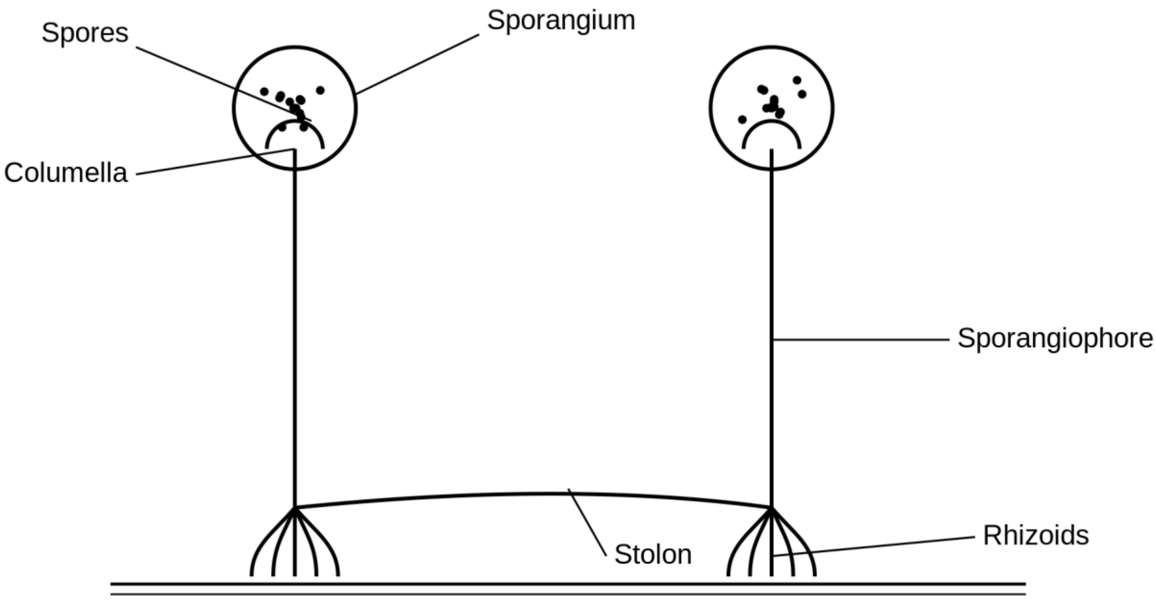


Figure 4.12: *The structure of Rhizopus, the bread mould.*

***Rhizopus* grows as a mycelium of aseptate hyphae over the bread, with several parts that each do a special job.**

Rhizoids: root-like hyphae that anchor the mould to the bread and absorb the digested food.

Sporangiophore: an upright hypha that holds the sporangium up into the air.

Sporangium: the rounded case at the tip in which spores are made and from which they are released to spread the mould.

Examiner's Note

The diagram earns most of the marks: the horizontal stolon, the rhizoids growing down into the bread, the upright sporangiophore and the rounded sporangium full of spores. The three stated functions then complete the answer.

Question 38

Fungi are divided into groups according to how and where they form their spores. Name the main divisions of the fungi, giving a representative and the spore-bearing structure of each.

Model Answer

The fungi are placed in three main divisions.

1) **Zygomycota:** the pin moulds, such as *Rhizopus*, which form their spores inside a sporangium.
2) **Ascomycota:** the sac fungi, such as yeast and *Penicillium*, which form their sexual spores in a sac called an ascus.
3) **Basidiomycota:** the club fungi, such as mushrooms and toadstools, which form their spores on a club-shaped basidium.

Examiner's Note

Each division must come with a representative and its spore-bearing structure: Zygomycota with Rhizopus and the sporangium, Ascomycota with yeast and the ascus, and Basidiomycota with the mushroom and the basidium.

Language Clinic

Give the three divisions in the same pattern each time: the division, a representative, and where its spores form. Holding to one order makes the three easy to compare and to remember.

Question 39

The mushrooms and toadstools that spring up after rain are the basidiomycetes, the club fungi. Explain the general and the distinctive features of the basidiomycetes.

Model Answer

The basidiomycetes share the general features of all fungi. Their body is a mycelium of fine, septate hyphae with chitin walls, they have no chlorophyll, and they feed by absorbing digested food; the main part of the fungus is this mycelium spreading unseen through the soil or wood.

Their distinctive feature is the way they bear their spores. From time to time the mycelium throws up a fruiting body, the familiar mushroom or toadstool, built of tightly packed hyphae; on the gills beneath its cap stand countless club-shaped cells, the basidia, and each basidium carries its spores, the basidiospores, usually four, on the outside, ready to be shed.

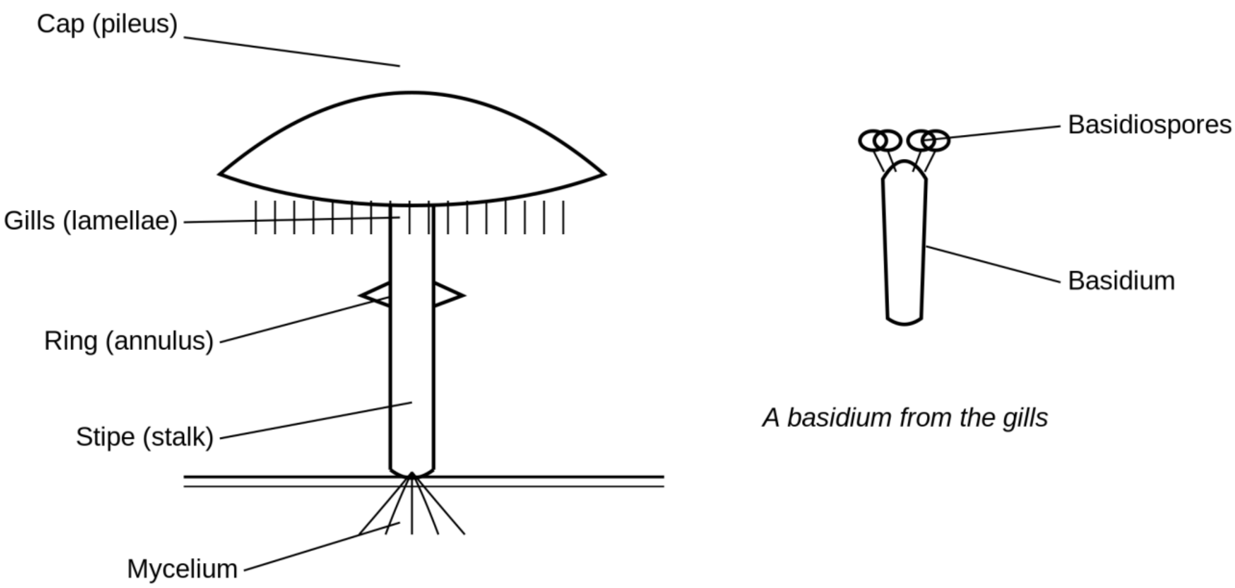


Figure 4.13: *A mushroom, the fruiting body of a basidiomycete, with a basidium.*

Examiner's Note

Give the two sides the question asks for: the general fungal features, that is a mycelium of septate hyphae, a chitin wall and feeding by absorption, and then the distinctive feature, that the spores are basidiospores borne on club-shaped basidia on the gills of a fruiting body.

Language Clinic

Set the answer out in two parts: first the features shared with all fungi, then the feature special to the basidiomycetes. Separating the general from the distinctive is exactly what the question is asking you to do.

Question 40

A fungus cannot swallow its food as an animal does, yet it thrives on bread, on dung and on living crops alike. Explain how fungi feed, and the difference between a saprophytic and a parasitic fungus.

Model Answer

Fungi feed by digesting their food outside the body and then absorbing it. The hyphae release digestive enzymes onto the food, the enzymes break it down where it lies, and the soluble products are then absorbed back through the hyphal walls; because the mycelium runs right through the food, the surface for absorption is very large.

Fungi obtain this food in two main ways. A saprophytic fungus feeds on dead organic matter, such as fallen leaves or old bread, which it rots down and so returns nutrients to the soil, whereas a parasitic fungus feeds on a living host, drawing food from its tissues and often causing disease, as the rusts and smuts do to crops.

Examiner's Note

The marks are for the method, digestion outside the body followed by absorption through the hyphae, and for the contrast: a saprophyte feeds on dead matter and decays it, whereas a parasite feeds on a living host and may cause disease.

False Confidence Alert

It is wrong to picture a fungus taking in lumps of food as an animal does. A fungus never engulfs its food; it pours enzymes onto it, digests it outside the body, and absorbs only the dissolved products.

Question 41

A single mould can cover a loaf in a few days and spread from it across a whole room. Explain how fungi reproduce, by both asexual and sexual means.

Model Answer

Fungi reproduce mainly asexually, by making vast numbers of spores. These spores are produced without any fusion of cells, in structures such as the sporangium of *Rhizopus*, and because they are light and numerous they are carried far by air and water, so a fungus spreads very quickly; yeast reproduces asexually in another way, by budding.

Fungi can also reproduce sexually when conditions turn harsh. Two hyphae of opposite mating strains, one a plus strain and the other a minus strain, grow together; their cytoplasm joins and then their nuclei fuse, forming a thick-walled resistant spore, the zygospore of *Rhizopus*; this spore survives the bad times and, by combining genes from two parents, brings variation into the offspring.

Examiner's Note

Credit is for both routes: asexual reproduction by spores made without fusion, produced in huge numbers and easily dispersed, and sexual reproduction by the fusion of nuclei from two hyphae to form a resistant spore that also gives variation.

Question 42

Some fungi live in a close partnership with another organism, to the benefit of both. Explain what a lichen and a mycorrhiza are, and how each partnership benefits the organisms that take part.

Model Answer

A lichen is a close partnership between a fungus and an alga (or a cyanobacterium), living together as a single body. The alga photosynthesises and supplies food to the fungus, while the fungus shelters the alga, holds water and absorbs mineral salts for it; because both partners gain, the partnership is a mutualism, and it lets a lichen grow even on bare rock, where neither partner could live alone.

A mycorrhiza is a partnership between a fungus and the roots of a plant. The fungal hyphae spread out from the root and greatly enlarge the surface for taking up water and mineral salts, which they pass to the plant, while the plant gives the fungus sugars made in photosynthesis; here too both partners benefit, so the plant grows better, especially in poor soils.

Examiner's Note

For each partnership name the two members and what each gives: in a lichen the alga makes food while the fungus gives shelter, water and minerals; in a mycorrhiza the fungus takes up water and minerals while the plant gives sugars. State that both are examples of mutualism.

Language Clinic

Show the give and take with while: the alga supplies food, while the fungus supplies water and shelter. The connector makes clear that each partner does something for the other, which is the heart of mutualism.

Question 43

From the moss on a damp wall to the maize in a farm, the green plants make up Kingdom Plantae. Explain the general characteristics that place an organism in this kingdom.

Model Answer

An organism is placed in Kingdom Plantae by a set of shared characteristics.

1) **Eukaryotic and multicellular:** the body is built of many cells, each with a true nucleus, organised into tissues.
2) **Photosynthetic (autotrophic):** the cells hold chlorophyll in chloroplasts and make their own food from carbon dioxide and water using light.
3) **Cellulose cell wall:** every cell is enclosed in a wall of cellulose, which gives the plant support.
4) **Food stored as starch:** the food reserve is starch, not the glycogen of fungi and animals.
5) **Fixed and non-motile:** a plant is rooted or held in place and cannot move from place to place, though it can still grow towards the light.

Examiner's Note

The marks reward the defining set: eukaryotic and multicellular, photosynthetic with chlorophyll in chloroplasts, a cellulose cell wall, and food stored as starch. The chloroplasts and cellulose wall are the features that separate plants most clearly from fungi and animals.

False Confidence Alert

It is tempting to call every green, fixed organism a plant. A pond alga is green and a mushroom is fixed, yet neither is a plant: the alga is a protist with no true tissues, and the fungus has a chitin wall and no chlorophyll.

Question 44

Kingdom Plantae is sorted into four divisions, which mark the great steps from simple water-bound plants to the flowering plants. Name the four divisions, giving a defining feature and an example of each.

Model Answer

The kingdom is divided into four divisions, in order of advance.

1) **Bryophyta:** simple plants with no vascular tissue and no true roots, stems or leaves, tied to damp places, as in the mosses.
2) **Filicinophyta (Pteridophyta):** the ferns, which have vascular tissue and true roots, stems and leaves but still reproduce by spores, not seeds.
3) **Coniferophyta:** the conifers, vascular seed plants that bear naked seeds in cones, as in the pines and cypresses.
4) **Angiospermophyta:** the flowering plants, vascular seed plants whose seeds are enclosed in a fruit and which bear flowers, as in maize and beans.

Examiner's Note

Each division must come with a defining feature and an example. The order tells a story: vascular tissue appears with the ferns, seeds with the conifers, and flowers and enclosed seeds with the angiosperms.

Language Clinic

List the divisions in their order of advance, each with one defining feature and an example. Keeping the order from the simplest, the mosses, to the most advanced, the flowering plants, shows the very trend the question is built on.

Question 45

The mosses, such as Funaria growing on a damp wall, are the simplest of the plants. Explain the distinctive features of the division Bryophyta.

Model Answer

The Bryophyta are marked out by their simple structure and their dependence on water.

1) **No vascular tissue:** they have no xylem or phloem, so water cannot be carried far and the plants stay small and low.

2) **No true roots:** they are anchored by thread-like rhizoids, not by roots, and absorb water over the whole surface.
3) **A simple body:** they have only simple leaf-like and stem-like parts, not true leaves and stems.
4) **Tied to water:** the male gametes must swim to the female in a film of water, so mosses live in damp, shady places.
5) **Reproduction by spores:** spores are made in a capsule and shed to start new plants.

Examiner's Note

The marks of a bryophyte are the absence of vascular tissue, the rhizoids in place of roots, and the need for water for fertilisation. These three together show why the moss stays small and damp-loving.

False Confidence Alert

A moss looks as though it has tiny roots, stems and leaves, so it is easy to label them as such. They are not true organs: the anchoring threads are rhizoids, and the green plant has only leaf-like and stem-like parts, because it has no vascular tissue to support true ones.

Question 46

Draw a large, labelled diagram of a moss plant, and name the part that anchors it and the part that makes its spores.

Model Answer

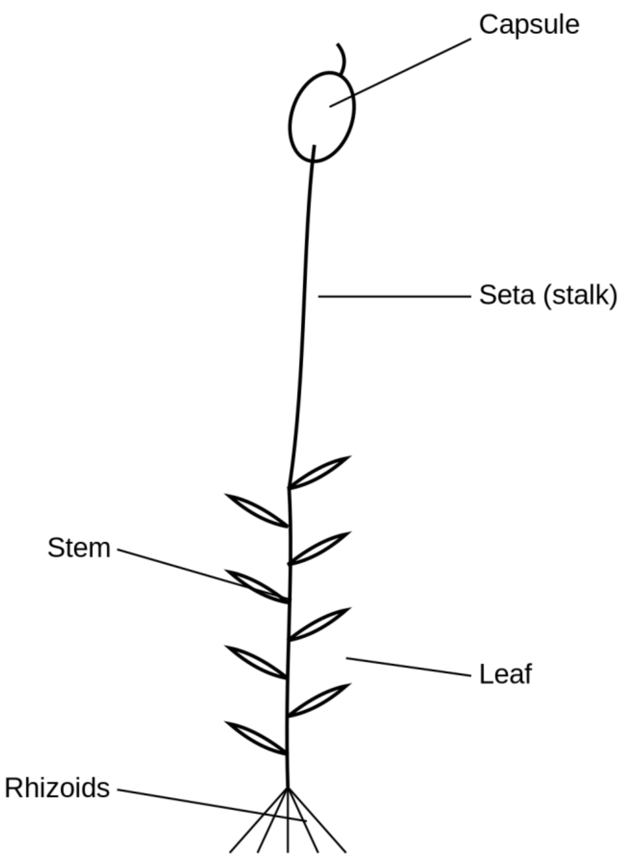


Figure 4.14: *The structure of a moss plant.*

A moss plant has a simple leafy shoot anchored below and a spore-making capsule held above.

Rhizoids: the thread-like structures at the base that anchor the moss and absorb water.

Capsule: the case at the top of the seta in which the spores are made and from which they are shed.

Examiner's Note

The diagram should show the rhizoids, the leafy stem, the seta and the capsule, all labelled. The two parts the question asks for are the rhizoids, which anchor the plant, and the capsule, which makes the spores.

Question 47

The ferns, such as those growing on a shady, moist forest floor, are more advanced than the mosses. Explain the distinctive features of the ferns (Filicinophyta).

Model Answer

The ferns are set apart by having true plant organs while still reproducing by spores.

1) **Vascular tissue:** ferns have xylem and phloem to carry water and food, so they grow much larger than mosses.
2) **True roots, stems and leaves:** the leaves are large fronds, which grow from an underground stem called the rhizome.
3) **Reproduction by spores:** the spores are made in sori, the clusters of sporangia on the underside of the fronds.
4) **Still tied to water:** the male gametes must swim to the female, so ferns also keep to damp, shady places.

Examiner's Note

The distinctive features are the vascular tissue and the true roots, stems and leaves, set against reproduction by spores and the continued need for water. The vascular tissue is what lets a fern stand far taller than a moss.

Language Clinic

Give each feature with what it allows: vascular tissue lets the fern grow tall, true roots draw up water. Saying what each feature does, and not only that it is present, is what turns a list into an explanation.

Question 48

Draw a large, labelled diagram of a fern, and show where its spores are made.

Model Answer

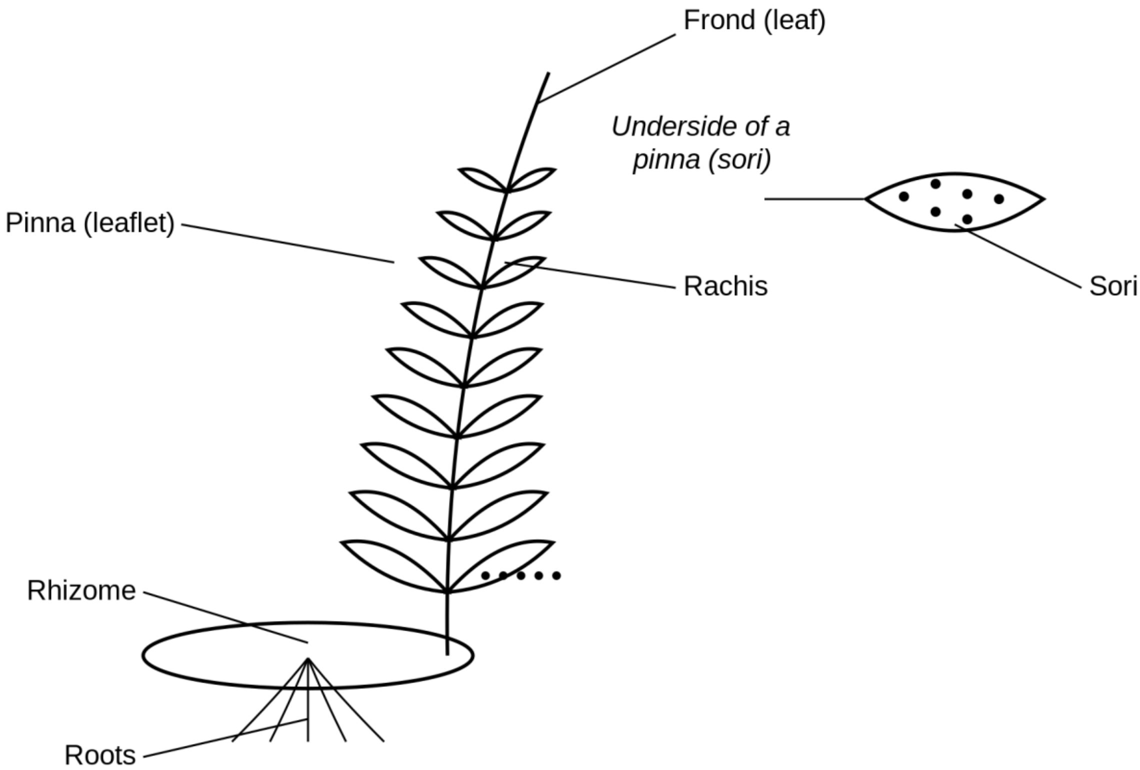


Figure 4.15: *The structure of a fern.*

A fern has large divided leaves, the fronds, growing from an underground stem, and it makes its spores on the underside of the fronds.

1) **Frond:** the large divided leaf, made of many leaflets called pinnae.
2) **Rhizome:** the underground stem from which the fronds and the roots grow.
3) **Sori:** the clusters of sporangia on the underside of the pinnae, in which the spores are made.

Examiner's Note

The diagram should show the frond with its pinnae, the rhizome and the roots, all labelled. The spores are made in the sori on the underside of the fronds, which is exactly what the question asks you to point out.

Question 49

In the life of a moss, two different plant forms follow one another, turn and turn about. Explain what is meant by alternation of generations, using the moss as your example.

Model Answer

Alternation of generations means that the life cycle runs through two different plant forms, one after the other: a gametophyte that reproduces by gametes and a sporophyte that reproduces by spores. The gametophyte is haploid (n) and the sporophyte is diploid (2n), and each gives rise to the other in turn.

In the moss, the familiar green leafy plant is the gametophyte. It produces male and female gametes by mitosis, and after fertilisation, which needs a film of water, the zygote grows into the sporophyte, the capsule on a stalk that lives on the gametophyte; the sporophyte then makes haploid spores by meiosis, and these spores grow into new gametophytes, so the two forms alternate.

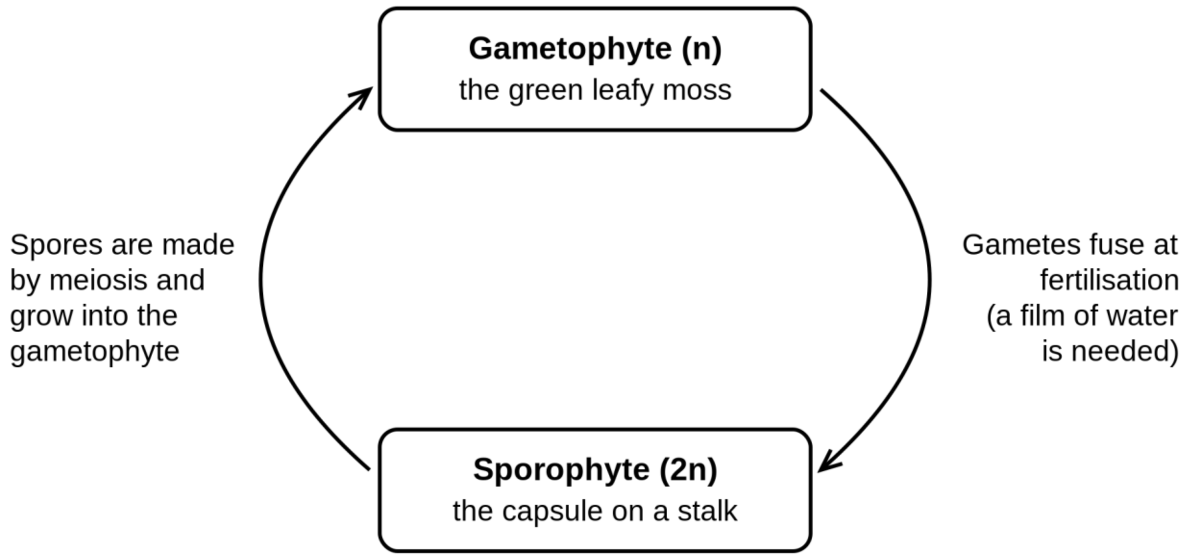


Figure 4.16: *Alternation of generations in a moss.*

Examiner's Note

The marks are for the two alternating forms named with what each makes and its chromosome number: the gametophyte makes gametes and is haploid (n), the sporophyte makes spores and is diploid (2n). Naming the leafy moss as the gametophyte and the capsule as the sporophyte completes it.

Language Clinic

State both halves of the cycle, not one: the gametophyte makes gametes, the sporophyte makes spores. The word alternation only makes sense once both forms, and the change from one to the other, are described.

Question 50

The step from mosses to the ferns and seed plants turned on a single tissue, one that let plants grow tall and spread onto dry land. Explain what vascular tissue is, and how it freed plants from a life tied to water.

Model Answer

Vascular tissue is the conducting tissue of a plant, made of xylem and phloem. The xylem carries water and mineral salts up from the roots to the rest of the plant, while the phloem carries the food made in the leaves to where it is needed; the xylem also strengthens the plant and helps to hold it upright.

This tissue freed plants from a life tied to water because it can carry water far up into a tall shoot. A plant with xylem can draw water from the soil up to leaves held high in the air, and its strengthened stem can stand upright, so vascular plants were able to grow large and spread into drier places; a moss, having no vascular tissue, cannot move water far and so stays small and close to damp ground.

Examiner's Note

The answer needs the two tissues with their jobs, xylem for water and minerals upward, phloem for food, and then the consequence: vascular tissue carries water up to a tall shoot and supports it, so the plant can grow large and live away from water.

Language Clinic
Join the two tissues with while: the xylem carries water up, while the phloem carries food. The connector shows that the two do different jobs within the one vascular system.

Question 51

Biologists call the bryophytes the most primitive of the plants, and note that they can never stray far from water. Explain why the bryophytes are regarded as primitive, and why they remain tied to water.

Model Answer

Bryophytes are regarded as primitive because they keep the simplest plant body and the oldest pattern of life. They have no vascular tissue and no true roots, stems or leaves, they stay small, and in their life cycle it is the simple gametophyte, rather than the sporophyte, that is the dominant, independent plant; in all these ways they resemble the earliest plants to reach land.

They remain tied to water chiefly because their male gametes must swim to the female. Fertilisation can happen only when a film of water lies over the plant, for the male gametes swim through it to reach the egg; and, lacking both vascular tissue and a thick waterproof cuticle, the plants dry out easily, so they are confined to damp, shady places.

Examiner's Note
Two strands earn the marks: primitive because there is no vascular tissue, no true roots, stems or leaves, and the gametophyte is dominant; tied to water because the male gametes must swim through a film of water for fertilisation, and the plants dry out easily.

Question 52

The conifers, such as the pines and cypresses grown for timber, were the first plants to free their reproduction from water. Explain the distinctive features of the division Coniferophyta.

Model Answer

The conifers are vascular seed plants with several distinctive features.

1) **Naked seeds in cones:** the seeds are borne uncovered on the scales of cones, not enclosed in a fruit, which is why conifers are called gymnosperms.
2) **No flowers:** they bear cones in place of flowers.
3) **Needle-like leaves:** the narrow, waxy needles cut down water loss, so conifers thrive even in cold or dry places.
4) **Woody plants with vascular tissue:** well-developed xylem and phloem allow them to grow into tall woody trees.
5) **Free of water for reproduction:** pollen carries the male gamete to the female cone by wind, so no film of water is needed for fertilisation.

Examiner's Note
The defining features are the naked seeds borne in cones (the gymnosperm condition) and the absence of flowers, supported by the needle leaves, the woody vascular body, and wind pollination that needs no water.

False Confidence Alert
A cone is easily mistaken for a fruit, and the conifer for a flowering plant. It is neither: a conifer bears no flowers and no fruit, and its seeds sit naked on the cone scales, which is the whole meaning of gymnosperm.

Question 53

The flowering plants, the angiosperms, are the most successful and widespread plants on Earth, from the maize in a farm to the great forest trees. Explain the distinctive features of the division Angiospermophyta.

Model Answer

The angiosperms are vascular seed plants set apart by their flowers and enclosed seeds.

1) **They bear flowers:** the flower is the organ of sexual reproduction, shaped to be pollinated by insects, by birds or by the wind.
2) **Seeds enclosed in a fruit:** after fertilisation the ovary becomes a fruit that encloses and protects the seeds, which is why they are called angiosperms, meaning enclosed seeds.
3) **True roots, stems and leaves with strong vascular tissue:** so they range from tiny herbs to great trees.
4) **Two groups:** the monocotyledons and the dicotyledons, told apart by the number of seed leaves and other features.
5) **The most successful land plants:** their flowers, fruits and efficient transport let them live in almost every habitat.

Examiner's Note
The two features that define the angiosperms are the flower and the seed enclosed in a fruit formed from the ovary. Naming these, and adding that the group splits into monocotyledons and dicotyledons, earns the marks.

Question 54

The flower is the organ of sexual reproduction in the angiosperms. Draw a large, labelled diagram of a flower in section, and state the function of the anther, the stigma and the ovary.

Model Answer

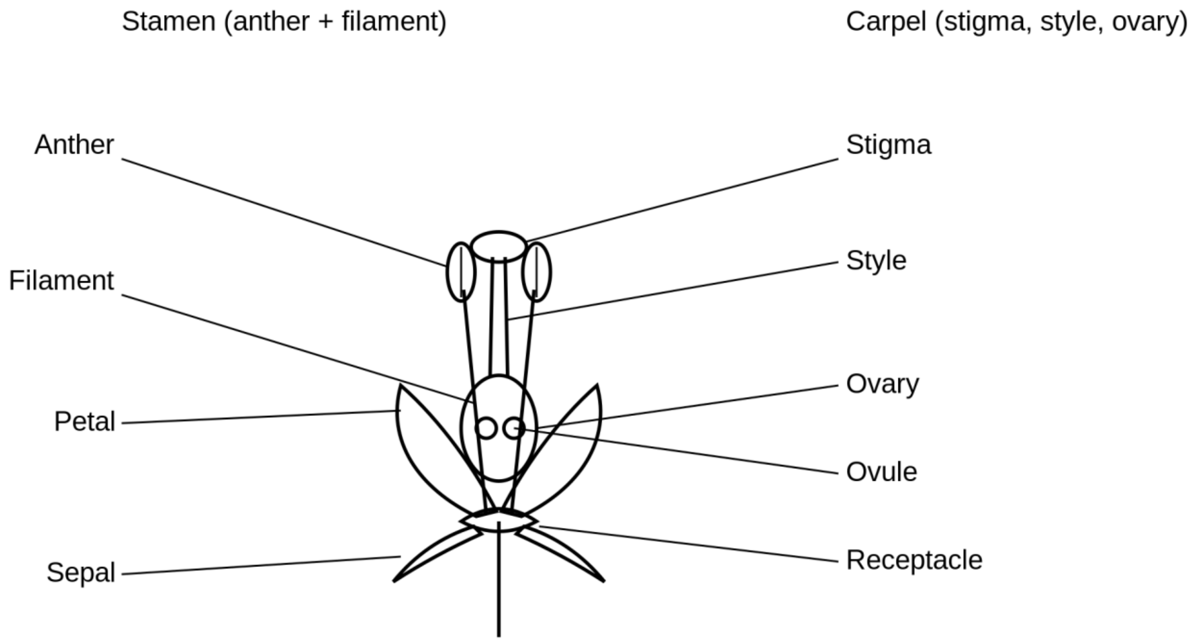


Figure 4.17: *The structure of a flower in section.*

A flower is built of four whorls attached to the receptacle, the sepals, the petals, the stamens and the carpel (also called the pistil), and three of its parts do the central work of reproduction.

Anther: the head of the stamen, which makes and holds the pollen grains that carry the male gametes.

Stigma: the top of the carpel, sticky so that it catches the pollen grains during pollination.

Ovary: the base of the carpel, holding the ovules; after fertilisation it grows into the fruit, while the ovules become the seeds.

Examiner's Note

The diagram should show the four whorls attached to the receptacle: the sepals, the petals, the stamens (each an anther on a filament) and the carpel (stigma, style and ovary with ovules). The functions wanted are the anther making pollen, the stigma receiving pollen, and the ovary forming the fruit and seeds.

False Confidence Alert

It is a common error to call the anther the stamen, or the ovary the carpel. The stamen is the whole male part, that is the anther on its filament; the carpel is the whole female part, that is the stigma, style and ovary together.

Question 55

All the flowering plants fall into two groups, the monocotyledons and the dicotyledons, which are told apart by several features. Explain how a monocotyledon differs from a dicotyledon.

Model Answer

A monocotyledon differs from a dicotyledon in a set of matched features.

1) **Cotyledons:** a monocotyledon seed has one cotyledon, or seed leaf, whereas a dicotyledon seed has two.
2) **Leaf veins:** the veins run parallel in a monocotyledon leaf, whereas they form a branching net in a dicotyledon leaf.
3) **Roots:** a monocotyledon has a fibrous root system, whereas a dicotyledon has a tap root with side branches.
4) **Stem bundles:** the vascular bundles are scattered through a monocotyledon stem, whereas they lie in a ring in a dicotyledon stem.
5) **Flower parts:** the parts are in threes in a monocotyledon, whereas they are in fours or fives in a dicotyledon.

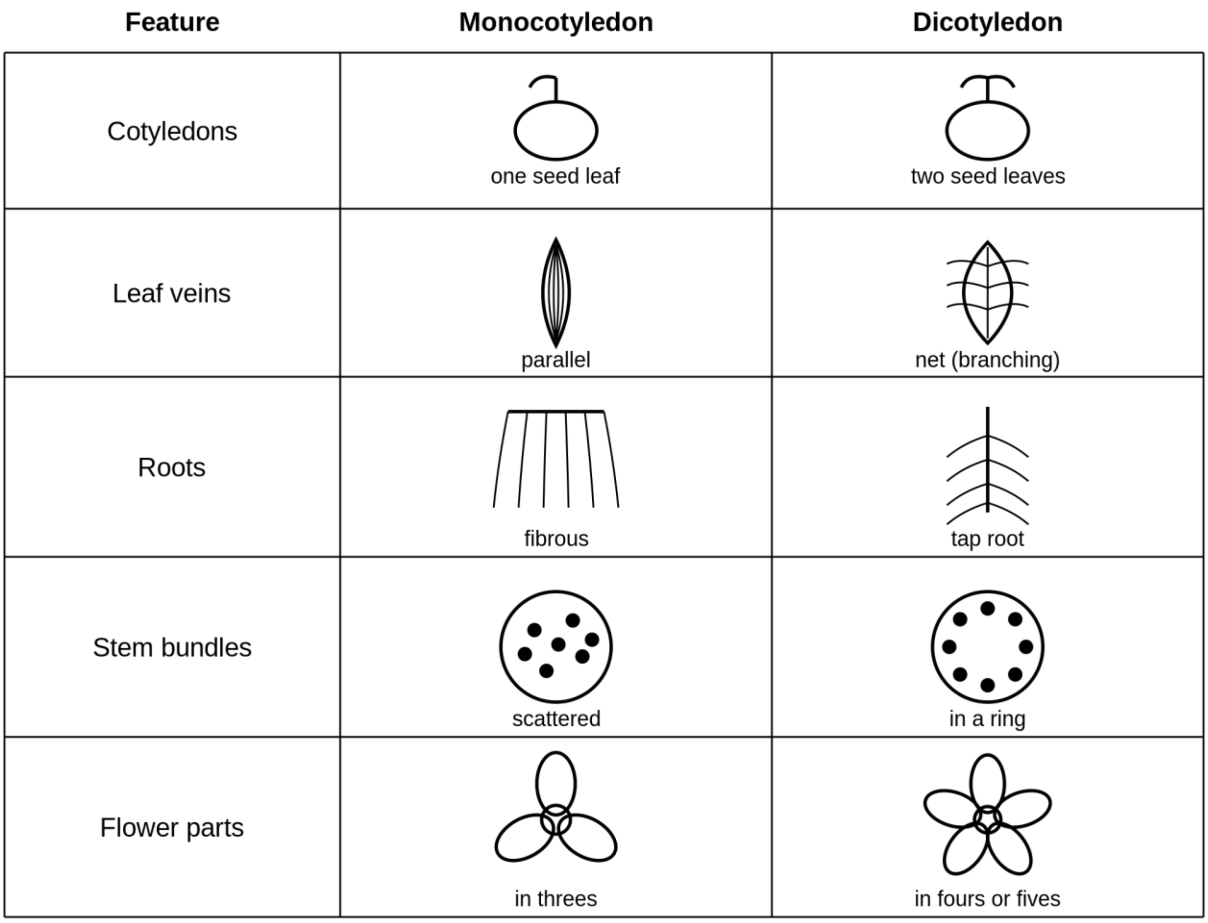


Figure 4.18: *Monocotyledons compared with dicotyledons.*

Examiner's Note

Full marks need the matched pairs, not loose single facts: one cotyledon against two, parallel veins against net veins, fibrous roots against a tap root, scattered bundles against a ring, and floral parts in threes against fours or fives.

Language Clinic

Mark every line of the comparison with whereas: parallel veins in a monocotyledon, whereas a net in a dicotyledon. The connector pairs each feature with its opposite and keeps the two groups side by side.

Question 56

From the sponge on a coral reef to the elephant on the plains, the animals make up Kingdom Animalia. Explain the general characteristics that place an organism in this kingdom.

Model Answer

An organism is placed in Kingdom Animalia by a set of shared characteristics.

1) **Eukaryotic and multicellular:** the body is made of many cells with true nuclei, organised into tissues and organs.
2) **Heterotrophic by ingestion:** animals take in ready-made food and digest it inside the body, having no chlorophyll to make their own.
3) **No cell wall:** the cells are bounded only by a membrane, so the body can be soft and flexible.
4) **Nervous coordination:** most animals have nerves and muscles, so they sense their surroundings and respond quickly.
5) **Usually able to move:** most animals move about, at least at some stage of life.

Examiner's Note

The defining set is eukaryotic and multicellular, feeding by ingestion, no cell wall, and nervous coordination. Feeding by ingestion and the lack of a cell wall are the features that most clearly separate animals from plants and fungi.

False Confidence Alert

A sponge is fixed and a coral may look like a plant, so it is tempting to file them away as plants. They are animals: they have no cell wall and no chlorophyll, and they feed by taking food in, not by making it.

Question 57

When biologists sort the animal phyla, two features of the body plan come first: its symmetry and its level of organisation. Explain how body symmetry and body organisation are used to classify animals.

Model Answer

Body symmetry describes how the body parts are arranged about a centre, and it sorts animals into three patterns. An asymmetrical animal, such as a sponge, has no regular plane of symmetry; a radially symmetrical animal, such as *Hydra*, has its parts set in a circle around a central axis, so any cut through the centre gives matching halves; a bilaterally symmetrical animal, such as a worm or a mammal, has a left and a right that mirror each other and a distinct head end.

Body organisation describes how many cell layers the body is built from. A diploblastic animal, such as a cnidarian, has just two cell layers, an outer and an inner, with jelly between; a triploblastic animal, the plan of all the higher phyla, has three layers, and within these many develop a body cavity, the coelom, that holds and cushions the organs.

Examiner's Note

The marks are for the three symmetries with examples, asymmetrical, radial and bilateral, and for the organisation, diploblastic against triploblastic, with the body cavity (coelom). Bilateral symmetry and a head end mark the more advanced animals.

Language Clinic

Pin each kind of symmetry to an example: asymmetrical, the sponge; radial, Hydra; bilateral, the worm. The example fixes the term in the mind far better than the definition on its own.

Question 58

The sponges, the simplest of all animals, sit in the phylum Porifera. Explain the distinctive features of the Porifera.

Model Answer

The Porifera are the simplest animals, marked out by a body built for filtering water.

1) **No true tissues or organs:** the body is multicellular but the cells are not organised into true tissues.
2) **A body full of pores:** water is drawn in through many pores, the name Porifera meaning pore-bearer, and leaves by a larger opening, the osculum.
3) **Filter feeders:** they sieve tiny food particles from the stream of water passing through them.
4) **Supported by spicules:** the body is held up by a skeleton of needle-like spicules or tough fibres.
5) **Sessile and aquatic:** they are fixed to a surface and live mostly in the sea.

Examiner's Note

The features that earn marks are the pores with the osculum, filter feeding, the spicule skeleton and the absence of true tissues. The pores and filter feeding are the heart of what makes a sponge a sponge.

Question 59

Jellyfish, sea anemones and the freshwater Hydra belong to the phylum Coelenterata, also called Cnidaria. Explain the distinctive features of this phylum.

Model Answer

The Coelenterata are radially symmetrical animals built around a single gut cavity.

1) **Radial symmetry:** the body parts are set around a central axis.
2) **Diploblastic:** the body wall has two cell layers, an outer and an inner, with jelly between.
3) **A single gut cavity:** the enteron has just one opening, which serves as both the mouth and the anus.
4) **Tentacles with stinging cells:** a ring of tentacles around the mouth bears stinging cells (cnidocytes) to capture prey and for defence.

5) **Two body forms:** the fixed polyp, as in *Hydra*, and the free-swimming medusa, as in a jellyfish.

Examiner's Note

Full marks need radial symmetry, the diploblastic body, the single gut opening, and the stinging tentacles. The one opening that acts as both mouth and anus, and the stinging cells, are the signature features.

Language Clinic

State both jobs of the single opening: the enteron has one opening that serves as both the mouth and the anus. Naming only the mouth misses half of what makes the gut distinctive.

Question 60

Draw a large, labelled diagram of Hydra, and name the part it uses to capture food and the cavity in which the food is digested.

Model Answer

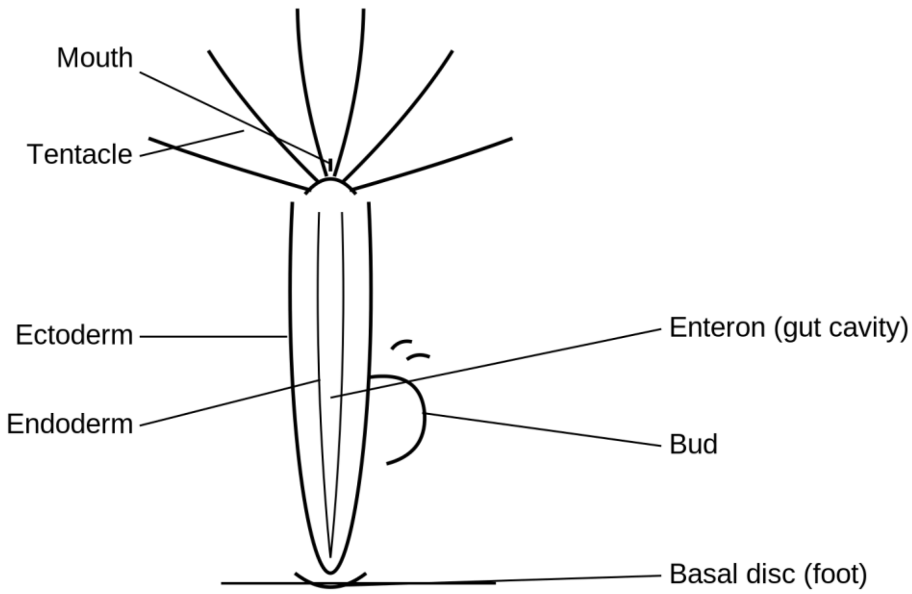


Figure 4.19: *The structure of Hydra.*

***Hydra* is a small tubular cnidarian, fixed by its base and crowned with a ring of tentacles.**

1) **Tentacles:** the ring of arms around the mouth which, with their stinging cells, capture the food.
2) **Enteron (gut cavity):** the central cavity into which the food is taken and where it is digested.

Examiner's Note

The diagram should show the tentacles, the mouth, the two-layered body wall, the enteron, the basal disc and a bud. The two parts asked for are the tentacles, which capture food, and the enteron, in which it is digested.

Question 61

The flatworms, including the tapeworm and the liver fluke, form the phylum Platyhelminthes. Explain the distinctive features of the Platyhelminthes, using a parasite as your example.

Model Answer

The Platyhelminthes are flat, soft-bodied worms, many of them parasites.

1) **A flattened body:** the body is flat and ribbon-like or leaf-like, flattened from top to bottom.
2) **Bilateral and triploblastic, but acoelomate:** they have a head end and three cell layers, but no body cavity.
3) **No anus:** where a gut is present it has a single opening, and the tapeworm has no gut at all.
4) **A thin body for diffusion:** the flat shape lets oxygen and food reach every cell by diffusion, for there is no blood system.
5) **Many are parasites:** the tapeworm lives in the gut and the liver fluke in the liver, gripping the host with hooks and suckers.

Examiner's Note

Credit goes to the flattened body, the lack of a body cavity and of an anus, and the parasitic way of life with hooks and suckers. The flat shape is tied to diffusion, since these worms have no blood system.

False Confidence Alert

It seems odd that a tapeworm, living in the gut, should have no gut of its own. It does not: bathed in the host's digested food, it simply absorbs that food over its whole flat surface, so it needs no gut at all.

Question 62

Draw a large, labelled diagram of a tapeworm, and name the part that attaches it to the host and the part that carries its eggs.

Model Answer

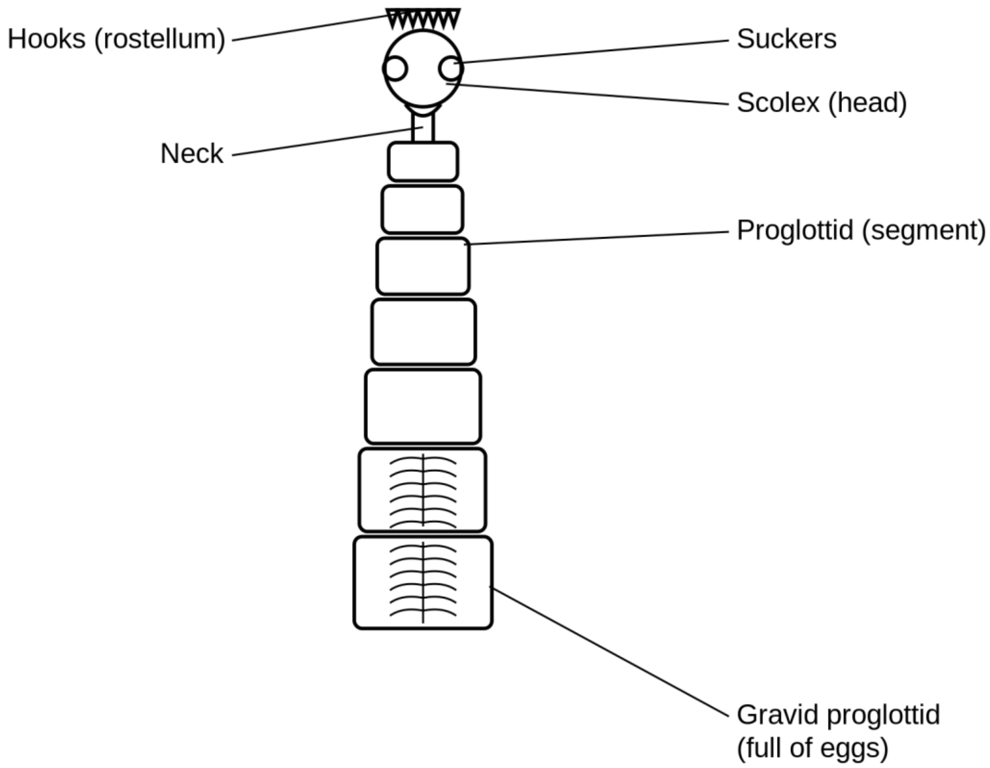


Figure 4.20: *The structure of a tapeworm.*

A tapeworm is a long, flat, segmented parasite of the gut, with a head, a neck and a chain of segments.

1) **Scolex (head):** the knob at the front, bearing suckers and hooks that grip the wall of the host's gut.
2) **Gravid proglottids:** the ripe segments at the far end, packed with eggs, which break off and pass out to spread the parasite.

Examiner's Note

The diagram should show the scolex with its suckers and hooks, the neck and the chain of proglottids, ending in the gravid ones. The scolex is the part that attaches to the host, and the gravid proglottids are the part that carries the eggs.

False Confidence Alert

The chain of segments is easily mistaken for true body segmentation like an earthworm's. It is not the same: each proglottid is mainly a reproductive packet, budded from the neck and filling with eggs as it is pushed towards the tail.

Question 63

The roundworms, many of them parasites of people and crops, make up the phylum Nematoda. Explain the distinctive features of the Nematoda, using a parasite as your example.

Model Answer

The Nematoda are slender round worms with a complete gut, many living as parasites.

1) **A cylindrical body:** long and slender, round in cross-section and pointed at both ends.
2) **Unsegmented, with a tough cuticle:** unlike the earthworm there are no segments, and a resistant cuticle covers the body.
3) **Bilateral and triploblastic, with a false body cavity:** there is a fluid-filled cavity, a pseudocoelom, between the gut and the body wall.
4) **A complete gut:** food passes one way through a gut with two openings, a mouth and an anus.
5) **Many are parasites:** such as *Ascaris* and the hookworm in the human gut, while others live free in the soil.

Examiner's Note

The marks are for the cylindrical, unsegmented body with its cuticle, and above all for the complete gut with both a mouth and an anus, which is the advance over the flatworms.

False Confidence Alert

Round worms and flat worms are easily muddled. The roundworm is cylindrical and unsegmented with a complete one-way gut, whereas the flatworm is flat and has a gut with a single opening, or none at all.

Question 64

The segmented worms, such as the earthworm and the leech, belong to the phylum Annelida. Explain the distinctive features of the Annelida, and name its three classes.

Model Answer

The Annelida have a long body built of many similar, ring-like segments, a pattern called metameric segmentation; they are bilateral and triploblastic, with a true body cavity (the coelom), a complete gut running the length of the body, and small bristles, the setae, that grip the ground as the muscles draw the worm along.

The phylum has three classes:

1) **Polychaeta:** marine worms with many setae carried on flap-like parapodia, such as the ragworm.
2) **Oligochaeta:** worms with only a few setae and no parapodia, such as the earthworm.
3) **Hirudinea:** the leeches, which have suckers and no setae, many of them feeding on blood.

Examiner's Note

Marks come from the segmentation, the true coelom, the complete gut and the setae, and then from naming the three classes with an example: Polychaeta, Oligochaeta and Hirudinea.

Language Clinic

Tell the three classes apart by their setae: many in the Polychaeta, few in the Oligochaeta, none in the Hirudinea. One clear feature, traced across all three, sorts them at a glance.

Question 65

The earthworm, found in any moist Tanzanian soil, is the best known annelid. Draw a large, labelled diagram of an earthworm showing its external features, and name the part used in reproduction and the structures that grip the soil.

Model Answer

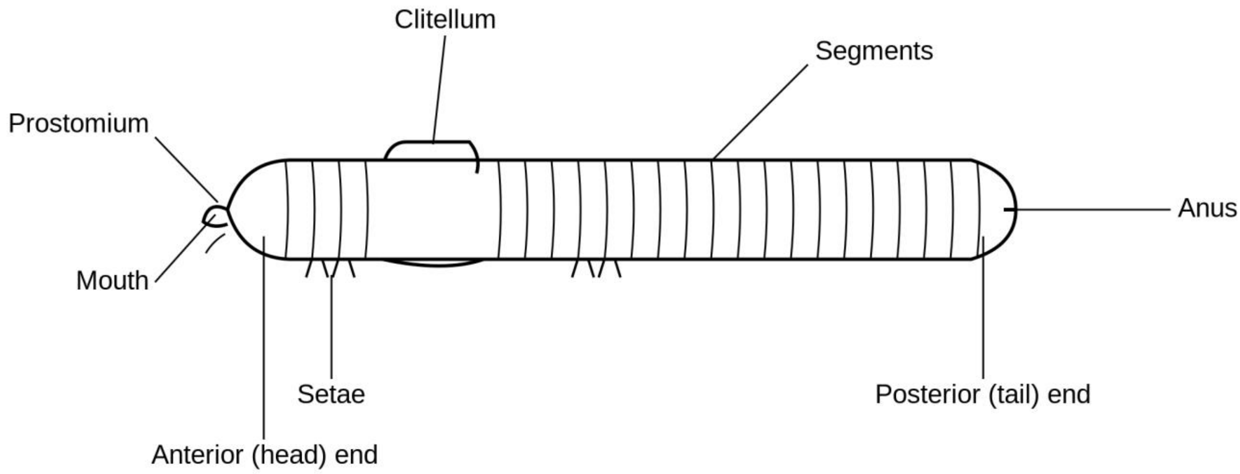


Figure 4.21: *The external features of an earthworm.*

An earthworm is a long, cylindrical worm of many similar segments, with a head end, a tail end and a smooth saddle near the front.

1) **Clitellum:** the smooth, swollen saddle near the front, which makes the cocoon that holds the eggs in reproduction.
2) **Setae:** the tiny bristles on the segments, which grip the soil as the worm moves.

Examiner's Note

The diagram should show the segmented body, the prostomium and mouth, the clitellum, the setae and the anus, with the head and tail ends marked. The clitellum is the part used in reproduction, and the setae are the structures that grip the soil.

Question 66

Snails, slugs, mussels and the octopus, soft-bodied animals often carrying a shell, make up the phylum Mollusca. Explain the distinctive features of the Mollusca.

Model Answer

The Mollusca are soft-bodied animals, most of them sheltered by a shell.

1) **A soft, unsegmented body:** usually protected by a hard shell of calcium carbonate.
2) **A mantle:** a fold of skin that makes the shell and encloses a cavity holding the gills.
3) **A muscular foot:** used to creep, to dig or to swim.
4) **A radula in many:** a rasping tongue bearing rows of tiny teeth, used for feeding.
5) **A wide range of forms:** from the snail and the mussel to the octopus, in which the shell is reduced and internal.

Examiner's Note

The defining features are the soft unsegmented body, the shell made by the mantle, and the muscular foot, with the radula as a common feeding structure. The mantle and foot are the marks of a mollusc.

False Confidence Alert

Because an octopus has no shell on the outside, it is tempting to put it outside the molluscs. It is one: it has the soft body, the mantle and the muscular foot, with only the shell reduced and tucked inside.

Question 67

Starfish, sea urchins and sea cucumbers, all of them living in the sea, form the phylum Echinodermata. Explain the distinctive features of the Echinodermata.

Model Answer

The Echinodermata are spiny-skinned marine animals with a unique water-driven system of movement.

1) **All are marine:** they live only in the sea.
2) **Radial symmetry as adults:** the body is often set in five rays, although the larvae are bilateral.
3) **A spiny skin:** the surface is spiny over an internal skeleton of chalky plates, which gives the phylum its name, the spiny-skinned animals.
4) **A water vascular system:** a set of water-filled canals works the tube feet, used for movement and for feeding.
5) **Power to regenerate:** many can grow back a lost part, as a starfish regrows an arm.

Examiner's Note

The features that carry the marks are the spiny skin, the radial (five-rayed) adult body, and above all the water vascular system working the tube feet, which is found in no other phylum.

Language Clinic

Link the system to what it does: the water vascular system works the tube feet, which move the animal and grip its food. Naming the system without its tube feet leaves the point half made.

Question 68

The arthropods, including insects, crabs, spiders and millipedes, are by far the largest phylum, with more species than all the other animals together. Explain the distinctive features of the Arthropoda, and why they have been so successful.

Model Answer

The Arthropoda are marked out by a hard exoskeleton and jointed legs.

1) **A chitin exoskeleton:** the body is covered by a tough, protective exoskeleton of chitin.
2) **A segmented body and limbs:** the body and its limbs are divided into segments.
3) **Jointed limbs:** each limb is jointed, which is what the name arthropod, meaning jointed foot, describes.
4) **The body in regions:** it is usually grouped into a head, a thorax and an abdomen.
5) **Growth by moulting:** the animal grows by moulting, or ecdysis, shedding the exoskeleton it has outgrown.

They have been so successful because these very features fit them for almost every habitat. The exoskeleton supports the body, shields it, and, being waterproof, lets arthropods live on dry land; the jointed legs allow many efficient kinds of movement, the wings of insects allow flight and wide dispersal, and small size together with rapid breeding and varied mouthparts lets them fill a great range of niches.

Examiner's Note

The features that carry the marks are the chitin exoskeleton, the jointed limbs and the segmented body in regions, with growth by moulting. The success then follows from these: a waterproof exoskeleton for land, jointed legs and wings for movement, and rapid breeding for filling many niches.

Language Clinic

Tie each feature to the advantage it brings: the exoskeleton is waterproof, so arthropods can live on dry land. An answer that links the feature to its benefit explains the success, rather than just listing traits.

Question 69

The arthropods are divided into four main classes, and a biologist tells them apart by the number of body regions, of legs and of antennae. Name the four classes of arthropods, with an example of each, and explain how they are distinguished.

Model Answer

The Arthropoda are divided into four classes, separated by their body regions, legs and antennae.

1) **Insecta:** for example the housefly or grasshopper; the body is in three parts (head, thorax and abdomen), with three pairs of legs, one pair of antennae and usually wings.
2) **Crustacea:** for example the crab or prawn; the body is in two parts (cephalothorax and abdomen), with five or more pairs of legs, two pairs of antennae and gills.
3) **Arachnida:** for example the spider, scorpion or tick; the body is in two parts (cephalothorax and abdomen), with four pairs of legs and no antennae.
4) **Myriapoda:** for example the centipede or millipede; a head and a long, many-segmented trunk, with one pair of antennae and many pairs of legs.

Examiner's Note

The marks are for the four classes with an example each, and for the separators: the number of pairs of legs (three in insects, four in arachnids, five or more in crustaceans, many in myriapods) and of antennae (one pair, none, two pairs and one pair in turn).

Language Clinic

Sort the four classes by counting: legs, antennae and body regions. A tick has four pairs of legs and no antennae, which alone marks it as an arachnid and not an insect; counting is the surest way to tell the classes apart.

Question 70

An insect such as a grasshopper shows the typical insect body plan very clearly. Draw a large, labelled diagram of an insect and describe the three main body regions, stating the structures found on each region.

Model Answer

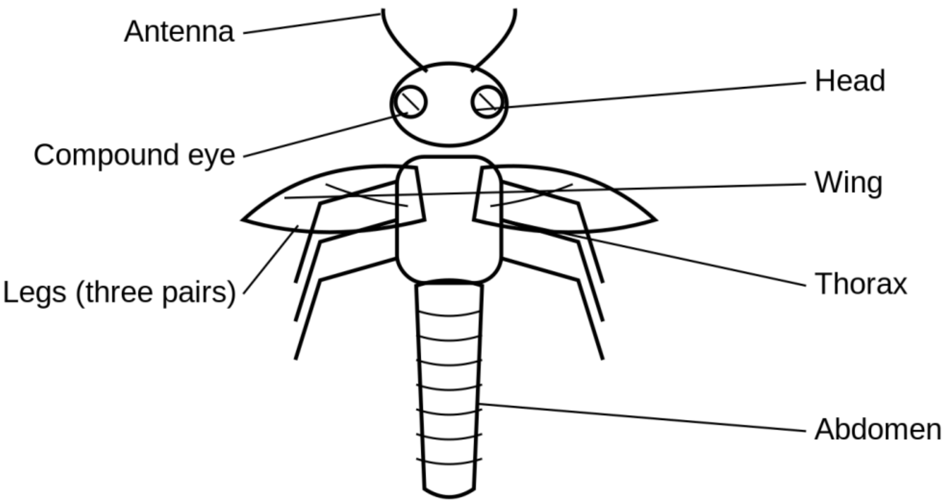


Figure 4.22: *The structure of an insect.*

An insect has its body in three regions, the head, the thorax and the abdomen, with three pairs of legs and usually wings borne on the thorax.

1) **Head:** it bears the antennae, the compound eyes and the mouthparts.
2) **Thorax:** the middle region, which carries the three pairs of legs and the wings (usually two pairs).
3) **Abdomen:** the hind region, segmented, holding most of the gut and the reproductive organs.

Examiner's Note

The diagram should show the three regions, head, thorax and abdomen, with one pair of antennae and the compound eyes on the head, and the three pairs of legs and the wings on the thorax.

False Confidence Alert

A frequent error is to draw the legs coming from the abdomen, or to draw too many. An insect has exactly three pairs of legs, and they, like the wings, are attached to the thorax, never to the abdomen.

Question 71

Every animal with a backbone, from a fish to a human being, belongs to one phylum, the Chordata. Explain the features that mark out a chordate, and name the main classes of backboned chordates, the vertebrates.

Model Answer

A chordate is recognised by four features that appear at some stage of its life.

1) **The notochord:** a stiff supporting rod running along the back.
2) **A dorsal hollow nerve cord:** a single, hollow nerve cord lying just above the notochord, so the nerve cord is dorsal.
3) **Pharyngeal gill slits:** a series of gill slits in the throat region.
4) **A post-anal tail:** a tail that reaches back beyond the anus.

In the great group called the vertebrates the notochord is, as the animal develops, largely replaced by a backbone, a column of bone or cartilage that forms around it and encloses and protects the nerve cord.

The backboned chordates, the vertebrates, fall into five main classes.

1) **Fishes:** aquatic and breathing by gills, sometimes divided into the cartilaginous and the bony fishes.
2) **Amphibia:** such as frogs and toads, living partly in water and partly on land.
3) **Reptilia:** such as lizards, snakes and tortoises, with a dry, scaly skin.
4) **Aves:** the birds, with feathers.
5) **Mammalia:** with hair and milk.

Examiner's Note

The marks are for the four chordate features, the notochord, the dorsal hollow nerve cord, the pharyngeal gill slits and the post-anal tail, and for naming the vertebrate classes. Add the point that, in the vertebrates, the notochord is replaced by a vertebral column.

Question 72

Fishes are the most numerous of the vertebrates, and they make up two classes. Distinguish the cartilaginous fishes from the bony fishes, and draw a large, labelled diagram of a bony fish.

Model Answer

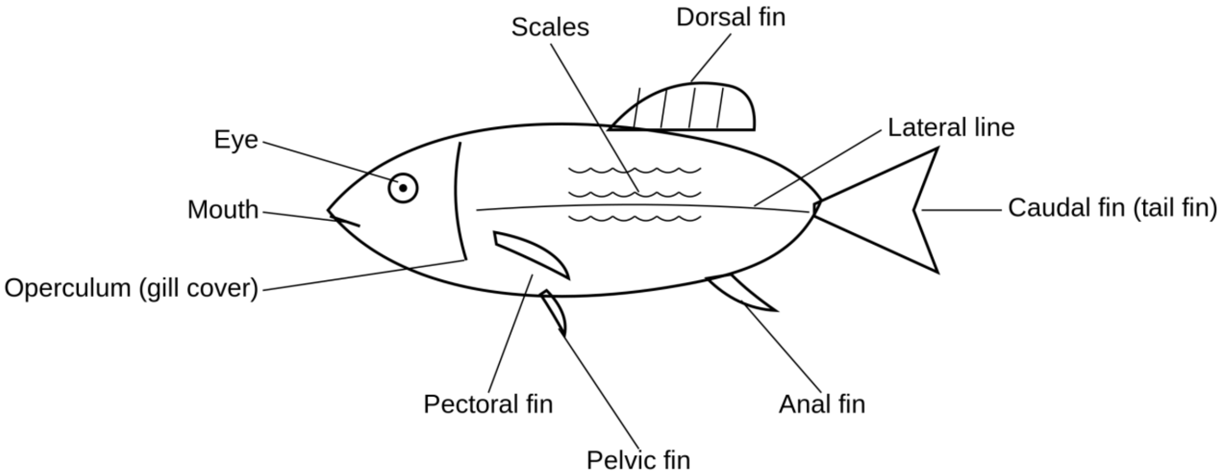


Figure 4.23: *The external structure of a bony fish.*

Fishes are aquatic vertebrates that breathe by gills and swim with fins, and they fall into two classes that differ in several ways.

1) **Skeleton:** cartilage in the cartilaginous fishes (Chondrichthyes), such as the shark and the ray, but bone in the bony fishes (Osteichthyes), such as the tilapia and the Nile perch.
2) **Gill opening:** separate gill slits with no cover over them in the cartilaginous fishes, but a single bony flap, the operculum, in the bony fishes.
3) **Scales:** small tooth-like scales in the cartilaginous fishes, but thin overlapping scales in the bony fishes.
4) **Swim bladder:** absent in the cartilaginous fishes, but present in the bony fishes, keeping them afloat without effort.

A bony fish shows clearly the parts that fit it for life in water. The body is streamlined and covered by scales and a slimy skin, so it slips easily through the water; the median fins (dorsal, caudal and anal) and the paired fins (pectoral and pelvic) steer and balance the fish, while the tail, or caudal fin, sweeps from side to side to drive it forward. Water taken in at the mouth is passed over the gills and out beneath the operculum, and the lateral line along each side detects vibrations and currents in the surrounding water.

Examiner's Note

The distinguishing pairs are skeleton (cartilage against bone), the gill opening (separate slits with no cover against a single operculum) and the swim bladder (absent against present). For the diagram the expected labels are the mouth, eye and operculum, the dorsal, caudal, anal, pectoral and pelvic fins, the lateral line and the scales.

False Confidence Alert

A shark is not just a large tilapia. It is a cartilaginous fish with no operculum and no swim bladder, which is why it must keep swimming to stop itself sinking, whereas the bony fish floats at rest on its swim bladder.

Question 73

The amphibians, such as the frog, are said to lead a double life. Describe the features of the class Amphibia, and explain how these features both fit it for land and keep it tied to water.

Model Answer

Amphibians are vertebrates that spend part of their life in water and part on land.

1) **A moist, scaleless skin:** soft and without scales, and gas exchange takes place through it.
2) **Gills then lungs:** the young breathe by gills, while the adult breathes by lungs and through the skin.
3) **A three-chambered heart.**
4) **Ectothermic:** the body temperature follows that of the surroundings.
5) **Jelly-covered eggs laid in water:** a tadpole larva hatches and changes, by metamorphosis, into the adult.

Familiar examples are the frog, the toad and the newt.

These features both allow life on land and hold the amphibian back to water. The lungs and the four legs let the adult live and move on land, but the moist skin must stay damp for breathing, so the animal keeps to wet, shady places; and the eggs, having no shell, would quickly dry, so they must be laid in water where the gilled tadpole can live until its lungs and legs have formed.

Examiner's Note

The features that score are the moist, scaleless skin, gills in the young and lungs in the adult, the three-chambered heart, ectothermy, and jelly eggs laid in water with a tadpole larva. The link to water comes through the breathing skin and the shell-less eggs.

Language Clinic

Show why the amphibian cannot leave water fully: both the breathing skin and the unprotected eggs need water. Naming that double dependence explains the double life far better than simply saying it lives in two places.

Question 74

The reptiles were the first vertebrates able to breed away from water. Describe the features of the class Reptilia, and explain how they are better suited to dry land than the amphibians.

Model Answer

Reptiles are land vertebrates with a dry, scaly skin and eggs that can be laid on land.

1) **A dry, scaly skin:** covered with horny scales that hold in water.
2) **Lungs only:** breathing is by lungs alone.
3) **A three-chambered heart:** with the ventricle partly divided, the crocodile being an exception, with a fully four-chambered heart.
4) **Ectothermic:** the body temperature follows that of the surroundings.
5) **Leathery, shelled eggs laid on land:** the young hatch already resembling small adults, with no larval stage.

Examples include the lizard, the snake, the tortoise and the crocodile.

These features free the reptile from water in the very ways the amphibian is held to it. The waterproof scaly skin checks the loss of water, so reptiles can live even in dry, hot places such as deserts; and the shelled egg, carrying its own food and water inside a protective cover, shields the developing young on land, so the reptile need never return to water to breed.

Examiner's Note

The features are the dry, waterproof scaly skin, lungs only, ectothermy, and shelled eggs laid on land with no larva. The two advances over the amphibians that must be named are the waterproof skin and the shelled egg.

False Confidence Alert

A reptile's egg is not like a frog's. It has a tough shell and is laid on land, not in water; treating reptiles as still tied to water for breeding, the way amphibians are, is a clear mistake.

Question 75

Birds are the vertebrates most fully adapted for flight. Describe the features of the class Aves, and explain how a bird is built for flying.

Model Answer

Birds are feathered, warm-blooded vertebrates whose forelimbs are wings.

1) **Feathers:** the body is covered with feathers.
2) **Wings:** the forelimbs are modified into wings.
3) **A toothless beak:** the jaws form a horny beak that bears no teeth.
4) **Endothermic:** holding a constant warm body temperature.
5) **A four-chambered heart.**
6) **Hard-shelled eggs:** which the parents keep warm until they hatch.

Examples are the domestic fowl, the dove and the eagle.

Nearly every feature of a bird answers the demands of flight. The feathers spread the wing into a surface that gives lift and smooth the body so air flows past it easily; the bones are thin and hollow, making the whole body light; the breast muscles that beat the wings are large and powerful; the toothless beak keeps the head light at the front; and a steady warm body temperature keeps the flight muscles working quickly and without tiring.

Examiner's Note

The features are feathers, wings, a toothless beak, endothermy, a four-chambered heart and hard-shelled eggs. The flight adaptations to draw out are the feathers, the light hollow bones, the large breast muscles and the light toothless beak.

Question 76

Mammals, the class to which the human being belongs, are set apart above all by how they feed and care for their young. Describe the features of the class Mammalia, and state which of them are found in no other class.

Model Answer

Mammals are warm-blooded vertebrates with hair and with glands that make milk.

1) **Hair or fur:** the skin bears hair or fur.
2) **Mammary glands:** the females have mammary glands that give milk to feed the young.
3) **Endothermic:** holding a constant warm body temperature.

4) **A four-chambered heart.**
5) **A diaphragm:** a muscular sheet that divides the chest from the abdomen and helps in breathing.
6) **Teeth of several kinds:** suited to different foods.
7) **Mostly live birth:** most mammals give birth to live young rather than laying eggs.

Examples range from the human and the dog to the bat and the whale.

Two of these features are found in no other class of animals. Hair, or fur, on the skin and the mammary glands that nourish the young with milk belong to mammals alone; together with a constant warm body temperature and the care given to the young, they have allowed mammals to spread into nearly every habitat, in the sea, on land and in the air.

Examiner's Note

The features are hair or fur, mammary glands giving milk, endothermy, a four-chambered heart, a diaphragm, teeth of several kinds, and mostly live-born young. The two that are unique to mammals, and must be named as such, are the hair and the mammary glands.

False Confidence Alert

A whale and a bat are mammals, not a fish and a bird. The whale lives in the sea yet breathes air, has hair and feeds its young on milk, while the bat flies yet has fur and suckles its young; the milk and the hair settle the matter.

REAL QUESTIONS

These questions take the same biology into real life in Tanzania, and test whether you can apply it, spot a mistake and judge an argument. Attempt each on paper, then check the model answer beneath. Every answer leads with the mark-bearing point in bold.

Question 77

A Form Five student learns the five kingdoms, then reads that scientists now also speak of three domains. Explain how advances in the microscope and, later, in the study of molecules refined classification, and say what the three-domain idea adds.

Model Answer

Better tools let biologists see differences that the unaided eye had missed. The light microscope uncovered a whole world of single-celled organisms and showed that bacteria have no visible nucleus while other tiny organisms do; the electron microscope then laid bare the fine structure of the cell and confirmed that bacteria lack a true, membrane-bound nucleus. With these differences clear, the simple plant-and-animal division gave way to five kingdoms, setting the Monera, the Protoctista and the Fungi apart from the plants and the animals.

The study of molecules, above all of DNA, then refined the system further. Comparing the base sequences of genes measured how closely organisms are truly related, and it revealed that the prokaryotes are not one uniform group but two very different lines, the bacteria and the archaea, which in turn, together with all the eukaryotes, form the three domains, Bacteria, Archaea and Eukarya, a rank set above the kingdoms that marks the modern direction of classification.

Examiner's Note

The mark-bearing link is tying each tool to what it revealed: the light microscope to cells without a visible nucleus, the electron microscope to the fine structure that gave the five kingdoms, and the comparison of DNA to true relationships and the split of the prokaryotes that gives the three domains. The last mark is for naming the three domains, Bacteria, Archaea and Eukarya, as a rank above the kingdoms, not a replacement for them.

Language Clinic

Two joins carry this answer. The word "then" sets the order of discovery, the light microscope, then the electron microscope, then the study of molecules; and "which in turn" chains one finding to the next, the split of the prokaryotes which in turn forms the three domains. Quoting these joins is how a sequence of discoveries is carried through one connected answer.

Question 78

A student is given five specimens: the bacteria that sour milk into mtindi, an *Amoeba* from pond water, a mushroom, a maize plant and a tilapia. Place each in its kingdom, and give the feature that decides each placing.

Model Answer

Each specimen is placed by the kingdom criteria, the kind of cell, the number of cells and the way the organism feeds.

1) **The bacteria of mtindi, Kingdom Monera:** they are prokaryotic, single cells with no true nucleus.
2) **The *Amoeba*, Kingdom Protoctista:** a single eukaryotic cell that is neither a plant, an animal nor a fungus.
3) **The mushroom, Kingdom Fungi:** many-celled, with a wall of chitin, feeding by absorbing digested food through thread-like hyphae.
4) **The maize plant, Kingdom Plantae:** many-celled, with cellulose walls and chloroplasts, making its own food by photosynthesis.
5) **The tilapia, Kingdom Animalia:** many-celled, with no cell wall, feeding on other organisms and able to move about.

Examiner's Note

The deciding criteria must show: prokaryotic cell sends an organism to Monera; among eukaryotes, a simple single cell that fits no other kingdom goes to Protoctista, while the many-celled forms are split by nutrition and wall, a chitin wall that absorbs food (Fungi), a cellulose wall with photosynthesis (Plantae), and no wall with feeding on others (Animalia).

False Confidence Alert

Most students place the *Amoeba* in Animalia because it moves and feeds on other cells. That scores nothing: a single eukaryotic cell belonging to no other kingdom is a protoctist, and being animal-like is not the same as being an animal.

Question 79

Kipanga writes: *"The five kingdoms are ranked from lowest to highest. Monera is the lowest and most primitive, and Animalia is the highest and most advanced, with the human being at the very top."* Identify the mistakes in what Kipanga has written and put them right.

Model Answer

Kipanga is wrong to treat the kingdoms as a ladder from lowest to highest. The five-kingdom system sorts organisms by the kind of cell they have, the number of their cells and the way they feed; it is a set of categories, not a ranking by worth. Each kingdom is a different and successful way of being alive, not a rung above or below another.

He is also wrong to crown the animals, and the human being, as the highest. The bacteria of the Monera are neither failures nor lowly: they are the most numerous and widespread organisms on Earth, and they carry out tasks no animal can, such as fixing nitrogen and breaking down dead matter. Because each kingdom is suited to its own way of life, none stands higher or lower than the rest.

Examiner's Note
The correction must make two points: classification groups organisms by shared features, so the kingdoms are categories and not ranks; and no kingdom is superior, since each is equally successful in its own way, with the Monera as numerous and as vital as any.

Language Clinic
The word "because" links the reason to the conclusion, "Because each kingdom is suited to its own way of life, none stands higher or lower". The contrast "a different and successful way of being alive, not a rung above or below" sets the right idea against the wrong one. State the reason first, then let the conclusion follow from it.

Question 80

In a class debate, one student argues that viruses are living things, while another insists they are not. Weigh the living characteristics of viruses against the non-living ones, and reach a reasoned conclusion.

Model Answer

On one side, viruses show several signs of life:

1) **Genetic material:** each virus carries DNA or RNA.
2) **Reproduction:** it makes many copies of itself.
3) **Mutation:** it can change over time, as living things do.
4) **Host specificity:** each kind attacks a particular host, much as a parasite does.

On the other side, in most respects a virus behaves as non-living, and this side decides the matter:

1) **No cell:** it has no cytoplasm, no organelles and no cell membrane of its own.
2) **No life processes outside a host:** it does not feed, respire, grow or respond, and can even be stored as lifeless crystals.
3) **No reproduction of its own:** it can copy itself only inside a living host cell, whose machinery it takes over.

A virus is therefore best placed on the borderline between the living and the non-living, showing the signs of life only inside a host.

Examiner's Note
Set the two sides against each other: living signs are genetic material, reproduction and mutation; non-living signs are the lack of cell structure and of any metabolism, the inert crystal form, and the inability to reproduce without a host. The conclusion is that a virus is on the borderline, living only inside a host.

Question 81

A student tries in vain to find viruses under the school light microscope. Explain why a light microscope cannot show viruses, and how this difficulty once held back their study.

Model Answer

A light microscope cannot show viruses because most of them are far smaller than the smallest object it can resolve. The resolving power of a light microscope is limited by the wavelength of light, so it cannot separate objects much closer than the size of a small bacterium; most viruses are many times smaller than that, so light cannot resolve them, and they even pass through the fine filters that hold back bacteria.

Because they could not be seen, viruses were for a long time studied only at one remove. They could not be observed under the microscope nor grown on the ordinary media used for bacteria, so at first they were known only by the diseases they caused and by their power to pass through bacteria-proof filters, which earned them the name filterable agents; only with the invention of the electron microscope could their true size, shape and structure at last be seen.

Examiner's Note

The marks turn on resolving power, not on magnification: the light microscope is limited by the wavelength of light to objects of roughly bacterial size, and viruses are smaller. The consequence is that viruses were known only by their effects and by filtration until the electron microscope revealed them.

False Confidence Alert

Most students say the light microscope simply lacks the magnification. That misses the point: the limit is resolution, set by the wavelength of light, so adding magnification only gives a bigger blur and never brings a virus into view.

Question 82

A health officer tells a village that viruses are not only enemies. Outline the economic importance of viruses, both the harm they do and the uses people make of them.

Model Answer

Viruses do great harm, chiefly by causing disease:

1) **In people:** they cause diseases such as measles, influenza, and HIV and AIDS.
2) **In livestock:** they cause foot-and-mouth disease and Newcastle disease of poultry.
3) **In crops:** they cause cassava mosaic disease and maize streak disease.

Yet viruses are also turned to good use:

1) **Vaccines:** they are used to make vaccines that protect people and animals against disease.
2) **Gene carriers:** in genetic engineering and gene therapy they carry useful genes into cells.
3) **Bacteriophages:** these are used to kill harmful bacteria and as tools in research.
4) **Pest control:** some viruses kill insect pests in place of chemical sprays.

Examiner's Note

Both sides must be shown with named examples: harm as human, animal and crop diseases (measles, Newcastle disease, cassava mosaic), and use as vaccines, gene carriers in genetic engineering, bacteriophages against bacteria, and the biological control of pests.

Question 83

Kipanga writes: *"Viruses are good for nothing but disease, so the world would be a better place if every virus were wiped out."* Identify the mistakes in what Kipanga has written and put them right.

Model Answer

Kipanga is wrong that viruses are good for nothing but disease. Although many viruses do cause disease, others are useful: viruses are used to make vaccines, to carry genes in genetic engineering and gene therapy, and, as bacteriophages, to destroy harmful bacteria. Viruses also help to hold natural populations in balance, including the vast numbers of bacteria in the sea.

He is also wrong that wiping out every virus would make the world better. Removing all viruses would take away these benefits and would upset natural food webs and the natural control of bacteria; and it is in any case impossible, for viruses are everywhere and are forever changing. The sensible aim is to control the harmful viruses, not to destroy viruses altogether.

Examiner's Note

The correction must make two points: not all viruses are harmful, since some give vaccines, carry genes and kill bacteria, and viruses help keep nature in balance; and destroying every virus is neither desirable nor possible, so the aim is to control the harmful kinds.

False Confidence Alert

Most students agree with Kipanga that because some viruses cause disease, all viruses must be harmful. That conflates some with all: the disease-causing viruses are a minority, while others give vaccines, carry genes and hold bacterial numbers in check.

Question 84

A rice farmer notices that paddies left under a blue-green scum grow a better crop. Explain how the cyanobacteria fix nitrogen and help to keep soils and paddy fields fertile.

Model Answer

The cyanobacteria are valuable because they fix nitrogen, turning the nitrogen gas of the air into a form that plants can use. Plants cannot use nitrogen gas directly, yet they need nitrogen to build proteins. Many cyanobacteria carry special cells, the heterocysts, in which they convert nitrogen gas into ammonium compounds; when the cyanobacteria die and decay, this fixed nitrogen is released into the soil and water as a natural fertiliser.

In a flooded paddy this enrichment is especially useful. The cyanobacteria thrive in the standing water of the rice field, some of them living within the leaves of the water fern *Azolla*, and the nitrogen they fix raises the fertility of the paddy without bought fertiliser; being photosynthetic, they also add oxygen to the water and form the base of its food chains.

Examiner's Note

The marks lie in the nitrogen-fixing role: cyanobacteria convert atmospheric nitrogen (which plants cannot use) into ammonium compounds in their heterocysts, and on dying release it as natural fertiliser. The paddy example, with *Azolla*, and the added oxygen complete the answer.

Language Clinic

Mark the pivot word "yet": "Plants cannot use nitrogen gas directly, yet they need nitrogen to build proteins." It sets the problem against the need, and the rest of the answer resolves it. Pairing a difficulty with "yet" before its solution is a habit worth copying.

Question 85

A food-science teacher tells the class that bacteria are at work in the dairy, the pharmacy and the sewage works alike. Describe how bacteria are used in Tanzanian food and industry, with an example of each use.

Model Answer

In food, bacteria are used to ferment milk and other foods. Lactic-acid bacteria added to milk ferment its sugar to lactic acid, which sours and thickens the milk into the fermented milk known as mtindi, giving it its flavour and helping it keep; the same kind of souring is used in making cheese and other fermented foods.

In industry and in sanitation, bacteria are put to two further uses. Certain soil bacteria, such as the *Streptomyces*, are grown to yield antibiotics like streptomycin, which are used to treat bacterial disease; and in the sewage works, bacteria break down the organic matter of waste water, cleaning it before it is returned to rivers. In each case people harness the feeding of bacteria to do useful work.

Examiner's Note

Three uses, each with an example: fermentation of milk into mtindi by lactic-acid bacteria; the making of antibiotics such as streptomycin by *Streptomyces*; and the breakdown of waste in sewage treatment. Tie each to what the bacteria actually do.

False Confidence Alert

Most students name penicillin as a bacterial antibiotic. That is wrong: penicillin comes from a fungus, not a bacterium; the antibiotic to credit bacteria with is one such as streptomycin, made by the soil bacterium *Streptomyces*.

Question 86

Beyond the dairy and the factory, bacteria keep the living world turning. Explain the beneficial roles of bacteria in nature and in everyday life.

Model Answer

Bacteria carry out several roles that keep the living world turning.

1) **Decomposition and recycling:** bacteria of decay break down dead plants, animals and droppings, and so return the locked-up nutrients to the soil for plants to use again.
2) **Driving the nitrogen cycle:** nitrogen-fixing bacteria such as *Rhizobium* in the root nodules of legumes enrich the soil with nitrogen, while nitrifying bacteria turn ammonia into the nitrates that plants absorb.
3) **Aiding digestion:** in the gut of animals, including the human being, helpful bacteria aid digestion and make vitamins such as vitamin K.

Examiner's Note

The beneficial roles to name are decomposition and the recycling of nutrients; the nitrogen cycle, with *Rhizobium* in legume nodules and the nitrifying bacteria; and the gut bacteria that aid digestion and make vitamins. Examples lift the answer above a bare list.

Question 87

A biology teacher warns that bacteria are not all friends. Describe the harmful roles of bacteria, and explain how their harm is kept in check.

Model Answer

Bacteria do harm chiefly by causing disease and by spoiling food.

1) **Disease in people:** some bacteria cause cholera, typhoid and tuberculosis.
2) **Disease in livestock and crops:** others bring disease to farm animals and to crops.
3) **Food spoilage:** many break food down so that it rots, and may cause food poisoning.

Their harm is held in check by keeping bacteria out, killing them, or slowing their growth:

1) **Keeping them out:** clean water, good sanitation and the washing of hands keep disease bacteria away.
2) **Killing them:** boiling, cooking and sterilising destroy them.
3) **Slowing their growth:** refrigerating, drying, salting or smoking food slows them so that it keeps.
4) **Guarding and treating:** vaccination and antibiotics protect and cure those already at risk.

Examiner's Note

Both sides are needed: the harm as disease in people, animals and crops (cholera, typhoid, tuberculosis) and the spoilage of food; and the control as sanitation and hygiene, heat and sterilisation, the preserving of food by cold, drying or salting, and vaccination with antibiotics.

False Confidence Alert

Most students answer the control side with antibiotics alone. Antibiotics treat infection, but prevention through clean water, hygiene and the proper keeping of food matters at least as much, and overusing antibiotics only breeds resistant bacteria.

Question 88

Kipanga writes: *"A bacterium is really just like a plant cell. Both have a cell wall, so a non-photosynthetic bacterium is simply a plant cell that has lost its green colour."* Identify the mistakes in what Kipanga has written and put them right.

Model Answer

Kipanga is wrong that a bacterium is just like a plant cell, for the two are built on wholly different plans. A bacterium is a prokaryotic cell: it has no true nucleus, its single loop of DNA lying free in the cytoplasm, and it has none of the membrane-bound organelles of a plant cell, no chloroplasts, no mitochondria and no large vacuole. A plant cell is eukaryotic, with a true nucleus and all these organelles, so the difference is far deeper than colour.

He is also wrong that a shared cell wall makes them the same. The two walls are not even of the same material: the bacterial wall is made of peptidoglycan, whereas the plant wall is made of cellulose. A non-photosynthetic bacterium is therefore not a plant cell that has lost its green; it is a different kind of cell altogether, one that never had chloroplasts to lose.

Examiner's Note

The correction must rest on the prokaryote-eukaryote divide: the bacterium has no true nucleus and no membrane-bound organelles (no chloroplasts, mitochondria or large vacuole), while the plant cell has all of these; and the walls differ, peptidoglycan against cellulose. The lack of chloroplasts is not a lost feature but one never present.

Language Clinic
Two joins carry the correction. The word "whereas" draws the contrast cleanly, "the bacterial wall is made of peptidoglycan, whereas the plant wall is made of cellulose", and "therefore" delivers the verdict, "A non-photosynthetic bacterium is therefore not a plant cell that has lost its green".

Question 89

A free-living *Amoeba* in a pond and the parasite *Entamoeba histolytica* in the human gut are close relatives that live very different lives. Explain how each feeds, and how *Entamoeba* harms its host.

Model Answer

The free-living *Amoeba* feeds by engulfing tiny food particles with its pseudopodia. Living in pond water and mud, it flows out arm-like pseudopodia that surround a food particle, such as a smaller organism, and take it into a food vacuole where it is digested. It harms nothing, feeding only on the small life of the water.

***Entamoeba histolytica* lives in the human large intestine and feeds on its wall, and so causes disease.** Swallowed as cysts in food or water fouled with faeces, it feeds on the lining of the gut and on red blood cells, digesting away the tissue so that it forms ulcers; the result is amoebic dysentery, with painful, bloody diarrhoea. New cysts pass out in the faeces and, where sanitation is poor, infect others.

Examiner's Note
Contrast the two: the free-living *Amoeba* engulfs food by pseudopodia into a food vacuole; *Entamoeba*, swallowed as cysts in faeces-fouled food or water, feeds on the gut wall and red cells, forming ulcers and causing amoebic dysentery, and spreads by cysts in the faeces.

Language Clinic
Let "and so" carry feeding into its effect, "feeds on its wall, and so causes disease", and "so that" carry the damage into its result, "digesting away the tissue so that it forms ulcers". These joins show one thing causing the next, which is what a disease answer must do.

Question 90

Plasmodium, the parasite that causes malaria, passes its life between two hosts, the human being and the mosquito. Explain how *Plasmodium* is adapted to life in each host.

Model Answer

***Plasmodium* is adapted to the human host by hiding inside cells and multiplying hugely.** Injected into the blood by a biting mosquito, it shelters first inside the liver cells and then inside the red blood cells, where the body cannot easily reach it; there it multiplies into enormous numbers, and it changes the proteins on its surface so as to keep ahead of the defences of the body. Some of these forms become the sexual stages that a mosquito will take up.

It is adapted to the mosquito host, which carries it from person to person. When a female *Anopheles* mosquito sucks blood, it takes up the sexual stages; these join and multiply in the mosquito, and the new infective stages gather in its salivary glands, ready to be injected into the next person the mosquito bites. The parasite is thus fitted to use the mosquito both as a place to breed sexually and as the means of its spread.

Examiner's Note
For the human host: entry by mosquito bite, hiding inside liver and red blood cells, vast multiplication and the changing of surface proteins to evade defence. For the mosquito host: uptake of the sexual stages in blood, sexual reproduction in the mosquito, and the infective stages collecting in the salivary glands for transmission.

False Confidence Alert
Most students write simply that mosquitoes spread malaria. That misses the marks: only the female *Anopheles* mosquito carries it, because only she sucks blood, and naming her is the point the question rewards.

Question 91

Malaria remains hard to control in Tanzania despite great effort. Explain why the two-host life cycle of *Plasmodium*, and the way of life of the parasite, make the disease so difficult to stamp out.

Model Answer

Because the parasite needs two hosts, the disease can only be stopped by breaking the cycle in two places at once. *Plasmodium* passes between people and mosquitoes, so control must attack both: treating sick people and clearing the parasite from them, and at the same time destroying mosquitoes and their breeding pools. As long as either host still carries the parasite, infection can begin again, and the warm, wet conditions of much of Tanzania let mosquitoes breed all year in any standing water.

The way of life of the parasite makes it harder still to reach. Inside the body *Plasmodium* hides within liver and red blood cells and keeps changing its surface, so the immune system and many drugs struggle to clear it, and infected people who feel well can still pass it on; on top of this the parasite has grown resistant to some drugs and the mosquito to some insecticides. All these together keep malaria a stubborn disease.

Examiner's Note
The core point is the two-host cycle: control must succeed against both the parasite in people and the mosquito vector, and failure against either lets the disease return. Add the parasite hiding inside cells, antigenic change, symptomless carriers, year-round mosquito breeding, and drug and insecticide resistance.

Language Clinic
The answer opens with "Because", tying cause to consequence: "Because the parasite needs two hosts, the disease can only be stopped by breaking the cycle in two places at once." Opening a control answer with the reason, then the measure it forces, is the connected form the marks reward.

Question 92

Sleeping sickness is another disease caused by a protist. Explain how *Trypanosoma*, the parasite that causes it, is suited to its way of life, and how it is spread.

Model Answer

***Trypanosoma* is a flagellate protist fitted for life and movement in the blood.** It is a single cell drawn out into a slender shape, with a flagellum and an undulating membrane along its side by which it swims through the blood plasma; it absorbs nourishment from the blood over its whole surface. Living in the bloodstream, and afterwards in the fluid around the brain, it brings the fever and the deep drowsiness that give sleeping sickness its name.

It is spread from person to person by the bite of the tsetse fly. The parasite is sucked up with the blood by a tsetse fly, multiplies within the fly, and is passed on when the fly bites the next person; and because it keeps changing the coat of proteins on its surface, the defences of the body can never quite catch up with it, so the infection persists.

Examiner's Note
Note that *Trypanosoma* is a flagellate (it swims by a flagellum and undulating membrane), lives in the blood and feeds over its surface, and is spread by the bite of the tsetse fly. The changing surface coat, which defeats the immune system, is the extra point that earns full marks.

Language Clinic

Trace the persistence with "because ... so": "because it keeps changing the coat of proteins on its surface, the defences of the body can never quite catch up with it, so the infection persists." The "because" gives the cause and the "so" gives the result, carrying the reader along the chain.

Question 93

Phytophthora, the water mould that causes blight, can ruin a field of potatoes in days. Explain how *Phytophthora* is adapted to its parasitic mode of life.

Model Answer

***Phytophthora* is adapted to feed as a parasite by growing threads into the living plant.** Like a fungus it forms fine threads, the hyphae, which spread through the tissues of the host plant and absorb food from its living cells, so that the leaves and tubers rot. Feeding directly on the crop in this way, it can destroy a potato or tomato field very quickly.

It is adapted to spread fast, above all in cool, wet weather. It produces vast numbers of spores that are carried by wind and rain to new plants, and some of these release swimming spores with flagella that move through a film of water on the leaf to begin fresh infections. Because it needs moisture to spread, it races through a crop in the damp, cool conditions it favours.

Examiner's Note

The adaptations are parasitic feeding by hyphae that grow into the host and absorb its food, and rapid spread by very many wind- and rain-borne spores, some releasing flagellated swimming spores that need a film of water. The need for damp, cool conditions explains the speed of an outbreak.

False Confidence Alert

Most students call *Phytophthora* a fungus, because it grows threads like one. That is the trap: it is a fungus-like protist, a water mould grouped with the Protoctista, not a true fungus.

Question 94

The protoctists touch human life for both good and ill. Outline the economic importance of the protoctists, giving an example for each point you make.

Model Answer

The protoctists matter to people in several ways, some harmful and some useful.

1) **They cause disease in human beings:** for example, *Plasmodium* causes malaria, and *Entamoeba* causes amoebic dysentery.
2) **They cause disease in crops:** for example, *Phytophthora* causes the blight that rots potatoes and tomatoes.
3) **They serve as food:** for example, seaweeds, such as those farmed on the Zanzibar coast, are eaten and fed to stock, and the tiny floating algae feed the animals of the water.
4) **They yield useful materials:** for example, agar is obtained from red seaweeds, and diatomite from the shells of diatoms.
5) **They support aquatic life and the air:** for example, the floating algae make food and release much of the oxygen of lakes and seas, forming the base of the food chains that feed the fish.
6) **They can foul water in excess:** for example, an algal bloom can poison the water and kill fish when it grows too thick and then dies.

Examiner's Note

Each point needs a named example: disease in people (*Plasmodium*, *Entamoeba*) and crops (*Phytophthora*); use as food (seaweeds, plankton); useful products (agar, diatomite); the support of food chains and oxygen; and the harm of algal blooms. Points without examples earn little.

Language Clinic

Anchor every point with "for example": "They yield useful materials: for example, agar is obtained from red seaweeds." The phrase signals the named instance the examiner waits for, and a point without its "for example" reads as an unsupported claim.

Question 95

Algae and diatoms are quietly useful organisms. Explain how they serve people as sources of food, of agar and of diatomite.

Model Answer

Algae are a valuable food, both for people and for the animals of the water. Many seaweeds are eaten directly or fed to livestock, and along the Tanzanian coast seaweed is farmed and sold; in lakes and seas the microscopic floating algae are grazed by countless small animals and so feed, in the end, the fish that people catch. Algae are rich in minerals and other nutrients.

Algae and diatoms also yield two prized materials, agar and diatomite. Agar is a jelly obtained from certain red seaweeds; it is used to set the culture media on which microbes are grown, and as a thickener in foods. Diatomite is the chalky, glassy deposit left by the shells of countless dead diatoms; because it is fine and porous, it is used as a filter, a mild abrasive and a heat insulator.

Examiner's Note

Three uses, each tied to its source: algae as food for people, stock and the animals of the water; agar from red seaweeds, used for culture media and as a food thickener; and diatomite from the silica shells of diatoms, used as a filter, abrasive and insulator.

False Confidence Alert

Most students suppose agar comes from a fungus or a bacterium, and that diatomite is a rock mined from the ground. Both mistake the source: agar comes from red seaweeds, which are algae, and diatomite is the shells of countless diatoms, which are protists.

Question 96

In Lake Victoria and along the coast, the algae are easy to overlook yet vital. Explain why algae matter so much in Tanzanian waters, and why too many of them spell trouble.

Model Answer

Algae are vital because they are the foundation of life in the water. Floating in the sunlit surface as the phytoplankton, the algae photosynthesise, making food and releasing oxygen into the water; they are eaten by small animals, which are eaten by fish, so the food chains of Lake Victoria, Lake Tanganyika and the coast all rest upon them, and the great fisheries depend on them.

Yet too many algae bring trouble, in the form of an algal bloom. When water is over-enriched, as when fertiliser or sewage drains into it, the algae multiply into a thick bloom; and when that bloom dies, the bacteria that rot it use up the oxygen of the water, so that the fish suffocate, while some blooms release poisons of their own. Algae are thus a blessing in the right amount but a danger in excess.

Examiner's Note

The vital roles are photosynthesis (making food and oxygen) and forming the base of the aquatic food chains that support the fishery. The trouble of a bloom is the over-enrichment of water, the multiplication and death of algae, the using-up of oxygen by decay bacteria, fish deaths, and the poisons some blooms release.

Language Clinic

Build the bloom as a chain with "when ... and when ... so that": "when that bloom dies, the bacteria that rot it use up the oxygen of the water, so that the fish suffocate." Each join carries one step into the next, so the examiner sees a process and not a bare fact.

Question 97

Kipanga writes: "*Euglena* is green and makes its own food by photosynthesis, so it is simply a plant and belongs in the kingdom Plantae." Identify the mistakes in what Kipanga has written and put them right.

Model Answer

Kipanga is right that *Euglena* photosynthesises, but wrong to call it simply a plant, for it is animal-like as well. *Euglena* does carry chloroplasts and make its own food in the light, as a plant does; but it also swims actively by a whip-like flagellum, it has a light-sensitive eyespot that guides it towards light, and in the dark it can feed on ready-made food from around it, as an animal does. It has no firm cellulose wall, only a flexible pellicle, which is also unlike a plant.

Because it mixes plant-like and animal-like features, *Euglena* is placed not in the Plantae but in the Protoctista. It is a single eukaryotic cell that fits neither the plants nor the animals cleanly, and it is exactly such in-between organisms that are gathered into the kingdom Protoctista. To file *Euglena* under Plantae on its green colour alone is to ignore the animal-like half of its nature.

Examiner's Note

The correction must grant the plant-like trait (chloroplasts and photosynthesis) but set against it the animal-like ones (movement by a flagellum, the eyespot, feeding in the dark, and a pellicle in place of a cellulose wall), and conclude that this mixture places *Euglena* in the Protoctista, not the Plantae.

False Confidence Alert

Most students file *Euglena* under Plantae because it is green and photosynthesises. That judges a kingdom from a single feature: *Euglena* also swims by a flagellum, has an eyespot and can feed in the dark like an animal, so it is a protoctist.

Question 98

A loaf of bread left for some days in a warm, damp corner becomes covered with a soft, cottony growth dotted with tiny black heads. Name the organism, state the kingdom to which it belongs, and give four features of that kingdom that the organism shows.

Model Answer

The growth is the bread mould, *Rhizopus*, and it belongs to the kingdom Fungi.

It shows four features of the kingdom Fungi:

1) **A body of hyphae:** the cottony growth is a mycelium, a mesh of fine threads called hyphae.
2) **Nutrition by absorption:** having no chlorophyll, it feeds as a saprophyte, releasing enzymes onto the bread and absorbing the digested food.
3) **A wall of chitin:** each hypha is bounded by a cell wall of chitin, not cellulose.
4) **Reproduction by spores:** the black heads are sporangia, which burst to scatter spores that grow into new moulds.

Examiner's Note
The three marks are the name (*Rhizopus*, the bread mould; *Mucor* is accepted), the kingdom (Fungi), and four features that belong to the whole kingdom. Features such as hyphae, absorption without chlorophyll, a chitin wall and spores score; naming a part such as the sporangium does not.

False Confidence Alert
Most students name the organism only as a mould or a fungus. That loses the mark: the specimen question wants it named as *Rhizopus*, and it wants features of the kingdom Fungi, not of one part such as the sporangium.

Question 99

Fungi are not only agents of decay and disease; several are turned to good use in Tanzanian homes, farms and clinics. Describe four ways in which fungi are useful to people, naming the fungus responsible in each case.

Model Answer

Fungi serve people in several important ways, each through a particular fungus.

1) **Baking and brewing:** the yeast *Saccharomyces* ferments sugar and so releases carbon dioxide, which raises bread, and alcohol, which makes local brews such as mbege.
2) **Food:** many mushrooms, the uyoga gathered and grown for the table, are eaten as a cheap source of protein.
3) **Medicine:** the mould *Penicillium* yields penicillin, an antibiotic that kills disease-causing bacteria.
4) **Decay and recycling:** as saprophytes, moulds rot dead leaves, wood and dung, and so return their nutrients to the soil for crops to use.

Examiner's Note
Each use must carry the fungus that performs it: the yeast *Saccharomyces* for baking and brewing, edible mushrooms for food, *Penicillium* for penicillin, and saprophytic moulds for decay. A use with no named fungus, or a fungus with no use, earns only half the mark.

Language Clinic
Tie each fungus to its benefit through what it does. "and so" carries the action into its result, "ferments sugar and so releases carbon dioxide", and "which" carries that result into its use, "carbon dioxide, which raises bread". These joins turn a bare list of fungi into uses the examiner can credit.

Question 100

In both the baking of bread and the brewing of a drink such as mbege, the same fungus, yeast, is at work, yet the baker and the brewer each prize a different product. Explain how yeast brings both about, and why each keeps a different product.

Model Answer

Yeast works by anaerobic respiration, also called fermentation. In the absence of air it breaks sugar down into ethanol and carbon dioxide, both products forming together from the one reaction.

The baker and the brewer simply keep different products of that single reaction. In baking, it is the carbon dioxide that matters, because the gas is trapped as bubbles in the dough, so the bread rises and is light, while the little alcohol bakes off. In brewing, it is the ethanol that matters, because the alcohol gathers in the liquid to make the drink, while the carbon dioxide escapes.

Examiner's Note
The marks are for naming anaerobic respiration (fermentation), giving both products (ethanol and carbon dioxide), and matching each to its use: carbon dioxide raises the dough in baking, ethanol makes the drink in brewing.

False Confidence Alert
Most students swap the products, saying the baker wants the alcohol or the brewer the gas, or that yeast needs air. Both are wrong: it is one anaerobic reaction giving both products, and baking keeps the carbon dioxide while brewing keeps the ethanol.

Question 101

For every useful fungus there is a harmful one. Describe three kinds of harm that fungi do, with an example of each, and state how such harm is controlled.

Model Answer

Fungi do harm in three main ways.

1) **Crop disease:** parasitic fungi attack growing plants, such as the rusts and smuts that ruin maize and other cereals.
2) **Food spoilage:** moulds rot stored food, and some, such as *Aspergillus* on damp maize and groundnuts, leave poisons called aflatoxins that are dangerous to eat.
3) **Disease in people:** some fungi infect the body, causing ringworm and athlete's foot on the skin and thrush in the mouth.

Such harm is controlled by keeping things dry and clean, because fungi need moisture to grow. Crops are sprayed with fungicides and grown as resistant varieties, food is dried hard and stored dry, and the skin is kept clean and dry, so the spores have no damp on which to settle and grow.

Examiner's Note
Three distinct kinds of harm are wanted, each with an example: crop disease (rusts, smuts), food spoilage (moulds and aflatoxins), and human infection (ringworm, thrush), followed by a means of control. Three crop diseases alone would not answer the question.

Language Clinic
Tie the control to the reason it works with "because" and "so": "controlled by keeping things dry and clean, because fungi need moisture to grow", so that "the spores have no damp on which to settle and grow". Naming why a measure works turns a list of tips into an explanation.

Question 102

A maize farmer in Tanzania loses part of the crop to disease in the field and more of the harvest to mould in the store. Explain how fungi cause these two losses, and describe how the farmer can reduce them.

Model Answer

Fungi attack the maize both as it grows and after it is harvested. In the field, parasitic fungi such as the rusts and smuts feed on the leaves and cobs and so lower the yield; in the store, saprophytic moulds such as *Aspergillus* grow on grain left damp, rotting it and leaving aflatoxins, poisons that make the maize unsafe to eat.

The farmer reduces both losses by attacking the fungus at each stage:

1) **Resistant varieties:** planting maize bred to withstand the rusts and smuts.
2) **Clean rotation:** changing the crop and clearing old stalks, so the fungus cannot build up.
3) **Fungicide or treated seed:** spraying the crop or dressing the seed to kill the fungus.
4) **Drying and dry storage:** drying the grain hard before storing and keeping the store dry, so moulds and aflatoxins cannot form.

Examiner's Note
The answer must separate the two losses, in the field (parasitic rusts and smuts) and in the store (moulds and aflatoxins), and give practical control for each: resistant varieties and fungicides for the field, and thorough drying with dry storage for the store.

False Confidence Alert
Most students think that scraping the mould off makes the maize safe again. It does not: the aflatoxins spread unseen through the grain and remain after the mould is gone, so badly mouldy maize must be thrown away, which is why drying before storage matters so much.

Question 103

Kipanga argues that *a mushroom must be a plant, because it grows up out of the ground, stays in one place, and has a wall around its cells.* **Kipute** says *it is no plant at all.* Say who is right, and give the reasons that settle the matter.

Model Answer

Kipute is right: a mushroom is not a plant but a fungus, a member of its own kingdom.

1) **No chlorophyll:** a plant makes its own food by photosynthesis, whereas a mushroom has no chlorophyll and must absorb ready-made food.
2) **A wall of chitin:** a plant's cell wall is cellulose, whereas a fungus has a wall of chitin.
3) **Glycogen, not starch:** a plant stores its food as starch, whereas a fungus stores it as glycogen.
4) **A body of hyphae:** a plant has true roots, stems and leaves, whereas a mushroom is a mass of hyphae with none of these.

Growing from the ground, standing still and having a cell wall are not the test. How an organism feeds is what decides, and because the mushroom cannot make its own food, it cannot be a plant.

Examiner's Note

The verdict must be backed by the differences that give fungi their own kingdom: no chlorophyll (so it absorbs food instead of making it), a chitin wall against cellulose, glycogen against starch, and a body of hyphae against true roots, stems and leaves. The way it feeds is the single most important reason.

Question 104

Although both conifers and flowering plants reproduce by seeds, they differ in several important features. Distinguish between Coniferophyta and Angiospermophyta using three characteristics, and give at least one example of each division.

Model Answer

Both are seed plants, but they differ in how they bear their seeds and flowers.

1) **Seeds:** the conifers bear naked seeds on the scales of cones, whereas the flowering plants enclose their seeds within a fruit.
2) **Flowers:** the conifers have no true flowers, while the flowering plants bear flowers that are pollinated and form fruits.
3) **Leaves:** the conifers usually have narrow, needle-like leaves, whereas the flowering plants have broad leaves of many shapes.

Examples: Pine and cypress are conifers; the mango, the bean and the maize are flowering plants.

Examiner's Note
The marks lie in how the seeds are borne: naked on the cone scales in the conifers, but enclosed in a fruit in the flowering plants. Add the absence of true flowers in conifers, and an example of each, to complete the answer.

Question 105

A student is shown two young crops, a maize seedling and a bean seedling. Classify each as a monocotyledon or a dicotyledon, and give the features that decide the placing.

Model Answer

The maize is a monocotyledon and the bean is a dicotyledon, told apart by several features.

1) **Seed leaves:** the maize seed has one cotyledon, whereas the bean seed has two.
2) **Leaf veins:** the maize leaf has parallel veins, whereas the bean leaf has a net of branching veins.
3) **Roots:** the maize has fibrous roots, whereas the bean has a tap root.
4) **Flower parts:** the maize has its flower parts in threes, whereas the bean has them in fours or fives.

Examiner's Note
Each placing must rest on a named feature: one cotyledon, parallel leaf veins, fibrous roots and flower parts in threes mark the monocotyledon (maize); two cotyledons, net veins, a tap root and parts in fours or fives mark the dicotyledon (bean).

False Confidence Alert
Most students classify maize and bean by guesswork, or by calling maize a grass. That earns nothing on its own: the placing must be argued from the cotyledons, the leaf veins, the roots and the flower parts.

Question 106

On a single walk a student finds a green carpet of moss on a damp wall, a fern in a shady ditch, a tall pine in a plantation, and a mango tree in flower. Place each plant in its division, and give the feature that decides the placing.

Model Answer

Each plant is placed by the feature that marks its division.

The moss, Bryophyta: it has no true roots, stems or leaves and no vascular tissue, and so keeps to the damp wall.

The fern, Filicinophyta: it has true roots, stems and leaves with vascular tissue, but bears spores in sori under the fronds, not seeds.

The pine, Coniferophyta: it is a tall woody plant that bears naked seeds in cones and has needle-like leaves.

The mango, Angiospermophyta: it bears flowers and encloses its seeds within a fruit.

> **False Confidence Alert**
> Most students lump the moss and the fern together as simple green plants. The fern has vascular tissue and true roots, stems and leaves, whereas the moss has none; and neither bears seeds, which sets both apart from the pine and the mango.

Question 107

The kingdom Plantae feeds, shelters and heals the people of Tanzania. Outline the economic importance of plants, giving an example of each use.

Model Answer

Plants serve people in many ways.

1) **Food:** crops such as maize, rice, beans and bananas feed people and livestock.
2) **Timber and building:** trees such as pine and mninga give wood for furniture, poles and houses.
3) **Medicine:** many plants give medicines, such as quinine from the cinchona, used against malaria.
4) **Fuel:** firewood and charcoal from trees are the chief cooking fuel in many homes.
5) **Other products:** plants also give fibres, oils, gums and paper.

Above all, as the producers, green plants make the food and the oxygen on which all other life depends.

> **Examiner's Note**
> Each use must carry an example: food (maize, beans, bananas), timber (pine, mninga), medicine (quinine), fuel (firewood and charcoal), and other products such as fibres and oils. A use without an example earns only half the point.

Question 108

Flowering plants outnumber and outgrow all other land plants, from the grasses of the plains to the great forest trees. Explain why the angiosperms are the dominant land plants today.

Model Answer

The angiosperms dominate because their whole design fits them for life on dry land. Their seeds are enclosed and protected within a fruit, which also scatters them widely. Their flowers attract animals that carry pollen efficiently from plant to plant. Their strong vascular tissue, with xylem vessels, carries water through even a tall tree.

These advantages let angiosperms thrive where other plants cannot. Because they need no water for the male cells to swim to the female, as mosses and ferns do, they can reproduce in dry places. Their broad leaves, varied forms and quick growth then let them fill almost every habitat, from desert to swamp.

> **Language Clinic**
> The word "because" carries the dominance back to its cause: "Because they need no water for the male cells to swim to the female, as mosses and ferns do, they can reproduce in dry places." Lead with the reason, then the result, and the examiner sees an explanation, not a list of traits.

Question 109

A moss grows only on a damp, shaded wall and a fern only in a moist ditch, yet a maize plant flourishes in an open, sunlit field. Explain why the non-seed plants are tied to damp places while the seed plants are not.

Model Answer

The non-seed plants are tied to water because they depend on it to reproduce and to survive. In the mosses and ferns the male cells must swim through a film of water to reach the female, so fertilisation fails without moisture. The moss has no vascular tissue and no true roots, so it cannot draw or hold much water and soon dries out. Both also scatter naked spores that need damp ground to grow.

The seed plants are freed from this dependence. They carry pollen to the female by wind or by animals, so no water is needed for fertilisation. Their strong vascular tissue and true roots draw water from deep in the soil. They shelter the young plant in a seed that can wait for rain, so a maize plant can live and breed in an open field.

Examiner's Note
The reason is reproduction and water transport, not merely a liking for shade: the mosses and ferns need water for the male cells to swim, and the moss cannot carry or hold water; the seed plants use pollen, have vascular tissue, and shelter the young in a drought-proof seed. Naming both halves earns full marks.

False Confidence Alert
Most students say only that mosses and ferns like the shade while maize likes the sun. The real reason is deeper: the moss and fern need water for the sperm to swim and cannot carry water far, whereas the seed plant uses pollen, draws water through vascular tissue, and shelters its young in a seed.

Question 110

Kipanga writes: *"All plants are green and make their own food, so every green plant is a flowering plant."* Identify the mistakes in what Kipanga has written and put them right.

Model Answer

Kipanga is wrong that every green plant is a flowering plant. Being green and making food by photosynthesis is true of the whole kingdom Plantae, but it does not make a plant a flowering plant. The flowering plants, the angiosperms, are only one of the four divisions.

Many green plants bear no flowers at all. The mosses and the ferns are green, yet they reproduce by spores, not by flowers or seeds. The conifers bear naked seeds in cones and have no true flowers. Only the angiosperms have flowers and seeds enclosed in a fruit, so green colour alone says nothing about the division.

Examiner's Note
The correction must make two points: that being green and photosynthetic belongs to the whole kingdom Plantae, not to flowering plants alone; and that mosses, ferns and conifers are all green yet bear no flowers, so only the angiosperms are flowering plants.

Language Clinic
Use "but" to overturn the false step: "but it does not make a plant a flowering plant", then "so" to draw the conclusion: "so green colour alone says nothing about the division." The two joins turn a flat denial into a reasoned correction.

Question 111

Walking on the Zanzibar shore, Kipanga calls the green seaweed a sea plant, because it is green and makes its own food. Kipute says it is no plant at all. Say who is right, and give the reasons.

Model Answer

Kipute is right: a seaweed is an alga, a protoctist, and not a member of the kingdom Plantae.

1) **No true organs:** a true plant has true roots, stems and leaves, whereas a seaweed is a simpler body, a thallus, with none of these.
2) **No protected embryo:** a true plant shelters its young embryo inside the parent, whereas an alga simply sheds its cells into the water.
3) **No vascular tissue:** a true plant has xylem and phloem to carry water and food, whereas a seaweed, bathed in water, has none.

Making food by photosynthesis is not enough to make a plant. The seaweed shares that one habit only; lacking true organs, a protected embryo and vascular tissue, it is grouped with the algae in the Protoctista.

Examiner's Note

The verdict must be backed by what a true plant has and an alga lacks: true roots, stems and leaves, a protected embryo, and vascular tissue. Making the point that photosynthesis alone does not make a plant is what secures the marks.

Language Clinic

Carry each contrast on "whereas": "a true plant has true roots, stems and leaves, whereas a seaweed is a simpler body, a thallus, with none of these." Setting plant against alga in one sentence shows the difference far better than describing each apart.

Question 112

In Tanzania, foresters plant pine and cypress for timber, while farmers grow maize, beans and bananas for food. Explain, in terms of the two divisions of seed plants, why each is chosen for its purpose.

Model Answer

The conifers are grown for timber because their wood suits building. Pine and cypress are tall, straight, fast-growing softwoods, easy to saw into planks and poles. This is why plantations on the southern highlands raise them for timber and paper.

The flowering plants are grown for food because they bear fruits and seeds we can eat. The angiosperms enclose their seeds in fruits and grains, such as the maize cob, the bean pod and the banana. These give the rich, edible harvests on which people live, which the cone-bearing conifers cannot provide.

Examiner's Note

The answer must tie each crop to its division: the conifers (pine, cypress) give straight, fast-growing softwood for timber and paper, while the flowering plants enclose their seeds in fruits and grains (maize, beans, bananas) that we can eat. The seed-bearing difference is the heart of it.

False Confidence Alert

Most students think any large tree gives both good timber and good food. The division decides: the cone-bearing conifers give softwood but no edible fruit, whereas the flowering plants give the grains and fruits people eat.

Question 113

A tapeworm lives in the gut of its host, bathed in food the host has already digested. Explain how the tapeworm is adapted to its parasitic way of life.

Model Answer

The tapeworm is fitted for parasitic life in the gut by a body stripped down for clinging, feeding and breeding.

1) **A hooked, suckered head:** the scolex bears hooks and suckers that anchor it to the gut wall so it is not swept away.
2) **A protective cuticle:** a resistant body covering shields it from the digestive enzymes of the host.
3) **No gut of its own:** it has lost its gut and absorbs the digested food straight through its body surface.
4) **A long, flat body:** its great surface area takes up food quickly, while flatness lets oxygen reach every part.
5) **Enormous reproduction:** each segment, the proglottid, is packed with eggs, so vast numbers pass out to find new hosts.

Examiner's Note
The adaptations that score are the hooked, suckered scolex that anchors it, the enzyme-proof cuticle, the lost gut with feeding by absorption over a large flat surface, and the huge output of eggs. Note that having no mouth or gut is itself the adaptation, not a lack.

Language Clinic
Tie each feature to what it does with "so": "hooks and suckers that anchor it to the gut wall so it is not swept away", and segments "packed with eggs, so vast numbers pass out to find new hosts." The word "so" turns a feature into the adaptation the question asks for.

Question 114

The earthworm spends its life burrowing through the moist soil of a Tanzanian farm. Explain how the earthworm is adapted to its life in the soil.

Model Answer

The earthworm is suited to burrowing and feeding in the soil in several ways.

1) **A streamlined, segmented body:** its long, narrow, ringed body slides easily through the burrow.
2) **Setae:** tiny bristles on each segment grip the soil so the muscles can drag the worm forward.
3) **Two sets of muscles:** circular and longitudinal muscles work against the fluid-filled body to drive it through the soil.
4) **A moist skin:** the thin, damp skin lets the worm take in oxygen straight from the air in the soil.
5) **Feeding on soil:** it swallows soil and digests the dead matter in it, passing out the rest as casts that enrich the land.

Examiner's Note
The marks are for the streamlined segmented body, the setae that grip, the antagonistic circular and longitudinal muscles, the moist skin for gas exchange, and feeding on soil. Each must be tied to burrowing or to living in the soil.

Language Clinic
Let "so" join the feature to its use: "tiny bristles on each segment grip the soil so the muscles can drag the worm forward." Naming what the setae achieve, not just that they exist, is what earns the mark.

Question 115

Insects such as the locust are the most successful animals on dry land. Explain how an insect is adapted to life on land.

Model Answer

The insect is fitted for dry land above all by holding water in and breathing air directly.

1) **A waterproof cuticle:** the waxy exoskeleton checks the loss of water, so the insect can live in dry, hot places.
2) **Tracheae:** fine air tubes carry oxygen straight to the tissues, so the insect breathes without lungs or wet surfaces.
3) **Wings:** most insects fly, which lets them escape danger, find food and spread far.
4) **Jointed legs:** these allow quick and varied movement over the land.
5) **Protected eggs:** the eggs are fertilised inside the body and laid with a tough covering, so they need no water.

Examiner's Note
The land adaptations are the waterproof, waxy cuticle and the tracheae above all, with wings, jointed legs and protected eggs. The cuticle keeps water in and the tracheae bring air to the tissues, which is what fits the insect for dry land.

False Confidence Alert
Most students say an insect breathes through lungs, or through its skin. It does neither: air reaches the tissues directly through tracheae, while the waxy cuticle is kept watertight, and these two are exactly what fit the insect for dry land.

Question 116

Bilharzia, caused by a blood fluke, is one of the commonest diseases in Tanzania. Explain how the blood fluke harms people, and how the spread of the disease can be checked.

Model Answer

The blood fluke harms people by living in the blood vessels and shedding spiny eggs. The adult flukes live in the veins around the gut or the bladder, where the female lays great numbers of eggs. The eggs, with their sharp spines, tear the lining as they pass out, causing bleeding in the urine or the stool, and over the years they damage the bladder, the gut and the liver.

The spread is checked by breaking the cycle between people and the water snail. The fluke passes part of its life in a freshwater snail, so the disease spreads where people pass infected urine or faeces into water and then bathe or wade in it. It is held back by treating the sick with drugs, by providing clean water and latrines, by clearing the snails, and by keeping people out of infected water.

Examiner's Note
Both halves are needed: the harm, as the flukes in the blood vessels and the spiny eggs that tear and scar the bladder, gut and liver; and the control, as breaking the human-and-snail cycle by drugs, clean water and latrines, snail clearance, and staying out of infected water.

Language Clinic
Trace the spread with "so": "The fluke passes part of its life in a freshwater snail, so the disease spreads where people pass infected urine or faeces into water." Showing the cause before the effect turns a bare fact into the reasoning the marks reward.

Question 117

A biologist is asked to place a tick and a crab. Name the class to which the tick belongs and the classes to which the crab belongs, and justify each placing by its features.

Model Answer

Both are arthropods, but their body regions, legs and antennae place them in different classes.

The tick, class Arachnida: it has a body in two parts, four pairs of legs and no antennae, which marks an arachnid, not an insect.

The crab, class Crustacea: it has two pairs of antennae, gills, and five or more pairs of legs, which mark a crustacean.

Language Clinic

Use "which" to turn the count into the verdict: "four pairs of legs and no antennae, which marks an arachnid, not an insect." Naming the feature and then what it proves is the connected form the marks reward.

Question 118

It may surprise a student that a human being is grouped with the fishes and the frogs in one phylum. Justify, in six points, why a human being is a chordate.

Model Answer

A human being is a chordate because it shows, at some stage of its life, the features that mark the phylum Chordata.

1) **A notochord:** in the embryo a notochord runs along the back, later replaced by the backbone.
2) **A dorsal hollow nerve cord:** a single hollow nerve cord lies along the back and forms the brain and spinal cord.
3) **Pharyngeal gill slits:** gill slits appear in the throat of the embryo, though they never become working gills.
4) **A post-anal tail:** a tail reaching beyond the anus shows in the embryo, later reduced to the tail bone.
5) **A ventral heart and closed blood system:** the heart lies on the underside and the blood runs in closed vessels, as in other chordates.
6) **A bilateral body with a true coelom:** the body is bilaterally symmetrical with a true body cavity.

False Confidence Alert

Most students object that a human has no notochord, no gill slits and no tail, so cannot be a chordate. The features need only appear at some stage: the human embryo shows the notochord, the gill slits and the tail, which are then changed or lost in the adult.

Question 119

On a Tanzanian farm a student sees a tilapia in the pond, a frog at its edge, a lizard on the wall, a fowl in the yard and a goat in the field. Place each in its class, and give the feature that decides the placing.

Model Answer

Each animal is a vertebrate, placed in its class by its skin, its breathing and its breeding.

The tilapia, class Osteichthyes: a bony fish with scales, gills and fins, living in the water.

The frog, class Amphibia: a moist, scaleless skin, gills in the tadpole and lungs in the adult, and jelly eggs laid in water.

The lizard, class Reptilia: a dry, scaly skin and shelled eggs laid on land.

The fowl, class Aves: feathers, wings and a beak, and hard-shelled eggs.

The goat, class Mammalia: hair on the skin and mammary glands that give milk to its young.

False Confidence Alert
Most students lump the frog and the lizard together as small crawling animals. Their skins and eggs separate them: the frog has a moist, scaleless skin and lays jelly eggs in water, whereas the lizard has a dry, scaly skin and lays shelled eggs on land.

Question 120

The kingdom Animalia gives people far more than meat. Outline the advantages of the kingdom Animalia to people, with an example of each.

Model Answer

Animals serve people in many ways.

1) **Food:** cattle, goats, fish and poultry give meat, milk and eggs.
2) **Work and transport:** oxen and donkeys pull ploughs and carts and carry loads.
3) **Hides and materials:** skins give leather, and bone, horn and wool are also used.
4) **Manure:** animal dung manures the fields and can be made into biogas.
5) **Pollination and pest control:** bees pollinate crops and make honey, while some animals eat crop pests.
6) **Income and company:** animals are kept for sale and as guards and pets, a living for many families.

Above all, animals form a vital part of the food chains and the balance of nature.

False Confidence Alert

Most students give only food, the meat and the milk. That leaves out half the marks: animals also give draught power, hides and leather, manure and biogas, honey and pollination, and a living to those who keep them.

Question 121

Kipanga writes: *"A whale lives in the sea and swims, so it is a fish; and a bat flies, so it is a bird."* Identify the mistakes in what Kipanga has written and put them right.

Model Answer

Kipanga is wrong that a whale is a fish. A whale is a mammal: it breathes air with lungs and must surface to do so, it is warm-blooded, it has some hair, and it feeds its young on milk from mammary glands. Living in the sea and swimming do not make it a fish, for a true fish breathes by gills and is cold-blooded.

He is also wrong that a bat is a bird. A bat is a mammal too: its wing is a flap of skin, not a feathered limb, it has fur, and it suckles its young on milk. Flying does not make it a bird, for a bird has feathers, a beak without teeth and lays eggs, whereas the bat has none of these.

Examiner's Note
The correction must rest on class features, not on where the animal lives or how it moves: the whale is a mammal (lungs, warm blood, hair, milk) and the bat is a mammal (fur, milk, a skin wing), not a fish or a bird. Swimming and flying decide nothing.

Language Clinic
Set the true class against the false one with "whereas": "a bird has feathers, a beak without teeth and lays eggs, whereas the bat has none of these." The contrast shows the examiner you are judging by features, not by where the animal lives.

Question 122

Selling his catch at the coast, Kipanga calls the starfish a fish, because it lives in the sea and carries the word "fish" in its name. Kipute says it is no fish at all. Say who is right, and give the reasons.

Model Answer

Kipute is right: a starfish is not a fish but an echinoderm, of the phylum Echinodermata.

1) **No backbone:** a fish is a vertebrate with a backbone, whereas a starfish has no backbone, only a spiny skeleton of chalky plates.
2) **Radial symmetry:** a fish has a head and a tail and two matching sides, whereas a starfish is built in five rays around a centre.
3) **Tube feet, not fins:** a fish swims with fins and breathes by gills, whereas a starfish creeps on tube feet driven by water.

Living in the sea does not make an animal a fish. The starfish has no backbone, no fins and no gills, and its radial body and tube feet place it firmly with the echinoderms.

Examiner's Note

The verdict must be backed by what a fish has and the starfish lacks: a backbone, fins and gills, and a head-and-tail body. The radial, five-rayed body and the tube feet of the water vascular system are what mark the echinoderm.

Question 123

A student has four vertebrates to identify: a tilapia, a frog, a tortoise and a dove. Construct a simple dichotomous key that would separate the four, using their distinctive features.

Model Answer

The four animals are separated by a key that asks one paired question at each step:

1 (a) Body covered with feathers: the dove.

1 (b) Body not covered with feathers: go to 2.

2 (a) Skin dry and covered with horny scales: the tortoise.

2 (b) Skin not dry and scaly: go to 3.

3 (a) Skin moist and without scales: the frog.

3 (b) Skin with wet scales, and with fins and gills: the tilapia.

Examiner's Note
A key must split the group at each step by one paired, contrasting feature, the choice leading either to a name or to the next step, until each animal is reached. Marks are lost when a step fails to divide the group or the feature chosen is vague.

False Confidence Alert
Most students simply list each animal's features instead of building a key. A key offers a paired choice at every step, each pair turning on one clear, contrasting feature, until only one animal is left.

Question 124

In Tanzania the insects are both a help and a plague. Describe the helpful and the harmful roles of insects in Tanzanian life, with an example of each.

Model Answer

Insects touch Tanzanian life on both sides, for good and for ill. On the helpful side:

1) **Pollination:** bees and other insects carry pollen and so set the fruit of crops such as mangoes and beans.
2) **Useful products:** bees give honey and beeswax, and the silkworm gives silk.
3) **Food and decay:** some insects such as edible grasshopper and termites are eaten, and others break down dung and dead matter.

On the harmful side, insects do great damage.

1) **Crop pests:** locusts, armyworms and weevils destroy crops in the field and in the store.
2) **Carriers of disease:** the mosquito carries malaria and the tsetse fly carries sleeping sickness.
3) **Pests of the home:** houseflies settle on food and spread the germs of disease.

Examiner's Note
Both sides must be shown with examples: helpful as pollination, honey and silk, and food and decay; harmful as crop pests (locusts, weevils), disease carriers (the mosquito, the tsetse fly) and houseflies. A one-sided answer loses half the marks.

False Confidence Alert
Most students name only the harmful insects, the locusts and the mosquitoes, and forget the helpful ones. Both sides are wanted: bees pollinate crops and give honey, and some insects are eaten or clear away waste, as well as the pests and disease carriers.

Question 125

Finding a spider in its web, **Kipanga** says *it must be an insect, because it is a small creature with many legs.* **Kipute** says *it is no insect.* Say who is right, and give the reasons.

Model Answer

Kipute is right: a spider is not an insect but an arachnid, of the class Arachnida due to the following reasons:

1) **Body in two parts:** an insect has three body parts, whereas a spider has only two, a joined head-and-thorax and an abdomen.
2) **Four pairs of legs:** an insect has three pairs of legs, whereas a spider has four pairs.
3) **No antennae or wings:** an insect has antennae and often wings, whereas a spider has neither.

Being small and many-legged is not the test. Counting the body parts and the legs settles it: with two body parts and four pairs of legs, the spider is an arachnid, not an insect.

Examiner's Note
The verdict rests on counting: an arachnid has two body parts, four pairs of legs and no antennae, against the insect's three body parts, three pairs of legs and antennae. The body parts and legs, not the small size, decide the class.

Language Clinic
Carry each contrast on "whereas": "an insect has three pairs of legs, whereas a spider has four pairs." One contrast word in each line shows the examiner the difference rather than two loose descriptions.

HOT QUESTIONS

These questions reach beyond a single topic. They ask you to weigh evidence, to reason about cases you have not met before, and to connect ideas across the whole chapter. Lead each answer with your point, then build the reasoning in connected English.

Question 126

Classification has changed from two kingdoms, to five, and now to three domains above them. Evaluate whether a final, settled classification of living things is ever possible while the evidence keeps changing.

Model Answer

No classification is ever final, because classification follows the evidence, and the evidence keeps growing. Classification is our attempt to mirror the true relationships of organisms, and that picture sharpens as our tools improve. The light and electron microscopes split the old two kingdoms into five; the study of DNA then split the prokaryotes into the domains Bacteria and Archaea. Each new tool can redraw the boundaries.

Yet this changing is a strength, not a weakness. A classification is the best summary of the evidence we have, and it is revised, not thrown away, as more evidence comes in. So the system is always open to improvement, never finished, but always a truer picture than the one before.

Examiner's Note
A good answer reaches a clear verdict, that no classification is ever final, and justifies it: classification tracks the evidence, and the evidence grows as tools such as the microscope and DNA study improve. The evaluation mark is for treating the changing as a strength, a system always revised rather than discarded.

Language Clinic
Two joins carry the verdict: "because classification follows the evidence, and the evidence keeps growing", and the conclusion word "So", "So the system is always open to improvement". Lead with the reason, then draw the conclusion, and the examiner sees reasoning, not opinion.

Question 127

Suppose a newly found organism is studied and seems to fit none of the five kingdoms. Predict how biologists would handle it, and support your prediction with what has happened before.

Model Answer

Biologists would first study the organism closely, then decide whether to place it or to make a new group for it. They would examine its cell type, whether prokaryotic or eukaryotic, the number of its cells, the way it feeds, and, above all, its DNA, to see which known group it lies nearest to.

If it truly fits no kingdom, a new group would be made for it, as has been done before. The five-kingdom system itself was built by making new kingdoms for the bacteria, the protoctists and the fungi, which the old plant-and-animal scheme could not hold; and the viruses, fitting no kingdom, were left outside the system altogether. A genuinely new organism would be handled the same way, by widening the classification to fit the evidence.

Examiner's Note
The prediction must follow the way classification actually works: study the cell type, cell number, nutrition and DNA to find the nearest group, and, if it fits none, make a new group for it. Marks come from citing the precedent, the making of Monera, Protoctista and Fungi, and the placing of viruses outside the kingdoms.

False Confidence Alert
Most students say such an organism would simply be forced into the nearest kingdom, or else ignored. Classification does not work by force: where an organism fits no group, a new group is made, exactly as the five-kingdom system was built and as the viruses were set outside the kingdoms.

Question 128

A virus needs a host cell to reproduce. Reason why a virus with a damaged protein coat, or one left outside any host, cannot reproduce.

Model Answer

A virus reproduces only by entering a host cell, so anything that stops it entering stops it reproducing. The protein coat, the capsid, both protects the genetic material and lets the virus attach to and enter the right host cell. A damaged capsid cannot attach or inject its genes, so the virus cannot get inside a cell to be copied.

A virus left outside a host cannot reproduce because it has no machinery of its own. It has no cytoplasm, no ribosomes and no enzymes for making copies, and so must borrow the machinery of a host cell. Outside a host, with nothing to borrow, it is as inert as a chemical crystal and cannot multiply.

Examiner's Note
The reasoning must run from what a virus is: the capsid is needed to attach to and enter a host, so a damaged capsid bars entry; and a virus has no machinery of its own, so outside a host, with nothing to borrow, it cannot copy itself. Both points trace back to its total dependence on the host.

Language Clinic
Let "so" carry cause to effect: "A damaged capsid cannot attach or inject its genes, so the virus cannot get inside a cell to be copied." Tracing the consequence from the cause, step by step, is the reasoning the marks reward.

Question 129

Whether viruses are alive and why they are excluded from the five kingdoms are important questions in biological classification. Reach a justified verdict on whether viruses are alive, and link your verdict to their placement outside the kingdoms.

Model Answer

Viruses are best judged as non-living, on the borderline, and this is the very reason they sit outside the five kingdoms. They carry genes and can mutate, which is life-like; but they have no cell, no metabolism of their own, and cannot reproduce without a host, which is decisive. On balance they are not truly alive.

Because the five kingdoms are kingdoms of cellular life, a non-cellular virus has no place among them. Every kingdom, from Monera to Animalia, is built of cells; the virus, having no cell, fits none, and so it is left outside the kingdom system altogether. The verdict on its life and its place in classification rest on the one same fact: it is not a cell.

Examiner's Note
The verdict, non-living and on the borderline, must be linked to the placement: the five kingdoms are kingdoms of cellular life, so a virus, having no cell, is both judged non-living and set outside the kingdoms by the same fact. The marks reward connecting the two, not treating them as separate questions.

Language Clinic
The word "Because" ties the verdict to the placement: "Because the five kingdoms are kingdoms of cellular life, a non-cellular virus has no place among them", and "and so" delivers the result, "and so it is left outside the kingdom system altogether". One fact, the lack of a cell, settles both.

Question 130

A nurse explains that antibiotics are useless against a cold or influenza. Reason why antibiotics do not work against viral diseases, from what a virus is and what it lacks.

Model Answer

Antibiotics do not work against viruses because they attack structures and processes that a virus does not have. An antibiotic kills or halts bacteria by striking targets such as the bacterial cell wall, the bacterial ribosomes, or the bacterial enzymes. A virus has none of these, no cell wall, no ribosomes and no enzymes of its own, so the antibiotic finds nothing to attack.

A virus also shelters inside the host cells, using the host machinery to multiply. To reach the virus there, a drug would have to harm the host cell as well. This is why viral diseases such as influenza and measles are met with vaccines and the defences of the body, not with antibiotics.

Examiner's Note
The reasoning must name what antibiotics attack, the bacterial cell wall, ribosomes and enzymes, then show that a virus has none of these and shelters inside host cells, so there is nothing for the antibiotic to strike. Naming vaccines and the body's defences as the real answer to viruses completes it.

False Confidence Alert
Most students expect antibiotics to cure any infection, a cold or influenza included. Antibiotics cannot touch a virus, which has no cell wall, ribosomes or enzymes to attack; taking them for a viral illness does no good, and only breeds resistant bacteria.

Question 131

A bacterium and a plant cell both have a cell wall, yet they belong to different domains of life. Compare the structure of a non-photosynthetic prokaryotic cell with that of a eukaryotic plant cell, and explain why this difference is the most fundamental in the living world.

Model Answer

The two cells differ above all in whether they have a true nucleus and membrane-bound organelles.

Nucleus: the bacterium has no true nucleus, only a loop of DNA free in the cytoplasm, whereas the plant cell has a true, membrane-bound nucleus.

Organelles: the bacterium has no membrane-bound organelles, no mitochondria, chloroplasts or large vacuole, whereas the plant cell has them all.

Cell wall: the bacterial wall is of peptidoglycan, whereas the plant wall is of cellulose.

This divide is the most fundamental of all because it splits every living thing into two great groups. Having or lacking a true nucleus separates the prokaryotes from the eukaryotes, a deeper division than any between the kingdoms or between plant and animal.

Examiner's Note
The deciding difference is the nucleus and membrane-bound organelles, which the bacterium lacks. The higher mark is for naming this as the prokaryote-eukaryote divide, the deepest split in life.

Language Clinic
Carry the comparison on "whereas": "the bacterial wall is of peptidoglycan, whereas the plant wall is of cellulose." One contrast word keeps the two cells side by side.

Question 132

Bacteria are often called the most successful organisms on Earth. Evaluate this claim, using evidence.

Model Answer

The claim is well justified, for bacteria outdo all other groups in numbers, range and staying power. They are the most numerous organisms on Earth and live almost everywhere, from hot springs to deep rock and the human gut, because their varied ways of feeding let them use almost any energy source.

They are also the oldest and the hardiest. They have lived for billions of years, they reproduce very fast, and many survive harsh times as endospores. On the evidence of abundance, range, age and resilience, the claim stands.

Examiner's Note
An evaluation needs the evidence, not just the verdict: abundance, range of habitat, varied feeding, fast reproduction and endospores. The mark is for weighing these into a clear judgement.

Language Clinic
Open with the verdict, then "for" to give the grounds: "The claim is well justified, for bacteria outdo all other groups in numbers, range and staying power." The reason-word turns a claim into an argument.

Question 133

Imagine every bacterium on Earth vanished overnight. Predict the consequence for soil fertility and the decay of dead matter.

Model Answer

Without bacteria, decay would largely stop and dead matter would pile up. Bacteria are the chief decomposers, so dead plants, animals and dung would no longer be broken down, and their nutrients would stay locked inside them.

The soil would lose its fertility. With no bacteria to release nutrients or to fix and recycle nitrogen, the soil would not be replenished, plants would fail for want of minerals, and in time the whole web of life would falter.

Examiner's Note
The prediction must link the lost decomposers to the result: no breakdown, so nutrients stay locked in dead matter and the nitrogen cycle stops, leaving the soil infertile.

False Confidence Alert
Most students say only that rubbish would pile up. The deeper loss is the broken nutrient and nitrogen cycles, which is what starves the soil and the plants.

Question 134

Of all the kingdoms, the Protoctista is the one biologists find hardest to define. Evaluate why this is so.

Model Answer

The Protoctista is hard to define because it is held together by what its members are not, rather than by what they share. It is the kingdom for the eukaryotes that are neither plants, animals nor fungi, so it became a home for every eukaryote that fitted nowhere else.

Its members are also extremely varied. It holds the plant-like algae, the animal-like protozoa and the fungus-like water moulds, some single-celled and some many-celled, so no single positive feature covers them all. That is why it is often called a ragbag kingdom.

Examiner's Note
The point that scores is that the kingdom is defined negatively, by exclusion, not by a shared feature, and that its members are hugely varied. Name the plant-like, animal-like and fungus-like members.

Language Clinic
The phrase "rather than" sets the real definition against the expected one: "held together by what its members are not, rather than by what they share." Naming that contrast is the heart of the answer.

Question 135

Because *Euglena* has both plant and animal features, some say it is the ancestor of both plants and animals. Weigh this claim and reach a verdict.

Model Answer

The claim is only loosely true and is best treated with caution. *Euglena* does show both sides, photosynthesising like a plant yet swimming and feeding like an animal, so it nicely illustrates that the plant and animal lines are not sharply separate at the simplest level.

But sharing features is not the same as being the ancestor. *Euglena* is a living organism of today, not an ancient form, and true ancestry is judged from DNA and fossils, not from a mix of features alone. The fair verdict is that *Euglena* hints at a common, protist-like origin, but is not itself the ancestor.

Examiner's Note
Credit the grain of truth, that mixed features hint at a shared origin, then the correction, that shared features are not ancestry and *Euglena* is a modern organism. The verdict must hold both.

False Confidence Alert
Most students take the mixed features as proof that *Euglena* is the ancestor. A living organism of today cannot be the ancestor of older groups; its features only suggest a shared, distant origin.

Question 136

The protozoa are grouped by how they move. Compare the three main means of movement, with an example of each, and show how movement is used to classify them.

Model Answer

The protozoa move in three main ways, and each way names a group.

1) **By flagella:** long whip-like threads lash to and fro, as in the flagellates such as *Trypanosoma*.

2) **By cilia:** many short hairs beat in waves, as in the ciliates such as *Paramecium*.

3) **By pseudopodia:** the cell flows out false feet, as in the sarcodines such as *Amoeba*.

Movement thus sorts the protozoa into groups. Because each kind of movement marks a different group, the means of locomotion is itself a classifying feature.

Examiner's Note
Each means needs its mechanism and a named example: flagella (*Trypanosoma*), cilia (*Paramecium*), pseudopodia (*Amoeba*). The mark is for tying each movement to the group it names.

Language Clinic
The phrase "as in" carries the rule to its example: "many short hairs beat in waves, as in the ciliates such as *Paramecium*." Giving the example straight after the mechanism is what the marks reward.

Question 137

In Lake Victoria the floating algae are easy to overlook. Predict the effect on the lake's food web and on its oxygen if all its algae disappeared.

Model Answer

The food web would collapse from the bottom up. The algae are the producers, the food on which the small water animals feed; without them the small animals would starve, the fish that eat those animals would die, and the fishery would fail.

The water would also lose much of its oxygen. The algae release oxygen as they photosynthesise, so without them the dissolved oxygen would fall and the animals that breathe it would suffocate. The lake would become almost lifeless.

Examiner's Note
The prediction must trace the chain: algae are the producers and the oxygen source, so losing them starves the food web from its base and lowers the dissolved oxygen, killing the fish.

False Confidence Alert
Most students mention only the fish that die. The root cause is the loss of the producers and of photosynthetic oxygen, which is why the whole web and the fishery fall.

Question 138

Fungi are both friends and foes of humankind. Weigh the advantages of fungi against the disadvantages, and reach a balanced judgement.

Model Answer

On the good side, fungi feed us, heal us and keep the soil alive. Yeast raises bread and brews drink, mushrooms are eaten, *Penicillium* gives the antibiotic penicillin, and as decomposers fungi rot dead matter and return its nutrients to the soil.

Against that, fungi cause disease and spoil food. They bring crop diseases such as rusts and smuts, spoil stored food with moulds and aflatoxins, and infect people with ringworm and thrush.

On balance the good outweighs the harm, because the harm can largely be controlled. Disease and spoilage are checked by hygiene, fungicides and dry storage, while the benefits, above all decomposition, are vital and cannot be replaced.

Examiner's Note
A weighing answer must give both sides with examples, then reach a clear verdict. The evaluation mark is for judging that the good outweighs the harm, with a reason.

Language Clinic
End on the verdict with "On balance ... because": "On balance the good outweighs the harm, because the harm can largely be controlled." The reason-word turns a verdict into a judgement.

Question 139

Fungi, with bacteria, are the great decomposers, and they alone rot tough wood and fallen leaves. Predict the consequence for an ecosystem if all the decomposer fungi vanished.

Model Answer

Dead wood, leaves and other tough matter would pile up, because fungi are the chief rotters of such material. Fungi, unlike most bacteria, can break down the lignin that toughens wood and leaf litter, so without them this woody dead matter would gather on the forest floor.

The nutrients locked in it would be lost to the living, and the soil would grow poor. With the nutrients trapped in undecayed wood and leaves, plants would be starved of minerals, and the whole ecosystem, resting on those plants, would slowly decline.

Examiner's Note
The key point is that fungi rot the tough material, the wood and leaf litter, that few bacteria can break down. So their loss locks up nutrients and starves the soil and the plants.

False Confidence Alert
Most students say bacteria would simply do the job instead. Few bacteria can break down the lignin of wood as fungi do, so the woody litter would still pile up.

Question 140

Fungi were once classed with the plants, but are now placed in a kingdom of their own. Compare a fungus with a green plant, and explain why fungi were grouped with plants at first but are not now.

Model Answer

A fungus and a green plant differ most in how they feed.

Feeding: a green plant makes its own food by photosynthesis, whereas a fungus has no chlorophyll and absorbs ready-made food.

Cell wall: a plant wall is of cellulose, whereas a fungal wall is of chitin.

Food store: a plant stores starch, whereas a fungus stores glycogen.

Fungi were grouped with plants at first because they look plant-like: they do not move, they have a cell wall, and many grow rooted in the soil. But once it was clear that they cannot photosynthesise and feed instead by absorption, they were given a kingdom of their own.

Examiner's Note
The deciding difference is nutrition: the plant makes its food, the fungus absorbs it. The history mark is for the plant-like look (no movement, a wall, rooted) set against the real test, how it feeds.

Language Clinic
Carry each difference on "whereas": "a green plant makes its own food by photosynthesis, whereas a fungus has no chlorophyll and absorbs ready-made food." The contrast word keeps plant and fungus side by side.

Question 141

A moss and a maize plant sit at the two ends of the plant kingdom. Compare the moss with the maize plant on vascular tissue, on seeds, and on their need for water, and justify which is the more advanced.

Model Answer

The maize plant is the more advanced, as the comparison on three counts shows.

1) **Vascular tissue:** the moss has none and stays small, whereas the maize has xylem and phloem and can grow tall.
2) **Seeds:** the moss has no seeds and spreads by spores, whereas the maize bears protected seeds.
3) **Water:** the moss needs a film of water for its sperm to swim, whereas the maize uses pollen and needs no such water.

On all three counts the maize is the more advanced. Vascular tissue, seeds and freedom from water for fertilisation make it fit for dry land, where the moss cannot live.

Examiner's Note
Compare on all three named counts, vascular tissue, seeds and water for fertilisation, then judge the maize the more advanced. The verdict, with its reasons, earns the top mark.

Question 142

The four plant divisions can be set in a line from the moss to the flowering plant. Trace the trend across the four divisions, and evaluate what drives it.

Model Answer

Across the four divisions the plants grow steadily more independent of water and better fitted for land.

1) **Bryophyta, the mosses:** no vascular tissue, no seeds, and bound to damp places by swimming sperm.
2) **Filicinophyta, the ferns:** vascular tissue appears, so they grow larger, but they still spread by spores and need water for fertilisation.
3) **Coniferophyta, the conifers:** seeds appear, carried in cones, and pollen replaces swimming sperm, freeing them from water.
4) **Angiospermophyta, the flowering plants:** flowers, fruits and broad leaves complete the conquest of the land.

The trend is driven by two advances above all: vascular tissue and the seed with pollen. Together they free the plant from water and let it grow tall and spread widely, which is why the flowering plants now rule the land.

Examiner's Note
Trace the steps in order, moss to fern to conifer to flowering plant, then name what drives the trend: vascular tissue and the seed with pollen. The evaluation mark is for the drivers, not just the list.

Language Clinic
Mark the cause with "so": "vascular tissue appears, so they grow larger". Tracing each advance to what it allows shows the trend, not just the divisions.

Question 143

A moss is never found growing in dry, open ground. Predict, from the features of a moss, why it is confined to damp, shaded places.

Model Answer

A moss is tied to damp places because it cannot gather or keep water, and needs water to breed. It has no vascular tissue and no true roots, so it cannot draw water from deep in the soil or carry it far, and it dries out quickly in the sun.

It also needs a film of water for reproduction. Its male cells must swim through water to reach the female, so without dampness it cannot complete its life cycle. Shade and moisture are therefore its only home.

Examiner's Note
The prediction must rest on two moss features: no vascular tissue or roots to gather and hold water, and swimming sperm that need a film of water. Both tie it to damp, shaded ground.

False Confidence Alert
Most students say the moss simply prefers shade. The real reason is that it cannot transport or conserve water and needs water for its sperm to swim, so it has no choice.

Question 144

An open, dry grassland bakes in the sun for much of the year. Predict which plant division would thrive best there, and justify your choice.

Model Answer

The flowering plants, the angiosperms, would thrive best, for they are the best fitted of all to dry, open land. The grasses of such country are themselves angiosperms, and they cover the plains where no moss or fern could survive.

Their features answer every demand of the dry grassland. Their deep roots and vascular tissue gather and carry water; their pollen needs no water for fertilisation; and their drought-proof seeds wait in the soil for the rains. So the angiosperms, not the mosses, ferns or even conifers, rule the open grassland.

Examiner's Note

The choice must be the angiosperms (the grasses), justified by features that suit dry land: roots and vascular tissue, pollen needing no water, and drought-proof seeds. Naming the grasses as angiosperms strengthens it.

False Confidence Alert

Most students pick a tough, low plant such as a moss for the harsh ground. A moss cannot survive dry, open sun at all; it is the deep-rooted, seed-bearing grasses, which are angiosperms, that thrive there.

Question 145

It is often said that the arthropods are the most successful animals of all. Justify this claim, drawing on several lines of evidence.

Model Answer

Arthropods are the most successful animals on several measures at once. They are by far the most numerous, with more named species than all other animals together; they live in every habitat, on land, in water and in the air; and they range from tiny mites to large crabs.

Their success rests on a few powerful features. The waterproof exoskeleton lets them live on dry land, jointed legs and wings give swift and varied movement, and metamorphosis lets the young and adult use different foods, so they avoid competing with their own offspring. On every line of evidence, numbers, range and adaptation, the claim holds.

Examiner's Note
A justification must marshal several lines: the huge number of species, the range of habitats, and the key features (exoskeleton, jointed legs, wings, metamorphosis). The mark is for the weight of evidence, not one reason.

Language Clinic
Let "so" turn a feature into its payoff: "metamorphosis lets the young and adult use different foods, so they avoid competing with their own offspring." Tying each strength to what it achieves builds the justification.

Question 146

An insect and a mammal solve the same problems of life in different ways. Compare and justify an insect against a mammal on skeleton, on gas exchange, and on body temperature.

Model Answer

An insect and a mammal meet the same needs by very different designs.

Skeleton: the insect has an exoskeleton on the outside that it must moult to grow, whereas the mammal has an endoskeleton of bone inside that grows with it.

Gas exchange: the insect breathes through tracheae that carry air straight to the tissues, whereas the mammal breathes with lungs that pass oxygen to the blood.

Body temperature: the insect is ectothermic, its temperature following the surroundings, whereas the mammal is endothermic, holding a steady warm temperature.

Each design has its price and its prize. The exoskeleton limits the insect's size but is light and protective; endothermy costs the mammal much food but lets it stay active in the cold. The two are different answers to the one problem of support, breathing and warmth.

Examiner's Note
Compare on all three named counts: exoskeleton that must moult against endoskeleton that grows; tracheae against lungs; ectothermic against endothermic. The justify mark is for naming each design's price and prize.

Question 147

An animal new to a student has a dry, scaly skin, breathes only by lungs, and lays leathery shelled eggs on land. The student calls it an amphibian. Use the features to place it correctly, and explain where the student went wrong.

Model Answer

The animal is a reptile, not an amphibian, as its skin, its breathing and its eggs all show. A dry, scaly skin that holds in water, breathing by lungs alone, and leathery shelled eggs laid on land are together the marks of the class Reptilia.

The student was misled by guesswork rather than by the features. An amphibian has a moist, scaleless skin, breathes partly through that skin, and lays jelly eggs in water; this animal shows the opposite of each, so it cannot be an amphibian. To place an animal you read its features, not its looks.

Examiner's Note
Place by the deciding features: a dry, scaly skin, lungs only, and shelled eggs on land mark a reptile. The correction is that these are the opposite of the amphibian's moist skin and jelly eggs.

False Confidence Alert
Most students place the animal by a single impression instead of weighing its features. Every feature here, the dry scaly skin, the lungs and the shelled land eggs, points to a reptile and away from an amphibian.

Question 148

The arthropods far outnumber the vertebrates, yet the largest land and sea animals are all vertebrates. Evaluate why the vertebrates dominate large-animal life although the arthropods are far more numerous.

Model Answer

The two groups are successful in different ways, so both facts are true at once. Arthropods win on numbers and variety, but their very body plan keeps them small, while the vertebrate plan allows great size.

The arthropod exoskeleton sets a limit on size. A large exoskeleton would be too heavy, it must be shed at every spell of growth, and the tracheae cannot carry enough air to a big body. The vertebrate endoskeleton grows with the animal, and lungs with a blood system supply a large body with oxygen, so the big land and sea animals are vertebrates. Each group rules the measure its body plan favours.

Examiner's Note
The evaluation must hold both facts: arthropods are most numerous, but the exoskeleton and tracheae cap their size, whereas the vertebrate endoskeleton and lungs allow large bodies. Success is measured in different ways.

Language Clinic
Reconcile the two facts with "so": "their very body plan keeps them small ... so the big land and sea animals are vertebrates." The joining word shows you are explaining, not just stating two facts.

Question 149

Predict how a frog would cope if it were taken from its pond to a hot, dry desert, and base your prediction on the features of its class.

Model Answer

A frog would not survive long in a hot, dry desert, because its amphibian features tie it to water. Its moist, scaleless skin, through which it partly breathes, would lose water fast in the dry heat, so the frog would soon dry out and be unable to breathe.

It could neither cool itself nor breed there. Being ectothermic, it cannot hold a steady temperature and would overheat in the sun; and with no water for its jelly eggs and tadpoles, it could not reproduce. The desert suits the dry-skinned, shelled-egg reptile, not the amphibian.

Examiner's Note
The prediction must come from the class features: the moist breathing skin loses water, ectothermy means it overheats, and jelly eggs need water it has not got. Contrast with the reptile, which is built for the desert.

False Confidence Alert
Most students say the frog would simply adapt, or hide in the shade. Its amphibian features make the desert deadly: the moist breathing skin loses water it cannot replace, and it must have water to breed.

Question 150

At the coast, Kipanga insists a dolphin is a fish, because it lives in the sea, swims, and is shaped like one. Kipute says it is a mammal. Settle the matter, weighing the dolphin's home against its features.

Model Answer

Kipute is right: a dolphin is a mammal, for its features outweigh its fish-like home and shape.

1) **Breathing:** a fish breathes by gills under water, whereas a dolphin breathes air with lungs and must surface to do so.
2) **Temperature:** a fish is cold-blooded, whereas a dolphin is warm-blooded, holding a steady temperature.
3) **Young:** a fish lays many eggs and leaves them, whereas a dolphin bears live young and feeds them on milk.

Living in the sea and being fish-shaped count for nothing against these features. The dolphin shares the water with fish only because both are streamlined for swimming; by how it breathes, warms itself and rears its young, it is a mammal.

Examiner's Note
The verdict must rest on the mammalian features, not the habitat: air-breathing by lungs, warm blood, and live young fed on milk. The fish-like shape and the sea are the trap, not the test.

Chapter 5

COORDINATION AND IRRITABILITY

BINDER QUESTIONS

Work through each question in order: attempt it on paper, then check the model answer beneath. The bold opening of every answer is the mark-bearing point; the notes in the boxes show how the marks are won and lost.

Question 1

A footballer in Dar es Salaam sees the ball coming, brings it under control with a single touch, and only minutes later notices that his heart is still pounding. Many parts of his body are acting at once, yet all of them pull together. Explain why a living body must coordinate its parts, and identify the systems that animals and plants use to achieve it.

Model Answer

Coordination is needed so that the separate organs of a body act as one whole and not against one another. A change picked up in one place, such as the sight of the ball, must be answered by the right action in another place, such as the muscles of the leg. Without this matching of stimulus to response the parts would work in isolation, and the organism could not feed, move or keep itself from danger.

The nervous system carries fast electrical impulses along nerve cells. It gives rapid, short-lived responses, and it is how the player traps the ball the instant he sees it.

The endocrine system releases chemical hormones into the blood. Its messages travel more slowly but last far longer, and it is why his heart is still racing minutes after the play.

Plants have no nerves, so they coordinate by chemicals alone. Hormones made in one part move to another and bring about slow responses that show as growth.

Examiner's Note
Two moves earn the marks: saying why coordination matters, that the parts must act as one, and then naming the three systems: the fast nervous and the slow endocrine of animals, and the chemical coordination of plants.

False Confidence Alert
It is easy to write that only animals have coordination, because only animals visibly move about. Yet plants coordinate too: they use slow chemical messengers in place of nerves, and answer their world by growing.

Question 2

Stepping barefoot on a thorn, a person snatches the foot away almost before feeling the pain. Three things must happen, in order, before the foot can move. Using this example, explain what a stimulus, a receptor and an effector are, and show how the three frame every nervous response.

Model Answer

Every nervous response runs as a chain from a stimulus, through a receptor, to an effector. The three are linked in one fixed order, and the response cannot happen if any link is missing.

1) **A stimulus is the change that sets the response going.** Here it is the sharp point of the thorn pressing into the skin of the foot.
2) **A receptor is the structure that detects the stimulus and turns it into a nerve impulse.** In the skin of the foot, pain receptors pick up the thorn and start the message.
3) **An effector is the part that carries out the response.** The leg muscles are the effectors; they contract and pull the foot clear of the thorn.

So the chain runs in that order every time: the stimulus is detected by a receptor, the impulse is relayed to the body's control, and an effector acts, which is why the foot lifts only after the thorn has been sensed.

Examiner's Note
The marks need all three terms and, above all, their fixed order: the stimulus is detected by a receptor, the impulse is relayed, and the effector responds. Defining the terms but losing the order drops the key mark.

Language Clinic
The answer keeps the sequence with through and So, and with the phrase in that order. These linking words show the marker that you understand the response runs one way, from stimulus to effector, and never backwards.

Question 3

The mammalian nervous system is built in two great divisions, and the nerves that run between them carry traffic in two directions. Explain how the central and peripheral nervous systems divide the work, and what the afferent and efferent nerves each carry.

Model Answer

The nervous system is divided into a central part and a peripheral part that work together. The central nervous system is the brain and the spinal cord, where information is received, sorted and acted upon. The peripheral nervous system is the network of nerves that branches out from it and reaches every part of the body.

Afferent (sensory) nerves carry impulses towards the central nervous system. They bring news of the outside world, and of the body's own state, inwards from the receptors.

Efferent (motor) nerves carry impulses away from the central nervous system. They take the orders outwards to the effectors, the muscles and glands that produce the response.

Examiner's Note
The marks ask for the make-up of each division (brain and spinal cord for the central, the branching nerves for the peripheral) and the direction each nerve carries: afferent inwards to the centre, efferent outwards to the effectors.

Language Clinic
Direction is everything here, so the answer leans on towards and away from, and on inwards and outwards. Pairing these opposite words in one breath makes the contrast between the two kinds of nerve unmistakable.

Question 4

Nervous tissue is not made of a single kind of cell but of two, and only one of them actually carries the message. Explain the two cell types that build nervous tissue, and the jobs done by the cells that merely support the message-carriers.

Model Answer

Nervous tissue is built from neurones and neuroglia. The neurones are the nerve cells proper; they receive and carry the electrical impulses, and so do the real work of signalling. The neuroglia, of which there are several types, do not carry impulses themselves but support and protect the neurones in a number of ways:

1) **They make the myelin sheath.** This fatty layer insulates the axon and lets the impulse travel much faster.

2) **They supply the neurones with nutrients.** The hard-working nerve cells are kept fed and supported.
3) **They give physical and electrical support.** They hold the delicate neurones in place and insulate them from one another.
4) **They clean up and defend.** Some neuroglia remove dead material and bacteria, guarding the nervous tissue.

Examiner's Note
The answer must name both cell types and keep their roles apart: the neurone carries the impulse, while the neuroglia only support it. Giving at least two support jobs, such as myelin, feeding and protection, secures the remaining marks.

False Confidence Alert
It is tempting to say the neuroglia also carry impulses, since they sit packed among the nerve cells. They do not: only the neurones conduct the message, and the neuroglia exist to feed, insulate and protect them.

Question 5

A clean section cut through the spinal cord shows two shades, a grey region and a white region. Explain what each region is made of, and why the two differ in colour.

Model Answer

The two regions differ because they are built from different parts of the neurones. The colour of each follows directly from what it contains.

Grey matter is made of cell bodies, dendrites and unmyelinated axons. Having little of the fatty sheath, this region takes on a greyish colour.

White matter is made mainly of myelinated axons. These axons are wrapped in the fatty myelin sheath, and it is the fat that gives the region its white colour.

So the white colour comes from the myelin, whereas the grey comes from the cell bodies and bare fibres that lack it.

Examiner's Note
The marks need the make-up of each region (cell bodies and bare fibres in the grey, myelinated axons in the white) and the reason for the colour, namely that the white is the fatty myelin sheath.

Language Clinic
The contrast turns on because and whereas. Using because to give the cause of the colour, and whereas to set the grey against the white, lets a single sentence carry both regions at once.

Question 6

Nervous tissue must pass its messages quickly, and without fail, right across the body. Explain how the make-up of nervous tissue fits it for this work of rapid and reliable signalling.

Model Answer

Nervous tissue is adapted so that impulses pass quickly, keep to their path, and never run short of energy. Its features are not chosen at random; each one serves the job of fast signalling:

1) **It is built mostly of neurones,** long cells that are specialised to carry electrical impulses over a distance.
2) **Its cells are packed tightly together,** so that an impulse passes from one cell to the next with very little delay.

3) **The cells hold very many mitochondria,** which supply the large amount of ATP that constant signalling demands.
4) **Neuroglia wrap and support the neurones,** and the myelin they make both speeds the impulse and protects the fibre.
5) **Peripheral fibres are able to regenerate,** because the neurilemma around them guides the repair of a damaged nerve.

Examiner's Note
The marks reward features tied to the job: tightly packed cells for quick passage, many mitochondria for the ATP that signalling needs, and glial myelin for speed and protection. A bare list of parts, with no reason, scores less.

Language Clinic
Each feature is welded to its purpose with so that and because. Naming the part, then saying so that or because the work follows, turns a bare list into an answer about adaptation, which is exactly what earns the marks.

Question 7

From the moment a stimulus arrives to the moment the body acts, and even afterwards, the nervous system performs several distinct jobs. Trace the main functions that the nervous system carries out.

Model Answer

The nervous system receives information, turns it into impulses, carries and processes those impulses, and stores some of what it learns. These functions follow one another in order:

1) **It receives stimuli from inside and outside the body,** the sensory input picked up by the receptors.
2) **It changes the stimuli into electrical impulses,** a conversion that is called transduction.
3) **It transmits and processes the impulses,** passing them from the receptor to the central nervous system and on to the effector that responds.
4) **It stores information,** keeping a record of past experience so that behaviour can be changed in the light of it.

Examiner's Note
Four jobs carry the marks: receiving the stimulus, transduction into an impulse, transmission to the effector, and the storing of information. Naming transduction by its proper term, not merely as changing, strengthens the answer.

False Confidence Alert
It is easy to stop at the idea that the nervous system only sends messages. Carrying impulses is just one of its jobs: it also detects the stimulus, performs transduction, and stores information that lets behaviour change.

Question 8

Draw a large, labelled diagram of a typical motor neurone. Beside each label, give the job that the part performs.

Model Answer

A motor neurone is built as a single long signalling cell. It has a cell body that houses the nucleus, short dendrites that gather impulses, and one long axon, wrapped in a myelin sheath, that carries the impulse all the way to the effector.

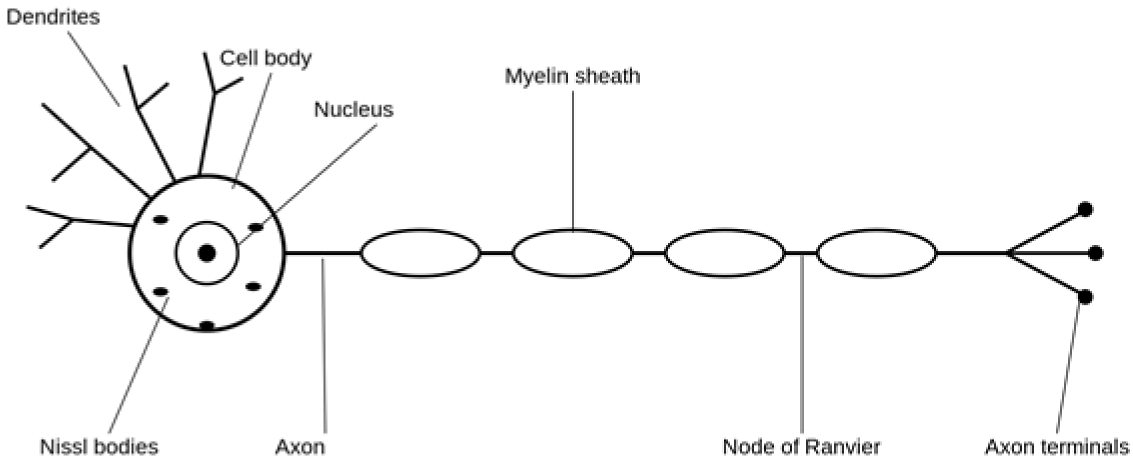


Figure 5.1: *Structure of typical motor neurone.*

1) **Cell body (with the nucleus and Nissl bodies):** controls the cell and makes the proteins and the transmitter that the neurone needs.
2) **Dendrites:** short branches that receive impulses and carry them towards the cell body.
3) **Axon:** the long fibre that carries the impulse away from the cell body to the effector.
4) **Myelin sheath:** the fatty layer that insulates the axon, speeds the impulse and protects the fibre.
5) **Nodes of Ranvier:** the gaps in the sheath at which the impulse leaps, making conduction faster.
6) **Axon terminals:** pass the impulse on to the next neurone or to the muscle.

Examiner's Note
A good answer is a large, clear line drawing in which every label carries a use beside it. The marks need the cell body with its nucleus, the dendrites, the long axon, the myelin sheath and the nodes of Ranvier, each tied to its job.

False Confidence Alert
A common slip is to label the axon as carrying impulses in both directions. The axon carries the impulse one way only, away from the cell body; it is the dendrites that carry impulses towards the cell body.

Question 9

A message travelling from the skin to a muscle is handed along by three kinds of neurone. Explain how the sensory, relay and motor neurones differ in their structure and in the direction each one carries the impulse.

Model Answer

The three neurones differ in the length of their fibres and in the direction each carries the impulse along the pathway. Set in the order the message travels, they are:

1) **The sensory (afferent) neurone has a long dendron and a short axon,** and carries the impulse from the receptor towards the central nervous system.
2) **The relay (intermediate) neurone is small and lies wholly inside the central nervous system,** where it passes the impulse between the sensory and the motor neurone.
3) **The motor (efferent) neurone has short dendrites and a long axon,** and carries the impulse out to the effector, the muscle or gland.

Examiner's Note
The marks turn on matching each neurone to the direction it carries the impulse: sensory in to the centre, relay across within it, and motor out to the effector. The fibre lengths add the structural detail the question also asks for.

Language Clinic
The pathway is told through direction words: towards, between and out to. Setting the three neurones in the order the impulse travels, and joining them with these words, makes one clear journey from skin to muscle.

Question 10

Neurones can also be sorted by the number of processes that leave the cell body. Explain how the unipolar, bipolar and multipolar neurones differ, and where each kind is found in the body.

Model Answer

The three kinds are told apart by how many processes leave the cell body, and each is found where its shape suits the work.

A unipolar neurone has a single short process leaving the cell body, found, for example, in the granular layer of the cerebellum.

A bipolar neurone has two processes, one dendron and one axon, found in the retina of the eye and in the sensory parts of the ear and the nose.

A multipolar neurone has one axon and many dendrites, the commonest kind, forming most of the central nervous system, including the relay and the motor neurones.

Examiner's Note
The marks need the count of processes for each kind, one, two and many, together with a place where each is found. Tying the multipolar neurone to the relay and motor neurones links this question back to the work the neurones do.

Language Clinic
The places are introduced with for example and including. These small signposts let the answer give a real site for each kind without breaking the sentence, which is just what the question's where is each found asks for.

Question 11

Before a neurone carries any message, its membrane sits at a steady voltage called the resting potential. Explain how this resting potential is set up and held at about -70 mV.

Model Answer

The resting potential is the steady voltage of about -70 mV across the membrane of a resting neurone, with the inside negative to the outside because positive ions are spread unequally across it. It is set up and held by two things working together:

1) **The sodium-potassium pump uses energy from ATP to drive sodium ions out of the axon and potassium ions in,** both against their concentration gradients.
2) **The membrane is far more permeable to potassium than to sodium,** so potassium leaks back out faster than sodium leaks in, leaving the inside negatively charged.

Examiner's Note
The marks need the value (about -70 mV) with the inside negative, and the two causes kept together: the active sodium-potassium pump and the membrane being more leaky to potassium. One without the other is only half the mechanism.

Language Clinic
The cause is carried by because and so: because the ions are spread unequally the inside is negative, and the membrane leaks potassium so the charge is held. These small links turn a description into an explanation.

Question 12

With the help of a graph of membrane potential against time, describe the action potential and the three phases it passes through.

Model Answer

An action potential is a rapid, brief reversal of the membrane potential, from the resting -70 mV up to about +40 mV and then back again, that carries the nerve impulse along the axon. It passes through three phases, shown on the graph below:

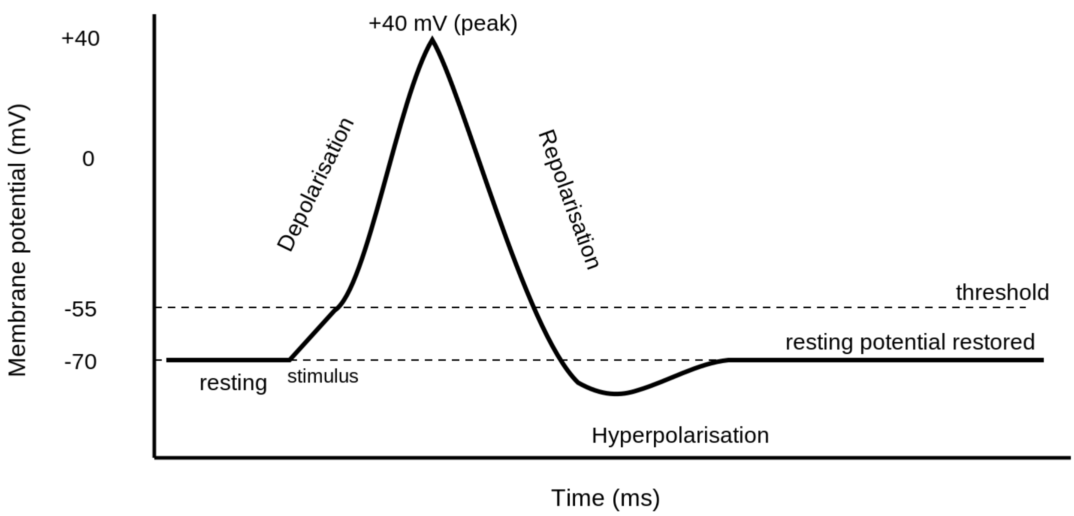


Figure 5.2: *Changes in membrane potential during an action potential.*

1) **Depolarisation:** sodium channels open and sodium ions rush in, so the inside rises from -70 mV to about +40 mV.
2) **Repolarisation:** the sodium channels close and potassium channels open, potassium ions leave, and the inside falls back towards negative.
3) **Hyperpolarisation:** the potassium channels close a little too late, so the potential dips just below -70 mV before the resting potential is restored.

Examiner's Note
For this Draw answer the graph must be labelled with the resting potential (-70 mV), the threshold, the peak (+40 mV) and the three phases. The commonest error is to draw the spike without the hyperpolarisation dip that follows it.

Question 13

During an action potential the inside of the axon swings from -70 mV up to +40 mV and then back. Explain why this happens, in terms of the movement of ions.

Model Answer

The voltage swings because sodium ions and then potassium ions move through voltage-gated channels in turn. When a stimulus depolarises the membrane to its threshold of about -55 mV, voltage-gated sodium channels open and sodium ions flood in, driving the inside up to about +40 mV. The more the membrane depolarises, the more sodium gates open, so the rise is rapid and self-reinforcing. The sodium channels then close and potassium channels open, so potassium ions leave and the inside becomes negative once more. Finally the sodium-potassium pump restores the original resting potential.

Examiner's Note
The marks need the threshold reached, sodium entry driving the rise to +40 mV, potassium exit bringing it back down, and the pump restoring rest. Calling the channels voltage-gated earns the mechanism mark.

False Confidence Alert
Most students say the sodium-potassium pump causes the action potential. It does not: the pump works slowly to set up and restore the resting potential, while the action potential itself is the fast opening of voltage-gated sodium and then potassium channels.

Question 14

Once an action potential is set off at one point on an axon, it does not stay there but travels the whole length. Explain how the impulse is conducted along the axon.

Model Answer

The impulse is conducted as a moving wave of depolarisation that sweeps along the axon. Where one region has an action potential, the inflow of sodium ions makes the inside positive there. This sets up small local currents between that active region and the resting membrane just ahead, which depolarises the region ahead to its threshold. An action potential is therefore triggered further along, while the region behind repolarises. In this way the impulse is regenerated point after point and travels in one direction to the axon ending.

Examiner's Note
The mark-bearing idea is regeneration: local currents depolarise the next region to threshold, so a fresh action potential forms ahead rather than the same one sliding along. Saying the impulse simply flows like electricity in a wire loses the mark.

Language Clinic
The chain is built with This sets up, therefore and In this way. These connectors carry the cause from one region to the next and show the impulse is renewed step by step, which is the point being marked.

Question 15

In a myelinated axon the impulse does not creep smoothly along but appears to jump. Explain how the myelin sheath and the nodes of Ranvier speed up conduction.

Model Answer

In a myelinated axon the impulse leaps from one node of Ranvier to the next, a faster process called saltatory conduction. Myelin is a fatty layer that insulates the axon, so ions cannot cross it and an action potential cannot form along the sheathed stretches. It can form only at the nodes of Ranvier, the small gaps in the sheath. The local currents therefore jump from node to node instead of depolarising every point of the membrane in turn. Because far fewer regions have to be depolarised, the impulse travels much faster than along an unmyelinated axon.

Examiner's Note
The marks turn on why myelin speeds the impulse: it insulates the axon so the action potential forms only at the nodes, and the impulse jumps between them. The reason, not just the word saltatory, earns the mark.

False Confidence Alert
It is tempting to say the impulse travels faster because it passes through the myelin. The opposite is true: the impulse cannot cross the insulating myelin at all, and it is the leap between the bare nodes that makes conduction fast.

Question 16

Nerve impulses do not all travel at the same speed. Explain the three main factors that decide how fast an impulse is conducted along an axon.

Model Answer

Three main factors decide how fast an impulse travels along an axon:

1) **Myelination:** a myelinated axon conducts faster than an unmyelinated one, because the impulse leaps between the nodes of Ranvier.
2) **Axon diameter:** a wide (giant) axon conducts faster than a thin one, because a wider axon offers less resistance to the local currents.
3) **Temperature:** a warm axon conducts faster than a cold one, because ions diffuse more quickly, so a warm-blooded mammal has faster impulses than a cold-bodied animal.

Language Clinic
Each factor is tied to its cause with because, and the comparisons run on faster than. Stating the factor and then because the reason follows is what lifts a bare list into a mark-winning answer.

Question 17

A weak touch and a hard knock both send impulses along the same sensory neurone, yet every impulse in that fibre is exactly the same size. Explain the all-or-nothing law, and how the body still tells a strong stimulus from a weak one.

Model Answer

By the all-or-nothing law, a neurone fires an impulse only if the stimulus reaches the threshold, and every impulse that fires is the same size whatever the strength of the stimulus. A stimulus below the threshold produces no impulse at all; once the threshold is reached, a full-sized action potential travels along the fibre. The strength of the stimulus is shown not by the size of the impulse but by its frequency: a stronger stimulus fires impulses more often, and excites more neurones at once, so the brain reads frequent impulses in many fibres as a strong stimulus.

Examiner's Note
Two points carry the marks: that below threshold nothing fires while at or above it a full, fixed-size impulse fires; and that stimulus strength is coded by the frequency of impulses and the number of fibres, not by impulse size.

False Confidence Alert
Most students think a stronger stimulus produces a bigger or a faster impulse. It does not: every impulse in a fibre is the same size and speed; a stronger stimulus simply triggers impulses more frequently and recruits more fibres.

Question 18

Just after a region of an axon has fired, it cannot fire again for a short time. Explain what the refractory period is, and how it makes sure the impulse travels in one direction only.

Model Answer

The refractory period is the short recovery time, just after an action potential, during which a region of the axon cannot fire another impulse. It has two parts: an absolute refractory period, when no new impulse can form at all because the sodium channels are inactivated, and a relative refractory period, when only a strong stimulus can fire one. This controls direction: the region just behind the impulse is still refractory and cannot be re-excited, so the impulse can only depolarise the resting region ahead. The refractory period therefore keeps the impulse moving one way, and it also sets a limit on how often a fibre can fire.

Examiner's Note
The marks need the refractory period defined as recovery time, split into absolute and relative, and then linked to one-way travel: the region behind is still refractory, so only the region ahead can be excited.

False Confidence Alert
Students often say the impulse goes one way because the axon points one way. The real reason is the refractory period: the membrane just behind the impulse cannot fire again at once, so the impulse can spread only forwards.

Question 19

Draw a large, labelled diagram of a chemical synapse. Beside each label, give the part its job.

Model Answer

A chemical synapse is the junction at which one neurone passes its impulse to the next across a tiny gap. Its parts and their jobs are:

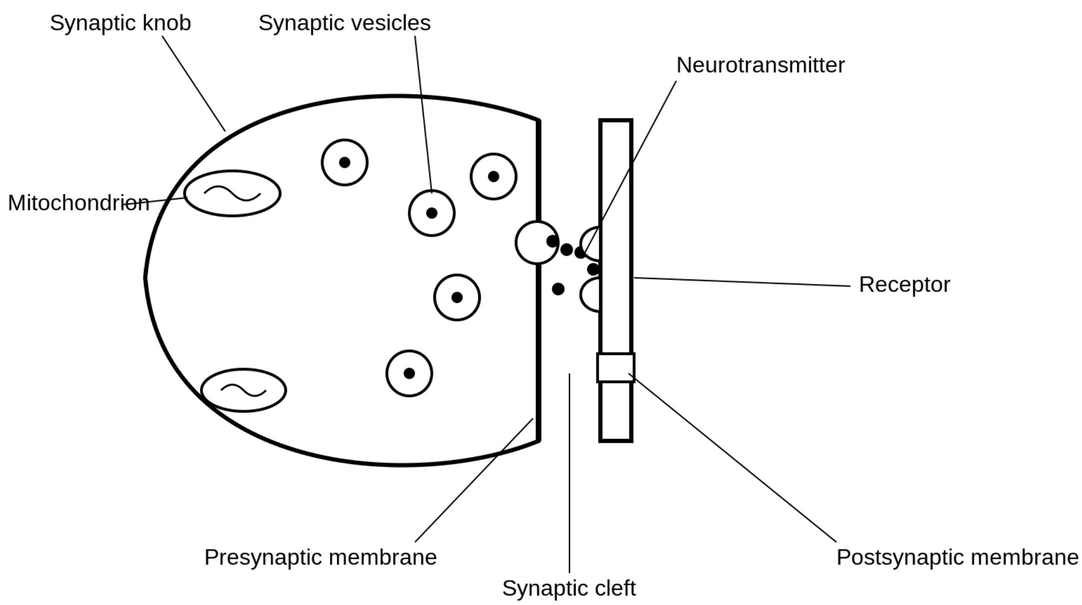


Figure 5.3: *The structure of a chemical synapse.*

1) **Synaptic knob:** the swollen ending of the presynaptic neurone that holds the vesicles and the mitochondria.
2) **Mitochondrion:** supplies the ATP needed to make the neurotransmitter and to reset the synapse.

3) **Synaptic vesicles:** small sacs that store the neurotransmitter ready for release.
4) **Presynaptic membrane:** the membrane the vesicles fuse with to release neurotransmitter into the gap.
5) **Synaptic cleft:** the narrow gap, about 20 nm wide, that the neurotransmitter diffuses across.
6) **Postsynaptic membrane:** carries the receptors and the ion channels that pass the impulse on.
7) **Receptor:** the protein the neurotransmitter binds to, opening ion channels in the next neurone.

Examiner's Note
The mark-bearing labels are the synaptic knob, the synaptic vesicles, the presynaptic membrane, the synaptic cleft, the postsynaptic membrane and the receptors. The commonest error is to draw the cleft so narrow that the two membranes seem to touch; the gap must be clearly shown.

Question 20

When an impulse reaches the end of one neurone, it must cross the synapse to reach the next. Explain how the impulse is carried across the synapse.

Model Answer

The impulse is carried across the synapse by a chemical neurotransmitter, not by electricity. When the action potential reaches the synaptic knob, it opens calcium channels and calcium ions enter. This causes the synaptic vesicles to fuse with the presynaptic membrane and release their neurotransmitter into the cleft. The neurotransmitter diffuses across and binds to receptors on the postsynaptic membrane, which open ion channels there. Sodium ions then enter the next neurone, and if the threshold is reached a new action potential is triggered, so the impulse continues on its way.

Examiner's Note
The marks follow the sequence: calcium entry, vesicles fuse and release transmitter, transmitter diffuses and binds the receptors, ion channels open, a new action potential forms. Missing the calcium step or the receptor step loses marks.

Language Clinic
The sequence is held together by When, This causes and so. Naming each step and joining it to the next with these words shows the marker that the impulse crosses as an ordered chain, not in a single jump.

Question 21

The message that crosses a synapse is carried by chemicals called neurotransmitters. Explain what neurotransmitters are, and how neurones are named after the ones they use.

Model Answer

Neurotransmitters are the chemical messengers that carry the impulse across a synapse from one neurone to the next. They are made in the neurone and stored in the synaptic vesicles of the knob, ready to be released when an impulse arrives. The two best known in mammals are acetylcholine and noradrenaline. Neurones are named after the transmitter they release: those that release acetylcholine are called cholinergic neurones, while those that release noradrenaline are called adrenergic neurones.

False Confidence Alert
It is easy to think the neurotransmitter carries an electric current across the gap. It does not: the transmitter is a chemical that diffuses across the cleft, and the electrical impulse only begins again once the transmitter has bound to the receptors on the other side.

Question 22

After a neurotransmitter has carried the impulse across the synapse, it must not be left to act again and again. Explain how the synapse is reset, and why this matters.

Model Answer

The synapse is reset by an enzyme that breaks the neurotransmitter down soon after it has acted. Once acetylcholine has bound to the receptors and passed on the impulse, the enzyme acetylcholinesterase in the postsynaptic membrane breaks it into acetyl and choline. These products diffuse back into the synaptic knob, where they are rebuilt into acetylcholine and stored in the vesicles for next time. This matters because, if the transmitter were not removed, it would keep the receptors switched on and fire the next neurone continuously, so the synapse could not respond to a fresh impulse.

Examiner's Note
The marks need the enzyme named (acetylcholinesterase), the breakdown of the transmitter, and the reason: without removal the postsynaptic neurone would keep firing and could not receive a new signal.

Language Clinic
The point turns on because and so, with the warning word if: the transmitter is removed because otherwise the neurone would fire on, so the synapse can reset. That reasoning is what the marks reward.

Question 23

The release of neurotransmitter at a synapse does not happen until calcium ions enter the synaptic knob. Explain the part that calcium ions play in synaptic transmission.

Model Answer

Calcium ions are the trigger that makes the synaptic vesicles release their neurotransmitter. When the action potential arrives at the synaptic knob, it opens voltage-gated calcium channels in the presynaptic membrane, and calcium ions flow in. The raised calcium level inside the knob causes the synaptic vesicles to move to the presynaptic membrane and fuse with it, emptying their neurotransmitter into the cleft by exocytosis. Without this inflow of calcium the vesicles would not release their contents, and the impulse could not cross the synapse.

Examiner's Note
The marks need calcium entering through voltage-gated channels when the impulse arrives, and the calcium causing the vesicles to fuse and release their transmitter. The link between calcium and vesicle release is the key point.

False Confidence Alert
Students often say sodium ions trigger the release of neurotransmitter, confusing the synapse with the axon. At the synaptic knob it is the inflow of calcium ions, not sodium, that makes the vesicles release their transmitter.

Question 24

Not every synapse passes its message by chemicals, and one special synapse links a neurone to a muscle. Explain how an electrical synapse differs from a chemical synapse, and what the neuromuscular junction is.

Model Answer

An electrical synapse passes the impulse directly as a current, whereas a chemical synapse passes it by a neurotransmitter. In an electrical synapse the two neurones are joined by channels so close that the current flows straight from one cell to the next, which gives very fast transmission. In a chemical synapse, which is far more common, the impulse must be carried across the cleft by a neurotransmitter, which is slower but lets the signal be controlled. The neuromuscular junction is a chemical synapse between the ending of a motor neurone and a muscle fibre, where the neurotransmitter makes the muscle contract.

Examiner's Note
The marks need the core difference, a direct current against a chemical transmitter, with a consequence such as speed or control, and the neuromuscular junction defined as the chemical synapse between a motor neurone and a muscle fibre.

Language Clinic
The comparison rests on whereas and which: whereas sets the electrical synapse against the chemical one, and which adds the consequence of each. These words let a single sentence weigh the two kinds of synapse.

Question 25

Your skin, eyes and ears are constantly meeting changes in the world around you, yet the brain understands only one language: the nerve impulse. Explain what a receptor is, and what is meant by transduction.

Model Answer

A receptor is a cell or nerve ending that detects a particular stimulus and changes it into a nerve impulse. Receptors are specialised, so each kind responds to one type of stimulus, such as light, sound, heat or a chemical. The change they perform, turning the energy of a stimulus into the electrical energy of a nerve impulse, is called transduction. Because the brain can read only impulses, transduction is the necessary first step that lets the body sense anything at all in its surroundings.

Examiner's Note
The marks need a receptor defined as a structure that detects a stimulus, and transduction defined as the change of that stimulus into a nerve impulse. Linking the two, that the receptor is where transduction happens, secures the answer.

Language Clinic
The point rests on the naming phrase is called and on Because. Naming the process as transduction and then saying Because the brain reads only impulses shows why the step matters, which is what the marks reward.

Question 26

An electrical microphone turns sound into an electrical signal. In a similar way, biologists call the body's receptors transducers. Explain why receptors are described as biological transducers.

Model Answer

Receptors are called biological transducers because, like any transducer, they convert energy from one form into another. A transducer changes one kind of energy into another; a microphone, for example, changes the energy of sound into an electrical signal. A receptor does the same living job: it takes the energy of a stimulus, whether light, sound, heat or pressure, and converts it into the electrical energy of a nerve impulse. Because they make this conversion inside a living body, they are called biological transducers.

Examiner's Note
The marks need the idea of energy conversion: a receptor changes the energy of the stimulus into the electrical energy of an impulse, just as a man-made transducer converts energy. The conversion, not the example, earns the mark.

Question 27

Some receptors are no more than the bare end of a single nerve cell, while others are elaborate organs. Explain how a single sensory-neurone receptor differs from a complex receptor.

Model Answer

A single sensory-neurone receptor is just one nerve cell that detects a stimulus, whereas a complex receptor is a whole sense organ built from many cells. A single-neurone receptor, such as a touch or pain ending in the skin, is a simple nerve ending that detects its stimulus and starts an impulse on its own. A complex receptor, such as the eye or the ear, contains modified receptor cells together with many supporting and accessory structures, which work together to detect the stimulus and to focus or sharpen it.

Examiner's Note
The marks turn on the contrast: one nerve cell acting alone against a sense organ of many cells. Giving an example of each, a skin ending against the eye or ear, confirms the distinction.

False Confidence Alert
Students often assume every receptor is a complex organ like the eye. Many receptors are simply the bare ending of a single neurone in the skin, and they need no organ built around them to detect their stimulus.

Question 28

The eye and the ear are not counted as simple nerve endings but as complex receptors. Explain why.

Model Answer

The eye and the ear are complex receptors because each is a sense organ of many cells, in which the actual receptor cells are helped by accessory structures. In the eye the receptor cells are the rods and cones, but they work only with the help of the lens, the iris and other parts that gather and focus light onto them. In the ear the receptor cells are sensory hair cells, helped by the ear drum, the ossicles and the cochlea that collect and pass on the sound. Because the receptor cells depend on these extra structures, the eye and the ear are complex receptors.

Language Clinic
The reason is carried by because and by the helper phrases with the help of and helped by. These words show that the receptor cells do not act alone but depend on accessory parts, which is the heart of the answer.

Question 29

Receptors are often grouped by the kind of stimulus each one detects. Name the main types of receptor classified in this way, and give the stimulus each detects.

Model Answer

Receptors are grouped by the stimulus they detect into the following main types:

1) **Mechanoreceptors:** detect mechanical forces such as touch, pressure, sound and gravity.
2) **Photoreceptors:** detect light.
3) **Thermoreceptors:** detect changes in temperature, both heat and cold.
4) **Chemoreceptors:** detect chemicals, as in smell and taste.
5) **Nociceptors:** detect pain.
6) **Osmoreceptors:** detect changes in the osmotic pressure of the body fluids.
7) **Electroreceptors:** detect electrical stimuli, mainly in aquatic animals.

Examiner's Note
The marks come from pairing each receptor with its stimulus, not merely naming the receptors. The four the examiner most expects are the mechano-, photo-, thermo- and chemoreceptors.

Question 30

A person picks up a hot cup of sweet tea in a noisy room. Several receptors are at work at once. Match each of the following to the receptor that detects it: the heat of the cup, the sweetness of the tea, the noise of the room, and the weight of the cup in the hand.

Model Answer

Each stimulus is picked up by a different type of receptor:

The heat of the cup: detected by thermoreceptors in the skin.

The sweetness of the tea: detected by chemoreceptors in the taste buds of the tongue.

The noise of the room: detected by mechanoreceptors, the sensory hair cells of the ear.

The weight of the cup: detected by mechanoreceptors, the touch and pressure endings of the skin.

> **False Confidence Alert**
> It is easy to lump everything the skin feels under one receptor. In fact the skin holds several kinds: thermoreceptors for the heat and separate mechanoreceptors for the touch and pressure of the cup, while the sweetness is not a skin sense at all but a chemical one.

Question 31

Draw a large, labelled diagram of a section of skin to show the receptors it contains. Beside each label, give what it detects.

Model Answer

A section of skin shows several receptors set at different depths, each detecting its own kind of stimulus. Their positions and roles are:

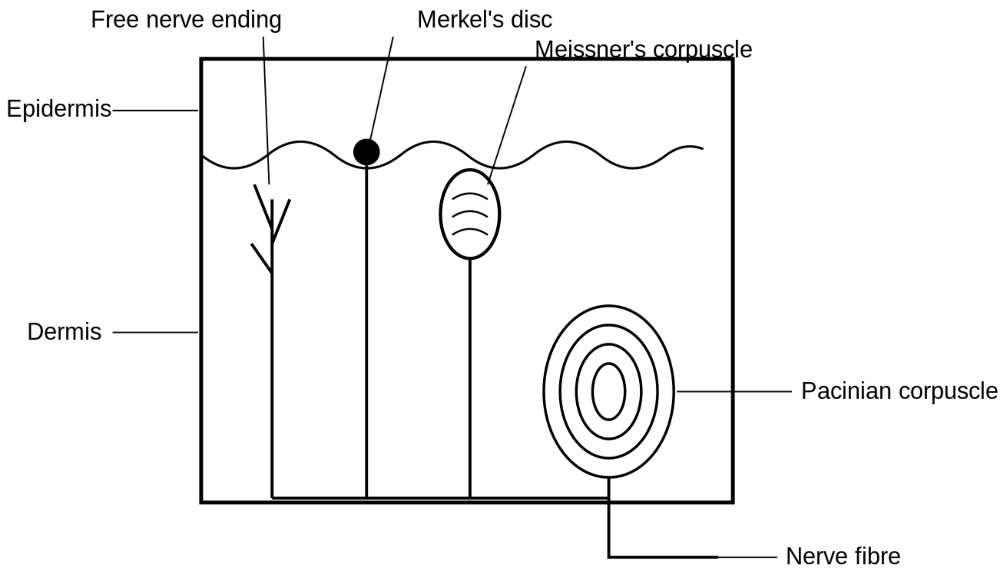


Figure 5.4: *Touch receptors in a section of skin.*

1) **Free nerve endings:** bare endings reaching up into the epidermis that detect pain and temperature.
2) **Merkel's discs:** lie near the surface and detect light, steady touch.
3) **Meissner's corpuscle:** lies just below the surface and detects light touch and gentle movement.
4) **Pacinian corpuscle:** lies deep in the dermis and detects deep pressure and vibration.

Examiner's Note
The mark-bearing labels are the free nerve endings, Merkel's discs, the Meissner's corpuscle and the Pacinian corpuscle, each shown at its correct depth. The commonest error is to draw them all at one level instead of at their different depths.

Question 32

Smell and taste both work by detecting chemicals, yet they use different receptors in different places. Explain how the receptors for smell and for taste work, and name the basic tastes the tongue can detect.

Model Answer

Smell and taste are both detected by chemoreceptors, which respond to chemicals dissolved in moisture. In smell, olfactory receptor cells high in the lining of the nose carry tiny hairs; when odour molecules in the air dissolve in the mucus and stimulate these hairs, impulses pass to the brain.

In taste, the receptors are the taste buds on the tongue, each holding sensory cells with tiny hairs that are stimulated by food and drink dissolved in saliva. The tongue detects five basic tastes: sweet, sour, salty, bitter and umami (savoury).

Examiner's Note
The marks need both senses tied to chemoreceptors, the olfactory cells in the nose and the taste buds on the tongue, and the five basic tastes named. Noting that the chemicals must first be dissolved is a useful extra point.

Question 33

A person with a heavy cold often complains that food has lost its taste, even though the tongue is working normally. Explain why smell and taste must work together to give the full flavour of food.

Model Answer

The full flavour of food comes from smell and taste working together, not from taste alone. The tongue can report only the five basic tastes, so on its own it gives a very limited picture. As food is eaten, odour molecules rise into the nose and the olfactory receptors add a far wider range of information. The brain then merges the two, and it is this combination that we experience as flavour. When a cold blocks the nose the smell input is lost, so the food seems to have little taste even though the tongue is still working.

Language Clinic
The answer is built on so and on the joining words together and combination. Saying the tongue is limited so smell must add to it, and that the brain merges the two, shows the marker you understand flavour as a joint sense.

Question 34

Receptors can also be grouped by where the stimulus they detect comes from. Explain what interoceptors, exteroceptors and proprioceptors each monitor.

Model Answer

Grouped by the source of their stimulus, receptors fall into three kinds:

Interoceptors: detect stimuli from inside the body, such as a pain or a change of blood pressure in the internal organs.

Exteroceptors: detect stimuli from outside the body, such as the light, sound, heat and chemicals picked up by the eye, ear, skin and nose.

Proprioceptors: detect the stretch of muscles and tendons, giving the body its sense of position and balance.

Examiner's Note
The marks need each kind tied to where its stimulus comes from: interoceptors from inside the body, exteroceptors from outside it, and proprioceptors from the muscles and tendons for position and balance.

Question 35

Draw a large, labelled diagram of a vertical section through the mammalian eye. Beside each label, give the part its job.

Model Answer

The eye is a hollow ball whose front parts gather and focus light, while the lining at the back turns it into nerve impulses. Its main parts and their jobs are:

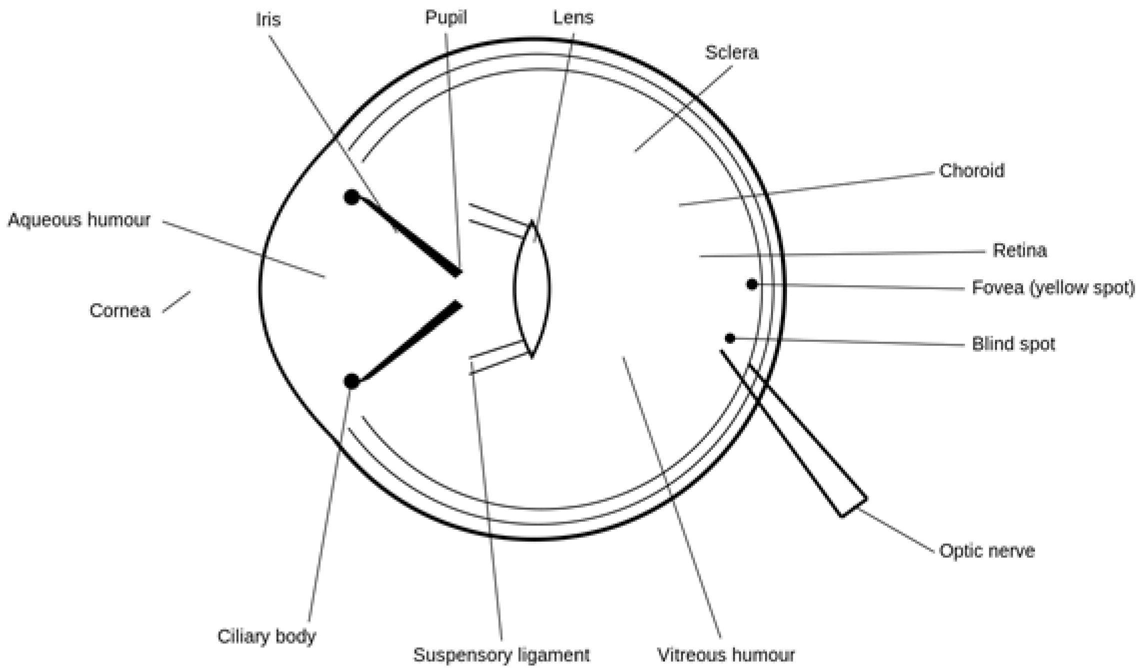


Figure 5.5: *Vertical section through the mammalian eye.*

1) **Cornea:** the clear front that lets light in and does most of the bending of the light.
2) **Iris:** the coloured ring of muscle that adjusts the size of the pupil.
3) **Pupil:** the opening that lets light through to the lens.
4) **Lens:** focuses light sharply onto the retina and changes shape to focus near or distant objects.
5) **Ciliary body and suspensory ligament:** hold the lens in place and change its shape.
6) **Aqueous and vitreous humours:** clear fluids that keep the eye in shape and let light pass through.
7) **Retina:** the light-sensitive lining carrying the rods and cones.
8) **Fovea (yellow spot):** the part of the retina with the sharpest vision.
9) **Blind spot:** where the optic nerve leaves; it carries no receptors.
10) **Optic nerve:** carries the impulses from the retina to the brain.
11) **Sclera and choroid:** the tough protective outer wall and the dark, blood-rich middle layer.

Examiner's Note
The mark-bearing labels are the cornea, iris, pupil, lens, ciliary body, suspensory ligament, retina, fovea, blind spot and optic nerve. The commonest errors are to leave out the blind spot or to draw the lens touching the cornea instead of sitting behind the iris.

Question 36

Walking from a dark room into bright sunlight, the pupil quickly becomes smaller. Explain how the iris changes the size of the pupil in bright and in dim light, and why this is useful.

Model Answer

The iris changes the size of the pupil by a reflex, using two sets of muscles, to control how much light reaches the retina. In bright light the circular muscles of the iris contract and the radial muscles relax, so the pupil becomes small and less light enters. In dim light the radial muscles contract and the circular muscles relax, so the pupil becomes wide and more light enters. This reflex is useful because it lets in enough light to see in the dark, while protecting the delicate retina from being damaged by very bright light.

Examiner's Note
The marks need both conditions with the correct muscles: circular muscles contracting in bright light to shrink the pupil, radial muscles contracting in dim light to widen it, together with the reason, adjusting the light and protecting the retina.

False Confidence Alert
Students often say the pupil grows in bright light to see better. The opposite is true: in bright light the pupil narrows to keep out excess light and protect the retina, and it widens only in dim light.

Question 37

The eye can switch from reading a book to looking at a distant hill and bring each image to a sharp focus on the retina. Explain how the eye accommodates to focus on near and on distant objects.

Model Answer

Accommodation is the way the eye changes the shape of its lens to focus light from near or distant objects sharply onto the retina. For a near object the ciliary muscles contract and the suspensory ligaments slacken, so the elastic lens becomes more rounded and fatter and bends the light strongly. For a distant object the ciliary muscles relax and the suspensory ligaments are pulled tight, so the lens is stretched thin and bends the light less. In each case the lens keeps changing shape until the image falls sharply on the retina.

Examiner's Note
The marks need both cases with the linked changes: for a near object the ciliary muscles contract, ligaments slacken and the lens fattens; for a distant object the ciliary muscles relax, ligaments tighten and the lens thins. The chain of three changes is the key.

False Confidence Alert
Students often reverse it, saying the lens becomes thinner for a near object. In fact the lens becomes fatter and more curved for a near object, to bend the light more; it is stretched thin only for distant objects.

Question 38

Draw a labelled diagram to show the main layers of the retina, and explain the path that light and the nerve signal take through it.

Model Answer

The retina is built in layers, and light has to pass through the nerve layers to reach the rods and cones at the back. Its layers and their roles are:

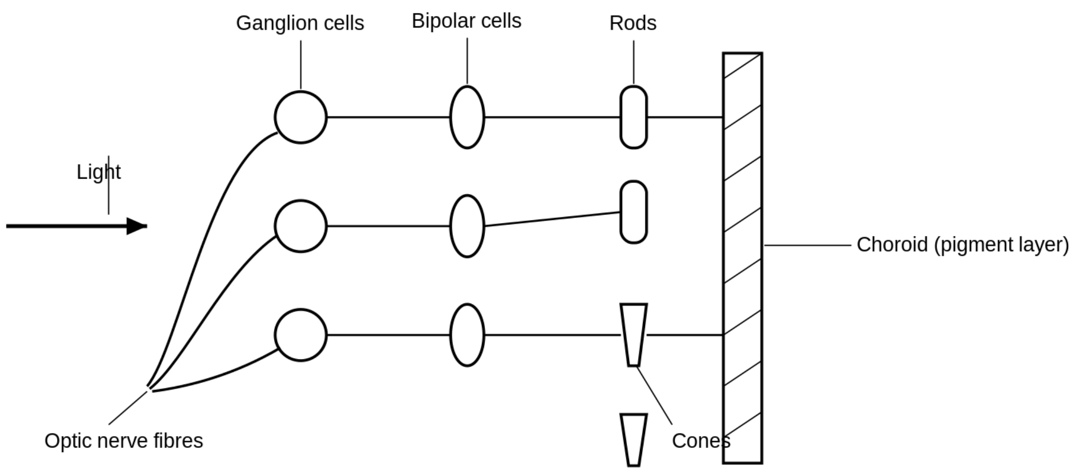


Figure 5.6: *The main layers of the retina.*

1) **Rods and cones:** the photoreceptors at the back that turn light into impulses; rods work in dim light, cones in bright light and for colour.
2) **Bipolar cells:** pass the impulse from the rods and cones on to the ganglion cells.
3) **Ganglion cells:** their long fibres gather together to form the optic nerve.

Light passes through the ganglion and bipolar layers first and reaches the rods and cones at the back. The impulse they make then travels back the other way, through the bipolar cells to the ganglion cells, and out along the optic nerve to the brain.

Examiner's Note
The mark-bearing labels are the rods and cones, the bipolar cells and the ganglion cells, in the right order, together with the optic-nerve fibres. The key point is that light reaches the photoreceptors last, after passing through the other layers.

Question 39

When light falls on a rod cell, a chemical change takes place that begins the nerve impulse for vision. Explain how the pigment in the rods responds to light and recovers in the dark.

Model Answer

The rods contain a light-sensitive pigment called rhodopsin, which is broken apart by light to start the visual impulse. Rhodopsin is made of a protein, scotopsin, joined to a light-absorbing molecule, retinene, which comes from vitamin A. When light strikes the rod, the rhodopsin breaks down into scotopsin and retinene; this change is called bleaching, and it triggers the nerve impulse. In the dark, the scotopsin and retinene join together again to reform rhodopsin, a recovery that is called dark adaptation, which is why we only slowly come to see after entering a dark room.

Examiner's Note
The marks need rhodopsin named and split into scotopsin and retinene (from vitamin A), the breakdown in light called bleaching, and the reforming in the dark called dark adaptation.

Question 40

Draw a large, labelled diagram of the mammalian ear. Beside each label, give the part its job.

Model Answer

The ear has three regions: the outer ear gathers sound, the middle ear passes it on, and the inner ear turns it into impulses and keeps the body balanced. Its main parts and their jobs are:

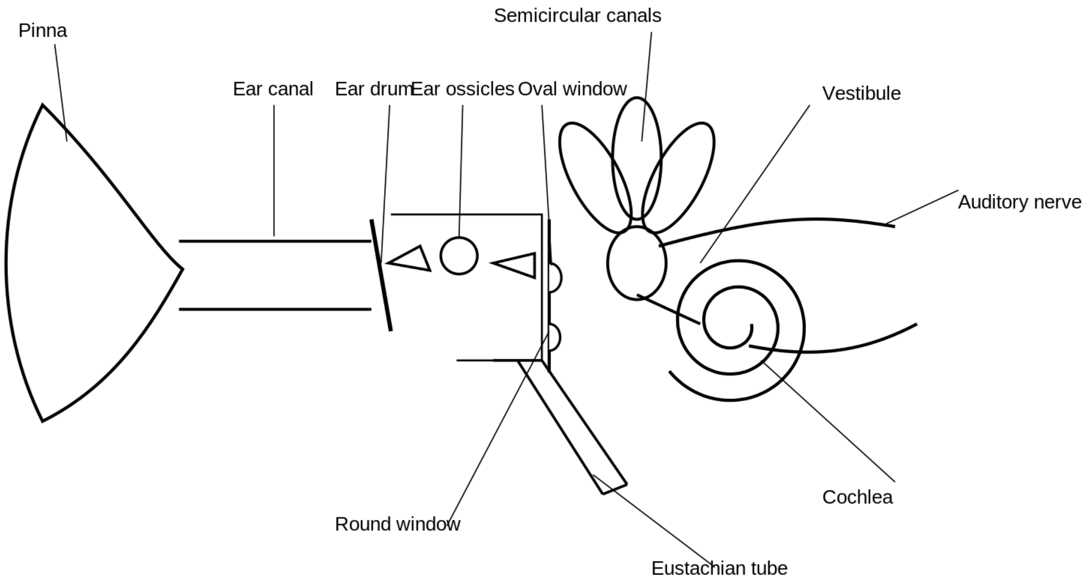


Figure 5.7: *Structure of the mammalian ear.*

1) **Pinna:** the flap that collects sound waves and directs them into the ear canal.
2) **Ear canal:** carries the sound waves inward to the ear drum.
3) **Ear drum (tympanic membrane):** vibrates when the sound waves strike it.
4) **Ear ossicles (malleus, incus, stapes):** three small bones that pass on and amplify the vibrations.
5) **Oval and round windows:** the membranes through which the vibrations enter and leave the cochlea.
6) **Eustachian tube:** links the middle ear to the throat to equalise the air pressure on the two sides of the ear drum.
7) **Cochlea:** the coiled organ of hearing, where vibrations are turned into nerve impulses.
8) **Semicircular canals:** detect movements of the head and help to keep the body balanced.
9) **Auditory nerve:** carries the impulses from the cochlea to the brain.

Examiner's Note
The mark-bearing labels are the pinna, ear canal, ear drum, the three ossicles, the oval window, the eustachian tube, the cochlea, the semicircular canals and the auditory nerve. A common error is to confuse the cochlea (hearing) with the semicircular canals (balance).

Question 41

The body has two kinds of gland, and only one kind makes the chemicals we call hormones. Explain how an endocrine gland differs from an exocrine gland, and what makes a chemical a hormone.

Model Answer

An endocrine gland is ductless and pours its secretion straight into the blood, whereas an exocrine gland releases its secretion through a duct. Endocrine glands, such as the thyroid and the pancreas, have no tubes; their products pass directly into the blood vessels around them. Exocrine glands, such as the salivary glands, carry their products along a duct to the place where they are used.

A chemical is a hormone if it is made by an endocrine gland, carried in the blood, and acts on a target some distance away. Hormones are chemical messengers: they are released in tiny amounts, travel in the bloodstream, and bring about a response in a distant organ or tissue.

Examiner's Note
The marks need the duct contrast, ductless endocrine straight into blood against ducted exocrine, and a hormone defined as a blood-borne chemical messenger acting on a distant target.

Language Clinic
The contrast rests on whereas, which sets the ductless endocrine gland against the duct-using exocrine gland in a single sentence, exactly the kind of link the examiner rewards.

Question 42

Under the microscope an endocrine gland is seen to be surrounded by an unusually rich network of blood vessels. Explain why this is so.

Model Answer

Endocrine glands are richly supplied with blood because they release their hormones directly into the bloodstream. Having no ducts, the only way their hormones can reach the rest of the body is through the blood. A dense network of capillaries around the gland lets the hormones pass quickly, and in quantity, into the circulation, so they can be carried to their target organs without delay.

Examiner's Note
The mark-bearing link is ductless, so the blood is the only route out; the rich capillary network is what carries the hormones away to their targets.

Question 43

Name the main endocrine glands of a mammal, and for each give a hormone it produces and the job that the hormone does.

Model Answer

The main endocrine glands, their hormones and their jobs are:

1) **Thyroid gland:** makes thyroxine, which controls the body's metabolic rate, growth and development.
2) **Parathyroid glands:** make parathyroid hormone, which controls the level of calcium in the blood.
3) **Adrenal glands:** make adrenaline, which prepares the body for action in the fight-or-flight response.
4) **Pancreas (islets of Langerhans):** makes insulin and glucagon, which control the level of glucose in the blood.
5) **Pineal gland:** makes melatonin, which controls daily rhythms such as sleep.
6) **Gonads (ovaries or testes):** make oestrogen or androgens, which control the secondary sexual characteristics.

Examiner's Note
The marks need each gland paired with a hormone and the job it does, not just a list of gland names. The thyroid, pancreas and adrenal glands are the ones the examiner expects first.

Question 44

In four different patients a doctor sees: a racing heart just before a race, a fall in blood glucose soon after a meal, poor growth in a child, and a low level of calcium in the blood. Name the gland and the hormone that controls each.

Model Answer

Each effect is controlled by a different gland and hormone:

The racing heart before a race: the adrenal gland, through adrenaline.

The fall in blood glucose after a meal: the pancreas, through insulin.

The poor growth in a child: the thyroid gland, through thyroxine.

The low blood-calcium level: the parathyroid glands, through parathyroid hormone.

> **False Confidence Alert**
> Many students say insulin raises the blood glucose. It is the opposite: insulin lowers blood glucose after a meal, while it is glucagon that raises it when the level falls.

Question 45

Although a hormone travels in the blood to every part of the body, it changes only certain organs, and it does so even though it is present in very tiny amounts. Explain why a hormone affects only its target, and why it is effective at such a low concentration.

Model Answer

A hormone affects only its target organ because only the cells of that organ carry the specific receptors the hormone fits. The hormone is carried everywhere in the blood, but a cell can respond only if it has the matching receptor. Cells without that receptor are not affected, so the hormone acts only where its receptors are found.

A hormone is effective at a very low concentration because it works by switching on reactions inside the target cell, rather than by being used up in them. A few molecules binding to the receptors are enough to set off a large response within the cell, so only minute amounts are needed to bring about a powerful effect.

> **Examiner's Note**
> The marks need two ideas kept apart: specificity comes from matching receptors on the target only; the low working concentration comes from the hormone triggering, not fuelling, the response.

> **Language Clinic**
> Each paragraph opens with because and closes with so: the cause is stated, then the result follows. This because and so pattern is the backbone of a mark-winning explanation.

Question 46

Hormones are often described as the body's chemical messengers. Explain why this description fits them so well.

Model Answer

A hormone is called a chemical messenger because it is a chemical that carries an instruction from the gland that makes it to the organ that must act on it. Made in one place, the endocrine gland, it travels in the blood to another place, the target organ, where it delivers its instruction and brings about a response. Like a message, it is made by a sender, carried to a receiver, and acted upon there.

> **Language Clinic**
> The point turns on the comparison Like a message and the chain made, travels and delivers. Naming a sender, a carrier and a receiver turns the phrase chemical messenger into a real explanation.

Question 47

The body keeps many of its internal conditions steady by feedback. Explain what is meant by a feedback mechanism, and how negative feedback in particular keeps a factor steady.

Model Answer

A feedback mechanism is one in which a change in a factor is detected and sets off a response that acts back on the original change. The system senses how far the factor has moved from its normal level, and the response it triggers feeds back to alter that factor again.

In negative feedback the response opposes the original change, so the factor is brought back towards its normal level. When the factor rises too high, the body acts to lower it; when it falls too low, the body acts to raise it. Because the correction always opposes the change, the factor is held steady around its set level.

> **Examiner's Note**
> The marks need a feedback loop defined as detect-then-respond, and negative feedback shown to oppose the change in both directions, so the factor is returned to normal.

> **Language Clinic**
> The loop is carried by Because and the paired when: when it rises... when it falls... Because the correction opposes the change. These words show the response always pushing back to normal.

Question 48

Using thyroxine as your example, describe how a hormone is kept at a steady level in the blood by negative feedback.

Model Answer

Thyroxine is held steady by a negative-feedback loop linking the hypothalamus, the anterior pituitary and the thyroid gland. When the level of thyroxine in the blood falls, the hypothalamus releases TRH, which makes the anterior pituitary release TSH; the TSH then makes the thyroid release more thyroxine, so the level rises again. When the level of thyroxine rises too high, it inhibits the hypothalamus and the pituitary, so less TSH is made and the thyroid slows down. In this way the level is held steady.

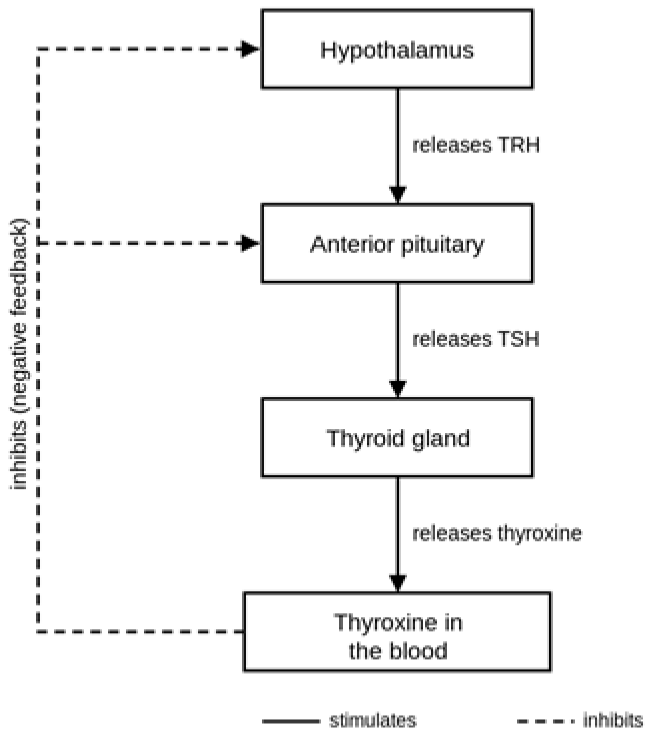


Figure 5.8: *The control of thyroxine by negative feedback.*

Examiner's Note
The marks need the chain (hypothalamus, TRH; pituitary, TSH; thyroid, thyroxine) and the return loop, that a high thyroxine level inhibits the hypothalamus and pituitary so its own production is turned down.

Question 49

The nervous system and the endocrine system do not work in isolation; they are joined at one point beneath the brain. Explain how, and where, the two control systems are linked.

Model Answer

The nervous and endocrine systems are linked at the hypothalamus and the pituitary gland, just beneath the brain. The hypothalamus is part of the brain, and so belongs to the nervous system, but it also controls the pituitary, which is an endocrine gland. It gathers information through nerves and, in response, makes the pituitary release or hold back its hormones. In this way a nervous signal is turned into a hormonal one, joining the fast nervous system to the slow endocrine system.

Examiner's Note
The marks need the place (hypothalamus and pituitary) and the link itself: the hypothalamus is nervous tissue that controls an endocrine gland, so it converts a nerve signal into a hormone signal.

Language Clinic
The link is summed up with In this way and the contrast but: the hypothalamus is part of the brain but also controls the pituitary. In this way ties the two systems together in one sentence.

Question 50

The anterior pituitary is a small gland with a large influence over the other endocrine glands. Explain how the anterior pituitary controls other glands, and what was learned when the pituitary was removed from laboratory animals.

Model Answer

The anterior pituitary controls other endocrine glands by releasing trophic hormones, which travel in the blood and make those glands secrete their own hormones. For example, thyroid-stimulating hormone (TSH) from the pituitary makes the thyroid release thyroxine, and other trophic hormones direct the adrenal cortex and the gonads.

When the pituitary was removed from laboratory animals, the glands it controlled stopped working, and the animals failed to grow, could not keep a normal body temperature, and their reproductive organs shrank. This showed that the pituitary controls a wide range of other glands and the processes they run.

Examiner's Note
The marks need trophic hormones named as the means of control, with an example such as TSH directing the thyroid, and the removal result read as proof that the pituitary governs many other glands.

Question 51

The pituitary gland is often called the master gland of the body. Explain why it has earned this name.

Model Answer

The pituitary is called the master gland because its trophic hormones control the activity of many other endocrine glands. By releasing hormones such as TSH, which directs the thyroid, and others that direct the adrenal cortex and the gonads, the pituitary sets the pace for glands all over the body. Because it governs so many other glands, it is regarded as the master of the endocrine system.

False Confidence Alert
It is wrong to think the master gland makes all the body's hormones itself, or that it runs the whole body. The pituitary directs several other glands through its trophic hormones, but it is itself controlled by the hypothalamus.

Question 52

The posterior pituitary releases two hormones, ADH and oxytocin, yet it does not make them itself. Explain how these hormones reach the body as a neuroendocrine reflex, and state what each one does.

Model Answer

ADH and oxytocin are made by nerve cells in the hypothalamus, pass down their nerve fibres to the posterior pituitary, and are released from there into the blood when nerve impulses arrive, which is a neuroendocrine reflex. Because a nervous signal triggers the release of a hormone, the response is at once nervous and hormonal, which is what the term neuroendocrine means.

ADH controls the loss of water, while oxytocin acts in birth and in the release of milk. ADH makes the kidney reabsorb more water, so that less is lost in the urine. Oxytocin makes the uterus contract during birth and squeezes milk from the breast during suckling.

Examiner's Note
The marks need the neuroendocrine route, made in the hypothalamus, released from the posterior pituitary on a nerve impulse, and a correct job for each: ADH conserves water, oxytocin acts in birth and milk release.

Language Clinic
The two roles are set side by side with while, and the joint nature is given with Because: Because a nervous signal triggers the release, the response is both nervous and hormonal.

Question 53

A plant has no brain and no nerves, yet it still responds to its surroundings. Explain how plants coordinate their activities, and why their responses are much slower than those of animals.

Model Answer

Plants coordinate their activities by chemical messengers called hormones and by changes in growth, not by nerves. A stimulus such as light or gravity causes hormones to be made and moved to where they are needed, and the plant answers by growing in a particular direction or by a change in the turgor of its cells.

Their responses are much slower than an animal's because they depend on the making, moving and action of hormones, and often on growth itself. Chemical messages travel and take effect far more slowly than the electrical impulses of a nervous system, so a plant may take hours or days to respond where an animal responds in a fraction of a second.

Language Clinic
The slowness is tied to its cause with because and so: because the plant works by hormones and growth, the message is slow, so the response takes hours or days. The link is what earns the mark.

Question 54

Some simple organisms and plant reproductive cells move bodily towards or away from a stimulus. Explain what a taxis is, the difference between a positive and a negative taxis, and give an example.

Model Answer

A taxis is a movement of a whole cell or organism towards or away from an external stimulus. It is a positive taxis when the organism moves towards the stimulus, and a negative taxis when it moves away from it. For example, *Euglena* and *Chlamydomonas* swim towards light of moderate intensity, a positive phototaxis that carries them to where they can photosynthesise.

Examiner's Note
The marks need a taxis defined as the movement of the whole organism, the positive/negative split by direction, and a named example such as the phototaxis of *Euglena*.

Language Clinic
The direction is carried by the opposite words towards and away: a positive taxis is towards the stimulus, a negative taxis away from it. Pairing them makes the difference clear in one line.

Question 55

Tactic movements are named after the stimulus that causes them. Name the main kinds of taxis, and for each give the stimulus involved.

Model Answer

The main kinds of taxis, named by their stimulus, are:

1) **Phototaxis:** movement in response to light.
2) **Chemotaxis:** movement in response to a chemical.
3) **Geotaxis:** movement in response to gravity.
4) **Aerotaxis:** movement in response to oxygen.
5) **Rheotaxis:** movement in response to a water current.

Examiner's Note
The marks come from pairing each taxis with its stimulus, not merely listing the names. Phototaxis and chemotaxis are the two the examiner expects first.

Question 56

Unlike a tropism, a nastic movement does not depend on the direction of the stimulus. Explain what a nastic movement is, and name the main kinds with the stimulus of each.

Model Answer

A nastic movement is a non-directional response of a plant part, in which the direction of the movement does not depend on the direction of the stimulus. The main kinds are:

1) **Photonasty:** a response to a change in light intensity, as in flowers that open by day and close at night.
2) **Nyctinasty:** the sleep movements of leaves and petals that fold at nightfall.
3) **Thermonasty:** a response to a change in temperature.
4) **Seismonasty (thigmonasty):** a response to touch, as in the folding leaves of the *Mimosa* plant.
5) **Chemonasty:** a response to a chemical, as when the sundew folds over an insect.

Examiner's Note
The marks need the key idea, that the response is non-directional, plus named kinds each tied to a stimulus. Tying photonasty to light and seismonasty to touch secures the examples.

False Confidence Alert
It is easy to confuse a nastic movement with a tropism. The difference is direction: a tropism grows towards or away from the stimulus, whereas a nastic movement is the same whichever way the stimulus comes from.

Question 57

The flowers of many plants open during the day and close again at night, whichever direction the light comes from. Explain why this is an example of photonasty.

Model Answer

The opening and closing of the flowers is photonasty because it is a response to the change in light intensity between day and night, and not to the direction of the light. When the light is bright by day the petals open, and when it grows dark at night they close. The petals move in the same way no matter which side the light comes from, which is what makes the movement nastic rather than a tropism. The movement itself is brought about by changes in turgor or growth on the two sides of the petals.

Examiner's Note
The marks turn on two points: the response is to the intensity of the light (day against night), and it is non-directional, the same whichever way the light falls. That is what makes it photonasty, not phototropism.

Language Clinic
The answer leans on because and the phrase no matter which side: it responds because the light changes, and it moves the same way no matter which side the light comes from. These mark the movement as non-directional.

Question 58

A tropism is a growth movement that is directed by the stimulus. Explain what a tropism is, and describe phototropism, geotropism and hydrotropism.

Model Answer

A tropism is a growth movement of part of a plant in a direction set by the direction of the stimulus, brought about by the uneven spread of the hormone auxin. The three common tropisms are:

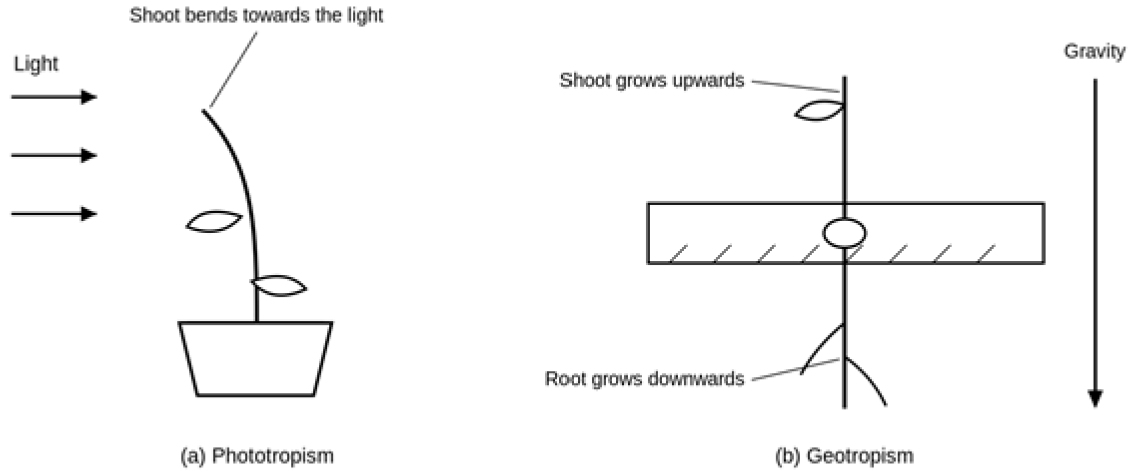


Figure 5.9: *Tropisms - (a) phototropism and (b) geotropism.*

1) **Phototropism:** growth in response to the direction of light; a shoot grows towards the light.
2) **Geotropism:** growth in response to gravity; a root grows downwards and a shoot grows upwards.
3) **Hydrotropism:** growth in response to water; a root grows towards the moisture in the soil.

Examiner's Note
The marks need a tropism defined as directional growth caused by auxin, then each named tropism tied to its stimulus and the direction of growth. Naming auxin as the cause lifts the answer.

Question 59

In a young seedling the shoot grows up towards the light while the root grows down into the soil. Explain why the shoot is positively phototropic, and why the root is positively geotropic.

Model Answer

The shoot is positively phototropic, growing towards the light, because it must reach the light in order to photosynthesise. By bending towards the light, the shoot brings its leaves into the best position to trap sunlight and make the food on which the whole plant depends.

The root is positively geotropic, growing downwards, because it must anchor the plant and reach water and minerals in the soil. By growing down with gravity, the root fixes the plant firmly in the ground and grows towards the water and mineral salts it needs, which lie deeper in the soil.

Examiner's Note
The marks need each direction tied to its benefit: the shoot grows to light for photosynthesis, the root grows down for anchorage and for water and minerals. The reason, not just the direction, earns the mark.

Language Clinic
Each paragraph is built on because and By: the part grows a certain way because of a need, and By growing that way it gains the benefit. This because-then-benefit pattern is the heart of the answer.

Question 60

Plants make their own chemical messengers that control how they grow. Explain what a plant hormone is, and give the features that set plant hormones apart.

Model Answer

A plant hormone, or phytohormone, is a chemical made within the plant that controls its growth and development and is active in very small amounts. Plant hormones share several features: each is made in one part of the plant and moved to another part where it acts; they work even at extremely low concentrations; and a single hormone usually produces several different effects, which may overlap with the effects of the others.

Examiner's Note
The marks need a plant hormone defined as a growth-controlling chemical made by the plant and active in tiny amounts, plus a distinguishing feature such as being made in one place and acting in another.

Question 61

A plant hormone made in one part of the plant must reach the part where it acts. Explain the ways in which plant hormones are moved within the plant.

Model Answer

Plant hormones are carried from where they are made to where they act in several ways:

1) **Localised movement:** passing slowly from cell to cell over short distances.
2) **Cytoplasmic streaming:** carried within the moving cytoplasm inside the cells.
3) **Slow diffusion:** spreading gradually through the tissue down a concentration gradient.
4) **Through the vascular tissue:** carried in the xylem and phloem to reach distant parts of the plant.

Examiner's Note
The marks need more than one named route, with the vascular tissue (xylem and phloem) recognised as the way hormones reach distant parts. Naming the routes, not just saying they move, earns the marks.

Question 62

There are five main groups of plant hormone, each with a job it is best known for. Name the five groups, and give the main effect of each.

Model Answer

The five main groups of plant hormone and their best-known effects are:

1) **Auxins:** promote cell elongation and the bending of shoots towards light.
2) **Gibberellins:** promote stem elongation and the germination of seeds.
3) **Cytokinins:** promote cell division.
4) **Ethene (ethylene):** promotes the ripening of fruit.
5) **Abscisic acid (ABA):** inhibits growth and brings on dormancy.

Examiner's Note
The marks need all five groups named correctly and each tied to its main effect. The contrast between the four growth promoters and ABA, the one inhibitor, is worth showing.

Question 63

Plant hormones are often called plant growth regulators. Explain why this name suits them.

Model Answer

Plant hormones are called growth regulators because their main work is to control the growth and development of the plant, speeding it up or slowing it down. Some, such as the auxins and gibberellins, promote growth, while others, such as abscisic acid, hold it back. Because they regulate growth in both directions rather than simply driving it, the name growth regulator describes them better than the term growth promoter.

Language Clinic
The reason rests on because and the contrast while: because they control growth both ways, and some promote while others inhibit. These words show regulation, not mere promotion, which is the point of the name.

Question 64

Plant hormones rarely act alone; they often work together or against one another. Explain what is meant by synergism and by antagonism, giving an example of each.

Model Answer

Synergism is when two hormones work together, so that their combined effect is greater than either would produce alone. For example, auxins and gibberellins act together to bring about the elongation of a stem.

Antagonism is when two hormones work against one another, so that one opposes the effect of the other. For example, auxins promote apical dominance, the growth of the main shoot tip, while cytokinins oppose it by encouraging the side buds to grow.

Examiner's Note
The marks need the two ideas kept apart: synergism, where hormones add to each other, and antagonism, where one opposes the other, each backed by a worked example.

Language Clinic
The two ideas are carried by the opposite words together and against, with while marking the opposition. Naming the partners (auxin with gibberellin; auxin against cytokinin) turns the terms into real biology.

Question 65

Auxin is the best-known plant hormone, with several effects on growth. Outline the main roles of auxin in a plant.

Model Answer

The main roles of auxin in a plant are:

1) **Cell elongation:** it makes cells grow longer, so the shoot lengthens.
2) **The phototropic response:** it brings about the bending of shoots towards light.
3) **Apical dominance:** it keeps the main shoot growing while holding back the side buds.
4) **Root growth:** it promotes the growth of roots, including roots from stem cuttings.

Examiner's Note
The marks reward several distinct roles, each stated as an effect on growth: elongation, phototropism, apical dominance and rooting. A bare mention of growth without these specific roles scores less.

Question 66

When light shines on a shoot from one side, the shoot bends towards the light. Explain how auxin brings this about.

Model Answer

Auxin makes the shoot bend towards the light by collecting on the shaded side and making the cells there grow longer. Auxin is made at the tip of the shoot. When light comes from one side, the auxin moves away from the lit side towards the shaded side. The extra auxin on the shaded side makes those cells elongate more than the cells on the lit side, so the shaded side grows faster. Because one side grows faster than the other, the shoot bends over towards the light.

Examiner's Note
The marks need the chain: auxin made at the tip, moved to the shaded side, greater cell elongation there, so the shaded side grows faster and the shoot bends to the light. The redistribution of auxin is the key point.

Language Clinic
The cause is carried by so and Because: the shaded side grows faster, so the shoot bends, Because one side grows faster than the other. These links turn a description of auxin into an explanation of the bending.

Question 67

Gibberellins are growth hormones that are widely used by farmers. Outline the main roles of gibberellins in a plant.

Model Answer

The main roles of gibberellins in a plant are:

1) **Stem elongation:** they make stems grow longer, and can restore normal height to genetically dwarf plants.
2) **Seed germination:** they start germination by mobilising the food stored in the seed for the growing embryo.
3) **Flowering:** they promote flowering in some plants.

Examiner's Note
The marks reward the distinct roles, stem elongation (including the reversal of dwarfism), germination, and flowering, each stated as an effect. Linking germination to the seed's food store strengthens the answer.

Question 68

Cytokinins are plant hormones closely linked to the youngest, most active parts of a plant. Outline the main roles of cytokinins.

Model Answer

The main roles of cytokinins in a plant are:

1) **Cell division:** they promote the division of cells, especially in growing seeds and fruits.
2) **Delaying ageing:** they slow the ageing of leaves, keeping them green and fresh for longer.
3) **Lateral bud growth:** they encourage the side buds to grow, opposing the apical dominance caused by auxin.

> **Examiner's Note**
> The marks reward cell division as the central role, plus the delaying of leaf ageing and the encouragement of side buds. Noting that cytokinins oppose auxin in bud growth shows the hormones interacting.

Question 69

Unlike the other plant hormones, ethene is a gas. State how ethene is formed, and outline its main effects in a plant.

Model Answer

Ethene is unusual among plant hormones in being a gas; it is formed from the amino acid methionine and is released by ripening fruit and by ageing parts of the plant. Its main effects are:

1) **Ripening fruit:** it speeds up the ripening of fruit, and is used to ripen fruit for market.
2) **Leaf and fruit fall:** it helps ageing leaves and fruit to drop, and inhibits the growth of side buds.
3) **Flowering:** it brings on flowering in some plants, such as the pineapple.

> **Examiner's Note**
> The marks need the unusual feature (a gas, made from methionine) together with at least two effects, ripening being the one the examiner expects first.

> **False Confidence Alert**
> Students sometimes refuse to count ethene as a hormone because it is a gas. It is a true plant hormone: it is made by the plant, acts in very small amounts, and controls ripening and the fall of leaves and fruit.

Question 70

Abscisic acid (ABA) is known as the plant's stress hormone, and it works against the growth-promoting hormones. Explain why ABA is called a stress hormone, and outline its main effects.

Model Answer

ABA is called a stress hormone because it is made in larger amounts when the plant is under stress, such as drought, and it acts to protect the plant by slowing its growth. It is a growth inhibitor, working against the growth-promoting hormones such as auxin and gibberellin.

Its main effects are to bring on dormancy, to make leaves and fruit fall, and to close the stomata when conditions are dry. By closing the stomata when water is short, ABA cuts down the loss of water and helps the plant to survive the drought.

> **Examiner's Note**
> The marks need the reason for the name (made under stress, slows growth to protect the plant) and its key effects: dormancy, abscission and the closing of stomata in drought.

Language Clinic
The point rests on because and By: ABA is named a stress hormone because it rises under stress, and By closing the stomata it saves water. These links tie the name to what the hormone actually does.

REAL QUESTIONS

These questions take the ideas of this chapter into real situations in health, farming and everyday Tanzanian life. Work each one, then check the model answer; the bold opening is the mark-bearing point and the boxes show what wins and loses marks.

Question 71

When you touch a hot pan you snatch your hand away even before you feel the pain. Name, in order, the three kinds of neurone that carry the message from the skin to the arm muscle, and give the role of each.

Model Answer

The message passes along three neurones in turn, from the skin to the muscle:

1) **The sensory (afferent) neurone:** carries the impulse from the pain receptor in the skin to the spinal cord.
2) **The relay (intermediate) neurone:** lies within the spinal cord and passes the impulse from the sensory neurone to the motor neurone.
3) **The motor (efferent) neurone:** carries the impulse from the spinal cord out to the arm muscle, the effector, which contracts to pull the hand away.

The message is dealt with in the spinal cord and acted upon before it reaches the brain, which is why the hand is pulled away before the pain is actually felt.

Examiner's Note
The marks need the three neurones in the right order and the role of each, with the impulse running from receptor, through the spinal cord, to the effector.

Language Clinic
The journey is carried by in turn and the direction words from the skin to the spinal cord and out to the muscle. Setting the neurones in the order the impulse travels makes one clear pathway.

Question 72

A learner examines three neurones under the microscope. The first has a long dendron and a short axon; the second is small, with short fibres, and lies entirely within the spinal cord; the third has short dendrites and a long axon. Identify each neurone, and state the direction in which it carries impulses.

Model Answer

Each neurone can be named from its shape and the direction it carries impulses:

The first is a sensory (afferent) neurone: it carries impulses towards the central nervous system.

The second is a relay (intermediate) neurone: it carries impulses within the central nervous system, between the sensory and the motor neurones.

The third is a motor (efferent) neurone: it carries impulses away from the central nervous system to an effector.

Examiner's Note
The marks come from naming each neurone and tying it to a direction: sensory in to the centre, relay across within it, motor out to the effector.

False Confidence Alert
It is tempting to say that any neurone with a long fibre must be a sensory neurone. Both sensory and motor neurones have a long fibre; they are told apart by which fibre is long and by the direction the impulse travels.

Question 73

A boda-boda rider brakes the instant a child runs into the road. Explain how the motor neurone that carries the order to his leg muscles is built so that the impulse travels fast enough for such a quick response.

Model Answer

The motor neurone is built for speed: it carries the impulse rapidly along one long fibre that is wrapped in a myelin sheath. Its long axon runs without a break from the spinal cord to the leg muscle, so the impulse does not have to cross extra cells on the way. The axon is wrapped in a myelin sheath broken by nodes of Ranvier, so the impulse leaps from node to node by saltatory conduction. Because it travels this way, and because a wide axon carries it with little resistance, the order reaches the muscle in a fraction of a second.

Examiner's Note
The marks need features tied to speed: a long unbroken axon, the myelin sheath with nodes of Ranvier giving saltatory conduction, and a wide axon. Naming saltatory conduction lifts the answer.

Language Clinic
Speed is explained with so and Because: the axon is unbroken so the impulse is not delayed, and Because it leaps between nodes it travels fast. These links turn structure into the reason for speed.

Question 74

Kipanga writes: *'A nerve and a neurone are just two names for the same thing, and a nerve impulse is simply electricity flowing along a wire inside the body.'* Identify and correct the two mistakes in his statement.

Model Answer

First, a nerve and a neurone are not the same thing: a neurone is a single nerve cell, whereas a nerve is a bundle of many neurone fibres bound together. So one nerve contains the fibres of a great many neurones, not just one.

Second, a nerve impulse is not electricity flowing along a wire; it is a wave of depolarisation that the neurone makes along its own membrane. The impulse is brought about by ions crossing the membrane and is regenerated at each point as it travels, rather than running through the cell like current through a metal wire.

Language Clinic
Each correction uses not...whereas and not...it is to set the wrong idea against the right one. Naming the error and then giving the correct version in the same sentence is what the marks reward.

Question 75

In leprosy the nerves in the hands and feet are damaged, and the person loses the sense of touch and of pain in those parts. Explain why this loss of feeling is dangerous.

Model Answer

The loss of feeling is dangerous because the damaged sensory neurones can no longer carry warnings of harm from the skin to the central nervous system. Pain and heat are normally detected by receptors in the skin and reported by the sensory neurones. When these neurones are damaged, the person feels no pain from a burn, a cut or a sharp stone, so injuries happen without being noticed, and the wounds are left untreated and grow worse.

Examiner's Note
The marks need the broken pathway, the sensory neurones can no longer warn the CNS, linked to the consequence: unfelt burns and injuries that go untreated.

Language Clinic
The danger is carried by because and so: because the warning cannot reach the centre, the person feels nothing, so injuries pass unnoticed. The chain of cause and effect is the point being marked.

Question 76

An impulse can cross a synapse in one direction only, from the pre-synaptic to the post-synaptic neurone. Give the factors that ensure this one-way transmission.

Model Answer

Transmission across a synapse is kept one-way by several features of its structure:

1) **The vesicles are on one side only:** the synaptic vesicles holding the neurotransmitter are found only in the pre-synaptic knob, so the transmitter can be released only on that side.
2) **The receptors are on the other side only:** the receptors that bind the neurotransmitter are found only on the post-synaptic membrane, so only that side can receive it.
3) **The neurotransmitter diffuses one way:** it crosses the cleft from the pre-synaptic to the post-synaptic side, and never back.
4) **The pre-synaptic side cannot receive:** it has no receptors, so the message cannot run backwards along the pathway.

Examiner's Note
The marks turn on the vesicles being on one side and the receptors on the other, so the transmitter can only be released by, and received on, opposite sides. That one point secures the direction.

Question 77

At a synapse the nervous system can do more than simply pass on an impulse. Explain how each of the following is brought about at a synapse: amplification, summation and inhibition.

Model Answer

A synapse can strengthen, add up or block a signal, in the following ways:

Amplification: weak but repeated impulses each release a little neurotransmitter, which builds up until there is enough to fire the post-synaptic neurone, so a weak signal is strengthened.

Summation: the small effects of several impulses, arriving close together in time or from several neurones at once, are added together until they reach the threshold and fire an impulse.

Inhibition: some synapses release a transmitter that makes the post-synaptic membrane harder to depolarise, so the impulse is held back instead of being passed on.

Examiner's Note
The marks need each effect tied to the neurotransmitter: amplification by building it up, summation by adding several inputs to reach threshold, and inhibition by a transmitter that makes firing harder.

Question 78

A myelinated axon and a wide (giant) axon both carry impulses faster than a thin, unmyelinated one. Explain why each conducts so quickly.

Model Answer

A myelinated axon is fast because the impulse leaps from one node of Ranvier to the next, instead of moving along every point of the membrane. This saltatory conduction skips the insulated stretches, so far fewer regions of membrane have to be depolarised and the impulse covers the distance more quickly.

A wide (giant) axon is fast because its greater diameter offers less resistance to the local electric currents that drive the impulse forward. The currents spread more easily along a thick axon, so the region ahead is brought to its threshold sooner and the impulse moves on faster.

Examiner's Note
The marks need each cause kept distinct: myelin gives saltatory conduction (leaping between nodes), while a wide axon lowers the resistance to the local currents. Two different reasons, both correct.

Language Clinic
Each paragraph runs on because and so: it is fast because of a feature, so the impulse moves quicker. Keeping myelination and diameter in separate paragraphs stops the two reasons from blurring.

Question 79

A nerve impulse travels in two quite different ways: along the length of a neurone, and across the synapse between two neurones. Compare how transmission happens in these two places.

Model Answer

Along a neurone, the impulse travels as an electrical wave of depolarisation passing down the membrane. Ions cross the membrane and the action potential is regenerated point after point, so the signal stays electrical and travels very fast.

Across a synapse, the impulse is carried by a chemical neurotransmitter that diffuses across the gap. The electrical impulse cannot leap the cleft, so it is turned into a chemical message and then back into an electrical one in the next neurone, which is slower but lets the signal be controlled.

Examiner's Note
The marks need the core contrast: electrical and self-regenerating along the axon, but chemical (a diffusing transmitter) across the synapse, with a consequence such as speed or control.

Language Clinic
The contrast is carried by Along... Across... and by so: along the neurone it is electrical, so it is fast; across the synapse it is chemical, so it is slower but controllable.

Question 80

No neurotransmitter is released at a synapse until calcium ions enter the pre-synaptic knob. Explain why calcium ions are essential for an impulse to cross a synapse.

Model Answer

Calcium ions are essential because they are the trigger that makes the synaptic vesicles release their neurotransmitter. When the impulse reaches the knob it opens calcium channels, and calcium ions flow in. The rise in calcium makes the vesicles move to the pre-synaptic membrane and empty their transmitter into the cleft. Without this inflow of calcium the vesicles stay shut, no transmitter is released, and the impulse cannot cross to the next neurone.

Examiner's Note
The marks need calcium named as the trigger for vesicle release: the impulse lets calcium in, the calcium makes the vesicles fuse and release transmitter. No calcium, no crossing.

Language Clinic
The point rests on because and Without: calcium matters because it triggers release, and Without it nothing is released. The pair shows calcium to be the necessary trigger, not just a detail.

Question 81

A farmer sprays an organophosphate pesticide without protection and soon suffers muscle twitching and difficulty in breathing. These pesticides block the enzyme acetylcholinesterase at the synapse. Explain, in terms of the synapse, why blocking this enzyme makes him ill.

Model Answer

Blocking acetylcholinesterase makes him ill because the neurotransmitter is no longer broken down, so it goes on firing the muscles without stopping. Normally acetylcholinesterase destroys the acetylcholine soon after it has acted, which resets the synapse for the next impulse. When the pesticide blocks the enzyme, the acetylcholine stays on the receptors and keeps triggering impulses, so the muscles are stimulated again and again. This causes the twitching, and when the breathing muscles are kept contracted it causes the difficulty in breathing.

Examiner's Note
The marks need the role of the enzyme (to break down the transmitter and reset the synapse) and the result of blocking it: transmitter left on the receptors, so the muscle is fired continuously.

False Confidence Alert
It is easy to think the pesticide kills the nerve cells. It does not: it blocks the enzyme that clears the transmitter, so the synapse is over-stimulated rather than killed, and the muscles are fired without rest.

Question 82

Kipanga says: *'A hard knock must send a bigger and faster impulse along the nerve than a gentle touch does.'* Put right the mistake in his statement.

Model Answer

Kipanga is wrong: every impulse in a given fibre is the same size and travels at the same speed, however hard or gentle the stimulus. By the all-or-nothing law, once the stimulus passes the threshold a full-sized impulse fires, and a stronger stimulus cannot make it any bigger or faster. Instead, a hard knock fires impulses more often and excites more fibres at once, and it is this greater frequency and number that the brain reads as a stronger stimulus.

Language Clinic
The correction turns on however and Instead: the impulse is the same however hard the knock; Instead, strength is shown by frequency. These words replace the wrong idea with the right one.

Question 83

Two learners disagree. **Kipanga** says *the impulse crosses the synapse as an electric spark that jumps the gap*. **Kipute** says *it crosses as a chemical that drifts across*. Judge which learner is right, and explain.

Model Answer

Kipute is right: at an ordinary synapse the impulse crosses as a chemical, not as an electric spark. The electrical impulse cannot leap the cleft. Instead it makes the pre-synaptic knob release a neurotransmitter, which diffuses across the gap and binds to receptors on the far side, starting a fresh impulse there. So Kipanga is wrong to picture a spark; the gap is bridged by a chemical messenger, although a few rare electrical synapses do pass a current directly.

Language Clinic
The verdict is carried by Instead and So: the spark cannot jump, Instead a chemical is released, So Kipute is right. Naming who is right and giving the reason is what the judgement question rewards.

Question 84

A child whose diet is short of vitamin A finds it hard to see in dim light, a condition called night blindness. Using what you know about the rods, explain why a lack of vitamin A causes this.

Model Answer

A lack of vitamin A causes night blindness because the rods can no longer make enough of their light-sensitive pigment, rhodopsin. Rhodopsin is built from a protein, scotopsin, joined to retinene, which the body makes from vitamin A. The rods are the cells that let us see in dim light, and they work by breaking down rhodopsin when light falls on them. When vitamin A is short, too little retinene is made, so too little rhodopsin is formed, and the rods can no longer respond to the faint light of dusk or night.

Examiner's Note
The marks need the chain: vitamin A makes retinene, retinene makes rhodopsin, and the rods need rhodopsin to work in dim light. Break the chain at vitamin A and night vision fails.

Language Clinic
The cause runs on because and so: the rods fail because rhodopsin cannot be made, so dim-light vision is lost. Following the shortage step by step is what earns the marks.

Question 85

By day you see the world in full colour, but at dusk colours fade and you see mostly in shades of grey. Explain this change in terms of the rods and cones.

Model Answer

The change happens because colour vision depends on the cones, which work only in bright light, while at dusk only the rods are still working. The cones, packed at the centre of the retina, need bright light and give us sharp, coloured vision by day. The rods are far more sensitive and work in dim light, but they cannot tell one colour from another. So as the light fades the cones stop responding and only the rods are left, which is why at dusk we still see shapes, but in shades of grey rather than in colour.

Language Clinic
The contrast is carried by because, while and so: colour fails because cones need bright light, while rods see in the dim, so only grey shapes remain. These links hold the comparison together.

Question 86

Walking from bright sunshine into a dark room, your pupils widen at once, yet you still cannot see properly for a short while. Explain why the pupils widen, and why you cannot see clearly straight away.

Model Answer

The pupils widen because, in the dim room, the radial muscles of the iris contract and the circular muscles relax, opening the pupil to let in as much of the little light as possible. This is the pupil reflex, which controls the amount of light reaching the retina.

You still cannot see clearly at first because the rods need time to rebuild their rhodopsin, a recovery called dark adaptation. In the bright sunshine the rhodopsin in the rods had been bleached away; in the dark it slowly reforms, and only as it builds up can the rods respond to the faint light, so vision improves after a few minutes.

Examiner's Note
The marks need two separate points: the pupil reflex (radial muscles contract, pupil widens) to let in more light, and dark adaptation (rhodopsin reforming in the rods) to explain the delay in seeing.

Language Clinic
Each paragraph opens with because, giving a cause for each effect: the pupil widens because of the muscles, and sight returns because the rhodopsin reforms. Keeping them apart stops the two ideas from blurring.

Question 87

In a NECTA question a student is asked what makes the retina such an efficient detector of light. Explain the features of the retina that make it work so well.

Model Answer

The retina works so well because it carries two kinds of receptor suited to different conditions, with a special region for the sharpest vision. It holds rods, which are very sensitive and let us see in dim light, and cones, which work in bright light and give colour. At the fovea, the yellow spot, the cones are packed most densely, giving the sharpest vision just where the image falls. Many rods share one nerve fibre, which makes them even more sensitive in dim light, while each cone has almost its own fibre, which keeps cone vision sharp. Together these features let the retina work from the faint light of night to bright sunshine, and pick out both fine detail and colour.

Examiner's Note
The marks reward the division of labour, sensitive rods for dim light and colour cones for bright, plus the fovea for sharpness. Mentioning the sharing of fibres by rods is a strong extra point.

Question 88

The eye is often compared to a camera. Explain how the eye captures an image, matching its main parts to those of a camera.

Model Answer

The eye captures an image in the same way as a camera, by letting in a controlled amount of light, focusing it, and recording it on a light-sensitive surface. Light enters through the clear cornea, which does most of the bending of the light, and then the pupil, whose size is set by the iris just as a camera's aperture is set. The lens then focuses the light, as a camera's lens does, throwing a small, upside-down image onto the retina at the back, which acts like the film or sensor of a camera. The rods and cones of the retina record the image and turn it into nerve impulses, which the optic nerve carries to the brain, where the picture is finally seen the right way up.

Examiner's Note
The marks come from matching parts to jobs: cornea and pupil/iris let light in (the aperture), the lens focuses, and the retina records the image (the film). Noting that the image is inverted and corrected by the brain lifts the answer.

Language Clinic
The comparison is carried by in the same way as and just as and as: the eye works in the same way as a camera, the iris sets the light just as an aperture does. These phrases keep the match clear.

Question 89

The inner ear does two very different jobs, both carried out by the fluid-filled membranous labyrinth. Explain the part the membranous labyrinth plays in hearing, and the part it plays in balance.

Model Answer

In hearing, the cochlea of the membranous labyrinth turns sound vibrations into nerve impulses. Vibrations passed in through the oval window set the fluid in the cochlea moving, and this bends the sensory hair cells of the organ of Corti, which send impulses along the auditory nerve to the brain, where they are heard as sound.

In balance, the semicircular canals and the vestibule detect movement and the position of the head. When the head moves, the fluid in the semicircular canals lags behind and bends the sensory hairs there, while granules in the vestibule press on hairs according to the position of the head; both send impulses to the brain, which uses them to keep the body balanced.

Examiner's Note
The marks need the two jobs kept apart: the cochlea for hearing (vibrations to impulses) and the semicircular canals and vestibule for balance (movement and head position).

Language Clinic
The two roles are set side by side with When and while: When the head moves the canals respond, while the vestibule reports its position. Keeping them in separate paragraphs stops hearing and balance from mixing.

Question 90

A child who spins round and round and then stops suddenly feels dizzy, as though still turning. Explain why, in terms of the inner ear.

Model Answer

The dizziness happens because the fluid in the semicircular canals keeps moving for a moment after the body has stopped. While the child spins, the endolymph in the semicircular canals swirls round and bends the sensory hairs, telling the brain that the head is turning. When the child stops, the fluid does not stop at once but keeps swirling for a few seconds, so it goes on bending the hairs; the brain still receives turning signals even though the body is now still, and reads this as dizziness.

Examiner's Note
The marks need the lag of the fluid: the endolymph keeps moving after the body stops, so it still bends the hairs and the brain is still told the head is turning.

Language Clinic
The cause runs on because and so: dizziness because the fluid keeps moving, so the hairs are still bent. The link between the lagging fluid and the false sense of turning is the point.

Question 91

Kipanga says: '*We see because the lens makes the picture, and the picture that lands on the retina is already the right way up.*' Put right the two mistakes in his statement.

Model Answer

First, the lens is not where most of the focusing happens: most of the bending of the light is done by the cornea, and the lens only fine-tunes the focus. The lens does change shape to focus on near and distant objects, but it is the cornea that does the greater part of the bending of the light.

Second, the image on the retina is not the right way up; it is upside-down. The lens throws an inverted image onto the retina, and it is the brain that turns the picture the right way up, so what actually lands on the retina is upside-down.

Language Clinic
Each correction uses not and it is to set the wrong idea against the right one: the lens is not the main focuser; the image is not upright, it is inverted. Naming the error and the correction together earns the marks.

Question 92

Two learners argue at lunch. **Kipanga** says *we taste food entirely with the tongue*. **Kipute** says *the nose helps as well*. Judge which learner is right, and explain.

Model Answer

Kipute is right: we taste food with the tongue and the nose working together, not with the tongue alone. The taste buds of the tongue can report only the five basic tastes: sweet, sour, salty, bitter and umami. As we eat, smells rise into the nose and the olfactory receptors add a far wider range of information, and the brain combines the two into what we call flavour. This is why food seems to lose its taste when a cold blocks the nose, so Kipanga is wrong to leave smell out.

Examiner's Note
The marks need the verdict (Kipute right) backed by the reason: the tongue gives only five basic tastes, while smell adds the rest, and the brain combines them into flavour.

Language Clinic
The judgement turns on not...alone and so: taste is not the work of the tongue alone, so Kipanga is wrong. The cold-blocked-nose example is the proof that clinches it.

Question 93

Coordination in a mammal is shared between the nervous system and the endocrine system. Give five ways in which nervous coordination differs from hormonal coordination.

Model Answer

Nervous and hormonal coordination differ in the following ways:

1) **Speed:** nervous coordination is very fast, whereas hormonal coordination is slow.
2) **Means of the message:** the nervous system sends electrical impulses, whereas the endocrine system sends chemical hormones.
3) **Route taken:** impulses travel along neurones, whereas hormones travel in the blood.
4) **How long it lasts:** nervous responses are brief, whereas hormonal responses last much longer.
5) **Where it acts:** a nerve impulse acts on one precise place, whereas a hormone may act widely on several organs.

Examiner's Note
The marks come from paired differences, not single facts: each point must say how the nervous side compares with the hormonal side. Speed and the electrical-against-chemical contrast are the two the examiner expects first.

Question 94

Just before a big race, an athlete's heart pounds, her breathing quickens and she feels ready for action. Explain how the hormone adrenaline brings about these changes, and why they are useful.

Model Answer

Adrenaline, released from the adrenal glands, prepares the body for sudden action in the fight-or-flight response. It makes the heart beat faster and harder, widens the airways so that breathing quickens, and causes the liver to release glucose into the blood.

These changes are useful because they rush more oxygen and glucose to the muscles, ready for hard effort. With the heart pumping fast and plenty of fuel and oxygen reaching the muscles, the athlete is primed to run as hard as she can.

Examiner's Note
The marks need adrenaline named from the adrenal glands and at least two of its effects (faster heart, quicker breathing, glucose released), tied to the purpose: getting oxygen and glucose to the muscles.

Language Clinic
The purpose is given with because and so: the changes help because they feed the muscles, so the body is ready for action. Linking each change to action is what lifts the answer.

Question 95

After a meal the level of glucose in the blood rises, yet in a healthy person it is soon brought back to normal. Explain how insulin and glucagon keep the blood glucose steady, and what goes wrong in a person with diabetes.

Model Answer

Insulin and glucagon, both from the pancreas, hold the blood glucose steady by acting against one another. When the glucose level rises after a meal, the pancreas releases insulin, which makes the liver and muscles take up glucose and store it as glycogen, so the level falls. When the level drops too low, the pancreas releases glucagon, which makes the liver turn glycogen back into glucose, so the level rises again.

In a person with diabetes the pancreas makes too little insulin, or the body cannot respond to it, so the high blood glucose is not brought down. The glucose level stays dangerously high after meals, and some glucose is lost in the urine, because without enough insulin the body cannot store the excess away.

Examiner's Note
The marks need the opposing pair: insulin lowers glucose by storing it as glycogen, glucagon raises it, and diabetes explained as a failure of insulin so the level is not controlled.

False Confidence Alert
It is commonly believed that diabetes is caused simply by eating too much sugar. The real fault is in the control: the pancreas does not make enough insulin, or the body cannot use it, so the blood glucose cannot be brought down.

Question 96

On a hot day, when a person sweats a great deal and drinks little, the body still manages to save water. Explain the part played by the hormone ADH.

Model Answer

ADH saves water by making the kidney return more water to the blood instead of losing it in the urine. When the blood loses water and becomes too concentrated, more ADH is released from the pituitary. ADH makes the kidney tubules hold back more water, so more is reabsorbed into the blood and only a little, concentrated urine is passed. In this way the body keeps its water until the person can drink again.

Language Clinic
The control runs on When, so and In this way: When the blood is concentrated more ADH is released, so more water is saved, and In this way the body is protected. These links show a response that answers a need.

Question 97

In some areas where the soil and food are short of iodine, people may develop a swelling of the thyroid gland in the neck, called a goitre. Explain why a lack of iodine makes the thyroid swell, and how it affects the body.

Model Answer

The thyroid swells because, without enough iodine, it cannot make enough thyroxine, and the pituitary keeps urging it to try. Thyroxine contains iodine, so when iodine is short the gland cannot make its normal amount. The pituitary senses the low thyroxine and sends out more and more TSH to stimulate the thyroid, and this constant stimulation makes the gland grow larger and larger, forming the goitre.

The shortage of thyroxine also slows the body down, because thyroxine controls the metabolic rate. With too little thyroxine the body's processes run slowly, so the person may feel tired, cold and sluggish, and in a child growth and development may be held back.

Examiner's Note
The marks need the loop: no iodine, so little thyroxine, so the pituitary sends more TSH, so the thyroid enlarges; plus the effect of low thyroxine, a slowed metabolism.

Language Clinic
The cause is carried by because and so: the gland swells because the pituitary keeps stimulating it, and the body slows because thyroxine is low. Following the shortage through each step is the point.

Question 98

Kipanga says: 'Hormones are carried to the organs they control along the nerves, which is how they reach them so fast.' Put right the mistakes in his statement.

Model Answer

First, hormones are not carried along the nerves; they are carried in the blood. An endocrine gland releases its hormone straight into the bloodstream, and the blood carries it all round the body to the organs it acts on.

Second, hormones do not act fast; they are slow compared with nerve impulses. Because they travel in the blood and work by chemical change, hormonal responses take much longer to appear than the fast, electrical responses of the nervous system.

Language Clinic
Each correction uses not...they are to set the wrong idea against the right one: hormones are not carried by nerves, they are carried in blood; they are not fast, they are slow. Naming both errors plainly is what the marks reward.

Question 99

Two learners disagree. Kipanga says that because the nervous system is so fast, the body does not really need the slow hormones at all. Kipute says the hormones do jobs the nerves cannot. Judge which learner is right, and explain.

Model Answer

Kipute is right: the body needs both systems, because each is suited to jobs that the other cannot do. The nervous system is best for fast, short-lived responses to sudden events, such as snatching the hand from a hot pan. But many of the body's needs call for slow, widespread and long-lasting control, such as growth, the steady level of blood glucose and the balance of water, and these are the work of the hormones. So Kipanga is wrong: the hormones are not a poor substitute for nerves but do a different and necessary job.

Examiner's Note
The marks need the verdict (Kipute right) supported by the division of labour: nerves for fast brief responses, hormones for slow, widespread and lasting control such as growth and blood-sugar balance.

Language Clinic
The judgement runs on because, But and So: both are needed because each has its own work, But the slow jobs are the hormones', So Kipanga is wrong. The contrast carries the verdict.

Question 100

In a classic experiment, oat coleoptiles (young shoots) are lit from one side. Explain each of these results in terms of auxin:

(a) a coleoptile with its tip cut off does not bend;
(b) a coleoptile whose tip is covered with an opaque cap does not bend;
(c) an untouched coleoptile bends towards the light.

Model Answer

All three results are explained by auxin, which is made at the tip of the coleoptile and controls how the cells below it grow:

(a) **With the tip cut off, the coleoptile does not bend:** because the tip is where auxin is made, so once it is removed there is no auxin to make the cells below elongate.
(b) **With the tip covered, the coleoptile does not bend:** because the covered tip cannot sense which side the light is on, so the auxin spreads evenly and both sides grow the same.
(c) **Left uncovered and lit from one side, the coleoptile bends towards the light:** because the auxin gathers on the shaded side and makes those cells elongate more, so the shoot curves towards the light.

Examiner's Note
The marks turn on two ideas: auxin is made in the tip (so no tip, or a covered tip, means no uneven growth), and auxin gathers on the shaded side to make the shoot bend to the light.

Language Clinic
Each result is explained with because and so: it does not bend because there is no auxin gradient, and it bends because auxin builds on the shaded side so that side grows faster.

Question 101

A potted plant on a windowsill grows bent towards the window. When the pot is turned round, the plant slowly bends the other way. Explain these movements.

Model Answer

The plant bends towards the window because it grows towards the light, a positive phototropism brought about by auxin. Light reaches the plant mainly from the window on one side, so auxin gathers on the shaded side of the stem and makes those cells elongate more, and the stem curves towards the light. When the pot is turned, the side that was shaded becomes the lit side, so the auxin now builds up on the new shaded side, and the plant slowly bends the other way to face the window once more.

Examiner's Note
The marks need phototropism named and explained by auxin gathering on the shaded side; the turning of the pot is then explained by the shaded side changing, so the bend reverses.

Language Clinic
The movement is carried by because and so: it bends because it grows to light, so when the pot turns and the shaded side changes, the bend changes too.

Question 102

The leaves of the *Mimosa* plant fold up quickly when they are touched. Explain what kind of movement this is, how it happens, and how it may help the plant.

Model Answer

This is a nastic movement called seismonasty (or thigmonasty): a response to touch that is the same whichever direction the touch comes from. It happens by a sudden change in turgor. When a leaf is touched, water moves out of the cells at the base of the leaflets, so those cells lose their firmness and the leaflets fold together.

The folding may help the plant by protecting it from harm. A sudden collapse of the leaves may startle or shake off a feeding insect, and may make the plant look smaller and less tempting to a grazing animal.

Examiner's Note
The marks need the movement named as nastic (seismonasty) and non-directional, the mechanism given as a turgor change at the leaf base, and a sensible protective value.

Language Clinic
The mechanism is carried by When and so: When the leaf is touched water leaves the cells, so the leaflets fold. Tying the touch to the turgor change is the key link.

Question 103

Kipanga says: *'A plant bends towards the light because it can sense the light and decides to move its stem that way, just as an animal moves a limb.'* Put right the mistakes in his statement.

Model Answer

First, a plant does not decide or choose to move; it has no nervous system and cannot sense or think as an animal does. The bending is a response controlled by the hormone auxin, not a decision made by the plant.

Second, the plant does not move its stem like an animal moving a limb; the bend is caused by uneven growth. Auxin makes the cells on the shaded side grow longer than those on the lit side, so the stem grows into a curve. It is growth, not muscle movement, that turns the shoot towards the light.

Language Clinic
Each correction uses not and it is to set the wrong idea against the right one: the plant does not decide, and it is growth, not a chosen movement, that bends the stem.

Question 104

Farmers and gardeners make use of synthetic auxins in two very different ways. Explain how synthetic auxins are used to root cuttings, and how they are used to stop fruit dropping too early.

Model Answer

Synthetic auxins are used to root cuttings by making new roots grow quickly from a cut stem. When the base of a cutting, such as a cassava stem, is treated with a synthetic auxin like IBA or NAA, the auxin makes roots grow fast from the stem, so the cutting becomes a new plant. This is a quick way to multiply a useful plant, and each new plant is identical to its parent.

Synthetic auxins are also used to stop fruit dropping before it is ready to pick. Sprayed onto a fruit tree, the auxin holds the fruit on the branch by preventing the abscission that would make it fall, so the crop can be left to grow until harvest time.

Examiner's Note
The marks need each use tied to the auxin: rooting, where it makes roots grow from a cutting, and fruit retention, where it prevents the abscission that causes early fruit fall.

Question 105

In an experiment, gibberellin was added to germinating seeds, and the seedlings grew much taller than the untreated ones. Explain the effects of gibberellin on the seed and the seedling.

Model Answer

Gibberellin makes seeds germinate and seedlings grow tall by setting off the use of the seed's food store and by lengthening the stems. It starts germination by making the seed produce enzymes that break down its stored food, giving the embryo the sugars it needs to grow. It then makes the stem cells elongate, so the seedling grows tall, and it can even restore normal height to plants that would otherwise be dwarf. In this way the treated seedlings shoot up far taller than the untreated ones.

Examiner's Note
The marks need both effects: gibberellin starts germination by mobilising the seed's food store (through enzymes), and it lengthens the stem by making cells elongate, giving the taller seedling.

Language Clinic
The result is carried by so and In this way: it lengthens the cells so the seedling grows tall, and In this way the treated plants overtake the rest. The links join the cause to the taller seedling.

Question 106

A fruit trader picks her mangoes while they are still hard and green, then treats them with ethene a few days before selling. Explain how ethene helps her sell ripe fruit at the right time.

Model Answer

Ethene helps because it speeds up the ripening of the fruit, so the trader can control when the mangoes become ripe. Mangoes can be picked and carried to market while hard and green, when they travel well and are not easily bruised. A few days before sale, treating them with ethene gas starts the ripening: the fruit softens, sweetens and changes colour. In this way she can have ripe, attractive fruit ready exactly when she needs to sell, instead of the whole load ripening at once.

Language Clinic
The use is carried by so and In this way: ethene speeds ripening so the timing can be chosen, and In this way ripe fruit is ready for sale. The links tie the hormone to the trader's purpose.

Question 107

Agriculture employs most Tanzanians, and plant hormones can help to raise what the land produces. Outline several ways in which synthetic plant hormones can help to increase crop production.

Model Answer

Synthetic plant hormones can raise crop production in several ways:

1) **Rooting cuttings:** synthetic auxins make cuttings of crops such as cassava root quickly, multiplying good plants fast.
2) **Killing weeds:** selective auxin weed killers destroy broad-leaved weeds in cereal fields without harming the crop.
3) **Setting and holding fruit:** auxins help fruit to set and stop it dropping before harvest, so more is gathered.
4) **Ripening for market:** ethene ripens fruit evenly and at the time the farmer chooses to sell.
5) **Better germination:** gibberellins break seed dormancy and speed up germination, giving an even, vigorous crop.

Examiner's Note
The marks reward several distinct, named uses, each tied to a hormone and to a gain for the farmer, rather than a vague statement that hormones help plants grow.

Question 108

A farmer sprays a hormone weed killer over his maize field. The broad-leaved weeds die, but the maize is unharmed. Explain why the weed killer kills the weeds but spares the maize.

Model Answer

The weed killer is a synthetic auxin that kills the broad-leaved (dicot) weeds but not the narrow-leaved (monocot) maize, because the two kinds of plant take it up and respond differently. At a high dose the auxin throws the broad-leaved weeds into uncontrolled, fatal growth, and their wide leaves catch much of the spray. The maize, a cereal with narrow, upright leaves, catches far less and does not respond in the same way, so the weeds die while the crop grows on. This lets the farmer clear the weeds without hoeing every plant by hand.

Examiner's Note
The marks need the selective action: the auxin kills broad-leaved dicot weeds but not the narrow-leaved monocot cereal, partly because the weeds catch and respond to more of it.

False Confidence Alert
It is easy to assume a hormone weed killer must kill every plant it lands on. A selective auxin weed killer does not: it kills broad-leaved weeds but leaves narrow-leaved cereals such as maize, rice and wheat unharmed.

Question 109

Two traders argue at the market. Kipanga says fruit ripened with ethene is unnatural and should be avoided. Kipute says ethene only speeds up what the fruit would do anyway. Judge which trader is right, and explain.

Model Answer

Kipute is right: ethene only speeds up the plant's own natural ripening, rather than doing anything unnatural to the fruit. Ethene is the very hormone that ripening fruit makes for itself, so adding a little simply brings on the same softening, sweetening and change of colour a bit sooner. The fruit ripens by its own normal process, and nothing foreign is forced into it. So Kipanga is wrong to call it unnatural, though, as with any treatment, it should be used in the right amount.

Language Clinic
The verdict is carried by so and though: ethene is the fruit's own hormone, so speeding ripening is natural, though it must be used sensibly. The contrast settles the judgement.

HOT QUESTIONS

These questions go further: they ask you to put ideas together, to weigh evidence, and to reason about situations you may not have met before. The difficulty is in the thinking, not in obscure facts. Work each one, then check the model answer; the bold opening is the mark-bearing point and the boxes show what wins and loses marks.

Question 110

Predict what would happen to a mammal whose nervous system was severely damaged, and explain your answer.

Model Answer

A mammal with a severely damaged nervous system would lose its rapid coordination and would soon be unable to survive on its own. Without a working nervous system it could not detect stimuli or respond to them quickly: it would not feel pain or danger, could not move its muscles to escape or to feed, and could not control automatic actions such as breathing and heartbeat. Because the nervous system links the senses to the muscles and organs, its loss would leave the body unable to act as one, and the animal would soon die.

Examiner's Note
The marks come from reasoning from the system's job to the consequences: no detection, no rapid response, no control of vital actions, so the body can no longer act as a whole.

Question 111

The neurone is one of the most oddly shaped cells in the body: very long, thin, branched at the ends and often insulated. Explain how each of these features suits the neurone to its job of fast signalling.

Model Answer

Every unusual feature of the neurone serves its one job, carrying messages quickly over a distance. It is very long so that a single cell can carry an impulse all the way from one part of the body to another without handing it on. Its dendrites are branched so that it can gather signals from many other cells at once. It is insulated by a myelin sheath so that the impulse leaps between the nodes and travels faster, and so that it does not leak away to neighbouring cells. In short, the strange shape is exactly what fast, reliable signalling demands.

Language Clinic
The form is tied to the function with so that, used again and again: it is long so that the message travels far, branched so that it gathers many inputs, insulated so that it leaps and does not leak. Each so that turns a feature into a reason.

Question 112

The nervous system is fast and precise. Evaluate whether a mammal could be fully coordinated by its nervous system alone, without any hormones.

Model Answer

A mammal could not be fully coordinated by the nervous system alone, because some kinds of control are better suited to hormones. The nervous system is excellent for fast, brief and pin-pointed responses, such as moving a single muscle. But many of the body's needs are slow, widespread and long-lasting, such as growth, the control of blood sugar over hours, and the changes of puberty over years. These are best managed by hormones carried in the blood to many organs at once. So although the nervous system is vital, the mammal also needs the endocrine system to handle the slow and the widespread.

Examiner's Note
The marks need a clear verdict (no) backed by the division of labour: nerves for fast, brief, local control, hormones for slow, widespread, long-lasting control, so both are needed.

Language Clinic
The judgement is carried by because, But and So: it cannot manage alone because some control suits hormones, But those jobs are slow and widespread, So both systems are needed.

Question 113

It seems strange that a fast nervous pathway should be interrupted by a slow chemical synapse. Evaluate what the synapse gives the body that makes it worth the delay.

Model Answer

The synapse is worth its small delay because it gives the nervous system control that a continuous nerve could not. Because the message must be handed on by a chemical, the synapse makes the impulse travel one way only, so signals cannot run backwards. It also lets the body filter out weak signals, add several inputs together before acting, and choose whether to excite or to inhibit the next cell. In this way the synapse turns a simple relay into a point of decision, and the slight delay is a small price for that control.

Examiner's Note
The marks need the synapse judged worthwhile because of what it allows: one-way flow, filtering, summation and the choice to excite or inhibit. The delay is weighed against this gain.

Language Clinic
The case is built with Because, so and In this way: Because the link is chemical the flow is one-way, so weak signals can be filtered, and In this way the synapse becomes a point of control.

Question 114

A certain poison binds to the receptors on the post-synaptic membrane so that the neurotransmitter can no longer fit them. Predict the effect of this poison on the body, and explain why.

Model Answer

The poison would stop impulses crossing the affected synapses, so the body would be paralysed at those points. Normally the neurotransmitter released into the cleft binds to the receptors and starts a new impulse in the next neurone or in a muscle. If the receptors are blocked, the transmitter is still released but can no longer act, so no fresh impulse is fired. Messages from the nervous system can then no longer reach the muscles, which cannot be made to contract, and the affected part is paralysed; if the breathing muscles are involved, the poison may be fatal.

Examiner's Note
The marks come from the broken step: with the receptors blocked the transmitter cannot act, so no new impulse forms and the muscle cannot be stimulated, giving paralysis.

Question 115

An impulse could in principle spread both forwards and backwards along an axon. Explain how the refractory period, on its own, makes sure the impulse travels in one direction only.

Model Answer

The refractory period keeps the impulse one-way because the stretch of axon just behind the impulse has briefly become unable to fire again. As the impulse moves forward, the region it has just left is in its refractory period: its sodium channels are inactivated and it cannot be re-excited for a short time. So when the active region depolarises its neighbours, only the region ahead, which is still at rest, can respond; the region behind cannot. The impulse is therefore driven forwards only, and cannot turn back on itself.

Examiner's Note
The marks need the link between the refractory region behind and the one-way flow: the region just passed cannot fire again, so only the resting region ahead is excited.

Language Clinic
The reasoning runs on because, So and therefore: it is one-way because the region behind is refractory, So only the region ahead responds, and the impulse therefore moves forward only.

Question 116

If every impulse in a nerve fibre is exactly the same size, how can the body tell a faint sound from a loud one? Explain how the strength of a stimulus is coded.

Model Answer

Because the all-or-nothing law keeps every impulse the same size, the body cannot signal a stronger stimulus with a bigger impulse; instead it uses the frequency of impulses and the number of fibres firing. A louder sound makes a sensory neurone fire its identical impulses more often, and it also sets off a greater number of neurones at once. The brain reads a rapid stream of impulses in many fibres as a strong stimulus, and a slow trickle in a few fibres as a weak one. In this way a code of fixed-size impulses can still carry every shade of strength.

Examiner's Note
The marks need the key reconciliation: since impulse size is fixed, strength must be carried by frequency and by the number of fibres recruited, which the brain reads as intensity.

Language Clinic
The answer turns on Because, instead and In this way: Because the size is fixed, strength is shown instead by frequency, and In this way intensity is still coded. The links resolve the puzzle in the question.

Question 117

In some diseases the myelin sheath around the neurones is gradually destroyed. Predict how this would affect the working of the nervous system, and explain why.

Model Answer

Destroying the myelin would slow or block the impulses, so the body's responses would become slow, weak or fail altogether. The myelin sheath normally insulates the axon and lets the impulse leap quickly from node to node. Without it the impulse can no longer leap but must creep along every point of the membrane, so it travels far more slowly, and in places may die out before reaching the end. Messages between the brain and the muscles would then arrive late or not at all, so movement, sensation and coordination would all be impaired.

Examiner's Note
The marks need the loss of saltatory conduction: without myelin the impulse cannot leap, so it slows or fails, and messages reach the muscles late or not at all.

False Confidence Alert
It is tempting to think the impulse runs inside the myelin, so losing it would stop the impulse outright. In fact the impulse leaps between the bare nodes; without myelin it still travels, but slowly and unreliably, creeping along the whole membrane.

Question 118

The eye is often said to work exactly like a camera. Evaluate how far this comparison holds, and where it breaks down.

Model Answer

The comparison holds for the basics of forming an image, but it breaks down because the eye is a living, adjusting organ in ways a camera is not. Like a camera, the eye controls the light entering it, with the iris and pupil acting as the aperture, focuses that light with a lens, and records an upside-down image on a light-sensitive surface, the retina, like a camera's film. But the likeness ends there: the eye focuses by changing the shape of its lens, not by moving it; its retina is alive, repairs itself and adjusts its sensitivity from bright sun to near darkness; and what it forms is not a finished picture but a pattern of impulses the brain must interpret. So the camera is a useful first comparison, yet the eye does far more than any camera.

Examiner's Note
The marks need a balanced judgement: where the analogy fits (aperture, lens, film) and where it fails (living lens that changes shape, self-adjusting retina, brain interpretation). A one-sided answer scores less.

Language Clinic
The evaluation is balanced with Like, But and So: Like a camera in the basics, But unlike it in being alive and adjusting, So the comparison only goes so far. The contrast words weigh the two sides.

Question 119

On a moonlit night you can see shapes but not colours, and a faint star is easier to see if you look slightly to one side of it. Explain, in terms of the rods, why night vision works like this.

Model Answer

Night vision depends on the rods, which are very sensitive but give no colour and lie away from the centre of the retina. Many rods feed into one nerve fibre, so their small responses are pooled into a signal large enough to register in dim light; this pooling is also why the rods cannot show colour or fine detail. Because the rods lie spread around the retina rather than packed at the fovea, a faint star is seen better when its light falls a little to one side of the centre, onto the rods, instead of onto the cone-packed fovea. So at night we see in grey, and slightly off-centre.

Examiner's Note
The marks reward linking the rod features to the observations: pooling of many rods gives sensitivity but no colour, and the rods being off-centre explains why faint things are seen better to one side.

Question 120

After an illness a person becomes completely deaf in one ear, yet has no trouble with balance. Predict which parts of the inner ear have been damaged and which have been spared, and explain.

Model Answer

The cochlea of that ear must have been damaged, while the semicircular canals and the vestibule have been spared. Hearing is the work of the cochlea, which turns sound vibrations into impulses, so if the person is deaf the cochlea, or its nerve, is no longer working. Balance is the separate work of the semicircular canals and the vestibule, which detect movement and the position of the head; since the person's balance is unaffected, these parts must still be working. So damage limited to the cochlea explains deafness without any loss of balance.

Examiner's Note
The marks need the two jobs separated and matched to the symptom: deafness points to the cochlea, while intact balance shows the semicircular canals and vestibule are unharmed.

Language Clinic
The reasoning is carried by while, since and So: the cochlea is hit while balance is spared, since balance is unaffected the canals work, So the damage is limited to the cochlea.

Question 121

A mammal carries many different kinds of receptor, each detecting only one sort of stimulus. Evaluate whether having so many separate receptors is worth the cost to the animal.

Model Answer

Having many separate receptors is well worth the cost, because together they give the animal a full and reliable picture of its surroundings and of its own body. Each receptor is specialised for one stimulus, so it can be very sensitive to that stimulus and turn it accurately into impulses, which a single all-purpose receptor could not do. Together the different receptors let the animal sense light, sound, heat, touch, chemicals and its own internal state, and answer each appropriately, which greatly improves its chances of finding food, escaping danger and keeping its balance. The cost of building and feeding them is small beside the survival they buy.

Language Clinic
The judgement turns on because and so: the receptors are worth it because each is specialised, so each is accurate and the set covers every kind of stimulus. The cost is then weighed against the gain.

Question 122

Predict the wide-ranging effects on the body if the pituitary gland were removed, and explain why one small gland has such large effects.

Model Answer

Removing the pituitary would upset many parts of the body at once, because the pituitary controls several other endocrine glands. Through its trophic hormones the pituitary directs the thyroid, the adrenal cortex and the gonads, and it also drives growth and, through ADH, water balance. Without it the thyroid would make too little thyroxine, so metabolism would slow; growth would stop; the reproductive organs would not develop; and the body could not control its water. Because one gland sets so many others to work, the loss of that single gland disturbs the whole body, which is why it is called the master gland.

Examiner's Note
The marks need the master-gland logic: the pituitary controls many other glands through trophic hormones, so removing it shuts down thyroid, growth, reproduction and water balance together.

Language Clinic
The wide effect is explained with because and so: because the pituitary controls many glands, removing it slows the thyroid, so metabolism falls, and growth and reproduction fail too. One cause, many effects.

Question 123

Most feedback in the body is negative, yet the release of oxytocin during birth is a positive feedback. Explain the difference between the two, and why positive feedback is useful in birth.

Model Answer

In negative feedback a change is opposed and the body is brought back to normal, whereas in the positive feedback of birth a change is made to grow stronger still. As the baby presses on the neck of the uterus, oxytocin is released, which makes the uterus contract harder, which presses the baby down more, which releases yet more oxytocin; so the effect builds up instead of being damped down.

Positive feedback is useful here because birth must be driven quickly to a finish, not held steady. The build-up of stronger and stronger contractions delivers the baby and then stops once the birth is over, so a self-strengthening loop is exactly what this moment needs, unlike the steady balance that negative feedback keeps elsewhere.

Examiner's Note
The marks need the contrast (negative opposes a change, positive amplifies it) and the reason positive feedback suits birth: it must build to completion, then end, rather than hold a steady level.

Language Clinic
The contrast rests on whereas and because: negative feedback steadies, whereas the birth loop amplifies, and it is useful because birth must be pushed to a finish. The pairing makes the difference plain.

Question 124

The nervous system and the endocrine system are usually described as two separate systems. Evaluate whether they are truly separate, or are better seen as working as one.

Model Answer

Although the two differ in how they work, they are so closely joined that they are better seen as one coordinating system acting in two ways. They do differ: one sends fast electrical impulses, the other slow chemical hormones. But they meet and work together at the hypothalamus and the pituitary, where a nervous signal makes a gland release a hormone, a neuroendocrine reflex. The hypothalamus, part of the brain, controls the pituitary, the master endocrine gland, so the two are linked at the very top. Because they share this control and constantly affect each other, it is fairer to call them two arms of one coordinating system than two systems with no connection.

Language Clinic
The evaluation is carried by But, so and Because: the systems differ, But they meet at the hypothalamus, so a nerve signal becomes a hormone, and Because they share control they act as one.

Question 125

A person who gets a sudden fright jumps at once, then feels shaky and on edge for several minutes afterwards. Explain why the response has a fast part and a slow part, naming the system behind each.

Model Answer

The instant jump is the work of the nervous system, which acts in a fraction of a second. Nerve impulses travel at once from the sense organs to the muscles, so the body reacts immediately, before there is even time to think.

The shaky, on-edge feeling that lasts for minutes is the work of the hormone adrenaline, which acts more slowly but lasts far longer. Adrenaline released into the blood keeps the heart pounding and the body tense for some time after the fright, because a hormone in the blood is cleared away only gradually. So the fast nervous response and the slower hormonal one together make up the whole reaction.

Examiner's Note
The marks need the two parts matched to the two systems: the instant jump to fast nerve impulses, and the lasting unease to adrenaline, slow to clear from the blood.

Language Clinic
The two parts are linked with so, because and So: nerves act so the jump is instant, adrenaline lingers because it clears slowly, So the reaction has a fast part and a slow part.

Question 126

Both a tropism and a nastic movement are responses of a plant, yet only one of them moves in a direction set by the stimulus. Explain the difference between them, and why only the tropism depends on the direction of the stimulus.

Model Answer

The difference is that a tropism is a directional growth movement, whereas a nastic movement is non-directional; only the tropism is shaped by where the stimulus comes from. In a tropism the plant grows towards or away from the stimulus, because the response works by uneven growth: auxin gathers on one side and makes that side grow more, so the direction of the bend is set by the direction of the stimulus.

In a nastic movement the response is a change in turgor or growth that is the same whichever way the stimulus comes from, as when a flower opens by day and closes at night; the stimulus only switches the movement on, it does not steer it. So only the tropism is directional, because only it is driven by an uneven, side-dependent growth.

Examiner's Note
The marks need the core distinction, directional growth (tropism) against non-directional response (nastic), and the reason: a tropism bends because growth is uneven on the side the stimulus reaches, while a nastic movement is merely switched on.

Language Clinic
The contrast is carried by whereas, because and so: a tropism is directional whereas a nastic movement is not, because only the tropism grows unevenly, so only it is steered by the stimulus.

Question 127

A potted seedling is laid on its side in the dark and left for a few days. Predict how its shoot and its root will grow, and explain why.

Model Answer

The shoot will turn and grow upwards, away from gravity, because it is negatively geotropic. Auxin gathers on the lower side of the shoot and makes those cells grow longer, so the shoot curves upward and lifts its tip away from the pull of gravity, even in the dark where there is no light to guide it.

The root will turn and grow downwards, towards gravity, because it is positively geotropic. In the root the auxin that gathers on the lower side slows the growth there instead of speeding it, so the upper side grows faster and the root curves downward, driving its tip down into the soil.

Examiner's Note
The marks need both predictions with the auxin reason, and the key subtlety that the same auxin makes the shoot's lower side grow more but slows the root's lower side, so they bend in opposite directions.

Language Clinic
Each paragraph runs on because and so: the shoot rises because it is negatively geotropic, so it bends up, while the root grows down because the lower-side auxin slows it, so the upper side grows faster.

Question 128

Auxin can make a shoot grow yet, at a higher dose, can kill a weed; and it makes the main shoot grow while holding back the side buds. Explain how a single hormone can have such opposite effects.

Model Answer

A single hormone can have opposite effects because its action depends on its concentration and on the tissue that receives it. At a low concentration auxin promotes the elongation of shoot cells, but at a high concentration it upsets growth so badly that it can kill a plant, which is how a selective weed killer works. In the same way, the auxin coming from the shoot tip promotes the growth of the main shoot yet suppresses the side buds below it, the effect called apical dominance. So the same chemical can speed up, slow down or even kill growth, according to how much is present and which part of the plant receives it.

Language Clinic
The puzzle is resolved with because, but and So: the effects differ because dose and tissue differ; a little promotes growth but a lot kills, So one hormone can act in opposite ways.

Question 129

A farmer growing tomatoes wants them to germinate evenly, to set a good crop of fruit, and to ripen together for market. Suggest how different plant hormones could help at each stage, and explain.

Model Answer

Different hormones can help at each stage: gibberellin at germination, auxin at fruit set, and ethene at ripening. At sowing, treating the seed with gibberellin breaks any dormancy and gives an even, vigorous germination, so the plants come up together. As the plants flower, a synthetic auxin can help the flowers to set fruit and can stop the young fruit dropping too early, so more tomatoes reach maturity. Finally, the picked tomatoes can be ripened together with ethene a few days before sale, so the whole crop is ready for market at one time. In this way hormones help the farmer from sowing right through to selling.

Examiner's Note
The marks reward a hormone matched to each stage with its effect: gibberellin for even germination, auxin for fruit set and retention, and ethene for ripening together at the chosen time.

Question 130

Synthetic plant hormones can clearly help farmers. Evaluate whether they are an unmixed blessing for the small-scale Tanzanian farmer, or whether they bring drawbacks too.

Model Answer

Synthetic plant hormones are a great help, but they are not an unmixed blessing, because they bring costs and risks alongside their benefits. On the benefit side, they let a small farmer do more with less: they root cuttings quickly, clear weeds without endless hoeing, set and hold fruit, and ripen a crop together for market, all of which can raise the yield and the income from a small plot.

On the other side, they also bring real drawbacks. They cost money the farmer may not have; they must be used in the right amount and at the right time, or they can harm the very crop they are meant to help; and careless use can endanger the user's health and the soil. So they are a powerful tool, but a blessing only when the farmer has the knowledge and the means to use them well.

Examiner's Note
The marks need a genuine evaluation: clear benefits (higher yield, less labour) weighed against real drawbacks (cost, need for skill and correct dose, health and soil risks), ending in a balanced verdict.

Language Clinic
The two sides are balanced with but, On the other side and So: they help, but they cost and carry risk; On the other side stands the danger of misuse, So they are a blessing only when used well.

Chapter 6

NUTRITION

BINDER QUESTIONS

Work through each question in order: attempt it on paper, then check the model answer beneath. The bold opening of every answer is the mark-bearing point; the notes in the boxes show how the marks are won and lost.

Question 1

A maize plant in a field and the person who eats its grain both depend on nutrition to stay alive. Explain what is meant by nutrition, and why no living organism can survive without it.

Model Answer

Nutrition is the taking in of food and its use by an organism for energy, for growth and for the repair of its body. It is one of the basic characteristics of life, because every living cell needs a steady supply of materials and energy to stay alive and keep working.

Food supplies the energy that drives every life process. Movement, transport across membranes and the building of new cytoplasm are all powered by energy released from food, so a body cut off from food soon fails.

Food also supplies the raw materials for growth and repair. A young organism builds new tissue from the substances in its food, and a worn or damaged part is mended from the same source.

Examiner's Note
The mark rewards both halves together: the taking in of food and its use for energy, growth and repair. Naming one without the other drops it.

False Confidence Alert
It is easy to write that nutrition is just eating. Yet eating is only the intake; the marks lie in the use of that food for energy, growth and repair.

Question 2

A green maize plant and a mushroom growing on a rotting log are both feeding, yet biologists place them in opposite nutritional groups. Distinguish between autotroph and heterotroph, and explain why a fungus is a heterotroph even though it neither moves nor hunts.

Model Answer

An autotroph makes its own food from simple inorganic raw materials such as carbon dioxide and water. Using an outside energy source, either light or chemical energy, it builds these into complex food, so a green plant feeds itself without taking in any ready-made food.

A heterotroph cannot make its own food and must take it in ready-made from other organisms. It feeds on the bodies or products of other living things, whereas an autotroph builds from raw materials; animals, fungi and most bacteria all feed in this way.

A fungus is a heterotroph because it cannot build food from inorganic raw materials, not because of the way it gathers food. It has no chlorophyll, so instead it absorbs ready-made food from the dead log it grows on; feeding, not movement, is what places an organism in its group.

Examiner's Note
The contrast must turn on the source of food: the autotroph builds it from inorganic materials, the heterotroph takes it ready-made. The fungus mark is won by nutrition, not movement.

Language Clinic
The answer leans on whereas and instead: whereas sets the food-builder against the food-taker, and instead marks what the fungus does in place of making food.

Question 3

Plants, green algae and some bacteria are all described as photoautotrophs. Explain what makes an organism a photoautotroph, and why the green pigment chlorophyll is the feature that defines this group.

Model Answer

A photoautotroph makes its own food from simple inorganic substances using the energy of light. It takes in carbon dioxide and water and builds them into sugar by photosynthesis, so it feeds itself with no ready-made food at all.

Chlorophyll is the defining feature because it is the pigment that traps the light energy the whole process depends on. Without chlorophyll the organism could not capture light, and so could not drive photosynthesis; this is why every photoautotroph, from a maize leaf to a green alga, carries it.

Examiner's Note
The marks need both halves: a photoautotroph builds food from inorganic materials, and uses light to do it. Chlorophyll scores as the pigment that traps the light, not as what makes the plant green.

Language Clinic
The answer turns on using and so: using ties the food-making to its light source, and so carries the reader from no chlorophyll to its result, no photosynthesis.

Question 4

Not every organism that makes its own food needs sunlight. Explain how chemoautotrophic bacteria obtain the energy to build their food, using the iron bacteria and the sulphur bacteria as your examples.

Model Answer

A chemoautotroph builds its own food from inorganic raw materials, but draws the energy for this from chemical reactions instead of from light. It releases energy by oxidising simple inorganic substances and uses that energy to build carbon dioxide into food, a process called chemosynthesis.

The iron bacteria and the sulphur bacteria show this clearly. The iron bacteria, such as *Ferrobacillus*, oxidise ferrous iron to ferric iron and capture the energy released, whereas the sulphur bacteria, such as *Thiobacillus*, oxidise inorganic sulphur for the same purpose. In each case the energy comes from a chemical reaction, not from light.

Examiner's Note
The mark turns on the energy source: a chemoautotroph oxidises an inorganic chemical instead of trapping light. Naming one reaction, such as ferrous iron to ferric, secures the example mark.

False Confidence Alert
It is tempting to assume every food-maker uses sunlight like a plant. Yet these bacteria use none; they take their energy from oxidising iron or sulphur, so they thrive in the dark.

Question 5

Both green plants and certain bacteria can photosynthesise, yet the two processes are not identical. Explain how photosynthesis in a green plant differs from photosynthesis in a photosynthetic bacterium.

Model Answer

A green plant releases oxygen during photosynthesis, whereas a photosynthetic bacterium usually releases none. The plant splits water and gives off the oxygen as a by-product, whereas the bacterium draws on raw materials other than water and so frees no oxygen.

The two also differ in their pigments and where these are held. A green plant uses chlorophyll packed inside definite chloroplasts, whereas a photosynthetic bacterium typically uses bacteriochlorophyll and has no chloroplasts, since its cell is prokaryotic.

Examiner's Note
Two real differences carry the marks: the plant frees oxygen while the bacterium usually does not, and it keeps chlorophyll in chloroplasts while the bacterium has only bacteriochlorophyll. Saying merely that both feed in sunlight scores nothing.

Language Clinic
The answer is built on whereas, repeated to set plant against bacterium in each line. One steady contrast word keeps both differences, in oxygen and in pigment, clear at a glance.

Question 6

Almost every food chain in a Tanzanian ecosystem begins with a green plant. Explain what photosynthesis is, and why it is described as the doorway through which energy and carbon enter the living world.

Model Answer

Photosynthesis is the process by which a green plant builds sugar from carbon dioxide and water, using light energy trapped by chlorophyll. The light energy is captured and stored as chemical energy in the sugar that is made.

It is the doorway for energy because:

1) **It is where the energy of sunlight first enters living things.** Animals cannot trap light, so they depend on the chemical energy a plant has already stored in its food.
2) **It fixes carbon dioxide gas into solid food.** The carbon in every plant and animal body was first taken from the air by a photosynthesising plant.

Examiner's Note
The marks need photosynthesis named as the building of sugar from carbon dioxide and water using light, and the point that it is where energy and carbon first enter life.

False Confidence Alert
It is tempting to say the purpose of photosynthesis is to give out oxygen. Yet oxygen is only a by-product; the plant carries it out to build its own food.

Question 7

Beyond feeding the plant that carries it out, photosynthesis shapes the whole living world. Outline the importance of photosynthesis to life on Earth.

Model Answer

Photosynthesis is important to life on Earth in several ways:

1) **It provides food for almost all life.** The plant feeds itself, and through food chains it feeds the animals that eat plants and one another.
2) **It releases the oxygen of the air.** The oxygen freed as a by-product is the gas almost every organism needs for respiration.

3) **It removes carbon dioxide from the air.** By fixing this gas into food, it helps to keep the level of carbon dioxide in the atmosphere in check.
4) **It stores energy for later use.** The energy locked in wood, and in fuels such as coal, was first captured by photosynthesis.

Examiner's Note
The marks come from naming distinct benefits: food for life, oxygen released, carbon dioxide removed, and energy stored. Repeating the same idea gains only one mark.

Question 8

The equation for photosynthesis is often written with six molecules of water, but the fuller, balanced form uses twelve. Write the balanced equation for photosynthesis and explain why twelve molecules of water are needed.

Model Answer

The balanced equation is $6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$, in the presence of light and chlorophyll. Carbon dioxide and water are the raw materials, while glucose, oxygen and water are the products.

Twelve molecules of water are needed because all the oxygen released comes from the splitting of water. Freeing six molecules of oxygen requires twelve molecules of water to be split, while six new molecules of water are reformed, which the shorter equation hides.

Examiner's Note
The marks need a correctly balanced equation and the reason for the twelve water: the oxygen all comes from water, so freeing six oxygen molecules demands twelve split.

False Confidence Alert
It is tempting to think the oxygen given off comes from carbon dioxide. Yet it comes entirely from water, which is why the balanced equation needs twelve water molecules.

Question 9

Photosynthesis takes place in the chloroplasts of a leaf, yet its two raw materials enter the plant in very different places. Trace where the carbon dioxide and the water come from, and the route each takes to reach the chloroplast.

Model Answer

The carbon dioxide comes from the air and enters the leaf through the stomata. It diffuses in through these pores, then passes through the air spaces and into the mesophyll cells where the chloroplasts lie.

The water comes from the soil and is taken up by the roots. It is absorbed by the root hairs, then carried up the stem in the xylem to the leaf, and finally into the photosynthesising cells.

Examiner's Note
The marks need both the source and the route for each raw material: carbon dioxide from the air through the stomata, and water from the soil up the xylem.

Language Clinic
The answer carries each raw material along its path with then and finally. These words trace one continuous route, showing the marker the order in which each material reaches the chloroplast.

Question 10

The chloroplast is the organelle in which photosynthesis takes place. Draw a well-labelled diagram of a chloroplast, and state which part carries out the light reaction and which carries out the dark reaction.

Model Answer

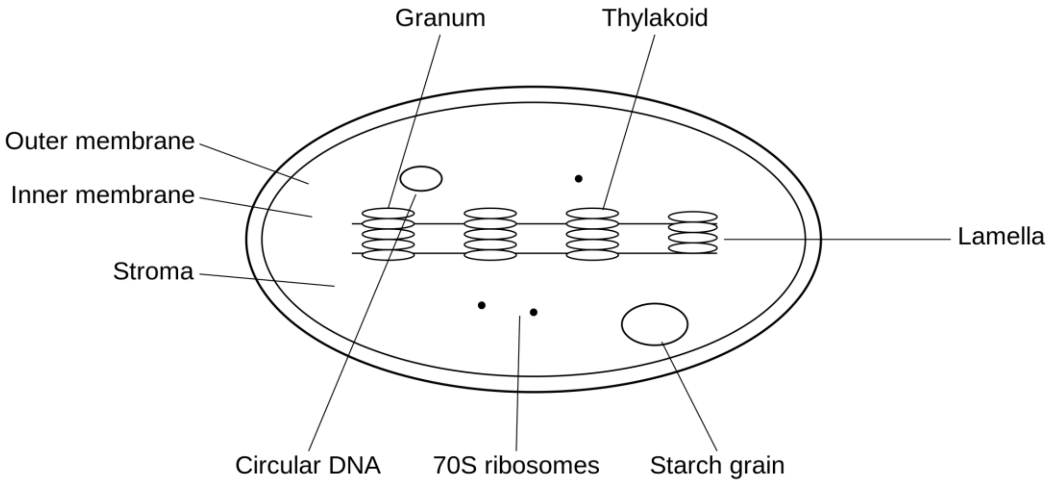


Figure 6.1: *The structure of a chloroplast.*

The two stages of photosynthesis are carried out in two different parts of the chloroplast.

1) **The grana carry out the light reaction.** Their stacked thylakoid membranes hold the chlorophyll that traps light and splits water.
2) **The stroma carries out the dark reaction.** This fluid holds the enzymes that fix carbon dioxide into sugar.

Examiner's Note
The mark-bearing labels are the double membrane, the stroma, the thylakoid and the granum. The commonest error is drawing the grana as solid blobs instead of stacks of flattened sacs; keep leader lines straight and not crossing.

Question 11

Inside a chloroplast the two stages of photosynthesis happen in two different places. Explain how the structure of the chloroplast suits it to carry out both the light reaction and the dark reaction.

Model Answer

The chloroplast works as a two-part factory, running the light reaction in the grana and the dark reaction in the stroma. Its structure keeps the two stages apart, yet close enough to pass the products of one to the other.

The grana suit the light reaction because their stacked membranes hold the chlorophyll. These thylakoid membranes give a large surface for trapping light and for splitting water and making ATP.

The stroma suits the dark reaction because it holds the sugar-building enzymes. Here the ATP and reduced NADP made in the grana are spent fixing carbon dioxide into sugar.

Examiner's Note
The marks tie each stage to its place: the grana to the light reaction through their chlorophyll-holding membranes, and the stroma to the dark reaction through its enzymes.

Language Clinic
The answer links each part to its job with because. Using because twice, once for the grana and once for the stroma, shows the marker that structure and function are joined, not merely listed.

Question 12

Chlorophyll is not the only pigment a plant uses to trap light. Name the main photosynthetic pigments, and explain the job of the accessory pigments.

Model Answer

The chief photosynthetic pigment is chlorophyll, present as chlorophyll a and chlorophyll b. Chlorophyll a is the main pigment, and the others work alongside it as accessory pigments.

The accessory pigments include the carotenoids and, in some algae, the phycobilins. They trap colours of light that chlorophyll a cannot, and pass the energy on to it.

The job of the accessory pigments is to widen the range of light the plant can use. By catching extra wavelengths and handing the energy to chlorophyll a, they let photosynthesis go on more fully.

> **Examiner's Note**
> The marks need chlorophyll a as the main pigment, the carotenoids and phycobilins as accessory, and their job: to trap extra wavelengths and pass the energy to chlorophyll a.

> **False Confidence Alert**
> It is tempting to treat chlorophyll as the only pigment that matters. Yet the accessory pigments catch light it misses and pass on the energy, widening the range the plant can use.

Question 13

A healthy maize leaf looks green to the eye. Using the way chlorophyll absorbs light, explain why a leaf appears green.

Model Answer

A leaf looks green because chlorophyll absorbs red and blue light but reflects green light. White light is a mixture of colours, and the colour a leaf shows is the one its pigment does not absorb.

The red and blue light are absorbed, while the green light is reflected back to the eye. It is this reflected green light that makes the leaf appear green.

> **Examiner's Note**
> The marks need the point that chlorophyll absorbs red and blue but reflects green, and that the reflected colour is the one the eye sees.

> **False Confidence Alert**
> It is tempting to think green light is the most useful to a leaf because leaves are green. Yet green is reflected, not absorbed, so it is the least used; red and blue do the work.

Question 14

A leaf contains several photosynthetic pigments mixed together. Explain how the pigments of a leaf can be separated by paper chromatography, and what the separation shows.

Model Answer

The pigments are separated by paper chromatography, which sorts them by how far each travels in a solvent. A spot of pigment extract is placed near the foot of the paper, the edge is dipped in a solvent, and the solvent carries the pigments up the paper at different rates.

Each pigment moves a different distance, so the mixture separates into a row of coloured bands. The most soluble pigment travels furthest, and each band is named by its colour and the distance it has moved.

The separation shows that a leaf contains several different pigments, not chlorophyll alone. Separate bands of chlorophyll a, chlorophyll b and the carotenoids appear, each a distinct pigment present in the leaf.

Examiner's Note
The marks need the method, a pigment spot carried up the paper by a solvent at different rates, and the result, several coloured bands showing several different pigments.

Question 15

The light reaction is the first stage of photosynthesis. State where the light reaction takes place, and explain what it produces, including what it hands on to the dark reaction.

Model Answer

The light reaction takes place in the grana of the chloroplast, on the thylakoid membranes that hold the chlorophyll. It happens only in the light, because it depends on light energy being trapped by the chlorophyll.

It produces ATP and reduced NADP, and hands both on to the dark reaction. These two products carry the energy and the hydrogen that the dark reaction uses to build sugar from carbon dioxide.

It also splits water, releasing oxygen and providing the hydrogen and the electrons. The hydrogen from water is carried to the dark reaction by reduced NADP, while the oxygen is given off as a by-product.

Examiner's Note
The marks need the place, the grana and their thylakoid membranes, and the products, ATP and reduced NADP handed on, with the splitting of water that frees oxygen.

False Confidence Alert
It is tempting to think the light reaction makes the sugar. Yet it only makes ATP and reduced NADP; the sugar itself is built later, in the dark reaction.

Question 16

The light reaction uses two photosystems. Name the two photosystems, and explain why each is given the number it carries, P700 and P680.

Model Answer

The two photosystems are photosystem I and photosystem II, each a cluster of pigments with a reaction-centre chlorophyll a molecule at its heart. Each traps light energy and begins the light reaction.

They are named P700 and P680 after the wavelength of light each reaction centre traps best. Photosystem I absorbs most strongly at 700 nm and photosystem II at 680 nm, and these wavelengths give the two their numbers.

Examiner's Note
The marks need the two named photosystems and the reason for the numbers: each reaction centre absorbs light best at that wavelength, 700 nm for one and 680 nm for the other.

False Confidence Alert
It is tempting to assume photosystem I acts before photosystem II because of its number. Yet in the non-cyclic path the electron passes through photosystem II first; the numbers show the order of discovery, not of use.

Question 17

Photosynthesis captures the energy of sunlight and stores it. Explain how a green plant changes light energy into chemical energy, naming the form the energy takes at each step.

Model Answer

The plant first traps light energy in its chlorophyll, raising electrons to a higher energy level. The light energy now becomes the energy of these excited electrons.

As the electrons pass down the electron transport chain, their energy is used to make ATP and reduced NADP. The energy is now held as chemical energy in these two molecules.

Finally, the ATP and reduced NADP are spent in the dark reaction to build sugar. The energy ends up stored as chemical energy in the bonds of the sugar.

Examiner's Note
The marks follow the energy as it changes form: light energy, then the energy of excited electrons, then chemical energy in ATP and reduced NADP, and finally chemical energy in sugar.

Language Clinic
The answer marks the stages with first, as and finally. These words carry the reader step by step along one chain, which is how the marker sees that each form of energy leads to the next.

Question 18

The splitting of water is a key event in the light reaction. Explain what happens during the photolysis of water, and why this one step supplies the electrons, the protons and the oxygen of photosynthesis.

Model Answer

Photolysis is the splitting of water by light energy during the light reaction. Light absorbed by photosystem II drives the breakdown of water into hydrogen ions, electrons and oxygen.

This single step supplies the electrons that replace those lost by chlorophyll. When chlorophyll passes its excited electrons on, the electrons from water take their place, so the light reaction can continue.

It also supplies the protons that reduce NADP and the whole of the oxygen given off. The hydrogen ions are taken up by NADP to form reduced NADP, while the oxygen is released as a by-product.

Examiner's Note
The marks need photolysis as water split by light at photosystem II, and the three things it supplies: electrons to replace those lost, protons to reduce NADP, and the oxygen released.

Language Clinic
The answer ties cause to result with when and so, and adds the parallel supply with while. These words show the marker that one splitting of water feeds three separate needs at once.

Question 19

With the aid of a diagram, trace the path of an electron through non-cyclic photophosphorylation, and name the products that are formed.

Model Answer

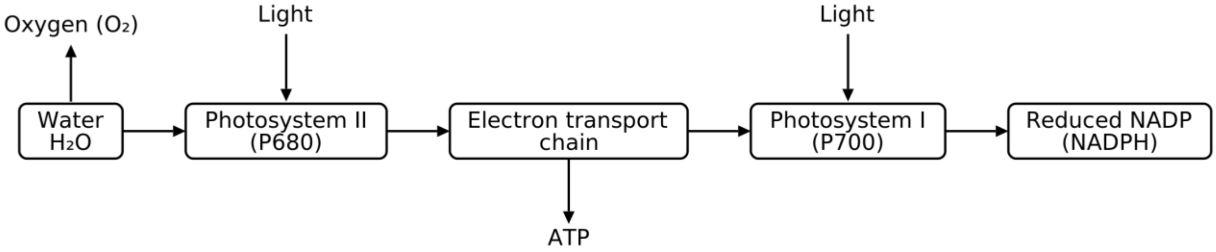


Figure 6.2: *Non-cyclic photophosphorylation.*

Light striking photosystem II raises an electron to a high energy level, and the electron is passed to an acceptor. The electron lost by photosystem II is replaced by one from the splitting of water.

The electron then flows down the electron transport chain, and its energy is used to make ATP. With its energy spent, it arrives at photosystem I.

Light striking photosystem I raises the electron again, and it is finally passed to NADP. The NADP takes up the electron and a hydrogen ion to become reduced NADP.

The path yields three products: ATP, reduced NADP and oxygen. The oxygen comes from the water that was split at the start.

Examiner's Note
The marks follow the ordered path, water, photosystem II, the transport chain where ATP forms, photosystem I, then NADP, and the three named products: ATP, reduced NADP and oxygen.

Language Clinic
The answer drives the path forward with then and finally. These ordering words show the marker that the electron moves one way only, from water to NADP, and never back.

Question 20

With the aid of a diagram, explain how cyclic photophosphorylation produces ATP using photosystem I alone, and why it yields no oxygen and no reduced NADP.

Model Answer

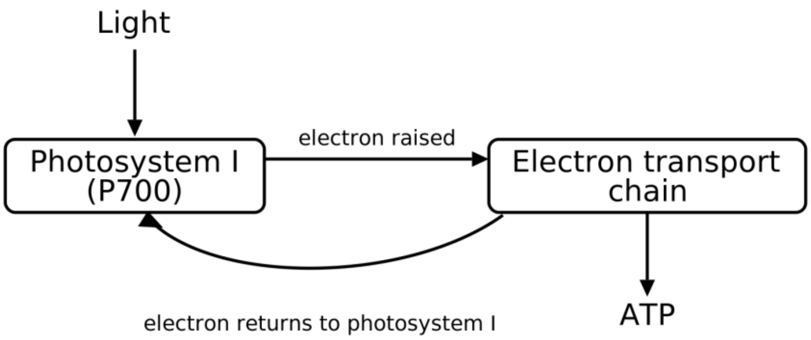


Figure 6.3: *Cyclic photophosphorylation.*

Light raises an electron from photosystem I to an acceptor, and from there it passes down the electron transport chain and back to photosystem I. The electron therefore travels in a closed loop, returning to where it began.

As the electron flows down the chain, its energy is used to make ATP. Because the same electron is reused, photosystem I alone is needed and ATP is the only product.

No oxygen is released because water is not split, and no reduced NADP is made because the electron returns to photosystem I instead of passing to NADP. Neither water nor NADP takes any part in the cycle.

Examiner's Note
The marks need the closed loop using photosystem I alone and the ATP it makes, with the two reasons for the missing products: no water is split, and the electron never reaches NADP.

Language Clinic
The answer leans on because, used twice, to give the reason for each missing product. Pairing because with the closed loop shows the marker why only ATP can come from this route.

Question 21

Cyclic and non-cyclic photophosphorylation are the two routes of the light reaction. Compare them in terms of the photosystems used, the fate of the electron, the splitting of water, and the products of each.

Model Answer

The two routes differ in four main ways:

1) **Photosystems used:** non-cyclic uses both photosystem II and photosystem I, whereas cyclic uses photosystem I alone.
2) **Fate of the electron:** in non-cyclic the electron takes a one-way path from water to NADP, whereas in cyclic it returns to photosystem I in a closed loop.
3) **Splitting of water:** non-cyclic splits water and releases oxygen, whereas cyclic does not split water and releases none.
4) **Products:** non-cyclic yields ATP and reduced NADP, whereas cyclic yields ATP only.

Examiner's Note
The marks need the contrast on all four counts; the clearest single difference is that non-cyclic splits water to make ATP and reduced NADP, whereas cyclic splits none and makes ATP only.

Language Clinic
The comparison is held together by whereas, repeated on every line. One steady contrast word keeps each pair, the photosystems, the electron, the water and the products, lined up side by side.

Question 22

The second stage of photosynthesis is called the dark reaction. State where in the chloroplast the dark reaction takes place, and explain why it can continue for a short time even in darkness.

Model Answer

The dark reaction takes place in the stroma of the chloroplast. This is the fluid around the grana, where the enzymes that build sugar are found.

It can run on for a short time in the dark because it does not use light directly. Instead it uses the ATP and reduced NADP made in the light reaction, so it keeps going until these are used up.

Examiner's Note
The marks need the place, the stroma, and the reason: the dark reaction does not use light itself but spends the ATP and reduced NADP the light reaction has already made.

False Confidence Alert
It is tempting to think the dark reaction happens only at night. Yet it runs in the light too; "dark" means only that it does not itself need light.

Question 23

The dark reaction is a cycle of three phases. With the aid of a diagram, outline the three phases of the Calvin cycle, naming the main molecules and the enzyme involved.

Model Answer

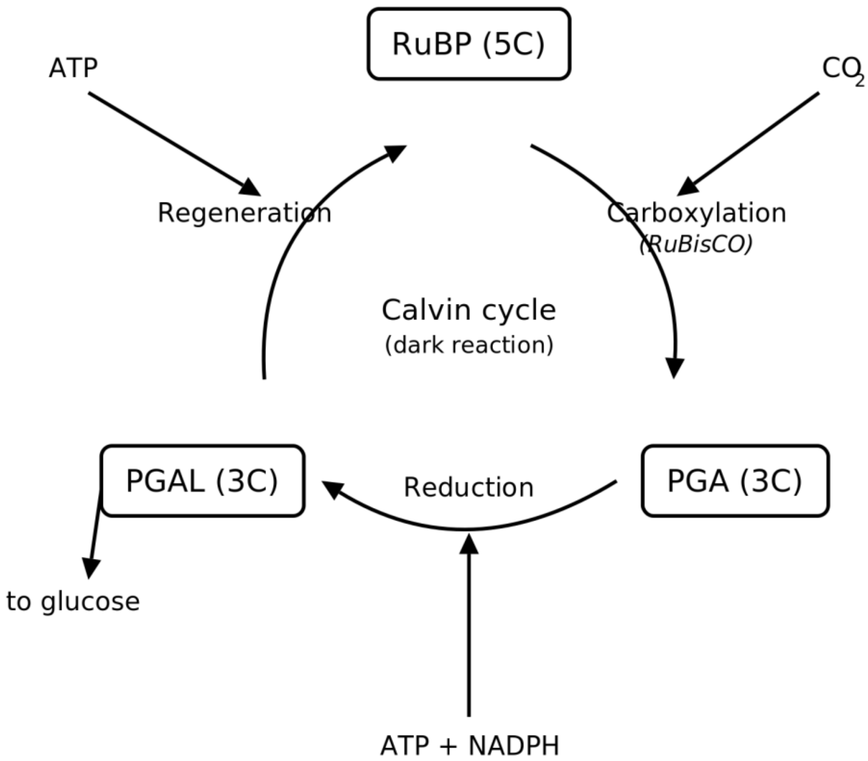


Figure 6.4: The Calvin cycle (the dark reaction).

The Calvin cycle turns through three phases:

1) **Carboxylation:** carbon dioxide joins the 5-carbon RuBP, in a reaction driven by the enzyme RuBisCO, to form two molecules of the 3-carbon PGA.
2) **Reduction:** the PGA is reduced to the 3-carbon PGAL, using the ATP and reduced NADP made in the light reaction.
3) **Regeneration:** most of the PGAL is rebuilt, with more ATP, into RuBP so the cycle can turn again, while some is drawn off to make glucose.

Examiner's Note
The marks need the three phases in order, the molecules RuBP, PGA and PGAL named with their carbon numbers, and RuBisCO as the carboxylation enzyme; the diagram must show the cycle turning.

Question 24

A single turn of the Calvin cycle fixes only one molecule of carbon dioxide. Explain why the cycle must turn six times to make one molecule of glucose.

Model Answer

The cycle must turn six times because each turn fixes only one carbon dioxide, and glucose holds six carbon atoms. Six turns are needed to bring in the six carbons of one glucose molecule.

Six turns make twelve molecules of PGAL, yet only two of these are used to build the glucose. The other ten rebuild the RuBP used up, so the cycle can keep running.

Examiner's Note
The marks need both counts: one carbon dioxide fixed per turn, so six turns for the six carbons of glucose, and twelve PGAL made, two for glucose and ten to regenerate RuBP.

Language Clinic
The answer reasons with because and so. Because gives the cause of the six turns, and so carries the reader from the spare PGAL to its job of rebuilding RuBP.

Question 25

Two three-carbon molecules, PGA and PGAL, appear in the Calvin cycle. Distinguish between PGA and PGAL, and explain why PGAL, not PGA, is counted the first true product of photosynthesis.

Model Answer

PGA is the first molecule formed when carbon dioxide is fixed, before any energy has been added. It is an acid, made when RuBP combines with carbon dioxide in carboxylation.

In contrast, **PGAL is formed when PGA is reduced, using the ATP and reduced NADP from the light reaction.** It is a sugar, a triose, now holding the energy and hydrogen brought from the light reaction.

PGAL is counted the first true product because it is the first energy-rich sugar the plant makes. From PGAL the plant builds glucose and its other foods, whereas PGA is only a stepping stone towards it.

Examiner's Note

The marks need PGA as the first fixed acid carrying no added energy, and PGAL as the reduced sugar that holds energy; PGAL scores as the first real sugar made.

Question 26

RuBP and reduced NADP each play a key part in the Calvin cycle. Explain the role of RuBP and the role of reduced NADP in the cycle.

Model Answer

RuBP is the molecule that accepts the carbon dioxide entering the cycle. This 5-carbon compound combines with carbon dioxide in carboxylation, and must be regenerated each turn so that more carbon dioxide can be fixed.

Reduced NADP supplies the hydrogen that reduces the fixed carbon. In the reduction phase it gives up its hydrogen to turn PGA into the sugar PGAL, then returns to the light reaction to be reduced again.

Examiner's Note
The marks need each role kept distinct: RuBP as the carbon dioxide acceptor that is regenerated, and reduced NADP as the hydrogen donor that reduces PGA to PGAL.

Question 27

The PGAL made in the Calvin cycle is the starting point for much of the chemistry of a plant. Outline what becomes of the PGAL that a leaf makes.

Model Answer

The PGAL a leaf makes has several fates:

1) **Most regenerates RuBP.** It is rebuilt into RuBP so that the Calvin cycle can keep turning.
2) **Some is built into glucose and sucrose.** These sugars are respired for energy or carried away to other parts of the plant.

3) **Some is stored as starch.** Glucose is joined into starch grains in the chloroplast and elsewhere for storage.
4) **Some is turned into cellulose, amino acids and fats.** With nitrogen and other elements, it provides the carbon skeletons for the plant walls, proteins and oils.

> **Examiner's Note**
> The marks come from naming distinct fates: regenerating RuBP, glucose and sucrose, storage starch, and the cellulose, amino acids and fats built from it.

Question 28

Photosynthesis has a light reaction and a dark reaction. Compare the two reactions in terms of where each takes place, what each needs, and what each makes.

Model Answer

The light and dark reactions differ in three main ways:

Where each occurs: the light reaction takes place in the grana, whereas the dark reaction takes place in the stroma.

What each needs: the light reaction needs light and water, whereas the dark reaction needs carbon dioxide and the ATP and reduced NADP from the light reaction.

What each makes: the light reaction makes ATP, reduced NADP and oxygen, whereas the dark reaction makes sugar.

> **Examiner's Note**
> The marks need the contrast on all three counts; the cleanest divide is that the light reaction traps energy in the grana, while the dark reaction spends it to build sugar in the stroma.

> **Language Clinic**
> The comparison rides on whereas, repeated on each line. One steady contrast word keeps the place, the needs and the products of the two reactions side by side.

Question 29

Most plants are described as C3 plants. Explain what makes a plant a C3 plant, and why this group includes most plants of cool, moist places.

Model Answer

A plant is a C3 plant when the first product of carbon fixation is the 3-carbon PGA. Its carbon dioxide is fixed straight away by RuBisCO in the Calvin cycle, with no separate step beforehand.

Most plants of cool, moist places are C3 because this path works well where carbon dioxide is plentiful and the air is not too hot. In such conditions the plant loses little water and RuBisCO fixes carbon efficiently, so the extra machinery of other paths is not needed.

> **Examiner's Note**
> The marks need C3 defined by its first product, the 3-carbon PGA fixed directly by RuBisCO, and the link to conditions where this simple path is efficient.

> **False Confidence Alert**
> It is tempting to think C3 names a plant with three carbons or three stages. Yet it names the first product of carbon fixation, the 3-carbon PGA.

Question 30

On a hot, bright day a plant may carry out photorespiration instead of fixing carbon. Explain how photorespiration sets in, and why it wastes some of what the plant has gained.

Model Answer

Photorespiration sets in when carbon dioxide runs low and oxygen builds up inside the leaf. On a hot, bright day the stomata close to save water, so carbon dioxide falls while oxygen from the light reaction rises.

RuBisCO then fixes oxygen instead of carbon dioxide onto RuBP. The enzyme can take either gas, and when oxygen wins, no useful sugar is made from that RuBP.

It wastes the plant's gains because it uses up RuBP and releases carbon dioxide without making food. Energy and fixed carbon are lost, so the plant's net photosynthesis falls.

Examiner's Note
The marks need the trigger, low carbon dioxide and high oxygen when the stomata shut, and the loss: RuBisCO fixes oxygen onto RuBP, so carbon and energy are spent for no sugar.

False Confidence Alert
It is tempting to think RuBisCO can fix only carbon dioxide. Yet it also fixes oxygen, and when carbon dioxide is scarce it does so, which is what causes photorespiration.

Question 31

Maize and sugarcane are C4 plants. Explain what makes a plant a C4 plant, and why fixing carbon first into a four-carbon acid helps these crops.

Model Answer

A plant is a C4 plant when the first product of carbon fixation is a four-carbon acid, not the three-carbon PGA. Carbon dioxide is first joined to PEP by the enzyme PEP carboxylase, before the Calvin cycle proper begins.

Fixing carbon into a four-carbon acid first lets these crops keep photosynthesising in hot, bright places. PEP carboxylase grabs carbon dioxide even when it is scarce, so maize and sugarcane can hold their stomata nearly shut to save water and still feed the Calvin cycle.

Examiner's Note
The marks need C4 defined by its four-carbon first product, fixed by PEP carboxylase, and the advantage: it captures carbon dioxide even when scarce, so the crop saves water in heat.

Language Clinic
The answer links cause to result with so. It carries the reader from PEP carboxylase seizing scarce carbon dioxide to the result, that the crop can keep its stomata nearly shut and still feed the Calvin cycle.

Question 32

With the aid of a diagram, describe the Hatch-Slack pathway by which a C4 plant fixes carbon dioxide.

Model Answer

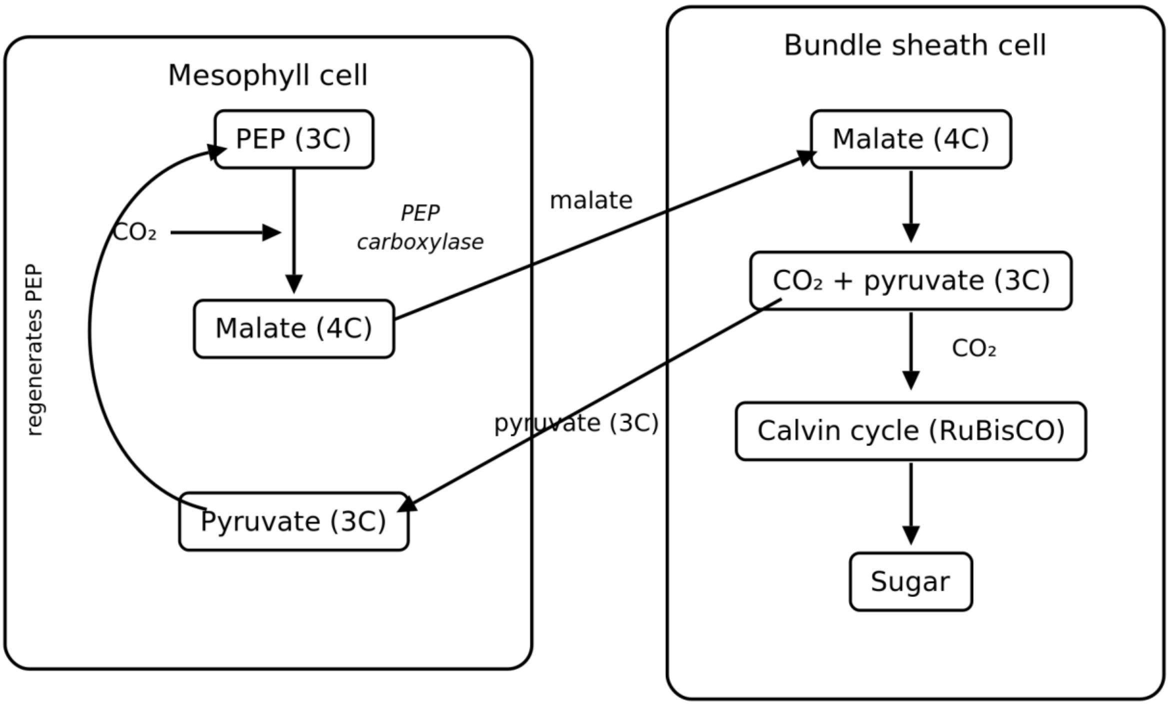


Figure 6.5: *The Hatch-Slack pathway of a C4 plant.*

In a C4 plant carbon is fixed in two stages, in two kinds of cell:

1) **In the mesophyll cell:** carbon dioxide is joined to PEP by the enzyme PEP carboxylase, forming a four-carbon acid, which is changed to malate.
2) **The malate moves into the bundle sheath cell:** here it breaks down, releasing the carbon dioxide again and leaving a three-carbon compound that returns to the mesophyll to remake PEP.
3) **In the bundle sheath cell:** the released carbon dioxide is now fixed by RuBisCO and built into sugar through the ordinary Calvin cycle.

Examiner's Note
The marks need the two cell types and the two-stage fixing: PEP carboxylase makes a four-carbon acid in the mesophyll, which carries carbon dioxide to the bundle sheath, where RuBisCO and the Calvin cycle make sugar.

Question 33

C3 and C4 plants fix carbon in different ways. Compare C3 and C4 plants in terms of the first product of fixation, the enzyme that fixes carbon dioxide, photorespiration, and the climate each suits.

Model Answer

C3 and C4 plants differ in four main ways:

1) **First product:** in a C3 plant it is the 3-carbon PGA, whereas in a C4 plant it is a 4-carbon acid.
2) **Carbon-fixing enzyme:** a C3 plant fixes carbon dioxide with RuBisCO alone, whereas a C4 plant first uses PEP carboxylase.
3) **Photorespiration:** a C3 plant loses carbon to photorespiration in hot, bright conditions, whereas a C4 plant largely avoids it.
4) **Climate suited:** C3 plants suit cool, moist places, whereas C4 plants such as maize and sugarcane suit hot, bright ones.

Examiner's Note
The marks need the contrast on all four counts; the deepest difference is that the C4 plant adds a first fixing step with PEP carboxylase, which lets it escape the photorespiration that costs the C3 plant.

Language Clinic
The comparison rests on whereas, repeated on each line. One steady contrast word sets each feature of the C3 plant against the matching feature of the C4 plant.

Question 34

The rate of photosynthesis often depends on just one condition at a time. Explain what is meant by a limiting factor, and why the factor in shortest supply sets the rate.

Model Answer

A limiting factor is the one condition, in shortest supply, that holds back the rate of a process. Photosynthesis needs light, carbon dioxide and a suitable temperature together, and the rate can rise only as fast as the scarcest of these allows.

The slowest factor alone caps the rate because the process cannot run faster than its scarcest need is met. Raising the other factors makes no difference until the limiting one is raised; then a different factor may take over as the limit.

Examiner's Note
The marks need a limiting factor as the scarcest condition that caps the rate, and the reason raising the others does nothing until the limiting one is increased.

False Confidence Alert
It is tempting to think adding more light always speeds photosynthesis. Yet if carbon dioxide is the limiting factor, more light makes no difference until the carbon dioxide is raised.

Question 35

Some of the things that set the rate of photosynthesis lie within the plant itself. Outline the internal factors that affect the rate of photosynthesis.

Model Answer

The internal factors that affect the rate of photosynthesis are:

1) **The amount of chlorophyll.** More chlorophyll traps more light, so a leaf short of chlorophyll photosynthesises slowly.
2) **The activity of the enzymes.** The Calvin cycle depends on enzymes such as RuBisCO, and anything that slows them slows the whole process.
3) **The structure of the leaf.** Features such as the number of stomata and the spread of chloroplasts decide how easily light, carbon dioxide and water reach the chloroplasts.

Examiner's Note
The marks come from naming the factors inside the plant: the amount of chlorophyll, the activity of the enzymes, and the structure of the leaf that brings the raw materials together.

Question 36

The conditions around a plant also set how fast it photosynthesises. Outline the external factors that affect the rate of photosynthesis, and how each acts.

Model Answer

The external factors that affect the rate of photosynthesis are:

1) **Light intensity and quality.** More light speeds the rate until another factor limits it, and the red and blue light is used while green is not.
2) **Carbon dioxide concentration.** More carbon dioxide raises the rate, since it is the raw material the Calvin cycle fixes.
3) **Temperature.** A rise warms the enzymes and speeds the rate to an optimum, after which the enzymes are denatured and the rate falls.
4) **Water.** Water is a raw material, and a shortage closes the stomata and shuts out carbon dioxide, slowing the rate.

Examiner's Note
The marks need the outside factors and how each acts: light, carbon dioxide, temperature with its optimum, and water, whose shortage closes the stomata.

False Confidence Alert
It is tempting to think a higher temperature always speeds photosynthesis. Yet past the optimum the enzymes are denatured, and the rate falls sharply.

Question 37

RuBisCO is often called both the most important and the most troublesome enzyme in the world. Explain why RuBisCO is both the key to carbon fixation and a bottleneck in it.

Model Answer

RuBisCO is the key to carbon fixation because it is the enzyme that joins carbon dioxide to RuBP. Every carbon atom built into a plant by the Calvin cycle is fixed by RuBisCO, so almost all the food on Earth passes through it.

It is a bottleneck because it works slowly and can fix oxygen as well as carbon dioxide. It catalyses only a few reactions each second, and when it seizes oxygen it causes wasteful photorespiration, holding back the plant's yield.

Examiner's Note
The marks need both sides: RuBisCO as the key that fixes carbon dioxide onto RuBP for nearly all food, and the bottleneck that is slow and also fixes oxygen, causing photorespiration.

Language Clinic
The answer turns on because, used twice: once to give why RuBisCO is the key, and once why it is the bottleneck. The same word frames both halves of its double character.

Question 38

At a certain light intensity a plant takes in and gives out gases at the same rate. Explain what is meant by the compensation point, and why the net exchange of gases there is zero.

Model Answer

The compensation point is the light intensity at which photosynthesis and respiration go on at exactly the same rate. It is reached at low light, around dawn and dusk.

The net exchange of gases is zero because the two processes cancel each other out. All the carbon dioxide released by respiration is used by photosynthesis, and all the oxygen used by respiration is supplied by it, so none enters or leaves the leaf.

Examiner's Note
The marks need the compensation point as the light intensity where photosynthesis and respiration run at equal rates, and the reason the net gas exchange is zero: each process supplies exactly what the other uses.

Language Clinic
The answer explains with because and so. Because gives the reason the net exchange is zero, and so carries the reader from the two processes cancelling to the result, that no gas enters or leaves.

Question 39

A heterotroph depends on its food for everything its body needs. Name the six classes of nutrient that a balanced diet must supply, and state the main job of each.

Model Answer

A balanced diet must supply six classes of nutrient, each with its own job:

1) **Carbohydrates:** the body's main source of energy for everyday activity.
2) **Fats (lipids):** a concentrated store of energy, and material for cell membranes and for insulation.
3) **Proteins:** the raw material for growth and for the repair of worn or damaged tissues.
4) **Vitamins:** needed in tiny amounts to keep particular reactions and body processes working.
5) **Mineral salts:** needed for healthy bones, blood and other functions, such as calcium and iron.
6) **Water:** the medium in which the body's reactions take place, and a major part of every cell.

Examiner's Note
The marks need all six nutrient classes named and a correct job for each; losing water, vitamins or minerals, or giving a wrong job, drops marks.

False Confidence Alert
It is tempting to list only the foods that give energy. Yet vitamins, mineral salts and water are nutrients too, needed for health even though they give no energy.

Question 40

Bread mould and yeast feed without a mouth or a gut. Explain how a saprophyte feeds, using Rhizopus and yeast as your examples.

Model Answer

A saprophyte feeds on dead organic matter by digesting it outside its body. It releases enzymes onto the dead material, such as bread or fruit, breaking it down where it lies.

It then absorbs the soluble products of this outside digestion. The bread mould *Rhizopus* pours its enzymes onto the bread and absorbs the digested food through its hyphae, while yeast absorbs the ready-made soluble sugars of fruit.

Examiner's Note
The marks need the two steps in order: enzymes released onto the dead matter to digest it outside the body, then the soluble products absorbed.

Language Clinic
The answer keeps the order with then. Releasing the enzymes and then absorbing the products shows the marker that the food is digested outside the body before it is taken in.

Question 41

Living things often live together in close partnership. Sort the three kinds of symbiosis, mutualism, commensalism and parasitism, by who gains and who loses in each.

Model Answer

The three kinds of symbiosis are told apart by who benefits:

1) **Mutualism:** both partners gain from living together.
2) **Commensalism:** one partner gains while the other neither gains nor loses.
3) **Parasitism:** one partner, the parasite, gains while the other, the host, is harmed.

Examiner's Note
The marks need each kind defined by its pattern of gain and loss: both gain, one gains while the other is unaffected, and one gains while the other is harmed.

False Confidence Alert
It is tempting to call any close partnership mutualism. Yet only mutualism benefits both; in commensalism one partner is unaffected, and in parasitism one is harmed.

Question 42

A cattle egret follows grazing cattle and feeds on the insects they disturb. Use this example to explain what is meant by commensalism.

Model Answer

Commensalism is a partnership in which one organism gains while the other is neither helped nor harmed. Only one of the two partners benefits from living alongside the other.

The cattle egret gains, while the cattle are unaffected. As the cattle graze they stir up insects from the grass, which the egret eats, yet the cattle neither gain nor lose by the bird's presence.

Examiner's Note
The marks need both halves: one partner gains and the other is unaffected, tied to the example, the egret gains while the cattle are neither helped nor harmed.

Language Clinic
The answer marks the one-sided benefit with while. Saying the egret gains while the cattle are unaffected shows the marker that only one partner profits from the partnership.

Question 43

In mutualism both partners benefit. Explain how mutualism feeds both partners, using the bacteria in a cow's rumen, the bacteria in a bean's root nodules, and the lichen as your examples.

Model Answer

In mutualism each partner gives the other something it needs. Three examples show this:

1) **The cow and its rumen bacteria:** the bacteria digest the cellulose the cow cannot, and in return they gain a steady supply of food and a warm home.
2) **The bean and its root-nodule bacteria:** the bacteria fix nitrogen into a form the plant can use, and in return they gain sugars from the plant.
3) **The lichen:** a fungus and an alga live as one body; the alga makes food by photosynthesis, while the fungus gives anchorage, water and protection.

Examiner's Note
The marks need each example to show both partners gaining; naming what one gives but not what it gets back earns only half the point.

Question 44

Many plants grow better when a fungus lives on their roots. Explain what a mycorrhiza is, and how the fungus and the plant each gain from it.

Model Answer

A mycorrhiza is a mutualistic partnership between a fungus and the roots of a plant. The fungus grows in and around the root, and the two live closely together.

The plant gains because the fungal threads spread far into the soil and bring it extra water and mineral salts. In return, the fungus gains sugars that the plant has made in photosynthesis, so both partners are fed.

> **Examiner's Note**
> The marks need the mycorrhiza named as a fungus-and-root mutualism, and both gains: the plant gets water and minerals, the fungus gets sugars.

> **Language Clinic**
> The answer balances the partnership with because and in return. Because gives the plant's gain, and in return marks what the fungus gets back, so both sides of the benefit are clear.

Question 45

A parasite feeds at the expense of another living organism. Explain how a parasite feeds, and distinguish between an endoparasite and an ectoparasite, using the tapeworm and the tick as your examples.

Model Answer

A parasite feeds on or in the body of a living host, taking its food at the host's expense. It gains its nourishment while the host is harmed, often weakened or made ill by the loss.

An endoparasite lives inside the host's body, whereas an ectoparasite lives on the outside. The tapeworm is an endoparasite that lives in the gut and absorbs the host's digested food, whereas the tick is an ectoparasite that clings to the skin and sucks blood from outside.

> **Examiner's Note**
> The marks need the parasite feeding at the host's expense with the host harmed, and the contrast: the endoparasite (tapeworm) lives inside, the ectoparasite (tick) lives outside.

> **Language Clinic**
> The answer draws the contrast with whereas. Setting the endoparasite that lives inside against the ectoparasite that lives outside, and the tapeworm against the tick, keeps the two kinds clearly apart.

Question 46

Animals such as a person or a goat feed by holozoic nutrition. Explain what holozoic nutrition is, and name, in order, the five stages that every holozoic feeder passes through.

Model Answer

Holozoic nutrition is the way of feeding in which an organism takes in solid food, digests it inside the body, and casts out the waste. It is the feeding of most animals, which have a gut to take in and handle the food.

Every holozoic feeder passes through five stages, in order:

1) **Ingestion:** taking the food into the body through the mouth.
2) **Digestion:** breaking the large food molecules down into small soluble ones.
3) **Absorption:** taking the digested food from the gut into the blood.
4) **Assimilation:** using the absorbed food in the cells for energy, growth and repair.
5) **Egestion:** passing out the undigested remains as faeces.

Examiner's Note
The marks need holozoic nutrition defined as taking in solid food and digesting it internally, and the five stages named in the right order.

False Confidence Alert
It is tempting to treat absorption and assimilation as one stage. Yet absorption is the food crossing into the blood, while assimilation is the cells actually using it.

Question 47

An animal cannot use the food it eats until that food has been digested. Explain why digestion is necessary.

Model Answer

Digestion is necessary because most food is made of large, insoluble molecules that cannot pass into the blood. Starch, protein and fat are too big to cross the gut wall, so they cannot reach the cells that need them.

Digestion breaks these large molecules down into small, soluble ones that can be absorbed. Starch becomes glucose, protein becomes amino acids, and fat becomes fatty acids and glycerol, and these can cross the gut wall into the blood to be carried to the cells.

Examiner's Note
The marks need the reason, large insoluble food cannot cross the gut wall, and the cure, digestion makes small soluble molecules that can be absorbed into the blood.

Language Clinic
The answer reasons with because and so. Because gives why digestion is needed, and so carries the reader from the food being too big to the result, that it cannot reach the cells.

Question 48

Holozoic animals are grouped by what they eat. Name the three feeding categories of holozoic animals, and explain how the teeth or gut of each is suited to its diet.

Model Answer

Holozoic animals fall into three feeding categories, each suited to its diet:

1) **Herbivores:** plant-eaters, such as a goat, with broad grinding teeth and a long gut to break down tough cellulose.
2) **Carnivores:** flesh-eaters, such as a lion, with sharp cutting and tearing teeth and a shorter gut for easily digested meat.
3) **Omnivores:** eaters of both plants and flesh, such as a person, with teeth of several kinds for a mixed diet.

Examiner's Note
The marks need the three categories named and an adaptation tied to the diet for each: grinding teeth and a long gut for the herbivore, tearing teeth and a short gut for the carnivore, mixed teeth for the omnivore.

Question 49

The alimentary canal is the long tube along which food passes and is digested. Draw a labelled diagram of the human alimentary canal and its accessory organs.

Model Answer

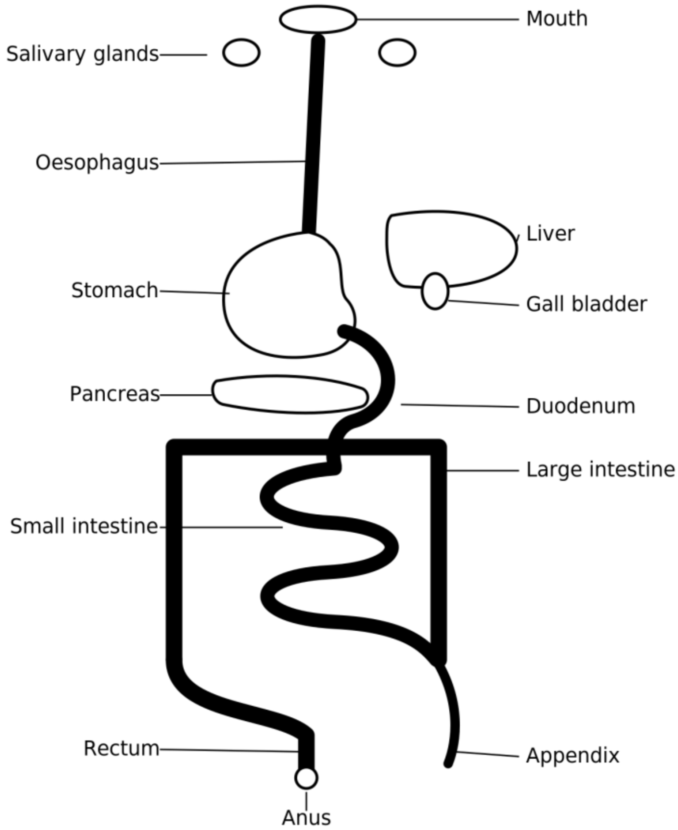


Figure 6.6: *The human alimentary canal and its accessory organs.*

The alimentary canal runs as one long tube from the mouth to the anus. Food is taken in at the mouth, swallowed down the oesophagus, churned in the stomach, digested and absorbed in the small intestine, and formed into waste in the large intestine before passing out at the anus.

The salivary glands, the liver, the gall bladder and the pancreas are accessory organs. They are not part of the tube itself, but they pour their juices into it to help with digestion.

Examiner's Note
The mark-bearing labels are the mouth, oesophagus, stomach, small intestine, large intestine, rectum and anus, with the accessory organs (salivary glands, liver, gall bladder, pancreas). The commonest error is putting the regions in the wrong order; keep leader lines straight and not crossing.

Question 50

The wall of the alimentary canal follows the same basic plan all the way along. Describe the layers of the gut wall, and explain why the canal is described as a tube open at both ends.

Model Answer

The gut wall is built of four main layers around a central space called the lumen. From the outside inwards these are the serosa, the muscle layer, the submucosa, and the mucosa that lines the lumen.

Each layer has its own work: the muscle layer churns and pushes the food, while the mucosa makes juices and absorbs the products. Glands in the wall pour their juices into the lumen, and the lining takes up the digested food.

The canal is a tube open at both ends because food enters at the mouth and leaves at the anus, with one continuous space between. In this sense the food in the lumen is still outside the body until it is absorbed through the gut wall.

Examiner's Note
The marks need the layers around the lumen (serosa, muscle, submucosa, mucosa) and the point that the canal opens to the outside at both ends, so its space is continuous from mouth to anus.

False Confidence Alert
It is tempting to think food in the gut is already inside the body. Yet the lumen opens to the outside at both ends; food is truly taken into the body only when it is absorbed through the gut wall.

Question 51

Three accessory glands pour their juices into the alimentary canal. Name these glands and state what each adds to digestion.

Model Answer

Three accessory glands add their juices to the canal:

1) **The salivary glands:** pour saliva into the mouth, which moistens the food and begins to digest starch with amylase.
2) **The liver:** makes bile, which is stored in the gall bladder and then emulsifies fat in the small intestine.
3) **The pancreas:** makes pancreatic juice, a mixture of enzymes that digests carbohydrate, protein and fat in the small intestine.

Examiner's Note
The marks need the three glands named with what each contributes: saliva with amylase, bile from the liver, and the enzyme-rich pancreatic juice.

False Confidence Alert
It is tempting to say the gall bladder makes bile. Yet the liver makes it; the gall bladder only stores it until it is needed.

Question 52

The inner lining of the gut is made of epithelial tissue. Name the kinds of epithelial tissue that line the gut, and state the job of each.

Model Answer

The gut is lined by epithelial tissues, each suited to its job:

1) **Columnar epithelium:** tall, close-packed cells that line the stomach and intestine for absorption and secretion.
2) **Glandular epithelium:** cells that form glands and secrete enzymes, mucus and other juices into the gut.
3) **Cuboidal epithelium:** cube-shaped cells found in the ducts and some glands, helping to secrete and to line.

Examiner's Note
The marks need the three epithelia named with a job for each: columnar for absorption and secretion, glandular for making juices, cuboidal for lining ducts and glands.

Question 53

Digestion begins in the mouth, before the food is even swallowed. Explain what happens to food in the mouth, both mechanically and chemically.

Model Answer

The teeth and the tongue break the food down mechanically into a soft ball, the bolus. The teeth cut and grind the food and the tongue mixes it with saliva, increasing the surface area on which enzymes can act.

Salivary amylase begins the chemical digestion of starch. This enzyme in the saliva starts to break starch down into the sugar maltose, even before the food is swallowed.

Examiner's Note
The marks need both kinds of action: mechanical breakdown by the teeth and tongue into a bolus, and chemical digestion of starch by salivary amylase.

False Confidence Alert
It is tempting to think the mouth only chews the food. Yet chemical digestion begins there too, as salivary amylase starts to break down starch.

Question 54

Food is pushed along the oesophagus even when a person is lying down. Explain how peristalsis moves food along the gut, naming the muscles involved.

Model Answer

Peristalsis is a wave of muscle contraction that pushes food along the gut. Behind the food the circular muscles contract to squeeze the tube narrow, while in front of it they relax.

The circular and the longitudinal muscles work together to drive the food forward. As the circular muscle squeezes behind the food, the wave moves it on, which is why food can travel even against gravity.

Examiner's Note
The marks need peristalsis as a wave of contraction, the circular muscle squeezing behind the food to push it on, and the point that this moves food even against gravity.

Language Clinic
The answer sets the two actions side by side with while. Saying the circular muscle contracts behind the food while it relaxes in front shows the marker how the wave drives the food one way.

Question 55

The stomach stores food and begins the digestion of protein. Draw a labelled diagram of the stomach and a gastric gland, and state the parts of gastric juice and the job of each.

Model Answer

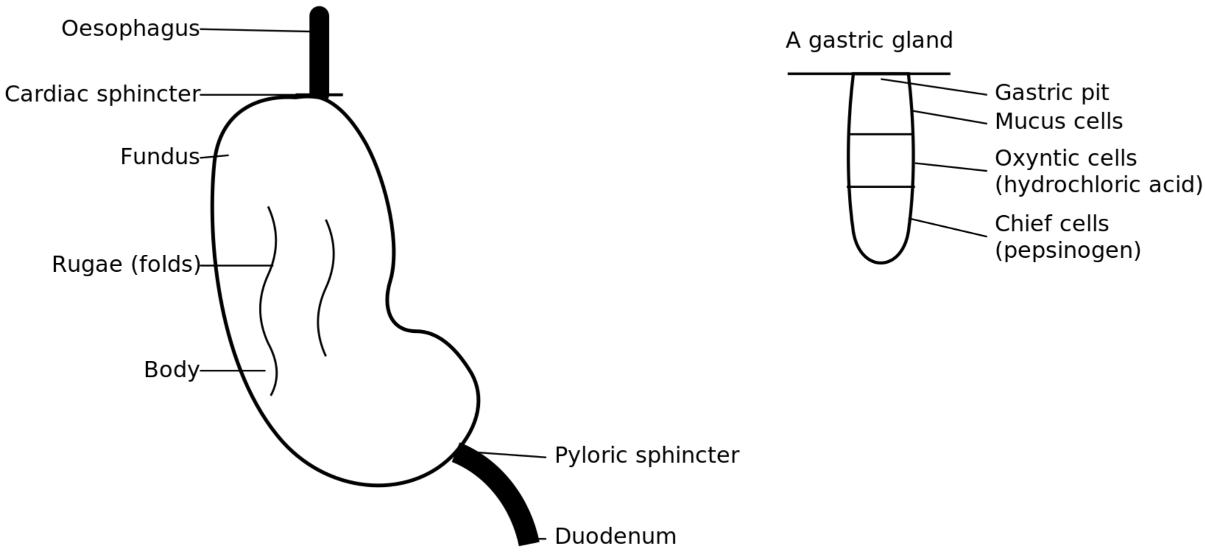


Figure 6.7: *The stomach and a gastric gland.*

The gastric glands pour gastric juice into the stomach. It has four main parts:

1) **Hydrochloric acid:** makes the stomach contents acid, kills many of the germs in food, and gives pepsin the acid conditions it needs.
2) **Pepsinogen:** the inactive form of pepsin, switched on by the acid to begin digesting protein.
3) **Rennin:** in a young mammal, curdles the milk so that it can be digested.
4) **Mucus:** coats and protects the stomach lining from the acid and the enzymes.

Examiner's Note
The mark-bearing labels are the oesophagus, cardiac sphincter, body, pyloric sphincter and duodenum, with the gastric gland cells. Name all four parts of gastric juice with a job for each to score in full.

Question 56

The stomach makes an enzyme that digests protein, yet the cells that make it are themselves built of protein. Explain how the stomach makes pepsin without digesting its own cells.

Model Answer

The stomach makes pepsin in an inactive form called pepsinogen, which cannot digest protein. Because the pepsinogen is inactive, it does no harm to the cell that makes it.

The pepsinogen is switched on to active pepsin only after it is safely out in the stomach space, by the hydrochloric acid there. The acid changes pepsinogen into pepsin in the lumen, away from the cells, so the gland cells are not digested.

A layer of mucus gives the lining further protection. The mucus coats the stomach wall, keeping both the acid and the active pepsin off the living cells.

Examiner's Note
The marks need pepsin secreted as inactive pepsinogen, switched on by acid only in the lumen, with mucus protecting the lining.

False Confidence Alert
It is tempting to think the cell makes active pepsin straight away. Yet it makes inactive pepsinogen; active pepsin made inside the cell would digest the cell's own protein.

Question 57

A young mammal feeds only on milk, and its gastric juice contains rennin. Explain why rennin is important to a young mammal.

Model Answer

Rennin is important because it curdles the milk in the stomach, turning it from a liquid into solid clots. It acts on the soluble milk protein, caseinogen, changing it into solid casein.

The curdled milk is then held in the stomach long enough to be digested. If the milk stayed liquid it would pass through too quickly, so the clots are kept back for pepsin to digest the protein.

Examiner's Note
The marks need rennin curdling the milk, changing soluble caseinogen into solid casein, so that the milk is held back long enough to be digested.

Language Clinic
The answer ties cause to purpose with so that and so. These words show the marker why curdling matters: the clots are held back so that pepsin has time to digest the milk protein.

Question 58

The small intestine is the longest part of the gut. Name its three regions in order, and explain why the first region, the duodenum, receives both bile and pancreatic juice.

Model Answer

The three regions of the small intestine, in order, are the duodenum, the jejunum and the ileum. Food leaving the stomach passes through them one after another.

The duodenum receives both bile and pancreatic juice because this is where most chemical digestion is completed. Bile from the liver emulsifies the fat, while pancreatic juice from the pancreas brings enzymes to digest carbohydrate, protein and fat, so both juices arrive together at the start of the small intestine.

Examiner's Note
The marks need the three regions in the right order, duodenum, jejunum and ileum, and the point that the duodenum receives bile and pancreatic juice because digestion is finished there.

Question 59

Bile contains no digestive enzyme, yet a person who cannot make bile is unable to digest fat properly. Explain how bile helps digestion, even though it has no enzyme.

Model Answer

Bile emulsifies fat, breaking the large fat drops into very many tiny droplets. This gives the fat a much larger surface area, so the fat-digesting enzyme lipase can work on it far faster, even though the bile itself does no digesting.

Bile also neutralises the acid chyme that arrives from the stomach. It makes the contents of the duodenum alkaline, which is the condition the pancreatic and intestinal enzymes need to work.

Examiner's Note
The marks need the two roles of bile without an enzyme: emulsifying fat to give lipase a larger surface to work on, and neutralising the stomach acid for the intestinal enzymes.

False Confidence Alert
It is tempting to say that bile digests fat. Yet bile has no enzyme; it only breaks the fat into tiny droplets, and it is lipase that does the digesting.

Question 60

The pancreas pours pancreatic juice into the duodenum. Name the enzymes in pancreatic juice and what each digests, and explain why one of them, trypsin, leaves the pancreas in an inactive form.

Model Answer

Pancreatic juice carries enzymes that act on all three classes of food:

1) **Amylase:** digests starch into the sugar maltose.
2) **Trypsin:** a protein-digesting enzyme that breaks protein into smaller peptides and amino acids.
3) **Lipase:** digests fats into fatty acids and glycerol.

Trypsin leaves the pancreas as inactive trypsinogen, so that it cannot digest the pancreas itself. Only in the duodenum is it switched on to active trypsin, by an enzyme of the gut wall called enterokinase, safely away from the gland that made it.

Examiner's Note
The marks need the three enzymes with what each digests, and the point that trypsin is released as inactive trypsinogen and switched on by enterokinase in the duodenum.

False Confidence Alert
It is tempting to think the pancreas releases active trypsin. Yet it releases inactive trypsinogen; active trypsin would digest the protein of the pancreas itself.

Question 61

The last enzymes to act on the food are found in the wall of the small intestine itself. Name the brush-border enzymes of the intestinal juice, and state what each one completes.

Model Answer

The intestinal juice, from the wall of the small intestine, carries the enzymes that finish digestion:

1) **Maltase:** finishes carbohydrate digestion by breaking maltose into glucose.
2) **Sucrase:** breaks sucrose into glucose and fructose.
3) **Lactase:** breaks lactose, the sugar of milk, into glucose and galactose.
4) **Peptidases:** finish protein digestion by breaking the remaining peptides into amino acids.

Examiner's Note
The marks need the brush-border enzymes named with what each completes: maltase, sucrase and lactase finishing the sugars, and the peptidases finishing the proteins into amino acids.

Question 62

By the time food reaches the end of the small intestine, each class of food has been fully digested. Summarise the chemical digestion of carbohydrate, of protein, and of fat, giving the enzymes, the places, and the final products.

Model Answer

Each class of food is digested by its own enzymes, ending as small soluble molecules:

Carbohydrate (starch): amylase in the mouth and the small intestine, and then maltase in the intestine, break starch down to glucose.

Protein: pepsin in the stomach, then trypsin and the peptidases in the small intestine, break protein down to amino acids.

Fat: lipase in the small intestine, helped by bile, breaks fat down to fatty acids and glycerol.

Examiner's Note
The marks need, for each food, the enzyme, the place, and the final product: starch to glucose, protein to amino acids, and fat to fatty acids and glycerol.

Question 63

Digestion does not stop until every food has been reduced to its smallest units. Explain why food must be broken down to molecules as small as glucose and amino acids before the body can use it.

Model Answer

Food must be reduced to its smallest soluble units because only these are small enough to pass through the wall of the gut into the blood. Large molecules such as starch and protein cannot cross the gut lining, but glucose, amino acids, fatty acids and glycerol can.

Once in the blood, these small molecules can be carried to every cell and used. The cells take them up to release energy, to build new materials and to repair themselves, which the large molecules could never reach to do.

Examiner's Note
The marks need the reason: only small soluble molecules can cross the gut wall into the blood, and from there be carried to the cells to be used.

Language Clinic
The answer turns on because and but. Because gives the reason food must be made small, and but sets the large molecules that cannot pass against the small ones that can.

Question 64

The lining of the small intestine is folded into millions of tiny villi. Draw a labelled diagram of a single villus, and show how its features make it good at absorbing food.

Model Answer

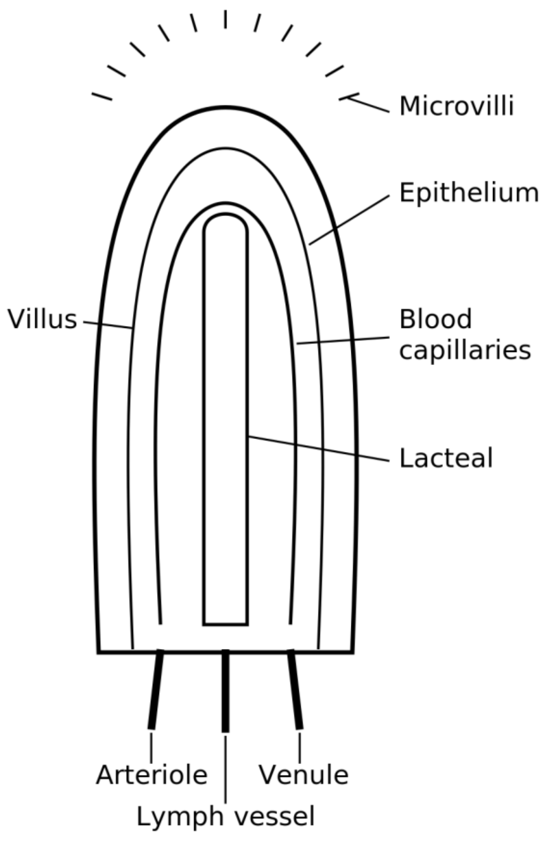


Figure 6.8: *A single villus of the small intestine.*

Each feature of the villus speeds the absorption of food:

1) **The thin wall, one cell thick:** lets the digested food cross quickly into the blood and the lacteal.
2) **The microvilli on the surface:** give a very large surface area for taking food in.
3) **The network of blood capillaries:** carries away the absorbed sugars and amino acids, keeping the gradient steep.
4) **The lacteal in the centre:** takes up the absorbed fatty acids and glycerol.

Examiner's Note
The mark-bearing labels are the microvilli, the thin epithelium, the blood capillaries and the lacteal, each tied to how it speeds absorption. Keep leader lines straight and not crossing.

Question 65

Most of the food a person eats is absorbed in the small intestine. Explain why the small intestine is so well suited to absorbing food.

Model Answer

The small intestine is very long, giving the food a large area and a long time over which to be absorbed. Its great length means the food moves through slowly, in long contact with the absorbing wall.

Its inner wall is folded and covered with millions of villi and microvilli, which together make an enormous surface area. This huge surface lets a great deal of food be taken in at once.

The wall is also thin and richly supplied with blood, which keeps absorption fast. The thin wall is quick to cross, and the blood carries the food away, so more can keep crossing.

Examiner's Note
The marks need the adaptations together: the great length, the folds with villi and microvilli for surface area, the thin wall, and the rich blood supply.

Question 66

The digested food does not all leave the villus by the same route. Explain how the products of digestion are absorbed from the small intestine, naming where each kind goes.

Model Answer

The sugars and the amino acids pass into the blood capillaries of the villus. Glucose, the other sugars and the amino acids cross the thin wall into the capillary network and are carried away in the blood.

The fatty acids and the glycerol pass into the lacteal. These products of fat digestion enter the central lacteal, which carries them away in the lymph before they later join the blood.

Examiner's Note
The marks need the two routes kept apart: sugars and amino acids into the blood capillaries, and fatty acids and glycerol into the lacteal.

False Confidence Alert
It is tempting to think all the absorbed food goes straight into the blood. Yet the fatty acids and glycerol enter the lacteal first and travel in the lymph before reaching the blood.

Question 67

Some food is absorbed even when there is already more of it in the blood than in the gut. Explain why the villus cannot rely on diffusion alone, but must also use active transport.

Model Answer

Diffusion alone cannot absorb all the food, because it moves substances only from where they are more concentrated to where they are less. Once the blood holds as much glucose as the gut, or more, diffusion would slow, stop or even reverse.

Active transport takes up glucose and amino acids against their concentration gradient, using energy. The epithelial cells spend energy from respiration to pump these foods into the blood even when the gut holds less, so that none is left behind.

Examiner's Note
The marks need the limit of diffusion (only down a gradient, stopping when equal) and active transport moving food against the gradient using energy, so all of it is absorbed.

False Confidence Alert
It is tempting to think all food is absorbed by simple diffusion. Yet diffusion stops once the gut and blood are equal; active transport is needed to take up the last of the glucose against the gradient.

Question 68

The food absorbed into the blood does not go straight to the rest of the body. Explain why the absorbed food is carried first to the liver, and name the vessel that takes it there.

Model Answer

The absorbed food is carried first to the liver by the hepatic portal vein. This vessel runs from the wall of the small intestine straight to the liver, before the blood reaches the rest of the body.

The liver acts as the gateway, sorting and storing the food before it goes on. It stores spare glucose as glycogen, handles the amino acids, and removes harmful substances, so the blood leaving the liver carries a steady, safe load to the cells.

Examiner's Note
The marks need the hepatic portal vein named as the vessel from the gut to the liver, and the liver as the gateway that stores glucose as glycogen and makes the blood safe before it goes on.

Language Clinic
The answer uses before and so to order events: the food reaches the liver before the rest of the body, so the liver can steady and clean the blood first.

Question 69

Absorbing the food into the blood is not the end of nutrition; the food must still be put to use. Explain what is meant by assimilation, and how the body uses the absorbed food.

Model Answer

Assimilation is the taking up and the use of the absorbed food by the cells of the body. It is the last stage of holozoic nutrition, in which the food becomes part of the body or is used to power it.

The liver, the muscles and the fat stores each use the absorbed food in their own way. The liver stores spare glucose as glycogen and builds new proteins, the muscles take up glucose and amino acids for energy and growth, and the fat stores lay down spare food as fat beneath the skin.

Examiner's Note
The marks need assimilation defined as the cells taking up and using the absorbed food, with examples: the liver storing glucose as glycogen, the muscles using it, and the fat stores laying down fat.

Question 70

By the time the food remains reach the large intestine, all the useful nutrients have already been absorbed. Explain the work that the large intestine does.

Model Answer

The large intestine does several jobs on the food remains:

1) **It reabsorbs water and salts.** It takes back most of the water and mineral salts from the remains, returning them to the blood.
2) **It houses helpful bacteria.** Bacteria living there feed on the remains and make some vitamins, such as vitamin K, which are then absorbed.
3) **It forms and stores the faeces.** As the water is removed, the remains are made into solid faeces, which are stored in the rectum until they are passed out.

Examiner's Note
The marks need the jobs of the large intestine: reabsorbing water and salts, housing helpful bacteria that make vitamins, and forming and storing the faeces.

Question 71

The caecum and appendix are large and important in a grazing animal, yet small and little used in a human. Explain the part the caecum and appendix play, and why they differ between a herbivore and a human.

Model Answer

In a herbivore the caecum and appendix form a large fermentation chamber where bacteria digest cellulose. A grazing animal eats tough plant cellulose, which its own enzymes cannot break, so it keeps bacteria here to digest it for it.

In a human the caecum and appendix are small and little used, because a human diet holds little cellulose to ferment. A human eats softer, mixed food, so the large fermentation chamber is not needed, and the appendix is left as a small remnant.

Examiner's Note
The marks need the caecum and appendix as a cellulose-fermenting chamber in the herbivore, and the reason they are reduced in a human: the human diet has little cellulose to digest.

Language Clinic
The answer joins cause to effect with because and so. Because gives the reason the human structures are small, and so links the herbivore diet to its need for a large fermentation chamber.

Question 72

The faeces leave the body at the anus, yet biologists are careful not to call this excretion. Explain why egestion is not the same as excretion, and how the faeces are held and then passed out.

Model Answer

Egestion is the passing out of undigested food, whereas excretion is the removal of the waste products of the body's own reactions. The faeces are mostly undigested remains that were never part of the body's chemistry, so getting rid of them is egestion, not excretion.

The faeces are held back by two anal sphincters and then expelled when it is convenient. An inner sphincter keeps the anus closed without thought, while an outer one is under voluntary control, so the faeces are released only when the person chooses.

Examiner's Note
The marks need the distinction: egestion gets rid of undigested food that was never part of the body, while excretion removes the body's own metabolic waste; plus the two anal sphincters, one involuntary and one voluntary.

False Confidence Alert
It is tempting to call the passing out of faeces excretion. Yet the faeces are undigested food that was never part of the body's chemistry; only the removal of the body's own waste is excretion.

Question 73

The stomach does not pour out gastric juice all the time, but only when food is on the way or present. Explain how the flow of gastric juice is controlled by both the nervous system and by hormones.

Model Answer

The flow of gastric juice is first set going by the nervous system, in the cephalic phase. The sight, the smell or the taste of food sends nerve signals to the stomach, which start the juice flowing even before the food arrives.

It is then kept going by hormones once the food is in the stomach and the small intestine. Food in the stomach makes its wall release the hormone gastrin, which keeps the juice flowing, while later the hormone secretin from the small intestine helps to slow it as the food moves on.

Examiner's Note
The marks need both controls: the nervous, or cephalic, phase that starts the flow at the sight or smell of food, and the hormones gastrin (which keeps it flowing) and secretin (which slows it).

Language Clinic
The answer orders the controls with first and then. First marks the nervous start of the flow, and then marks the hormones that take over once the food has arrived.

REAL QUESTIONS

The REAL questions take this biology out into the field, the farm and the examination room. Attempt each one on paper, then check the model answer and the notes beneath it.

Question 74

A student gathers five living things from around her home: a maize plant, a mushroom, a cow, a green alga from a pond, and a sulphur bacterium from a hot spring. Sort these five into autotrophs and heterotrophs, and justify where you place each.

Model Answer

The five are sorted by whether they make their own food or take it ready-made:

Autotrophs (make their own food): the maize plant and the green alga, which photosynthesise with chlorophyll, and the sulphur bacterium, which builds its food by chemosynthesis from sulphur.

Heterotrophs (take food ready-made): the cow, which eats plants, and the mushroom, a fungus that absorbs its food from dead matter.

Examiner's Note
The marks need the correct group for each, with a reason: chlorophyll and photosynthesis for the maize and the alga, chemosynthesis for the sulphur bacterium, and eating or absorbing food for the cow and the mushroom.

False Confidence Alert
Most students place the mushroom with the green plants, because it does not move and grows from the soil. Yet a mushroom has no chlorophyll and cannot make its own food, so it is a heterotroph that absorbs its food.

Question 75

On a Tanzanian farm, maize is eaten by a grasshopper, the grasshopper by a lizard, and the lizard by a hawk. Use this food chain to explain the place of autotrophs and heterotrophs, and trace the energy in the chain back to its source.

Model Answer

The maize is the autotroph that starts the chain, the producer that makes the food. Using sunlight, it builds food by photosynthesis, so every other organism in the chain depends on it.

The grasshopper, the lizard and the hawk are heterotrophs that take their food ready-made. Each feeds on the one before it, so the food the maize made is passed along the chain from one consumer to the next.

The energy in the whole chain can be traced back to the sun. The maize trapped the energy of sunlight, and this same energy then flows on, in the food, to the grasshopper, then the lizard, then the hawk.

Examiner's Note
The marks need the maize named as the autotroph or producer, the animals as heterotrophs or consumers, and the energy traced back through the maize to the sun.

Language Clinic
The answer carries the energy along with so and then. So links each feeding to the passing-on of food, and the repeated then traces the same energy up the chain from the maize to the hawk.

Question 76

Kipanga says, *"It is simple: every green thing makes its own food, so it is an autotroph, and anything that moves must hunt for food, so it is a heterotroph."* Identify what is wrong with Kipanga's rule, and put it right.

Model Answer

Kipanga is wrong to use colour and movement as the test; the real test is how an organism gets its food. An organism is an autotroph if it makes its own food and a heterotroph if it takes it ready-made, whatever its colour or however it moves.

***Euglena* breaks the rule that moving means heterotroph.** *Euglena* swims about, yet it is green and makes its own food by photosynthesis, so it is largely an autotroph.

The fungi break the rule that green, or staying still, means autotroph. A mushroom neither moves nor is green, yet it cannot make its own food, so it is a heterotroph that absorbs food from dead matter.

Examiner's Note
The marks need the error named (colour and movement are the wrong test) and the correct test put in its place (the mode of feeding), backed by the awkward cases of *Euglena* and the fungi.

Language Clinic
The answer overturns the rule with yet, used twice. Each yet sets an awkward case against Kipanga's test: *Euglena* moves yet feeds itself, and the mushroom stays still yet cannot.

Question 77

The simple equation for photosynthesis gives glucose as the product and seems to suggest that the oxygen comes from carbon dioxide. Explain why this simple equation is not the whole truth.

Model Answer

The first sugar made is not glucose but a triose, a three-carbon sugar. Glucose is built up later from these triose units, so the simple equation hides the true first product.

The oxygen given off comes from water, not from carbon dioxide. When water is split in the light reaction its oxygen is released, and the heavy-oxygen isotope experiment proved this, by tracing the labelled oxygen of the water into the gas given off.

Examiner's Note
The marks need both corrections: the first product is a triose, not glucose, and the oxygen comes from the splitting of water, as the heavy-oxygen experiment shows.

False Confidence Alert
Most students write that the oxygen comes from the carbon dioxide, because both contain oxygen. Yet the heavy-oxygen experiment shows that all the oxygen comes from the water that is split.

Question 78

A leaf is the main organ of photosynthesis. Explain how the leaf and its mesophyll cells are suited to bringing light, carbon dioxide and water together for photosynthesis.

Model Answer

The leaf is broad and thin, so it catches plenty of light and lets gases reach the cells quickly. Its broad blade gives a large surface for trapping light, and its thinness means carbon dioxide has only a short way to travel inside.

The mesophyll cells are packed with chloroplasts and served by air spaces and veins. The palisade cells near the top hold most of the chloroplasts for trapping light, the air spaces let carbon dioxide diffuse in from the stomata, and the veins bring water up from the roots.

Examiner's Note
The marks need the leaf features tied to the three raw needs: the broad thin blade for light and gases, the chloroplast-packed palisade cells for light, the air spaces and stomata for carbon dioxide, and the veins for water.

Question 79

It is often said that photosynthesis would be impossible without the photolysis of water. Explain why this statement is true.

Model Answer

Photolysis is essential because it replaces the electrons that chlorophyll loses when it traps light. Without these replacement electrons the chlorophyll could not keep working, and the light reaction would soon stop.

Photolysis also supplies the hydrogen that reduces NADP and the oxygen that is given off. The hydrogen from the split water is carried to the dark reaction to help build sugar, so without photolysis no sugar could be made and no oxygen released.

Examiner's Note
The marks need photolysis shown as the source of three things: the electrons that keep chlorophyll working, the hydrogen for reducing NADP, and the oxygen given off; without it the whole process halts.

Language Clinic
The answer reasons with because and so. Because gives the reason photolysis is essential, and so carries the reader from its loss to the result, that no sugar is built and no oxygen freed.

Question 80

Kipanga writes, *"The chlorophyll in a leaf takes in carbon dioxide and gives off the oxygen during photosynthesis."* Identify Kipanga's mistake, and correct it.

Model Answer

Kipanga is wrong that the chlorophyll gives off the oxygen; the oxygen comes from the splitting of water. Chlorophyll does not release any oxygen at all; it is the water, split by light, that frees the oxygen.

The true work of chlorophyll is to trap the light energy. Chlorophyll absorbs the light and passes on the energy that drives the reaction, while the oxygen given off is only a by-product of the water being split.

Examiner's Note
The marks need the correction that the oxygen comes from water, not chlorophyll, and the true job of chlorophyll stated: to trap the light energy that drives photosynthesis.

Language Clinic
The answer keeps the two jobs apart with while. Saying chlorophyll traps the light while the water gives off the oxygen makes clear which part does which, the very point Kipanga confused.

Question 81

A farmer notices that her crops grow fastest on warm days but suffer in extreme heat. Describe how temperature affects the rate of photosynthesis, from low temperatures up to very high ones.

Model Answer

At low temperatures the rate of photosynthesis is slow, but it rises as the temperature increases. The warmth speeds up the enzymes of the dark reaction, so the rate climbs steadily towards an optimum.

At the optimum temperature the rate is at its highest. Here the enzymes are working fastest; for many plants this best temperature is around 25 to 35 degrees Celsius.

Above the optimum the rate falls sharply, because the high heat denatures the enzymes. The enzymes lose their shape and stop working, so the rate drops, which is why the crops suffer in extreme heat.

Examiner's Note
The marks need the three stages: the rate rising with temperature as the enzymes speed up, the optimum where it peaks, and the sharp fall above it as the enzymes are denatured.

Language Clinic
The answer reasons with because and so. Because gives the cause of the fall, the denaturing of the enzymes, and so carries the reader from that to the drop in the rate and the harm to the crops.

Question 82

Two simple experiments can show what photosynthesis needs. Describe how a destarched leaf can be used to show that light is needed, and how a variegated leaf shows that chlorophyll is needed.

Model Answer

A destarched leaf, partly covered, shows that light is needed. The plant is first kept in the dark to use up its starch; then part of a leaf is covered with foil and the plant is left in the light. Only the uncovered part later turns blue-black with iodine, so light is needed for starch to be made.

A variegated leaf, green in only some parts, shows that chlorophyll is needed. After being left in the light and tested with iodine, only the parts that were green turn blue-black, while the white parts do not, so chlorophyll is needed.

Examiner's Note
The marks need each result tied to its conclusion: only the lit part of the destarched leaf makes starch, so light is needed; only the green part of the variegated leaf makes starch, so chlorophyll is needed.

False Confidence Alert
Most students forget to destarch the plant first. Yet without removing the old starch, a positive iodine test could come from starch made earlier, and would not prove that light was needed.

Question 83

The second stage of photosynthesis is often called the dark reaction, yet it usually goes on in daylight. Explain why the name dark reaction is misleading.

Model Answer

The name misleads because the dark reaction does not need darkness and usually runs in the light. It is called the dark reaction only because it does not itself use light directly.

In truth it depends wholly on the products of the light reaction. It needs the ATP and the reduced NADP that the light reaction makes, so when the light stops these soon run out and the dark reaction stops too.

Examiner's Note
The marks need the point that the dark reaction does not require darkness, and the reason the name misleads: it depends on the ATP and reduced NADP from the light reaction, so it cannot run long without light.

Language Clinic
The answer turns on so. It links the stopping of the light to the running-out of ATP and reduced NADP, and so to the halting of the dark reaction, showing the two stages are tied together.

Question 84

A farmer in Morogoro leaves the crop remains and fallen leaves to rot on her farm. Explain why the saprophytic fungi and bacteria that rot this dead matter are so important to her soil.

Model Answer

The saprophytes break down the dead crop remains and leaves, freeing their nutrients back into the soil. They pour out enzymes that digest the dead matter, and the minerals locked inside it, such as nitrates, are released into the soil.

These freed nutrients are then taken up again by the next crop. Without the saprophytes the dead matter would pile up and its nutrients stay locked away, so the soil would slowly lose its fertility.

Examiner's Note
The marks need the saprophytes shown to decompose the dead matter and free its mineral nutrients into the soil, where the next crop can take them up again.

Language Clinic
The answer carries the consequence with so. It links the absence of saprophytes to the locking-away of nutrients, and so to the slow loss of the soil fertility.

Question 85

Farmers often plant beans or groundnuts to improve the soil for the next crop. Explain how the partnership between these legumes and the bacteria in their root nodules enriches a Tanzanian field.

Model Answer

Legumes such as beans and groundnuts carry nitrogen-fixing bacteria in their root nodules. These bacteria take nitrogen gas from the air and fix it into nitrogen compounds the plant can use, and in return the plant feeds them with sugars.

When the legume crop dies or is ploughed in, the fixed nitrogen enriches the soil. The nitrogen compounds are left behind in the soil, so the next crop, such as maize, grows better with little or no added fertiliser.

Examiner's Note
The marks need the root-nodule bacteria fixing nitrogen from the air into a usable form for the plant, and that nitrogen being left in the soil to enrich the next crop.

False Confidence Alert
Most students think the legume itself makes the nitrogen. Yet it is the bacteria in its root nodules that fix the nitrogen from the air; the plant only shelters and feeds them in return.

Question 86

Kipanga says *a lichen is a single, simple organism*. **Kipute** says *it is really two organisms living together*. Decide who is right, and justify your answer.

Model Answer

Kipute is right: a lichen is two organisms living together, not one. A lichen is a partnership of a fungus and an alga, or a cyanobacterium, living so closely that they look like a single organism.

The two live in mutualism, each giving the other what it needs. The alga photosynthesises and makes food for both, while the fungus gives anchorage, water and protection, so both partners gain.

Examiner's Note
The marks need the verdict that Kipute is right, with the justification: a lichen is a fungus and an alga living in mutualism, each gaining from the other.

Language Clinic
The answer balances the partnership with while. Saying the alga makes the food while the fungus gives shelter shows the marker that both partners gain, which is what makes it two organisms in mutualism.

Question 87

A tapeworm lives in the gut of its host, bathed in the host's digested food. Explain how the tapeworm is adapted to its parasitic life in the gut.

Model Answer

The tapeworm shows several adaptations to life inside the gut of its host:

1) **Hooks and suckers on its head:** the scolex grips the gut wall so the worm is not swept out with the food.
2) **A long, thin, flat body:** this gives a large surface area for absorbing the host's digested food straight through its skin.
3) **No gut of its own:** it does not need one, since the food around it is already digested.
4) **A protective cuticle:** this resists the host's digestive enzymes, so the worm is not digested itself.
5) **Very many eggs:** it makes huge numbers of eggs, so that some survive to reach a new host.

Examiner's Note

The marks need adaptations tied to the parasitic life: the scolex to grip, the flat body for absorbing digested food, no gut needed, a cuticle resisting the host enzymes, and many eggs for spreading.

False Confidence Alert
Most students give the tapeworm a mouth and a gut. Yet it has neither; its flat body absorbs the host's already-digested food straight through its surface.

Question 88

Kipanga says, *"The tapeworm and its host help each other, so they live in mutualism."* Identify Kipanga's mistake, and put it right.

Model Answer

Kipanga is wrong: the tapeworm and its host live in parasitism, not mutualism. Mutualism means both partners gain, but here only the tapeworm gains.

The host is harmed, not helped. The tapeworm robs the host of its digested food, so the host may grow thin and weak, while the tapeworm thrives at its expense.

Examiner's Note
The marks need the relationship corrected to parasitism, with the reason: only the tapeworm gains, while the host is harmed by the loss of its food.

Language Clinic
The answer overturns the claim with but and while. But denies that both gain, and while sets the suffering host against the thriving worm, which is the mark of parasitism.

Question 89

Four animals are common in Tanzania: a goat, a lion, a fowl and a person. Sort them into herbivores, carnivores and omnivores, and give a reason for each.

Model Answer

The four animals are sorted by what they eat:

Herbivore - the goat: it eats only plants, and has broad grinding teeth for chewing tough leaves.

Carnivore - the lion: it eats only flesh, and has sharp pointed teeth for catching and tearing meat.

Omnivores - the fowl and the person: each eats both plant and animal food, and so takes a mixed diet.

Examiner's Note
The marks need each animal in the right group with a reason from its diet: the goat a plant-eating herbivore, the lion a flesh-eating carnivore, and the fowl and person mixed-feeding omnivores.

False Confidence Alert
Most students call the fowl a herbivore because it pecks grain. Yet a fowl also eats insects and worms, so it is an omnivore, not a herbivore.

Question 90

Your mother often tells you to chew your food well before swallowing it. Explain, in terms of digestion, why this is good advice.

Model Answer

Chewing breaks the food into small pieces, giving a much larger surface area for the digestive enzymes to act on. The more surface the enzymes can reach, the faster and more completely the food is digested.

Chewing also mixes the food with saliva and rolls it into a soft bolus that is easy to swallow. The saliva moistens the food, and its amylase begins to digest the starch even before the food is swallowed.

Examiner's Note
The marks need the larger surface area that chewing gives the enzymes, and the mixing with saliva whose amylase starts the digestion of starch in the mouth.

False Confidence Alert
Most students think chewing only makes the food small enough to swallow. Yet its real value for digestion is the larger surface area it gives the enzymes to work on.

Question 91

A boy eats a piece of *mshikaki*, which is mostly protein. Follow this protein through the gut, naming where it is digested and the enzymes that act on it.

Model Answer

The protein of the meat is digested in stages as it passes along the gut:

1) **In the mouth:** it is chewed into small pieces but not chemically digested, as the saliva has no protein-digesting enzyme.
2) **In the stomach:** pepsin, helped by the hydrochloric acid, begins to break the protein into shorter chains called peptides.
3) **In the duodenum:** trypsin from the pancreas breaks these peptides into still shorter chains.
4) **In the ileum:** peptidases finish the work, breaking the peptides into amino acids, which are then absorbed.

Examiner's Note
The marks need pepsin with acid starting the protein in the stomach, trypsin from the pancreas continuing in the duodenum, and peptidases finishing it into amino acids in the ileum.

False Confidence Alert
Most students think protein digestion begins in the mouth. Yet the saliva has no protein-digesting enzyme; the first attack on protein is by pepsin in the stomach.

Question 92

The gastric juice in the stomach contains an acid strong enough to attack flesh, yet the stomach does not digest its own wall. Explain how the stomach is protected.

Model Answer

The wall of the stomach is lined with a layer of mucus that protects it. This slimy mucus coats the lining, so the acid and the pepsin cannot reach and attack the living wall.

The cells of the lining are also replaced very quickly. Any cells that are worn away or damaged are soon renewed, so the stomach keeps its protective barrier.

Examiner's Note
The marks need the mucus layer shielding the wall from the acid and pepsin, and the quick replacement of the lining cells that keeps the barrier whole.

Language Clinic
The answer leans on so. It links the coat of mucus to the fact that the acid and pepsin cannot reach the wall, showing the marker the protection is the reason the stomach is safe.

Question 93

A patient whose bile duct is blocked has difficulty digesting fatty foods. Explain why the blockage causes this difficulty.

Model Answer

Bile is needed to emulsify fats, and a blocked duct stops the bile from reaching the food. To emulsify means to break the large fat droplets into many tiny ones, which gives a far larger surface area for the fat-digesting enzyme to act on.

Without bile, the enzyme lipase works only slowly on the fat. The fat stays in large droplets with little surface exposed, so much of it passes through undigested, which is why the patient cannot digest fatty foods well.

Examiner's Note
The marks need bile emulsifying the fat into tiny droplets to enlarge the surface for lipase, and the point that without bile the lipase works slowly and the fat is poorly digested.

Language Clinic
The answer carries the result with so and which is why. So links the large droplets to the undigested fat, and which is why ties that straight back to the difficulty the patient feels.

Question 94

When food leaves the acid stomach and enters the small intestine, the surroundings are made alkaline. Explain why this change is necessary.

Model Answer

The acid from the stomach must be neutralised, because the enzymes of the small intestine work best in alkaline conditions, not in acid. The bile and the pancreatic juice contain sodium hydrogen carbonate, which neutralises the acid and makes the surroundings alkaline.

Only in these alkaline conditions can the intestinal enzymes do their work. Enzymes such as trypsin and lipase would be slowed or stopped by the acid, so neutralising it lets digestion go on in the small intestine.

Examiner's Note
The marks need the stomach acid being neutralised by the sodium hydrogen carbonate in the bile and pancreatic juice, because the intestinal enzymes need alkaline conditions to work.

Language Clinic
The answer reasons with because and so. Because gives the reason the acid is neutralised, the enzymes needing alkali, and so carries that to the enzymes being able to finish the digestion.

Question 95

Kipanga says, *"Once food has left the stomach, it is already fully digested."* Identify Kipanga's mistake, and put it right.

Model Answer

Kipanga is wrong: most digestion is not finished in the stomach but in the small intestine. The stomach only begins the digestion of protein; it does little to starch and not much to fat.

It is in the small intestine that digestion is completed. Here the pancreatic and intestinal enzymes finish breaking the proteins, carbohydrates and fats into small soluble molecules, so the food is fully digested only after it leaves the stomach, not before.

Examiner's Note
The marks need the correction that the stomach only starts protein digestion, while the small intestine is where the digestion of all three food classes is completed.

Language Clinic
The answer settles the point with so. It links the finishing work of the intestinal enzymes to the conclusion that the food is fully digested only after the stomach, putting Kipanga right.

Question 96

If you chew a mouthful of *ugali* for a long time without swallowing, it slowly begins to taste sweet. Explain why.

Model Answer

The sweet taste comes from a sugar made by an enzyme in the saliva. Ugali is rich in starch, and the salivary amylase in the mouth digests this starch into maltose, which is a sugar.

The longer you chew, the more maltose is made, so the taste grows sweeter. The sugar was not in the ugali to begin with; it is produced in the mouth by the action of the enzyme on the starch.

Examiner's Note
The marks need the salivary amylase digesting the starch of the ugali into maltose, a sugar, which is what gives the sweet taste as chewing goes on.

False Confidence Alert
Most students think the ugali must contain hidden sugar. Yet no sugar is there at the start; it is made in the mouth by the amylase acting on the starch.

Question 97

Explain how a swallowed piece of food is moved along the gut to the stomach, even when a person is lying down.

Model Answer

The food is pushed along by peristalsis, the waves of muscle action in the wall of the gut. Behind the food the circular muscles contract while in front of it they relax, squeezing the food forward in a wave.

Because the food is pushed by muscle and not pulled by gravity, it moves even when the person is lying down. The muscular waves work in any position, so a person can swallow and move food along the gut even when lying flat.

Examiner's Note
The marks need peristalsis described as waves of circular muscle contracting behind the food and relaxing in front, and the point that it is muscular, not gravity, so it works in any position.

Language Clinic
The answer turns on Because. Because the food is pushed by muscle and not gravity explains, in one connected step, why the food still travels when the person is lying down.

Question 98

A disease flattens the villi that line a person's small intestine. Explain why this person becomes poorly nourished even though they eat enough food.

Model Answer

The villi normally give the small intestine a very large surface area for absorbing the digested food. Each one is tiny and finger-like, and their great number spreads the lining into a huge surface through which food can pass into the blood.

When the villi are flattened, this surface area is greatly reduced, so much less food can be absorbed. The digested food passes on and is lost in the faeces instead of entering the blood, so the person is poorly nourished even though they eat enough.

Examiner's Note
The marks need the villi giving a large surface area for absorption, and the point that flattening them reduces that surface, so much less digested food is absorbed into the blood.

Language Clinic
The answer leans on so, twice. It links the smaller surface to the food not being absorbed, and that in turn to the poor nourishment, carrying the reader along one chain of cause and effect.

Question 99

Follow a molecule of glucose from the moment it is absorbed in the small intestine to where it is finally used in the body.

Model Answer

An absorbed glucose molecule takes the following path through the body:

1) **Into the blood:** it passes through the wall of a villus into a blood capillary inside it.
2) **To the liver:** the blood carries it first to the liver through the hepatic portal vein.
3) **Controlled by the liver:** the liver keeps the blood sugar steady, storing any excess as glycogen for later.
4) **To the body cells:** the blood then carries the glucose to the cells all over the body.
5) **Used in respiration:** inside the cells the glucose is broken down in respiration to release the energy the body needs.

Examiner's Note
The marks need the glucose absorbed into a villus capillary, carried by the hepatic portal vein to the liver, which stores the excess as glycogen, then on to the cells to be used in respiration.

False Confidence Alert
Most students think absorbed glucose goes straight to the cells to be used. Yet it travels first to the liver, which controls how much sugar stays in the blood.

Question 100

Explain why a person suffering from severe diarrhoea can quickly become dangerously dehydrated.

Model Answer

The large intestine normally reabsorbs most of the water from the undigested material passing through it. This water is returned to the body, and the faeces are left firm.

In diarrhoea the material rushes through too fast for this water to be reabsorbed, so it is lost from the body. Large amounts of water leave in the watery faeces, so the body quickly loses water and becomes dangerously dehydrated.

Examiner's Note
The marks need the large intestine normally reabsorbing water, and the point that in diarrhoea the material passes too fast for this, so the water is lost and the body is dehydrated.

Language Clinic
The answer carries the harm with so. It links the rushing-through to the water not being reabsorbed, and then to the dehydration, showing the marker each step follows from the one before.

Question 101

Kipanga says that *passing out faeces is a form of excretion, just like passing urine.* Identify Kipanga's mistake, and put it right.

Model Answer

Kipanga is wrong: passing out faeces is egestion, not excretion. Excretion is the removal of waste made by the reactions of the body, such as the urea in urine, whereas faeces is mostly undigested food that the body never took in.

The undigested food in the faeces was never part of the chemistry of the body. It is food that passed through the gut without being absorbed, so getting rid of it is egestion; only the removal of true waste, like the urea in urine, counts as excretion.

Examiner's Note
The marks need faeces named as egestion, being undigested food that was never absorbed, set against excretion, the removal of metabolic waste such as urea that the body itself made.

Language Clinic
The answer divides the two with whereas, and concludes with so. Whereas sets the body-made waste against the undigested food, and so draws the verdict that getting rid of faeces is egestion.

Question 102

Explain why your mouth waters, and your stomach begins to prepare itself, when you smell *nyama choma* cooking, before you have eaten any of it.

Model Answer

The smell of the food is carried to the brain, which sets off the release of digestive juices in readiness. The brain sends nerve signals to the salivary glands, so saliva flows and the mouth waters before the food even arrives.

The same signals prepare the stomach to receive the food. Nerve signals tell the stomach to begin making its gastric juice, so the gut is ready to digest the meal as soon as it is swallowed.

Examiner's Note
The marks need the smell being detected by the brain, which then sends nerve signals that make the salivary glands and the stomach release their juices in readiness, before the food arrives.

Language Clinic
The answer ties cause to effect with so. The brain sends nerve signals, so the saliva flows: this small connector shows the watering mouth is the result of the signal, not chance.

Question 103

Kipute says that *once food has been absorbed into the blood, the body has "used" it.* Decide whether Kipute is right, and justify your answer.

Model Answer

Kipute is wrong: absorbing food into the blood is not the same as using it. Absorption only carries the digested food from the gut into the blood; at that point the body has not yet used it at all.

The food is used only when it is assimilated by the cells. Assimilation is when the cells take the food from the blood and build it into their own substance, or break it down for energy, so using the food is a later step than absorbing it.

Examiner's Note
The marks need absorption distinguished from assimilation: absorption only moves food into the blood, while the food is truly used only at assimilation, when the cells take it in and build it in or burn it for energy.

False Confidence Alert
Most students treat absorption and assimilation as the same thing. Yet absorption only puts food into the blood; it is assimilated, and truly used, only when the cells take it in.

HOT QUESTIONS

These final questions are the highest climb in the chapter. They do not test a single fact but ask you to join ideas from across the whole of nutrition, to weigh up evidence, and to reason your way through situations you have not met before. Read each one slowly, for here the thinking itself is what earns the marks.

Question 104

It is often said that nearly all life on Earth depends on autotrophs such as green plants. Evaluate how far this claim is true, even for a flesh-eating animal such as a lion.

Model Answer

The claim is true, because autotrophs are the only organisms that make food from simple raw materials, and every other living thing depends on that food. Green plants trap the energy of sunlight and build it into sugars, and this is the food on which all heterotrophs in the end feed.

Even a lion, which never eats a plant, still depends on autotrophs. The lion eats a zebra, but the zebra built its flesh by eating grass, so the energy in the lion's meal was first captured by a green plant; trace any food chain back and it begins with an autotroph.

Examiner's Note
Credit the point that autotrophs alone make food, so every heterotroph, even a top flesh-eater, traces its food and energy back to a green plant through the food chain.

False Confidence Alert
Most students think only plant-eaters depend on plants. Yet flesh-eaters depend on them too, since their prey, and the prey's food, trace back to autotrophs.

Question 105

The sundew is a small green plant of wet, poor soils. It photosynthesises like other green plants, yet its leaves also trap and digest insects. Decide how its nutrition should best be described, and justify your decision.

Model Answer

The sundew is mainly an autotroph, because it makes its own food by photosynthesis just as other green plants do. Being green, it traps sunlight and builds its own sugars, so for its energy and its carbon it does not depend on other organisms.

It traps insects not for energy but to gain the minerals that its poor soil cannot supply. The wet soil it grows in is short of nitrogen, so the digested insects provide nitrogen and other minerals; in this one respect it feeds heterotrophically, but its nutrition is autotrophic at heart.

Examiner's Note
Credit judging it as mainly autotrophic, since it photosynthesises for its food and energy, with the insect-trapping supplying only minerals rather than energy.

False Confidence Alert
Most students would call it a heterotroph because it eats insects. Yet it makes its own food by photosynthesis and traps insects only for extra minerals.

Question 106

Photosynthesis is carried out in two stages, the light reaction and the dark reaction. Explain why neither stage could feed the plant on its own, and how each one depends on the other.

Model Answer

The light reaction cannot feed the plant on its own, because it makes no sugar. It uses light to split water and to make ATP and reduced NADP, giving off oxygen, but it builds no food, so the energy it captures would be wasted without a second stage to use it.

The dark reaction cannot work on its own either, because it depends on the products of the light reaction. It fixes carbon dioxide into sugar, but only by using the ATP and reduced NADP that the light reaction supplies, so the two stages must work together for the plant to be fed.

Examiner's Note
Credit the contrast: the light reaction makes ATP and reduced NADP but no sugar, while the dark reaction makes sugar but only by spending those products, so the two are interdependent.

Language Clinic
The answer is built on because and so. Because gives the reason each stage fails alone, and so draws out that the two must work together, making the dependence clear in plain steps.

Question 107

Trace the journey of a carbon atom from carbon dioxide in the air until it becomes part of a sugar. Then use your trace to explain why a leaf cannot build this sugar in darkness, even though carbon dioxide can still reach the chloroplast.

Model Answer

The carbon enters the leaf as carbon dioxide and travels to the stroma of a chloroplast. It diffuses in through a stoma, then through the air spaces of the leaf, and into a chloroplast, reaching the stroma where the dark reaction takes place.

In the stroma the carbon is fixed onto RuBP and then reduced into a sugar. It is joined to the five-carbon compound RuBP, and the product is then reduced, using the ATP and reduced NADP made by the light reaction, until the carbon is part of a sugar.

In darkness the carbon can still reach the stroma, but it cannot be reduced into sugar. Without light the light reaction makes no ATP or reduced NADP, so the reducing step has no power supply; the carbon dioxide arrives but simply cannot be built into a sugar.

Examiner's Note
Credit the route to the stroma and the fixing onto RuBP, and then the real reasoning: in the dark there is no ATP or reduced NADP, so the carbon reaches the stroma yet cannot be reduced to sugar.

Language Clinic
The trace is ordered by then, and the dark case turns on so. Then walks the carbon in step by step, and so shows why, with no ATP or reduced NADP, the arrived carbon still cannot become sugar.

Question 108

Explain how the structure of a chloroplast suits it to carry out both the light reaction and the dark reaction of photosynthesis.

Model Answer

The grana hold the chlorophyll, and this is where the light reaction is carried out. The pigments are packed onto the stacked membranes of the grana, giving a large surface on which to catch the light and split water.

The stroma around the grana holds the enzymes, and this is where the dark reaction is carried out. This fluid bathes the grana and contains the enzymes that fix carbon dioxide, so the products made in the grana pass straight across to the dark reaction in the stroma.

Examiner's Note
Credit the grana holding the pigments for the light reaction and the stroma holding the enzymes for the dark reaction, the two sites lying together so the products pass easily between them.

Language Clinic
The answer uses where and so to map structure onto job. Where pins each reaction to its part of the chloroplast, and so shows why placing them together helps the work flow on.

Question 109

A green plant is given plenty of light, but only light of a pure green colour. Predict how well it will photosynthesise, and explain your reasoning.

Model Answer

The plant will photosynthesise only poorly in pure green light. Its chlorophyll absorbs mostly red and blue light and uses these to drive photosynthesis, while green is the colour it absorbs least of all.

The reason the leaf looks green is that it reflects green light instead of using it. Light that is reflected cannot be used in photosynthesis, so a plant given only green light is starved of the colours it needs and makes very little food.

Examiner's Note
Credit the prediction of poor photosynthesis, with the reason that chlorophyll absorbs red and blue but reflects green, so green light is the least useful of all.

False Confidence Alert
Most students expect green light to be best because leaves are green. Yet the green is the light the leaf reflects and cannot use, not the light it absorbs.

Question 110

In a leaf, the palisade cells lie just beneath the upper surface and contain far more chloroplasts than the cells lower down. Explain how this arrangement helps the leaf to photosynthesise.

Model Answer

The palisade cells lie at the top of the leaf because that is where the light is strongest. Light strikes the upper surface first, so the cells placed there receive more light than any others in the leaf.

Packing the most chloroplasts into these well-lit cells captures the most light for photosynthesis. The chloroplasts are gathered just where the light is brightest, so little light is wasted and the leaf makes as much food as it can.

Examiner's Note
Credit the palisade cells sitting where the light is strongest, and the gathering of most chloroplasts there to catch the most light, so little of it is wasted.

Language Clinic
The answer joins place to purpose with because and so. Because explains why the cells sit at the top, and so explains why crowding chloroplasts there pays off in more food.

Question 111

When the rate of photosynthesis is plotted against light intensity, the rate first rises steeply as the light increases, but then levels off and stays flat however bright the light becomes. Explain what is happening in each part of this graph.

Model Answer

On the rising part of the graph, light is the factor that is limiting the rate. Here there is too little light, so as more is given the rate climbs steeply; light is in short supply and is setting how fast the photosynthesis can go.

On the flat part, light is no longer limiting, because some other factor has taken over. However bright the light becomes, the rate cannot rise any further, because now it is held back by a shortage of carbon dioxide or by the temperature, so more light can no longer help.

Examiner's Note
Credit light as the limiting factor on the rising part, so the rate climbs with it, and on the flat part light no longer limiting while carbon dioxide or temperature now caps the rate.

Language Clinic
The answer hinges on because and so. Because names the new factor that flattens the curve, and so draws the conclusion that adding more light, once it is plentiful, can no longer help.

Question 112

A farmer growing crops in a glasshouse already keeps them in bright light. He raises the temperature, hoping to speed up their photosynthesis, but the rate hardly changes. Suggest, with reasons, which factor is most likely limiting the rate, and what he should change instead.

Model Answer

Because raising the temperature did almost nothing, temperature cannot be the factor that is limiting the rate. If temperature had been in short supply, warming the glasshouse would have sped the photosynthesis up; since it did not, the rate must be held back by something else.

The most likely limiting factor is the carbon dioxide, so that is what he should raise. In a closed glasshouse, in bright and warm conditions, the carbon dioxide is soon used up, so adding more carbon dioxide is the change most likely to speed the photosynthesis up.

Examiner's Note
Credit the reasoning that temperature is not limiting, since raising it did nothing, and the identifying of carbon dioxide as the likely limiting factor that the farmer should raise instead.

False Confidence Alert
Most students reach for more heat, sure that warmth always speeds photosynthesis. Yet if temperature is not the factor in short supply, raising it changes nothing at all.

Question 113

If you raise the light or the carbon dioxide too far, the rate of photosynthesis simply stops rising; but if you raise the temperature too far, the rate falls and may stop altogether. Explain why temperature behaves so differently from the other two.

Model Answer

Light and carbon dioxide are the energy and the raw material of photosynthesis, so any excess of them is simply not used. Once the plant has all the light or carbon dioxide it can use, the extra has no effect, so the rate just levels off and stays flat.

Temperature is different because it acts on the enzymes that carry out the reactions. A little more warmth makes the enzymes work faster, but too much heat denatures them, so they lose their shape and stop working, which is why too high a temperature makes the rate fall rather than merely level off.

Examiner's Note
Credit light and carbon dioxide as raw materials whose excess goes unused so the rate plateaus, set against temperature acting on the enzymes, which are denatured by too much heat so the rate falls.

Language Clinic
One word, so, does two jobs here. With light or carbon dioxide the excess is unused, so the rate levels off; with heat the enzymes are denatured, so the rate falls: the same connector, two different ends.

Question 114

Maize and sugarcane are C4 plants, and they grow faster than many other crops in the hot, bright conditions found over much of Tanzania. Using what you know of how C4 plants fix carbon, suggest why they do so well here.

Model Answer

C4 plants such as maize have a way of concentrating carbon dioxide around the enzyme that fixes it. They first trap carbon dioxide in their outer cells and pass it inward, so the carbon-fixing enzyme is kept well supplied with it even when little is about.

This lets them keep photosynthesising quickly in the hot, bright conditions where ordinary plants struggle. In strong heat a plant often half-closes its stomata to save water, which starves an ordinary plant of carbon dioxide; but a C4 plant already has carbon dioxide concentrated inside, so it goes on fixing carbon fast and outgrows its rivals.

Examiner's Note
Credit the C4 plant concentrating carbon dioxide around its fixing enzyme, so it keeps photosynthesising fast in heat, when the stomata half-close and carbon dioxide would otherwise run short.

Language Clinic
The answer balances the two plants with but and so. But sets the struggling ordinary plant against the C4 plant, and so explains why the stored carbon dioxide lets the C4 plant keep racing ahead.

Question 115

At dawn, and again at dusk, there is a brief moment when a green plant in dim light takes in no carbon dioxide from the air and gives out none, although it is alive and lit. Explain what is happening at this moment.

Model Answer

At this moment the plant's photosynthesis is going at exactly the same rate as its respiration. The dim light lets it photosynthesise only slowly, and it happens that this slow rate exactly matches the rate at which the plant is respiring.

Because the two processes balance, there is no net exchange of gas with the air. The carbon dioxide given out by respiration is just enough to feed photosynthesis, and the oxygen given out by photosynthesis is just enough for respiration, so neither gas needs to pass in or out; this balance is called the compensation point.

Examiner's Note
Credit photosynthesis and respiration going at equal rates, so each uses the gas the other gives off and there is no net exchange with the air, which is the compensation point.

False Confidence Alert
Most students think a lit plant must always take in carbon dioxide. Yet in dim light its photosynthesis can exactly balance its respiration, so no gas needs to pass either way.

Question 116

A student leaves a potted plant in the light with part of one leaf covered, then tests that leaf for starch to prove that light is needed for photosynthesis. He did not destarch the plant first. Explain why his experiment proves nothing, and what he must do to put it right.

Model Answer

His experiment proves nothing, because the starch he finds may have been in the leaf before the experiment even began. A plant that has been standing in the light already holds starch in its leaves, so finding starch in the lit part does not show that this starch was made during his test.

To put it right, he must first destarch the plant by keeping it in the dark until its leaves hold no starch. Then any starch found at the end must have been made during the experiment, so a result that is positive only in the lit part would truly show that light is needed.

Examiner's Note
Credit the flaw that without destarching the starch could be old, so the test proves nothing, and the fix of destarching first so any starch found must be newly made in the light.

Language Clinic
The answer turns on because and so. Because exposes the hidden flaw, the old starch, and so carries the reader to the cure: destarch first, and only then does a positive test mean anything.

Question 117

Compare the way a green plant, a mushroom and a tapeworm each obtain their food, and use this to explain why, of the three, only the green plant can live entirely on its own.

Model Answer

The three feed in three different ways: the green plant makes its own food, while the mushroom and the tapeworm must take theirs from other organisms. The green plant is an autotroph, building its food from simple raw materials; the mushroom is a saprophyte, feeding on dead remains; and the tapeworm is a parasite, taking its food from a living host.

Only the green plant is truly independent, because it needs no other living thing to feed it. The mushroom must have dead matter to live on, and the tapeworm must have a living host, so both depend on other organisms, while the green plant alone can make all it needs from sunlight, air, water and minerals.

Examiner's Note
Credit the three modes named correctly, the autotroph making its own food, the saprophyte feeding on dead matter and the parasite on a living host, and the conclusion that only the autotroph is independent.

Language Clinic
The answer is held together by while. It sets the self-feeding plant against the two that must take their food, so the reader sees at a glance why only the green plant can stand alone.

Question 118

A herbivore such as a cow has a much longer gut than a carnivore such as a lion of similar size. Suggest why the cow needs the longer gut.

Model Answer

The cow needs a longer gut because its plant food is much harder to digest than the lion's meat. Plant food is full of tough cellulose that is difficult to break down, so it must be held in the gut a long time and worked on over a great length before its goodness can be taken in.

The lion's meat is far easier to digest, so a shorter gut is enough for it. Meat is rich and quickly broken down, so the lion need not hold it as long or pass it through so great a length; the cow, living on poorer and tougher food, needs the extra length to draw enough from it.

Examiner's Note
Credit plant food being tough and hard to digest, so the herbivore needs a long gut and a long time, set against meat being easily digested, so the carnivore manages with a shorter one.

False Confidence Alert
Most students think a longer gut simply means a bigger animal. Yet the cow's gut is long because its plant food is hard to digest, not because the cow itself is large.

Question 119

A tapeworm lives inside a person, and nitrogen-fixing bacteria live inside the root nodules of a bean plant. Both involve one organism living within another, yet the first is called parasitism and the second mutualism. Explain what makes the difference.

Model Answer

The difference lies in who benefits from the partnership, not in the living together itself. In both cases one organism lives inside another, so the mere fact of living together cannot be what tells them apart.

In parasitism only one partner gains while the other is harmed, whereas in mutualism both partners gain. The tapeworm robs the person of food and gives nothing back, so the person is harmed; but the bacteria give the bean plant nitrogen and receive sugars in return, so both gain, and that is why one is parasitism and the other mutualism.

Examiner's Note
Credit the point that the classifying difference is who benefits, parasitism with one gaining and the other harmed, mutualism with both gaining, rather than the simple fact of living together.

Language Clinic
The answer pivots on whereas. Whereas balances the one-sided gain of the parasite against the shared gain of the partners, so the marker sees exactly which feature decides the name.

Question 120

Explain why the food we eat must be digested at all, instead of simply being absorbed into the blood just as it is.

Model Answer

Much of the food we eat is made of molecules that are far too large and insoluble to pass through the wall of the gut into the blood. Starch, protein and fat are large molecules that cannot cross the lining of the gut, so as they are, they could never reach the blood at all.

Digestion breaks these large molecules into small, soluble ones that can be absorbed and used. It turns starch into sugars, protein into amino acids and fat into its own units, all small enough to pass into the blood, so that the body can then build them into its own substance.

Examiner's Note
Credit the point that food molecules are too large and insoluble to be absorbed, and that digestion breaks them into small soluble molecules that can pass into the blood and be used.

False Confidence Alert
Most students think food can be absorbed just as it is eaten. Yet large insoluble molecules cannot pass into the blood until digestion has made them small and soluble.

Question 121

A meal of *ugali*, beans and meat cannot be digested by a single enzyme. Explain why the body needs many different digestive enzymes rather than just one.

Model Answer

Each enzyme is specific, working only on one kind of food and on no other. An enzyme that digests starch cannot digest protein or fat; it fits only its own kind of food, much as a key fits only its own lock.

A mixed meal contains several kinds of food, so each kind must have its own enzyme. The ugali is starch, the beans and meat are rich in protein, and there is some fat as well, so the body must make a different enzyme for each, or the others would pass through undigested.

Examiner's Note
Credit enzymes being specific, each acting on one food only, so that a mixed meal of starch, protein and fat needs a different enzyme for each of the three.

Language Clinic
The little word so links the rule to its result. Because each enzyme is specific, so each food must have its own; the connector turns one fact about enzymes into the reason for many.

Question 122

Predict what would happen to a person's digestion if their pancreas stopped making its juice, and explain your reasoning.

Model Answer

The person would fail to digest much of their food, because the pancreas supplies enzymes for all three main kinds of food. Its juice carries an enzyme for starch, one for protein and one for fat, so without it, starch, protein and fat would all be poorly digested in the small intestine.

The acid from the stomach would also no longer be neutralised. The pancreatic juice is alkaline and normally neutralises that acid, so without it the small intestine would stay too acid for its enzymes to work, and the person would become poorly nourished.

Examiner's Note
Credit the pancreas serving starch, protein and fat alike, so all three are poorly digested, and the loss of its alkali, so the stomach acid is no longer neutralised in the small intestine.

False Confidence Alert
Most students expect only one food to suffer. Yet the pancreas serves starch, protein and fat together, so losing its juice harms the digestion of all three at once.

Question 123

Explain why it is an advantage that food passes through the gut slowly, and in one direction only, from the mouth to the anus.

Model Answer

Because the food moves in one direction, each region of the gut can act on it in turn, in the right order. The teeth and saliva work on it first, then the stomach, then the small intestine, so the food meets the right treatment at each stage along the way.

Because the food moves slowly, there is time for the digestion and the absorption to be completed. The slow passage gives the enzymes time to finish their work and the digested food time to be absorbed, before the waste that is left is passed out; a rushed or two-way movement would let food escape only half digested.

Examiner's Note
Credit the one-way flow letting each region act in turn in the right order, and the slow passage giving time for digestion and absorption to be completed before the waste is egested.

Language Clinic
The answer marches through the gut with then, and rests each advantage on Because. Then sets the regions in order, and Because ties the slow, one-way flow to the time the work needs.

Question 124

In a villus there are two kinds of vessel: a blood capillary and a lacteal. The products of digested fat are absorbed into the lacteal, while the glucose and amino acids are absorbed into the blood capillary. Explain the reason for this difference.

Model Answer

Glucose and amino acids dissolve in water, so they pass easily into the watery blood of the capillary. Being soluble in water, they mix at once with the blood plasma and are carried away in the bloodstream.

The products of fat do not dissolve in water, so they cannot be carried in the blood in the same way and enter the lacteal instead. The lacteal holds a milky lymph that can take up the tiny fatty droplets, so the fat travels first by the lymph and only later joins the blood; this is why the villus needs both kinds of vessel.

Examiner's Note
Credit glucose and amino acids being water-soluble so they enter the blood capillary, while the fat products are not water-soluble so they enter the lacteal, which is why the villus has both.

Language Clinic
One word, so, carries the reasoning twice. The food dissolves, so it enters the blood; the fat does not, so it enters the lacteal: the same connector marks the two opposite routes.

Question 125

All the blood that carries food away from the gut is taken first to the liver. Explain what the liver does with the glucose and with the excess amino acids it receives, and why the amino acids must be treated so differently from the glucose.

Model Answer

The liver keeps the blood glucose steady, storing any excess as glycogen and giving it back when the blood runs low. Glucose can be stored and returned as the body needs it, so the liver uses it to keep a steady supply for the whole body.

Excess amino acids, however, cannot be stored at all, so the liver must break them down. It strips off their nitrogen part to form urea, which the kidneys then remove from the body, while the rest is used for energy; this is why the amino acids are dealt with so differently from glucose, which can simply be kept in store.

Examiner's Note
Credit the liver storing excess glucose as glycogen and releasing it when low, set against excess amino acids, which cannot be stored, so the liver removes their nitrogen as urea for the kidneys to excrete.

False Confidence Alert
Most students think the body stores spare protein the way it stores fat. Yet amino acids cannot be stored; the liver strips off their nitrogen as urea and uses what is left for energy.

Question 126

A plate of *ugali* and beans gives a person the energy to work and to play. Trace the energy in this meal back to its very first source, and use your answer to explain how nutrition in animals is linked to nutrition in plants.

Model Answer

The energy in the ugali and the beans was first captured from sunlight by green plants. The maize and the bean plants used the energy of the Sun in photosynthesis to build sugars and other foods, locking the energy of the sunlight into the plant.

When the person eats and digests this plant food, that same energy is set free for their own life. Digestion and assimilation break the food down and build it into the body or release its energy, so the person is really living on energy that began in the Sun, which shows how closely animal nutrition depends on the nutrition of plants, and through it on the Sun itself.

Examiner's Note
Credit the energy being traced from sunlight, trapped by photosynthesis in the plants, to the person who frees it again by digesting and assimilating the food, so that animal nutrition rests upon plant nutrition and the Sun.

Language Clinic
The closing word so seals the whole chapter. The Sun energy is locked into the plant, so the person who eats it lives on the Sun, joining the two halves of nutrition in a single line of thought.

Chapter 7

GAS EXCHANGE AND RESPIRATION

BINDER QUESTIONS

Work through the questions in order. Attempt each one on paper before consulting the model answer beneath it. Then study the annotations carefully before moving on to the next question. Every model answer begins with the mark-scoring point in bold, helping you focus on what examiners reward most.

Question 1

Every cell in a mammal needs a steady supply of oxygen, yet most of its cells lie deep inside the body, far from the air. Explain what is meant by a respiratory surface, and why the gases always cross it by diffusion rather than being pumped across.

Model Answer

A respiratory surface is the part of an organism where oxygen is taken in and carbon dioxide is given out. It is the thin, moist, permeable boundary between the body and its surroundings, and in a mammal it is the lining of the millions of alveoli in the lungs.

The gases cross it by diffusion because a respiring cell is forever using up oxygen and producing carbon dioxide. This keeps oxygen more concentrated in the air than in the blood, and carbon dioxide more concentrated in the blood, so each gas moves down its own concentration gradient, with no energy spent by the body on the crossing.

Examiner's Note
The marks need the respiratory surface defined as the thin, moist boundary where gases are exchanged, and diffusion explained as passive movement down a concentration gradient that respiration keeps steep.

False Confidence Alert
Most students say the body pumps the gases across the surface. The crossing itself is passive diffusion; the body spends energy only on breathing, which keeps the gradient steep, and not on moving the gases across the surface.

Question 2

A flatworm exchanges gases over its whole body surface, but a large, active mammal cannot survive that way. Describe the features that every good respiratory surface must have, and explain how each one helps the gases to cross quickly.

Model Answer

A good respiratory surface shares several features, each of which speeds the diffusion of gases:

1) **Thin, often one cell thick:** the gases have only a short distance to diffuse across.
2) **Moist:** the gases dissolve in the film of moisture before they pass through.
3) **Large in surface area:** a great area lets many gas molecules cross at once.
4) **Permeable:** the respiratory gases can pass freely through it.
5) **Well supplied with blood:** capillaries carry the gases away, keeping the concentration gradient steep.

Examiner's Note
Each feature must be tied to its effect on the rate of diffusion; a bare list of features without the reasons earns few of the marks.

Question 3

The breathing system carries air from the nose down to the gas-exchange surface deep in the chest. Draw a large, labelled diagram of the human breathing system, and beside it trace the route a breath of air takes to reach an alveolus.

Model Answer

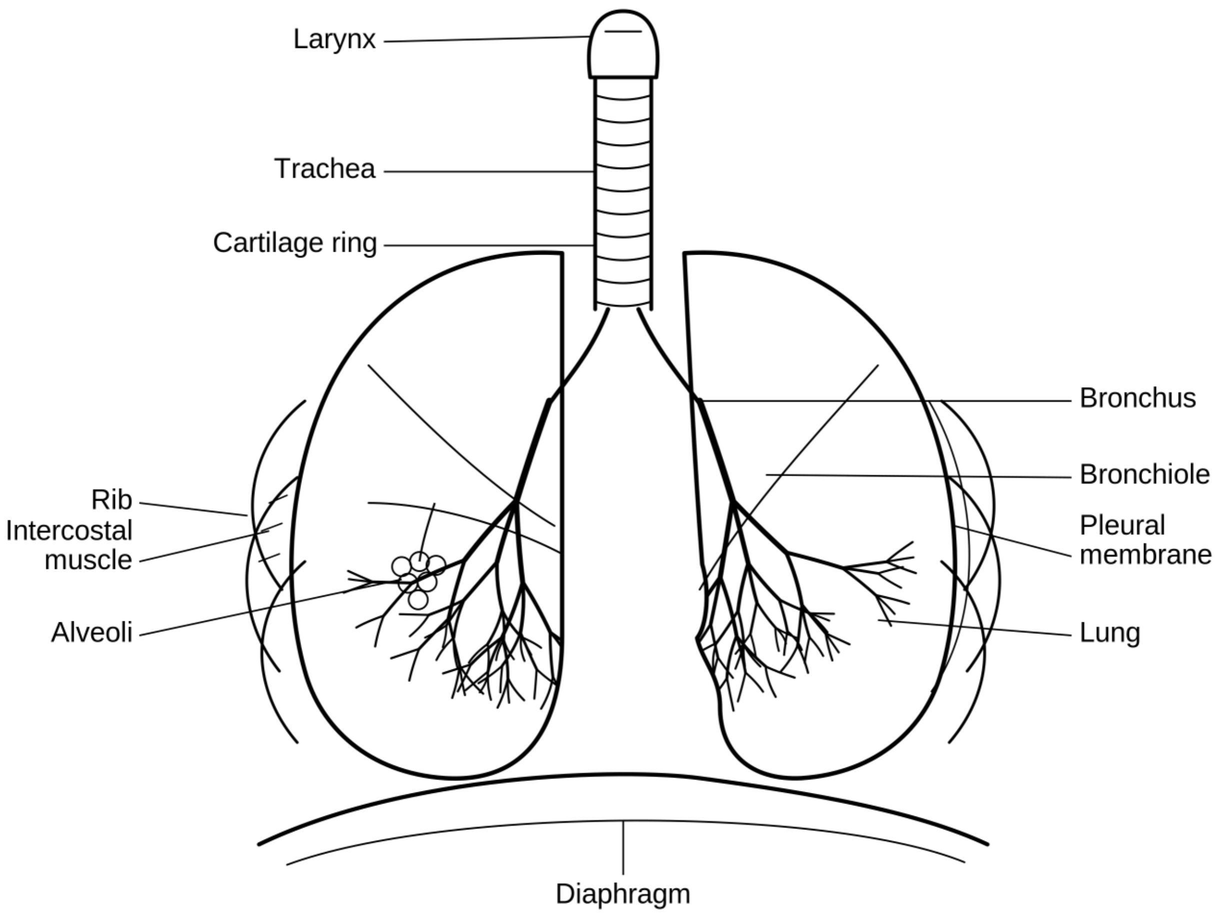


Figure 7.1: *The human breathing system.*

A breath of air passes from the nose, through the larynx, and into the trachea, the windpipe held open by rings of cartilage. The trachea divides into two bronchi, one to each lung, and each bronchus branches into finer and finer bronchioles. The finest bronchioles open into the alveoli, the tiny air sacs where gas exchange takes place. The ribs with their intercostal muscles around the lungs, and the diaphragm below them, move the air in and out.

Examiner's Note
The mark-bearing labels are the larynx, the trachea with its rings of cartilage, the bronchus, the bronchioles, the alveoli, the lung, the ribs, the intercostal muscles and the diaphragm. Draw the diagram large; the commonest error is a cramped diagram with crossing leader lines, so keep each leader straight and ending on the structure it names.

Question 4

The lungs have no muscles of their own and never touch the wall of the chest directly. Describe the thoracic cavity, and explain how the pleural membranes and the pleural fluid allow the lungs to move smoothly as a person breathes.

Model Answer

The thoracic cavity is the airtight space inside the rib cage that holds the lungs, with the ribs and the intercostal muscles as its walls and the muscular diaphragm as its floor, separating it from the abdomen below.

Two pleural membranes line the cavity, one covering each lung and one lining the chest wall, with a film of pleural fluid in the narrow space between them. The fluid works as a lubricant, so that the two surfaces slide over each other without friction as the lungs fill and empty. Because the fluid also holds the two membranes together, the lung is pulled out to follow the chest wall whenever the chest expands.

Examiner's Note
The marks need the thoracic cavity as the closed space holding the lungs, and the pleural fluid acting both as a lubricant that prevents friction and as a film that keeps the lung against the moving chest wall.

Language Clinic
The answer turns on two connectors. "So that" names the result the lubricant achieves, and "because" supplies the cause of the lung following the chest wall; these cause-and-result links are what a marker rewards.

Question 5

The wall of an alveolus is only one cell thick and is easily damaged. Explain why the air must be cleaned and moistened before it reaches the alveoli, and how the lining of the airway does this.

Model Answer

The air must be cleaned because it carries dust and microbes that could block or infect the delicate alveoli, and moistened because a stream of dry air would dry out and damage the thin alveolar walls.

Goblet cells in the wall of the trachea and bronchi make sticky mucus that traps the dust and the microbes, and the ciliated cells beside them beat to sweep this dirty mucus up and away from the lungs, to be swallowed or coughed out. The moist lining of the nose also warms and moistens the air on its way down.

Examiner's Note
The marks need both jobs: the mucus of the goblet cells trapping the dust and the cilia sweeping it away, and the moist lining warming and moistening the air to protect the thin alveolar walls.

Question 6

When a person breathes in hard, the air pressure inside the airway falls sharply. Explain why the trachea and bronchi are strengthened with rings of cartilage, and why these rings are C-shaped rather than complete circles.

Model Answer

The trachea and bronchi are held open by rings of cartilage so that they do not collapse when the pressure inside them falls during a strong breath in. Without the cartilage the soft tube would be sucked flat and the air could no longer pass to the lungs.

The rings are C-shaped, with a gap at the back, so that the soft oesophagus lying directly behind the trachea can bulge into that gap when a large lump of food is swallowed. The cartilage thus keeps the airway open while still letting the food pass freely down the food pipe behind it.

Examiner's Note
The marks need the cartilage holding the airway open against the fall in pressure, and the C-shape leaving room for the oesophagus behind to expand during swallowing.

Question 7

Breathing draws fresh air deep into the lungs and drives stale air out again, yet the lungs themselves contain no muscle. Explain the mechanism of ventilation, describing what the muscles do during breathing in and during breathing out.

Model Answer

During breathing in, the diaphragm contracts and flattens and the external intercostal muscles contract to pull the ribs upwards and outwards. This makes the thoracic cavity larger, so the pressure of the air inside the lungs falls below the air pressure outside the body, and air is pushed in through the airway until the pressures are equal.

During breathing out, the diaphragm and the intercostal muscles relax. The diaphragm domes upwards again and the ribs fall downwards and inwards, so the cavity becomes smaller, the pressure inside rises above the outside, and the stale air is forced out.

Examiner's Note
The marks need the chain in each case, from the muscles, to the change in volume, to the change in pressure, to the flow of air, for both breathing in and breathing out.

False Confidence Alert
Most students say the lungs suck the air in. The lungs have no muscles of their own; the diaphragm and the intercostal muscles change the volume of the chest, and air then flows in or out down the pressure gradient.

Language Clinic
The word "so" carries the mechanism, linking the muscle action to the change in volume and then to the airflow. Reading "so ... so ..." trains the student to write a connected pressure-and-volume chain rather than a list of separate facts.

Question 8

A person who has just run a race is said to be 'breathing hard' and also 'respiring fast', as though the two words meant the same thing. Explain the difference between breathing (ventilation) and respiration.

Model Answer

Breathing, or ventilation, is the movement of air into and out of the lungs. It is a physical, mechanical process, brought about by the muscles of the chest, that keeps fresh air at the gas-exchange surface.

Respiration, in contrast, is the chemical breakdown of food inside the cells to release energy as ATP. It goes on in every living cell, whereas breathing happens only at the lungs; breathing simply supplies the oxygen that respiration needs and carries away the carbon dioxide that respiration makes.

Examiner's Note
The marks need breathing defined as the mechanical movement of air and respiration as the chemical release of energy in the cells, with the link that breathing serves respiration.

False Confidence Alert
Most students use breathing and respiration to mean the same thing. Breathing only moves the air, while respiration is the chemical reaction inside the cells; a cell can respire even when no breathing is taking place.

Language Clinic
The phrase "in contrast" sets the two processes against each other, and "whereas" draws the precise line between them. These are the comparison connectors a marker looks for in a difference question.

Question 9

A person breathes in and out about fifteen times a minute, all through life, never stopping for long. Explain why ventilation must go on continuously, and how this keeps gas exchange at the alveolus fast.

Model Answer

Ventilation must go on continuously to keep the air in the alveoli fresh. Each breath in brings in air rich in oxygen and poor in carbon dioxide, and each breath out removes the stale air that has given up its oxygen and taken up carbon dioxide.

Fresh air keeps the concentration gradients between the alveolar air and the blood steep, because the oxygen in the alveolus stays higher than in the blood and the carbon dioxide lower. This steep gradient keeps oxygen diffusing quickly into the blood and carbon dioxide out of it; if breathing stopped, the gradients would level off and exchange would cease.

Examiner's Note
The marks need the chain from continuous fresh air, to a steep concentration gradient, to fast diffusion of the gases.

Language Clinic
"Because" supplies the reason the gradient stays steep, and the conditional "if breathing stopped ..." shows the consequence of losing it; together they build the fresh-air-to-fast-diffusion chain a marker rewards.

Question 10

Gas exchange in a mammal takes place across the wall of the alveolus, between the air and the blood. Draw a labelled diagram of an alveolus and its blood capillary, and use it to show how oxygen and carbon dioxide are exchanged.

Model Answer

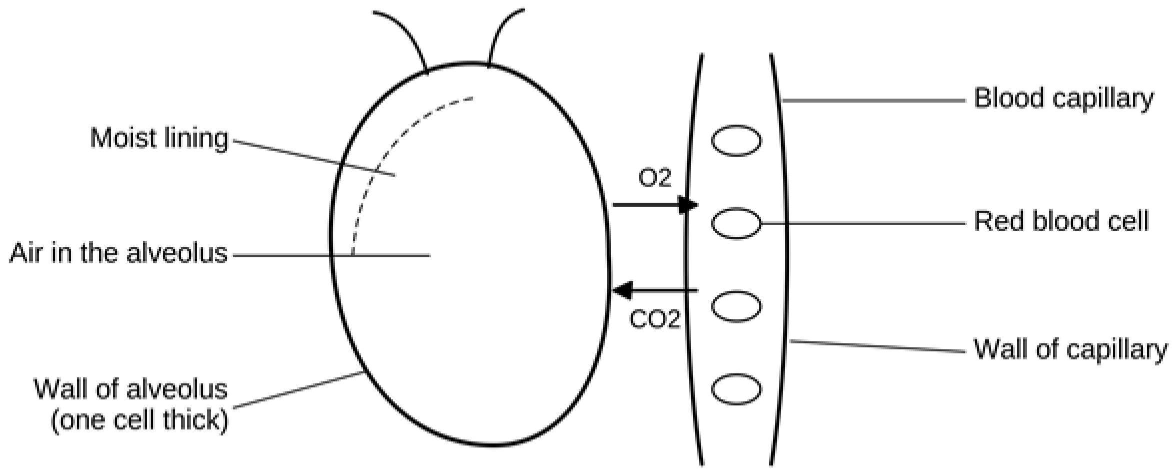


Figure 7.2: *An alveolus and its blood capillary, showing the exchange of gases.*

Oxygen in the alveolar air dissolves in the moist lining and diffuses across the thin alveolar wall and the thin capillary wall into the red blood cells, which carry it away. Carbon dioxide diffuses the opposite way, from the blood into the alveolus, and is breathed out. The two walls the gases cross are each only one cell thick, so the diffusion distance is very short.

Examiner's Note
The mark-bearing labels are the air in the alveolus, the thin alveolar wall, the moist lining, and the blood capillary with its red blood cells, together with arrows showing oxygen diffusing into the blood and carbon dioxide diffusing out. The commonest error is to omit the arrows that prove the direction of exchange.

Question 11

The two lungs together hold about three hundred million alveoli. Explain how the features of a single alveolus suit it for the rapid exchange of gases.

Model Answer

Each feature of the alveolus speeds the exchange of gases:

1) **A very thin wall, one cell thick:** it lies against an equally thin capillary wall, so the gases cross only a tiny distance.
2) **An enormous total surface area:** the millions of alveoli give an area of the order of eighty square metres for gases to cross at once.
3) **A moist lining:** the gases dissolve in it before they diffuse into or out of the blood.
4) **A dense network of capillaries:** the blood carries oxygen away and brings carbon dioxide, so the gradients stay steep.

> **Examiner's Note**
> The marks need the features taken together and each tied to faster diffusion: the thin wall for a short distance, the huge area for more crossing at once, the moist film for the gases to dissolve, and the rich blood supply for a steep gradient.

Question 12

A film of liquid lines the inside of every alveolus, and on its own this film would tend to make the tiny alveolus collapse. Explain what surfactant is and how it keeps the alveoli open.

Model Answer

Surfactant is a soapy substance made by cells in the wall of the alveolus, and it lowers the surface tension of the moist film that lines it. Surface tension is the inward pull of the water molecules on one another, which by itself would draw the wet walls of a small alveolus together.

By lowering this surface tension, surfactant stops the alveoli from collapsing as the air leaves them during breathing out, and makes them easier to reopen on the next breath in. Without enough surfactant, as in a baby born too early, the alveoli tend to stick shut.

> **Examiner's Note**
> The marks need surfactant named as a substance that lowers the surface tension of the alveolar film, and the result that the alveoli are kept from collapsing and are easier to reinflate.

> **False Confidence Alert**
> Most students think surfactant is there simply to keep the lung moist. Its job is to lower surface tension; without it the wet walls of a small alveolus would pull together and the alveolus would collapse.

Question 13

Even after the mucus and cilia of the airway have done their work, some dust and microbes still reach the alveoli, where there are no cilia to remove them. Explain how the alveoli are protected from these invaders.

Model Answer

The alveoli are guarded by macrophages, large white cells that move freely over the alveolar surface. They protect the delicate gas-exchange surface by engulfing and digesting the dust particles and microbes that have reached the alveoli, a process called phagocytosis.

In this way the macrophages act as the last line of defence, cleaning up whatever the mucus and cilia of the airway failed to trap, and keeping the thin alveolar walls clear so that gas exchange is not blocked.

Examiner's Note
The marks need the macrophages named as the guarding cells and phagocytosis named as the way they engulf and digest the dust and microbes that reach the alveoli.

Question 14

Most of the oxygen a mammal needs is carried not in the watery plasma but on the red pigment inside its red blood cells. Explain how haemoglobin carries oxygen from the lungs to the respiring tissues.

Model Answer

Haemoglobin is a red pigment, packed into the red blood cells, that combines with oxygen where oxygen is plentiful. In the lungs, where the oxygen is at a high concentration, each haemoglobin molecule binds oxygen to form oxyhaemoglobin, and in this way the blood is loaded with oxygen.

Where the oxygen is scarce, the haemoglobin releases it again. In the respiring tissues the oxygen is at a low concentration, so the oxyhaemoglobin breaks down and gives up its oxygen to the cells, and the haemoglobin then returns to the lungs to be loaded once more.

Examiner's Note
The marks need haemoglobin combining with oxygen to form oxyhaemoglobin in the lungs where oxygen is plentiful, and releasing it again in the tissues where oxygen is scarce.

Language Clinic
The whole answer turns on where. It combines with oxygen where oxygen is plentiful and releases it where oxygen is scarce; the one connector ties the loading and the unloading to the two places.

Question 15

Oxygen will dissolve a little in blood plasma, yet without a respiratory pigment a large, active mammal would soon suffocate. Explain why a pigment such as haemoglobin is needed to carry the oxygen.

Model Answer

Oxygen dissolves only very slightly in water, so the plasma on its own could carry only a tiny fraction of the oxygen an active mammal needs. A body that relied on dissolved oxygen alone could never supply its busy tissues.

Haemoglobin overcomes this, because each molecule can pick up four molecules of oxygen, and the red cells are packed full of it. In this way the blood can carry many times more oxygen than the plasma could ever dissolve, which is enough to keep a large and active body supplied.

Examiner's Note
The marks need the point that oxygen barely dissolves in plasma, far too little for an active mammal, and that haemoglobin greatly increases the oxygen the blood can carry.

False Confidence Alert
Most students think the plasma carries the oxygen. Yet plasma dissolves very little; almost all the oxygen is carried combined with the haemoglobin of the red cells.

Question 16

The way haemoglobin loads and unloads its oxygen can be read from a graph called the oxygen dissociation curve. Draw this curve, and use it to explain how haemoglobin loads oxygen in the lungs and unloads it in the tissues.

Model Answer

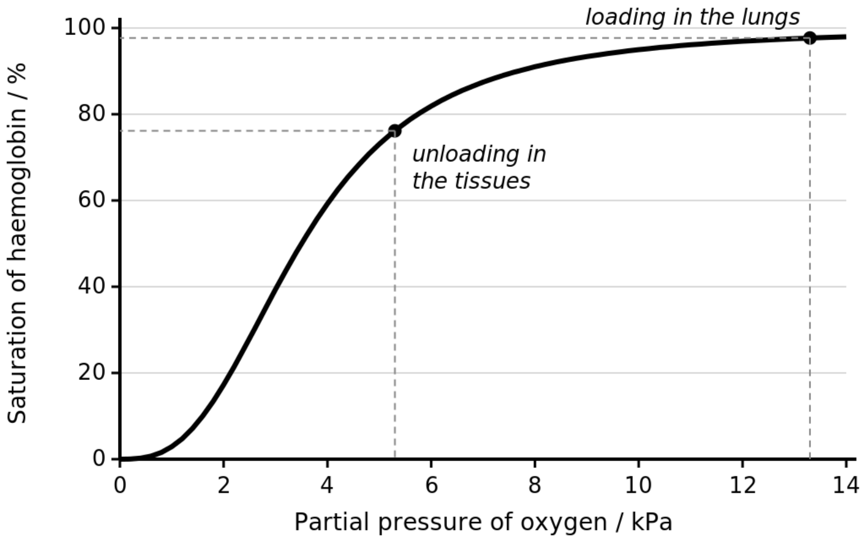


Figure 7.3: *the oxygen dissociation curve of haemoglobin.*

The curve has an S-shape, called a sigmoid curve. It plots the percentage saturation of the haemoglobin with oxygen against the partial pressure of the oxygen around it.

Where the partial pressure of oxygen is high, as in the lungs, the haemoglobin is almost completely saturated, so it loads up fully with oxygen. Where the partial pressure is low, as in the respiring tissues, the saturation falls, so the haemoglobin unloads a large part of its oxygen to the cells that need it.

Examiner's Note
The marks need the S-shaped curve correctly drawn, with high saturation and loading at the high partial pressure of the lungs, and falling saturation and unloading at the low partial pressure of the tissues.

False Confidence Alert
Most students read the flat top of the curve as meaning little oxygen is taken up. Yet that high, flat part shows the haemoglobin is almost fully loaded in the lungs.

Question 17

The oxygen dissociation curve is not a straight line but an S-shape, and this shape is of great value to the working tissues. Explain why the sigmoid shape lets a small fall in oxygen tension unload a large amount of oxygen.

Model Answer

Along the steep middle part of the S-shaped curve, a small drop in the partial pressure of oxygen brings a large drop in the saturation of the haemoglobin. The curve is steepest exactly across the range of oxygen tensions found in the respiring tissues.

So when a tissue uses up oxygen and its oxygen tension falls only a little, the haemoglobin passing through it gives up a large share of its oxygen. The harder a tissue works, and the lower its oxygen falls, the more oxygen the blood unloads to it.

Examiner's Note
The marks need the steep middle of the curve, where a small fall in the partial pressure of oxygen causes a large fall in saturation, so a large amount of oxygen is unloaded where the tissues need it.

Language Clinic
The pivot word is so. A small fall in oxygen tension, so a large unloading of oxygen: the connector turns the shape of the curve into its benefit for the tissues.

Question 18

When a tissue works hard it pours out carbon dioxide, and this makes the haemoglobin there give up its oxygen even more readily. Explain what the Bohr effect is, and how it helps the hardest-working tissues.

Model Answer

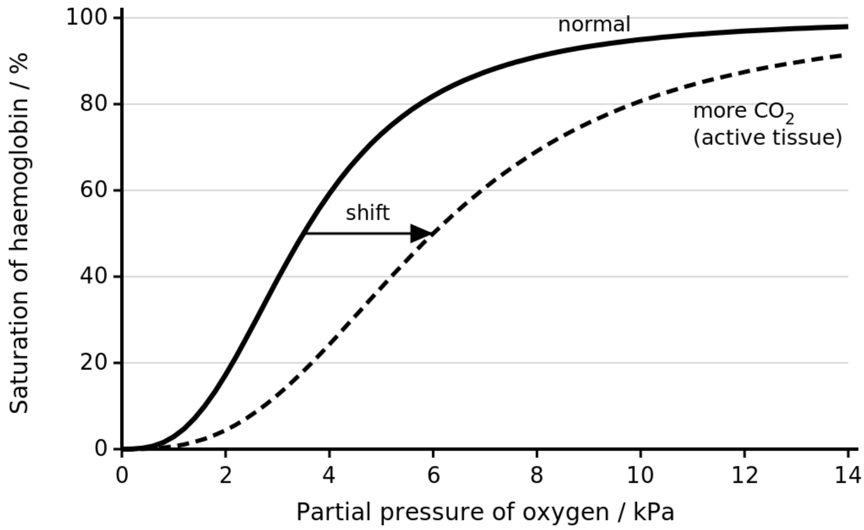


Figure 7.4: *the Bohr effect; more carbon dioxide shifts the curve to the right.*

The Bohr effect is the shifting of the oxygen dissociation curve to the right when the carbon dioxide around the haemoglobin rises. The extra carbon dioxide makes the surroundings slightly more acid, and this lowers the affinity of the haemoglobin for oxygen.

Because the curve shifts to the right, at any given oxygen tension the haemoglobin now holds less oxygen, so it unloads more. A hard-working tissue makes a great deal of carbon dioxide, so the Bohr effect makes the blood release extra oxygen exactly where the demand is greatest.

Examiner's Note
The marks need the Bohr effect as the rightward shift of the curve when carbon dioxide rises, so that at a given oxygen tension the haemoglobin unloads more oxygen, delivering most to the most active tissue.

Language Clinic
The reasoning hangs on because and so. Because the curve shifts right, the haemoglobin holds less, so it unloads more; the two connectors carry the cause to its useful result.

Question 19

The carbon dioxide made in the respiring tissues must be carried in the blood back to the lungs to be breathed out. Describe the three ways in which carbon dioxide is carried, and say which of them carries the most.

Model Answer

Carbon dioxide is carried from the tissues to the lungs in three ways:

1) **Dissolved in the plasma:** a small part of it simply dissolves in the watery plasma and is carried along in solution.
2) **As carbaminohaemoglobin:** some combines with the haemoglobin of the red cells, away from the oxygen-carrying site, and rides back on the pigment.

3) **As hydrogencarbonate ions:** most of it is changed inside the red cells into hydrogencarbonate ions, which pass out into the plasma and are carried to the lungs.

By far the greatest share of the carbon dioxide is carried as the hydrogencarbonate ions in the plasma, with much less travelling dissolved in solution or combined with the haemoglobin.

Examiner's Note
The marks need the three routes named, dissolved in the plasma, as carbaminohaemoglobin, and as hydrogencarbonate ions, with the hydrogencarbonate ions carrying by far the most.

False Confidence Alert
Most students think carbon dioxide is mostly carried bound to haemoglobin. Yet much the largest share travels as hydrogencarbonate ions dissolved in the plasma.

Question 20

Most of the carbon dioxide that reaches the blood is changed inside the red blood cells before it can be carried. Explain how the enzyme carbonic anhydrase deals with the carbon dioxide, and what becomes of the hydrogen ions it produces.

Model Answer

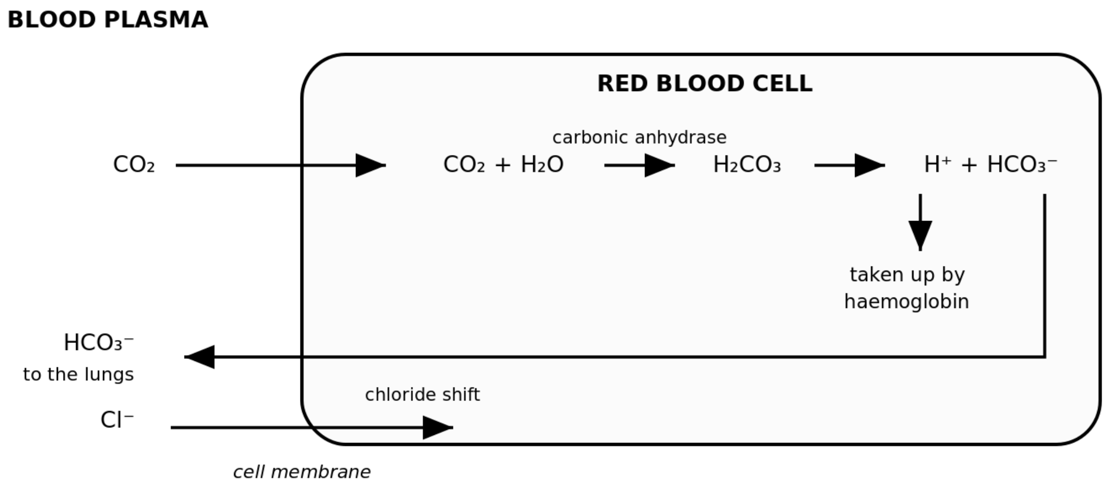


Figure 7.5: *how carbon dioxide is carried, and the chloride shift, in a red blood cell.*

Inside the red cell, carbonic anhydrase speeds the joining of carbon dioxide with water to form carbonic acid, which at once splits into hydrogen ions and hydrogencarbonate ions. The enzyme makes this reaction go very fast, so the carbon dioxide arriving from the tissues is quickly turned into hydrogencarbonate ions, and these pass out into the plasma to be carried to the lungs.

The hydrogen ions left behind are taken up by the haemoglobin, which acts as a buffer. By mopping up the hydrogen ions, the haemoglobin keeps the blood from becoming too acid, and this also helps the haemoglobin to release its oxygen to the respiring tissues.

Examiner's Note
The marks need carbonic anhydrase catalysing carbon dioxide plus water into carbonic acid, which splits into hydrogen ions and hydrogencarbonate ions, the hydrogencarbonate passing to the plasma and the hydrogen ions taken up by haemoglobin.

Language Clinic
The reasoning rests on so. The enzyme works fast, so the carbon dioxide is swiftly turned into hydrogencarbonate; the one connector links the speed of the enzyme to the carrying of the gas.

Question 21

As the hydrogencarbonate ions leave the red cell for the plasma, chloride ions move into the cell to take their place. Explain why this chloride shift is necessary.

Model Answer

The chloride shift is necessary to keep the electrical charge of the red cell balanced. Each hydrogencarbonate ion that leaves the cell carries a negative charge out with it, so without some replacement the inside of the cell would be left too positive.

Chloride ions, which are also negatively charged, move in from the plasma to take the place of the hydrogencarbonate ions. This inward movement of negative chloride ions restores the balance of charge across the membrane, and it is this movement that is called the chloride shift.

Examiner's Note
The marks need the point that hydrogencarbonate ions leaving carry negative charge out of the cell, and that chloride ions move in to restore the charge balance, which is the chloride shift.

False Confidence Alert
Most students think the chloride shift helps to carry the carbon dioxide. Yet its only task is to balance the charge left behind as the hydrogencarbonate ions leave the cell.

Question 22

Carbon monoxide, the gas given off by a charcoal stove burning in a closed room, can kill a person even while there is still oxygen in the air. Explain why carbon monoxide is so deadly.

Model Answer

Carbon monoxide is deadly because it combines with haemoglobin far more tightly than oxygen does, forming a stable compound called carboxyhaemoglobin. It binds to the very sites that should be carrying oxygen, and it holds on so firmly that it will not let go as oxygen would.

Once the haemoglobin has been seized by carbon monoxide, it can no longer carry oxygen to the tissues. So even while there is oxygen in the air, the blood cannot pick it up, and the tissues are starved of oxygen until the person dies.

Examiner's Note
The marks need carbon monoxide binding haemoglobin much more tightly than oxygen, forming carboxyhaemoglobin, so the haemoglobin can no longer carry oxygen and the tissues are starved.

Language Clinic
The pair Once and So carry the argument. Once names the moment the haemoglobin is seized, and So draws the deadly result: the blood cannot carry the oxygen that is still in the air.

Question 23

High on a mountain the air is thin and holds less oxygen, yet people live there and climbers can in time cope with it. Explain how the body becomes adapted to the thin air of a high altitude.

Model Answer

At a high altitude the body adapts in several ways to take up more of the scarce oxygen:

1) **More red blood cells:** the body makes extra red cells over time, so the blood can carry more oxygen with each beat of the heart.
2) **More haemoglobin:** with more haemoglobin in the blood, more oxygen can be loaded from each breath of the thin air.

3) **A haemoglobin of higher affinity:** some animals native to high altitude have a haemoglobin that grips oxygen more tightly, loading it well even at a low pressure.

Examiner's Note
The marks need the adaptations to the thin air, more red blood cells and more haemoglobin to carry more oxygen, and in some species a haemoglobin of higher affinity that loads oxygen at a low pressure.

False Confidence Alert
Most students think the air high up holds a smaller fraction of oxygen. Yet the fraction is the same; the air is merely thinner, so its oxygen is at a lower pressure.

Question 24

A seal can dive deep and stay under the water for a long time without breathing. Explain how such a diving mammal is able to stay submerged for so long.

Model Answer

A diving mammal stores a large amount of oxygen before it dives, much of it held on a pigment called myoglobin in its muscles. Myoglobin grips oxygen even more tightly than haemoglobin does, so it holds a store of oxygen that the muscles can draw on while the animal is under the water.

While it is submerged, the animal slows its heartbeat and saves the stored oxygen for the organs that need it most. By slowing the heart and sending the blood mainly to the brain, the seal makes its store of oxygen last far longer than ours ever could.

Examiner's Note
The marks need oxygen stored on myoglobin in the muscles, and the slowing of the heart with the blood directed to the brain, so the stored oxygen is spared and made to last.

Language Clinic
The connector By does the work in the second point. By slowing the heart and directing the blood to the brain explains, in one breath, how the seal stretches its store of oxygen.

Question 25

An unborn baby gets its oxygen not from the air but from its mother's blood, across the placenta. Explain why the baby's haemoglobin must hold oxygen more tightly than the mother's.

Model Answer

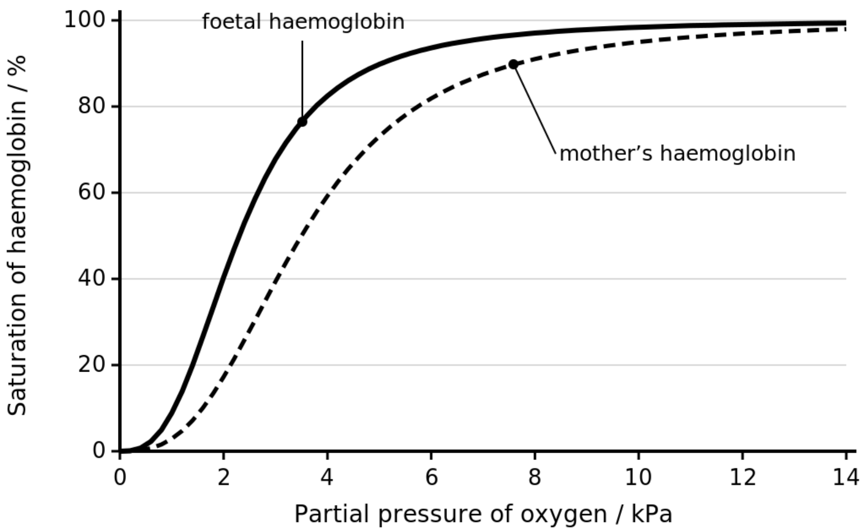


Figure 7.6: *the foetal and the maternal oxygen dissociation curves.*

The unborn baby has a special foetal haemoglobin that holds oxygen more tightly than the mother's haemoglobin does. Its dissociation curve lies to the left of the mother's, which means that at any given oxygen pressure the foetal haemoglobin is the more fully saturated of the two.

This higher affinity is what lets the baby draw oxygen from the mother across the placenta. Because the foetal haemoglobin grips oxygen more tightly, it takes up the oxygen that the mother's haemoglobin gives off at the placenta, and so oxygen passes from mother to baby.

Examiner's Note
The marks need the foetal haemoglobin having a higher affinity, its curve lying to the left, so that at the placenta it takes up the oxygen released by the mother's haemoglobin.

False Confidence Alert
Most students think the mother simply pushes oxygen into the baby. Yet the oxygen is drawn across because the foetal haemoglobin grips it more tightly than the mother's does.

Question 26

A plant has no lungs and no blood, yet every one of its living cells must take in and give out gases. Explain how a plant exchanges its gases with the air around it.

Model Answer

A plant exchanges its gases simply by diffusion, through small pores called stomata in its leaves. It needs no lungs and no bloodstream, for the gases pass straight in and out through the open stomata, each moving down its own concentration gradient.

From the stomata the gases diffuse through the air spaces of the leaf to reach the living cells, and out again by the same path. Each gas moves to where it is in shorter supply, so oxygen and carbon dioxide travel into and out of the leaf without being pumped or carried by any transport system.

Examiner's Note
The marks need gas exchange by diffusion through the stomata, with no lungs or blood, the gases moving down their concentration gradients through the air spaces to and from the cells.

Language Clinic
The connector so does the work in the second point. Each gas moves to where it is scarcer, so the gases travel in and out unaided: it ties the diffusion to the plant needing no transport system.

Question 27

Both by day and by night, a plant must exchange gases with its surroundings. Explain why a plant needs to exchange gases at all.

Model Answer

A plant needs to exchange gases because, like every living thing, its cells respire and must take in oxygen and give out carbon dioxide. Respiration goes on day and night in every living cell, so the plant must keep taking in oxygen and removing the carbon dioxide that its respiration produces.

A plant also needs gases for photosynthesis, drawing in carbon dioxide and giving out oxygen in the light. In daylight its green cells photosynthesise, so they take in carbon dioxide as a raw material and release the oxygen that the process makes.

Examiner's Note
The marks need both processes: oxygen in and carbon dioxide out for respiration, going on day and night, and carbon dioxide in and oxygen out for photosynthesis, going on in the light.

False Confidence Alert
Most students think a plant only takes in carbon dioxide and only gives out oxygen. Yet it respires day and night as well, taking in oxygen and giving out carbon dioxide like any living thing.

Question 28

Inside a leaf the gases must travel between the stomata and the photosynthesising cells deep within it. Draw the internal structure of a leaf, and use it to show the path a molecule of carbon dioxide takes to reach a mesophyll cell.

Model Answer

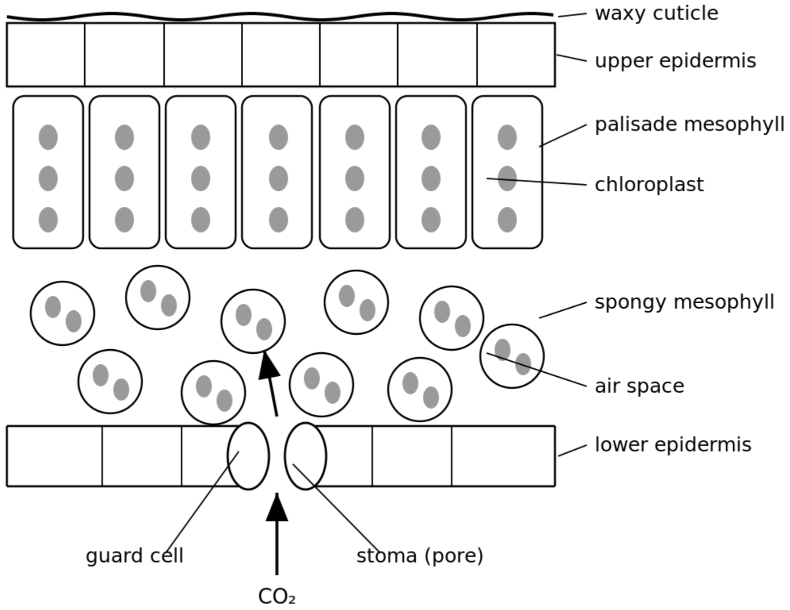


Figure 7.7: *the internal structure of a leaf, with the path of carbon dioxide to a mesophyll cell.*

A leaf is built in layers, with the photosynthesising mesophyll cells held between an upper and a lower epidermis, and air spaces running among them. The tall palisade mesophyll lies near the top where the light is strongest, and the looser spongy mesophyll below it is threaded with air spaces that open to the outside air through the stomata.

A molecule of carbon dioxide enters through a stoma, diffuses through the air spaces, and dissolves in the moist wall of a mesophyll cell before passing in. Because the air spaces link every mesophyll cell to a stoma, the carbon dioxide can reach even the cells set deep in the leaf and be used there in photosynthesis.

Examiner's Note
The marks need the layers labelled, the upper and lower epidermis, the palisade and spongy mesophyll, the air spaces and the stomata, and the path of carbon dioxide from a stoma through the air spaces to a mesophyll cell.

Language Clinic
The answer leans on Because. Because the air spaces link every cell to a stoma, the carbon dioxide reaches the deep cells: the connector turns the structure of the leaf into the reason the gas arrives.

Question 29

Each stoma is opened and closed by a pair of special cells, and these are the only cells of the leaf surface to hold chloroplasts. Describe the structure of a stoma and its guard cells, and explain why most stomata are found on the lower surface of the leaf.

Model Answer

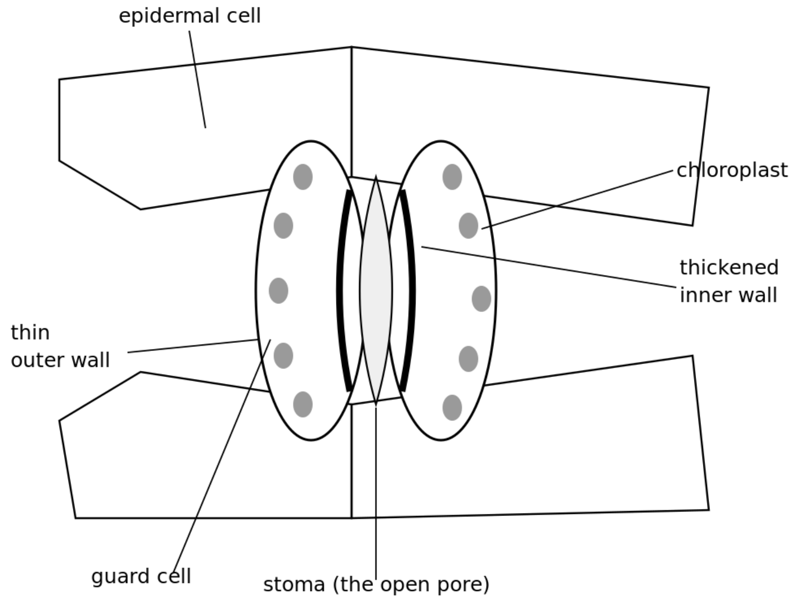


Figure 7.8: *a dicot stoma, open, with its two guard cells.*

A stoma is a tiny pore in the epidermis, bounded by two sausage-shaped guard cells whose inner walls, next to the pore, are thicker and less stretchy than their thin outer walls. Unlike the ordinary, clear cells of the epidermis around them, the two guard cells contain chloroplasts, so they alone of the surface can photosynthesise.

Most stomata lie on the lower surface of the leaf, where they are shaded and cooler. Because the lower surface is kept out of the direct sun, a leaf loses less water by evaporation through stomata placed there than it would through stomata on the hot upper surface.

Examiner's Note
The marks need the stoma as a pore between two guard cells with thick inner and thin outer walls, the guard cells alone holding chloroplasts, and most stomata on the lower surface to reduce water loss.

False Confidence Alert
Most students think every cell of the leaf surface holds chloroplasts. Yet of the epidermis only the guard cells do; the ordinary epidermal cells are clear and have none.

Question 30

A stoma opens and closes as its two guard cells take in or lose water. Explain how the changing turgor of the guard cells opens and closes the pore between them.

Model Answer

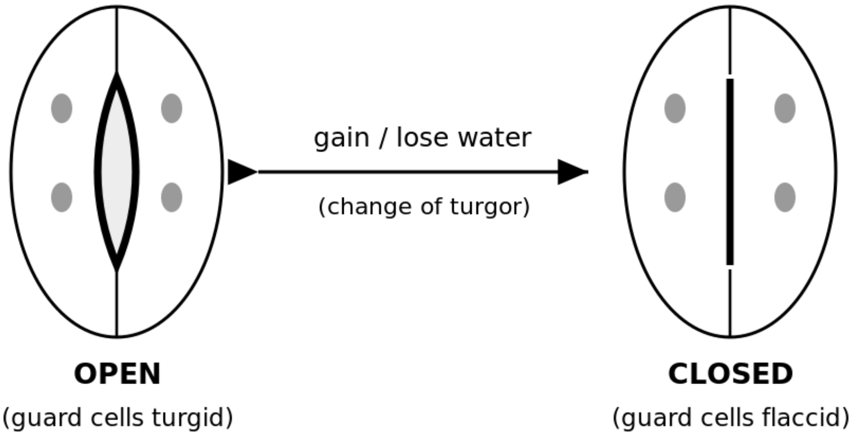


Figure 7.9: *a stoma open and closed, as the guard cells gain or lose water.*

When the guard cells take in water and become turgid, the pore between them opens. As each guard cell swells, its thin outer wall stretches more easily than its thick inner wall, so the cell curves away from the pore; the two cells bow apart, and the stoma opens.

When the guard cells lose water and become flaccid, the pore closes. With less water inside, the guard cells go limp and straighten, falling back against each other, so the pore between them is shut.

Examiner's Note
The marks need the turgid guard cells bowing apart because the thin outer wall stretches more than the thick inner wall, opening the pore, and the flaccid cells straightening and closing it again.

Language Clinic
The hinge of the answer is so. The thin outer wall stretches more than the thick inner wall, so the cell curves away from the pore: the connector turns the wall difference into the opening of the stoma.

Question 31

Before a guard cell can take in the water that opens the stoma, it must first make its contents more concentrated. Explain how the guard cells draw in this water, and why the opening of a stoma costs the plant energy.

Model Answer

The guard cells actively pump potassium ions into themselves, and this lowers their water potential. They move potassium ions in from the cells around them, so the contents of the guard cells grow more concentrated and their water potential falls below that of their neighbours.

Water then follows the potassium ions in by osmosis, and the swelling guard cells open the stoma. Because pumping the potassium ions in is active transport, it uses ATP, so the opening of a stoma costs the plant energy; the guard cells' own chloroplasts help to supply that energy.

Examiner's Note
The marks need potassium ions actively pumped in to lower the water potential, water following by osmosis to make the cells turgid, and the pumping being active transport that uses ATP.

False Confidence Alert
Most students think water simply seeps into the guard cells by itself. Yet the cell must first spend energy pumping in potassium ions to lower its water potential, and only then does water follow by osmosis.

Question 32

The trunk and the older roots of a woody plant are wrapped in bark, through which gases cannot easily pass. Explain how these woody parts exchange their gases with the air.

Model Answer

Woody stems and roots exchange their gases through small openings in the bark called lenticels. Where the bark would otherwise seal the surface, a lenticel is a patch of loosely packed cells with air gaps between them, through which the gases can diffuse.

Through these lenticels the living cells inside the wood take in oxygen and give out carbon dioxide. Even though the bark itself is waterproof and airtight, the lenticels keep the inner living tissues supplied with the oxygen they need for respiration.

Examiner's Note
The marks need lenticels named as openings of loosely packed cells in the bark, letting gases diffuse in and out, so the living tissues of a woody stem or root can still exchange oxygen and carbon dioxide.

Language Clinic
The phrase Even though concedes that the bark is sealed, and the sentence then turns to how the lenticels still let gases through; this is the concession connector a marker looks for in an apparent-contradiction answer.

Question 33

People sometimes speak of respiration as the burning of food inside the body, yet a cell does not burst into flame. Explain what respiration really is, and why it is described as a controlled release of energy.

Model Answer

Respiration is the breaking down of food inside living cells to release the energy it holds, captured in a usable form called ATP. It is carried out not in one burst but as a long series of small, enzyme-controlled steps, so the energy is set free little by little and can be trapped rather than wasted.

It is called a controlled release because the energy is let out in small, manageable amounts that the cell can put to work. If the food were simply burned, all its energy would escape at once as heat; instead respiration releases it gradually and stores much of it in ATP for the cell to spend.

Examiner's Note
The marks need respiration as the enzyme-controlled breakdown of food in the cells, releasing energy in small steps and storing it as ATP, rather than a single burst of burning.

False Confidence Alert
Most students think respiration is simply the burning of food. Yet burning frees all the energy at once as heat, while respiration frees it gradually, in small steps, and traps much of it as ATP.

Question 34

Respiration may go on with or without oxygen, and the two ways differ greatly in the energy they yield. Distinguish between aerobic and anaerobic respiration.

Model Answer

Aerobic respiration uses oxygen, whereas anaerobic respiration goes on without it. This presence or absence of oxygen is the basic difference between the two ways of respiring.

Because aerobic respiration breaks the glucose down completely, it yields far more energy than anaerobic respiration does. Aerobic respiration, mostly in the mitochondria, breaks glucose right down to carbon dioxide and water for many molecules of ATP, while anaerobic respiration, in the cytoplasm, breaks it only partly, into lactic acid or ethanol, for very little ATP.

Examiner's Note
The marks need oxygen as the dividing line, with aerobic respiration breaking glucose down completely in the mitochondria for much ATP, and anaerobic only partly in the cytoplasm for little ATP.

Language Clinic
The answer is built on whereas and while, the two great comparison connectors. Whereas opens the contrast and while keeps it running, so the marker sees the two ways set cleanly side by side.

Question 35

The energy released by respiration is not used directly but is first packed into a molecule called ATP. Explain why ATP is called the energy currency of the cell, and how it stores and releases its energy.

Model Answer

ATP is called the energy currency of the cell because it is the form in which energy is stored and then spent for all the cell's work, much as money is earned and spent. Respiration loads energy into ATP, and the cell draws on this ATP whenever it needs energy, for movement, for building molecules, or for active transport.

ATP holds its energy in its third phosphate group, and releases it when that phosphate is removed. When ATP loses its third phosphate it becomes ADP and sets free a usable packet of energy; when respiration adds the phosphate back, the ADP is recharged to ATP.

Examiner's Note
The marks need ATP as the universal store and supply of energy for the cell, holding energy in its third phosphate bond and releasing it as it becomes ADP, then being recharged by respiration.

Language Clinic
The connector when marks the two halves of the cycle. When the phosphate is removed energy is freed; when it is added back the ATP is recharged: one word carries the give and the take.

Question 36

Although glucose is the usual fuel of respiration, the body can also burn other foods, and it calls on them in a set order. Name the three respiratory substrates, and give the order in which the body uses them.

Model Answer

The three respiratory substrates are carbohydrates, lipids and proteins. Carbohydrate, in the form of glucose, is the everyday fuel, while lipid (fat) and protein are the other two that the body can break down for energy.

The body uses them in order, burning carbohydrate first, then lipid, and protein only as a last resort. Glucose and other carbohydrates are spent first; when these run low the body turns to its fat stores, and only in starvation, when the fat too is gone, does it begin to break down its own proteins.

Examiner's Note
The marks need the three substrates, carbohydrate, lipid and protein, and the order of use: carbohydrate first, then lipid, and protein only as a last resort.

False Confidence Alert
Most students think the body burns protein freely for energy. Yet protein is used only as a last resort, in starvation, once the carbohydrate and the fat have run out.

Question 37

Gram for gram, a lipid releases more than twice as much energy as a carbohydrate when it is respired. Explain why a lipid is such an energy-rich fuel.

Model Answer

A lipid yields more energy than a carbohydrate because its long fatty-acid chains carry far more hydrogen for their mass. It is the hydrogen, carried to the later stages of respiration, that is used to make most of the ATP, so the more hydrogen a fuel holds, the more energy it can finally yield.

A carbohydrate already holds a good deal of oxygen within it, which a lipid does not. Because so much of a carbohydrate is already partly oxidised, less of it is left to oxidise for energy, while the hydrogen-rich fatty acids of a lipid can be oxidised much further, releasing more than twice the energy per gram.

Examiner's Note
The marks need the lipid being rich in hydrogen along its long fatty-acid chains, and that it is this hydrogen which yields the ATP, whereas a carbohydrate is already part-oxidised and so yields less.

Language Clinic
The reasoning runs on so and because. So links more hydrogen to more energy, and because explains why the part-oxidised carbohydrate yields less: together they carry the comparison to its conclusion.

Question 38

Two kinds of chemical change happen again and again as a fuel is respired: oxidation and decarboxylation. Explain what each of these means in respiration.

Model Answer

Oxidation in respiration means removing hydrogen, or electrons, from a substance, or else adding oxygen to it. Most often a respiratory substance is oxidised by having its hydrogen taken off and carried away on a hydrogen carrier such as NAD, a step that releases energy and is repeated along the pathway.

Decarboxylation means removing a carbon atom from a substance as a molecule of carbon dioxide. One by one the carbons of the fuel are taken off as carbon dioxide, which is why respiration gives out carbon dioxide as its waste gas.

Examiner's Note
The marks need oxidation as the removal of hydrogen or electrons (or the adding of oxygen), often onto a carrier such as NAD, and decarboxylation as the removal of carbon as carbon dioxide.

Language Clinic
The phrase which is why turns a fact into its consequence. The carbons leave as carbon dioxide, which is why respiration breathes carbon dioxide out: the connector ties the chemistry to what we observe.

Question 39

The very first stage of respiration, glycolysis, is the same whether or not oxygen is present. Explain where glycolysis takes place and what it does, and say why it needs no oxygen.

Model Answer

Glycolysis takes place in the cytoplasm of the cell, outside the mitochondria, and it splits a molecule of glucose into two molecules of pyruvate. It is the first stage of all respiration, breaking the six-carbon glucose into two three-carbon pyruvate molecules and releasing a little energy as ATP.

Glycolysis needs no oxygen, which is why it can go on in both aerobic and anaerobic respiration. None of its steps uses oxygen, so glycolysis runs in the same way whether oxygen is present or not, and it is the one stage shared by almost every living thing.

Examiner's Note
The marks need glycolysis placed in the cytoplasm, splitting one glucose into two pyruvate, and needing no oxygen, so it is common to both aerobic and anaerobic respiration.

False Confidence Alert
Most students place glycolysis in the mitochondria. Yet it happens in the cytoplasm; only the later stages of aerobic respiration take place inside the mitochondria.

Question 40

Glycolysis can be set out as three stages, one after another. Draw a diagram of glycolysis, and name its three stages in order, saying briefly what happens in each.

Model Answer

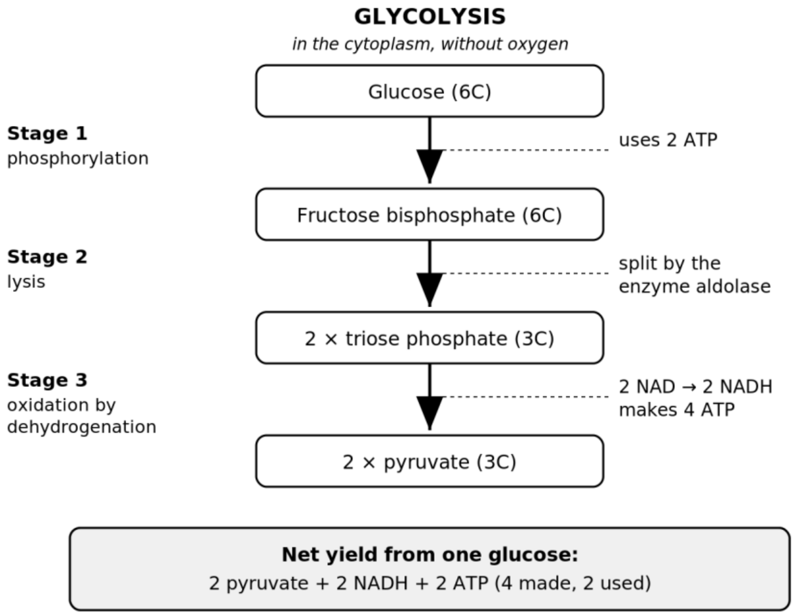


Figure 7.10: *the three stages of glycolysis, from glucose to pyruvate.*

In the first stage, phosphorylation, the glucose is given two phosphate groups from two molecules of ATP, forming a sugar bisphosphate. Spending the ATP makes the sugar more reactive and ready to be split, so this first stage prepares the glucose for the rest of the pathway.

In the second stage, lysis, the six-carbon sugar is split into two three-carbon molecules; in the third stage, oxidation by dehydrogenation, these are changed into pyruvate. As the three-carbon molecules are oxidised by having hydrogen taken off onto NAD, they yield NADH and enough ATP to give the pathway its net gain, ending as two molecules of pyruvate.

Examiner's Note
The marks need the three stages named in order, phosphorylation (two ATP used, a sugar bisphosphate formed), lysis (the six-carbon sugar split into two three-carbon molecules), and oxidation by dehydrogenation (NADH and ATP made, ending in pyruvate).

Language Clinic
The connector As ties cause to product in the third stage. As the molecules are oxidised by losing hydrogen to NAD, they yield NADH and ATP: the one word shows the making of NADH and the oxidation are the same event.

Question 41

It seems strange that glycolysis, whose very job is to make ATP, must first spend two molecules of ATP. Explain why the glucose has to be phosphorylated at the start, even though this costs the cell ATP.

Model Answer

The glucose is phosphorylated to make it more reactive, so that it can be broken down in the steps that follow. Adding the phosphate groups raises the energy of the glucose and leaves the molecule unstable and ready to split, which a plain glucose molecule would not be.

Phosphorylating the glucose also traps it inside the cell. A phosphorylated sugar cannot slip back out through the cell membrane, so spending the two ATP keeps the fuel inside the cell, and the small outlay is repaid with interest later in the pathway.

Examiner's Note
The marks need the two ATP being spent to make the glucose reactive and ready to split, and to trap the charged sugar inside the cell, with the outlay repaid by the greater yield later.

False Confidence Alert
Most students think spending ATP at the start is simply a waste. Yet it is an investment: it makes the glucose reactive and traps it in the cell, and far more ATP is won back further along.

Question 42

One particular enzyme, phosphofructokinase, controls the step that fixes the second phosphate onto the sugar, and this step is called the committed step of glycolysis. Explain why this step is described as the committed step.

Model Answer

The step controlled by phosphofructokinase is called the committed step because, once it has happened, the sugar can only go on through glycolysis. When phosphofructokinase adds the second phosphate to form the sugar bisphosphate, the molecule is set firmly on the glycolytic path and cannot easily turn back.

Before this step the sugar might still have taken another route, but after it the sugar is fully committed to being broken down to pyruvate. So this is the step at which the cell decides to spend the glucose in glycolysis, and it is here that the whole pathway is most tightly controlled.

Examiner's Note
The marks need phosphofructokinase fixing the second phosphate to make the sugar bisphosphate, after which the sugar can only continue to pyruvate, so the step commits the glucose to glycolysis and is the main control point.

Language Clinic
The little word So turns the fact into its meaning. After the step the sugar cannot turn back, so this is where the cell commits the glucose: the connector marks the moment of no return.

Question 43

Once the glucose has been phosphorylated into a six-carbon sugar bisphosphate, it is split in two. Explain what happens in the lysis stage of glycolysis.

Model Answer

In the lysis stage, the enzyme aldolase splits the six-carbon sugar bisphosphate into two smaller, three-carbon molecules. Each half is a three-carbon sugar called triose phosphate, so the one six-carbon molecule gives rise to two three-carbon ones.

It is this splitting that gives glycolysis its name, for glycolysis means the splitting of sugar. From this point on, everything that follows happens twice over, once to each of the two triose phosphate molecules.

Examiner's Note
The marks need the enzyme aldolase splitting the six-carbon sugar bisphosphate into two three-carbon triose phosphate molecules, which is the lysis that gives glycolysis its name.

Language Clinic
The little word for explains the name. It gives glycolysis its name, for glycolysis means the splitting of sugar: here for works like because, linking the splitting to the word itself.

Question 44

In the last stage of glycolysis each triose phosphate is changed into pyruvate, and it is here that glycolysis at last makes some ATP. Explain what happens when the triose phosphate is oxidised by dehydrogenation.

Model Answer

Each triose phosphate is oxidised by having hydrogen removed from it, and this hydrogen is picked up by the carrier NAD to form NADH. The removal of the hydrogen is the oxidation, and it releases energy; the NAD that carries the hydrogen away becomes reduced to NADH.

As the triose phosphate is oxidised it is converted into pyruvate, and enough energy is set free to make ATP directly. Making ATP by handing a phosphate straight to ADP in this way is called substrate-level phosphorylation, and it is how glycolysis earns the ATP that gives it its net gain.

Examiner's Note
The marks need the triose phosphate oxidised by the removal of hydrogen onto NAD to form NADH, its conversion to pyruvate, and ATP made directly by substrate-level phosphorylation.

False Confidence Alert
Most students think all the ATP of respiration is made in the mitochondria. Yet glycolysis makes its ATP out in the cytoplasm, directly, by substrate-level phosphorylation.

Question 45

Glycolysis makes four molecules of ATP, yet it is said to give a net gain of only two. Explain the full balance sheet of glycolysis from one molecule of glucose.

Model Answer

From one glucose, glycolysis makes four molecules of ATP, but two were already spent at the start, so the net gain is only two ATP. The two ATP used to phosphorylate the glucose must be taken away from the four made later, which leaves a net profit of two ATP.

Besides the two ATP, glycolysis also yields two molecules of NADH and two molecules of pyruvate from each glucose. So the full tally from one glucose is two pyruvate, two NADH and a net two ATP, all of it made in the cytoplasm and without any oxygen.

Examiner's Note
The marks need the balance sheet: four ATP made minus two ATP used leaves a net two ATP, together with two NADH and two pyruvate from each glucose.

Language Clinic
The connector so carries the subtraction to its result. Two ATP were spent at the start, so the net gain is only two: the word turns the four-made and two-used into the figure that matters.

Question 46

The pyruvate made by glycolysis can take one of two paths, and which one it takes depends on whether oxygen is available. Explain the two fates of pyruvate.

Model Answer

1) **When oxygen is available, the pyruvate passes into the mitochondria and is broken down further along the aerobic pathway.** There, in the presence of oxygen, it enters the link reaction and the Krebs cycle, to be oxidised completely and to yield a great deal more ATP.
2) **When oxygen is lacking, the pyruvate is instead turned into the products of fermentation, in the cytoplasm.** Unable to enter the aerobic pathway, it is converted to lactic acid, or to ethanol and carbon dioxide, in the anaerobic pathway, which yields only a little ATP.

Examiner's Note
The marks need the two fates set by the oxygen: with oxygen, pyruvate enters the mitochondria for the link reaction and Krebs cycle and much ATP; without oxygen, it goes to fermentation in the cytoplasm for little ATP.

False Confidence Alert
Most students think pyruvate always goes on to the Krebs cycle. Yet that happens only when oxygen is present; without oxygen the pyruvate is sent to fermentation instead.

Question 47

Before the pyruvate from glycolysis can enter the Krebs cycle, it must first be prepared in a short step called the link reaction. Explain what happens to the pyruvate in the link reaction.

Model Answer

In the link reaction, each three-carbon pyruvate loses one carbon as carbon dioxide and is oxidised, leaving a two-carbon group. The carbon is removed by decarboxylation and given off as carbon dioxide, while hydrogen is removed by dehydrogenation and taken up by NAD to form NADH.

The two-carbon group that is left then joins a carrier called coenzyme A to form acetyl coenzyme A. It is this acetyl coenzyme A, carrying its two-carbon group, that feeds into the Krebs cycle, so the link reaction is the bridge from glycolysis to the cycle.

Examiner's Note
The marks need the pyruvate losing carbon dioxide by decarboxylation and hydrogen to NAD by dehydrogenation, the two-carbon group then joining coenzyme A to form acetyl coenzyme A.

Language Clinic
The pivot is so. The acetyl coenzyme A feeds the Krebs cycle, so the link reaction is the bridge between the stages: the connector turns the product into the purpose of the step.

Question 48

Glycolysis makes two molecules of pyruvate from each glucose, and the link reaction takes place inside the mitochondria. Explain why the link reaction happens twice for every glucose, and say where in the mitochondrion it occurs.

Model Answer

The link reaction happens twice for each glucose because glycolysis produces two molecules of pyruvate from one glucose. Each pyruvate must be dealt with on its own, so the link reaction, and every stage after it, runs through twice for every glucose that is broken down.

The link reaction takes place in the matrix, the fluid-filled inner space of the mitochondrion. The pyruvate passes from the cytoplasm into the mitochondrion, where the enzymes of the matrix carry out the reaction.

Examiner's Note
The marks need the link reaction running twice per glucose, since glycolysis gives two pyruvate, and its place named as the matrix, the inner space of the mitochondrion.

False Confidence Alert
Most students forget that the link reaction and the Krebs cycle each run twice for one glucose. Yet glycolysis gives two pyruvate, so every stage after it happens twice over.

Question 49

The link reaction is short, yet it is counted as a separate stage of respiration, neither part of glycolysis nor part of the Krebs cycle. Explain why it is treated as a stage of its own.

Model Answer

The link reaction is counted separately because it stands between glycolysis and the Krebs cycle, joining the two but belonging to neither. Glycolysis ends with pyruvate in the cytoplasm, and the Krebs cycle begins with acetyl coenzyme A in the mitochondrion; the link reaction is the step that turns the one into the other.

It is distinct, too, because it happens in its own place and does its own job. Unlike glycolysis it takes place inside the mitochondrion, and unlike the Krebs cycle it does not turn in a circle; it simply prepares the pyruvate, and so it earns its name as the link between the stages.

Examiner's Note
The marks need the link reaction bridging glycolysis (which ends with pyruvate in the cytoplasm) and the Krebs cycle (which begins with acetyl coenzyme A in the mitochondrion), with its own site and its own preparing job.

Language Clinic
The word Unlike marks the two contrasts. Unlike glycolysis it is in the mitochondrion, and unlike the Krebs cycle it does not cycle: the connector sets the link reaction apart from the stages on either side.

Question 50

The Krebs cycle takes the two-carbon acetyl group and, turn by turn, strips it down completely. Draw the Krebs cycle, and trace what happens as it turns once, naming what enters, what is given off, and what is made.

Model Answer

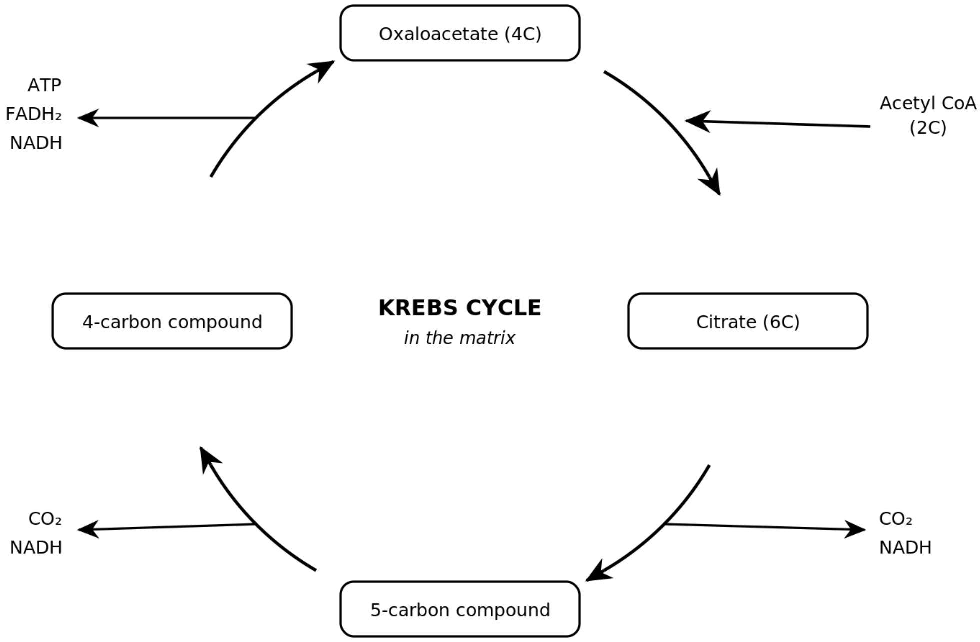


Figure 7.11: *the Krebs cycle, turning once in the matrix of the mitochondrion.*

The cycle begins when the two-carbon acetyl group from acetyl coenzyme A joins a four-carbon oxaloacetate to form a six-carbon citrate. The coenzyme A is set free to be used again, and the citrate now carries the carbons that the cycle will strip away.

As the citrate is changed step by step back into oxaloacetate, carbons are given off as carbon dioxide and hydrogen is removed onto the carriers. In one turn the cycle gives off two molecules of carbon dioxide and makes three NADH, one $FADH_2$ and one ATP, ending again as oxaloacetate ready to accept the next acetyl group.

Examiner's Note
The marks need the acetyl group (2C) joining oxaloacetate (4C) to form citrate (6C), and the cycle turning back to oxaloacetate while giving off two carbon dioxide and making three NADH, one $FADH_2$ and one ATP.

Language Clinic
The connector As keeps the trace moving. As the citrate is changed back into oxaloacetate, the carbon dioxide and the carriers come off: the one word lets the whole turn unfold as a single journey.

Question 51

For every glucose that is respired, the Krebs cycle turns not once but twice. Explain why the cycle turns twice for each glucose, and give the full tally it then yields.

Model Answer

The cycle turns twice for each glucose because glycolysis and the link reaction give two acetyl groups from every glucose. One glucose makes two pyruvate, and each pyruvate gives one acetyl coenzyme A, so two acetyl groups enter the cycle and turn it twice.

For one glucose, then, the two turns together give off four molecules of carbon dioxide and make six NADH, two $FADH_2$ and two ATP. This is simply twice the yield of a single turn, since everything that happens in the first turn happens again in the second.

Examiner's Note
The marks need two acetyl groups per glucose driving two turns, and the doubled tally for one glucose: four carbon dioxide, six NADH, two $FADH_2$ and two ATP.

False Confidence Alert
Most students give the Krebs cycle's yield for a single turn. Yet one glucose gives two acetyl groups, so the cycle turns twice and its yield must be doubled.

Question 52

At the end of each turn, the Krebs cycle remakes the very oxaloacetate it began with. Explain why this regeneration of oxaloacetate is so important.

Model Answer

The regeneration of oxaloacetate is important because the cycle cannot accept a new acetyl group without it. Oxaloacetate is the molecule that picks up the incoming two-carbon acetyl group, so it must be present again at the start of every turn.

Because each turn remakes the oxaloacetate it used at the start, the cycle can keep turning over and over. The oxaloacetate is not used up but is restored at the end of every turn, ready to receive the next acetyl group, so a small amount of it can serve again and again.

Examiner's Note
The marks need oxaloacetate being the acceptor of the incoming acetyl group, and its remaking at the end of each turn, so the cycle can keep running and a little oxaloacetate is used over and over.

Language Clinic
The pair Because and so drives the point home. Because the oxaloacetate is remade, the cycle can keep turning, so only a little is ever needed: the connectors tie the regeneration to the endless turning.

Question 53

The Krebs cycle makes only one molecule of ATP directly per turn, yet it is one of the most important stages of respiration. Explain why the Krebs cycle matters so much, beyond the little ATP it makes itself.

Model Answer

The Krebs cycle matters most because it loads the hydrogen carriers that drive the next stage, where the great bulk of the ATP is made. Each turn fills NADH and $FADH_2$ with the hydrogen it strips from the substrate, and these carriers pass on to the electron transport chain to make far more ATP than the cycle itself does.

The cycle is important, too, because its intermediates can be drawn off to build other molecules the cell needs. Several of the compounds in the cycle are starting points for making amino acids and other substances, so the Krebs cycle is a crossroads of the cell's chemistry as well as a maker of energy.

Examiner's Note
The marks need the cycle loading NADH and $FADH_2$ for the electron transport chain, where most of the ATP is made, and its intermediates being used to build amino acids and other molecules.

False Confidence Alert
Most students judge the Krebs cycle by the single ATP it makes. Yet its real value is the NADH and $FADH_2$ it loads for the electron transport chain, which yields far more ATP.

Question 54

Most of the energy of respiration is released inside the mitochondrion. Draw a labelled diagram of a mitochondrion, and show which of its parts carries out which stage of respiration.

Model Answer

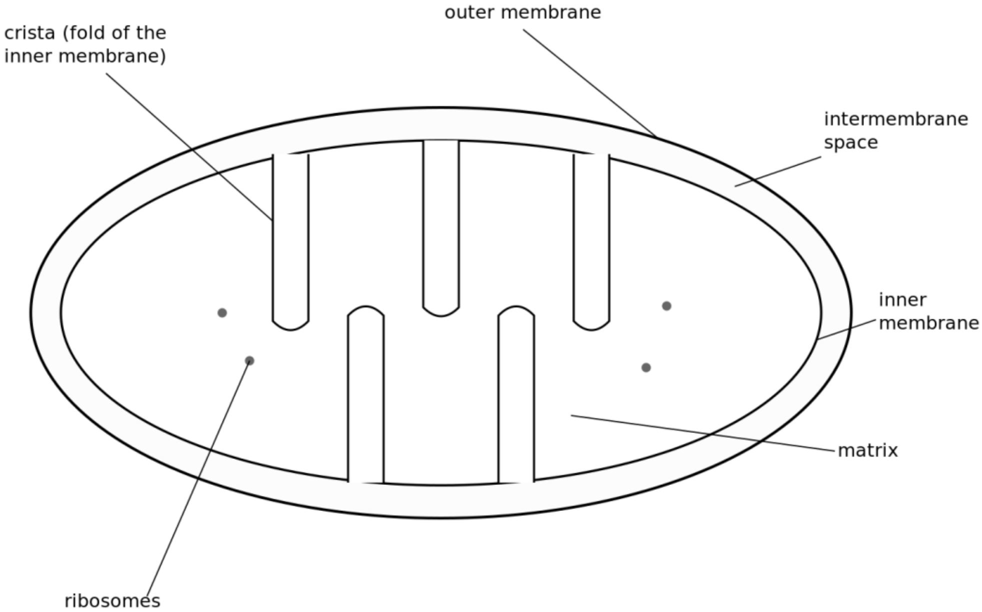


Figure 7.12: *the structure of a mitochondrion, where the link reaction, Krebs cycle and electron transport chain take place.*

A mitochondrion is bounded by two membranes, a smooth outer one and a folded inner one, which together enclose a fluid centre called the matrix. Between the two membranes lies the intermembrane space, and the inner membrane is thrown into folds, called cristae, that project into the matrix; the matrix also holds the small ribosomes the mitochondrion uses to make some of its own enzymes.

Each region carries out its own part of respiration. The matrix holds the enzymes of the link reaction and the Krebs cycle; the inner membrane and its cristae carry the electron transport chain; and the intermembrane space is where the hydrogen ions gather that drive the making of ATP.

Examiner's Note
The marks need the six parts labelled, outer membrane, intermembrane space, inner membrane, cristae, matrix and ribosomes, with the matrix tied to the link reaction and Krebs cycle, and the inner membrane and cristae to the electron transport chain.

False Confidence Alert
Most students think the whole of respiration happens in the mitochondrion. Yet glycolysis comes first, out in the cytoplasm; only the link reaction, the Krebs cycle and the electron transport chain are inside the mitochondrion.

Question 55

The inner membrane of a mitochondrion is not smooth like the outer one but is thrown into many folds. Explain why the inner membrane is folded into cristae, and how this helps respiration.

Model Answer

The inner membrane is folded into cristae so as to give it a much larger surface area. By folding the same membrane into many cristae, far more of it can be packed inside the mitochondrion than a smooth membrane could provide.

This large surface matters because the inner membrane carries the electron transport chain, where most of the ATP is made. The more membrane there is, the more electron transport chains it can hold, so the cristae let the mitochondrion make its ATP all the faster.

Examiner's Note
The marks need the cristae increasing the surface area of the inner membrane, and that this membrane carries the electron transport chain, so a larger area holds more chains and makes more ATP.

Language Clinic
The connector so links the area to the yield. There is more membrane, so there are more electron transport chains, so more ATP is made: the one word builds the chain from fold to surface to ATP.

Question 56

The last stage of aerobic respiration, the electron transport chain, makes most of the cell's ATP. Draw the electron transport chain, and explain how it works.

Model Answer

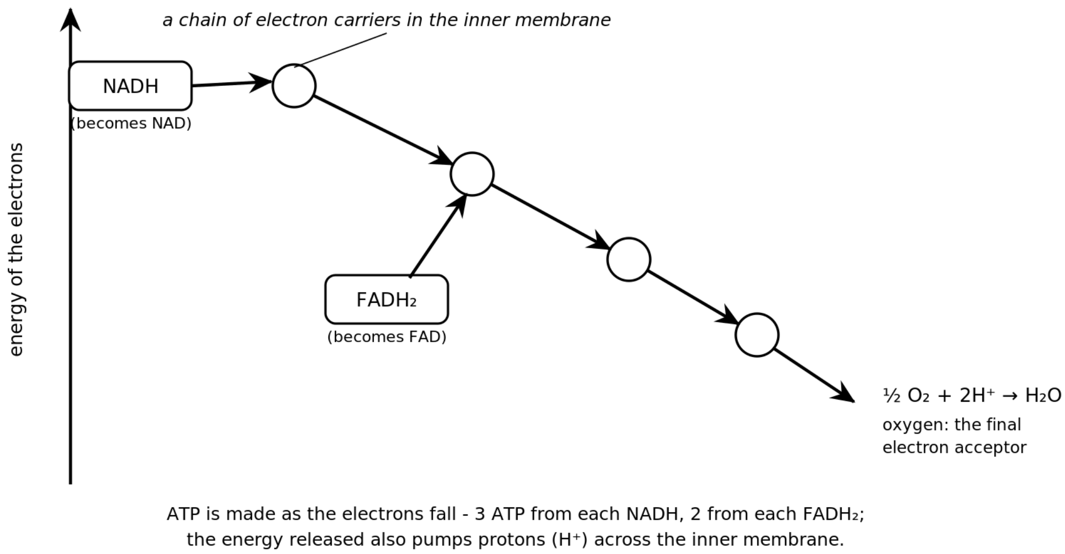


Figure 7.13: *the electron transport chain on the inner membrane of the mitochondrion.*

The hydrogen carriers NADH and $FADH_2$, made in the earlier stages, bring their hydrogen to the chain on the inner membrane and give up its electrons. The electrons are then passed from one carrier to the next along the chain, falling from a higher to a lower energy level as they go.

At each step the energy released is used to pump protons across the inner membrane, and the return of these protons drives the making of ATP. In this way the steady fall of the electrons down the chain is harnessed, step by step, to build most of the cell's ATP.

Examiner's Note
The marks need NADH and $FADH_2$ delivering electrons to the carriers of the inner membrane, the electrons falling from a higher to a lower energy level, and the released energy pumping protons across the membrane to drive the making of ATP.

Language Clinic
The little word as keeps the action and its result together. The electrons fall from a higher to a lower energy level as they go: the connector ties the passing-along to the losing of energy in one breath.

Question 57

Oxygen takes no part in the chain until the very last step, yet without it the whole chain stops. Explain the role of oxygen in the electron transport chain, and why it is needed only at the end.

Model Answer

Oxygen acts as the final acceptor of the electrons at the end of the chain. Once the electrons have passed all the way down the carriers, oxygen takes them up and joins them with hydrogen ions to form water, with the help of the enzyme cytochrome oxidase.

Although it is used only at the end, the whole chain depends on the oxygen being there. If there is no oxygen to collect the electrons at the end, they cannot leave the last carrier, so the whole chain backs up and stops, and almost all the ATP of respiration is lost.

Examiner's Note
The marks need oxygen as the final electron acceptor, joining the electrons and hydrogen ions to form water (under cytochrome oxidase), and the point that without it the chain backs up and stops.

False Confidence Alert
Most students think oxygen is used all the way through respiration. Yet it acts only at the very end of the chain, as the final acceptor that joins the electrons and hydrogen to make water.

Question 58

The ATP made by the electron transport chain is said to come from oxidative phosphorylation, and there is far more of it than from any other stage. Explain what oxidative phosphorylation is, and why it makes so much more ATP than the earlier stages.

Model Answer

Oxidative phosphorylation is the making of ATP from the energy released as electrons pass down the chain to oxygen. It is called oxidative because it depends on the oxidation of the carriers and the final use of oxygen, and phosphorylation because it joins phosphate to ADP to make ATP.

It makes far more ATP than the earlier stages because it harvests the energy of all the NADH and $FADH_2$ gathered from glycolysis, the link reaction and the Krebs cycle. Those earlier stages make only a little ATP directly, but they load many hydrogen carriers, and it is here that the carriers are at last cashed in for the bulk of the ATP.

Examiner's Note
The marks need oxidative phosphorylation as the making of ATP from the energy of electrons passing down the chain to oxygen, and that it yields the most ATP because it spends all the NADH and $FADH_2$ from the earlier stages.

Language Clinic
The hinge is but. The earlier stages make little ATP directly, but they load the carriers that are cashed in here: the connector turns their small direct yield into the reason the chain reaps so much.

Question 59

Although both are hydrogen carriers, a molecule of NADH yields three molecules of ATP in the chain while a molecule of $FADH_2$ yields only two. Explain why NADH yields more ATP than $FADH_2$.

Model Answer

NADH yields more ATP because it delivers its electrons at the very start of the chain, at a higher energy level. Entering at the top, its electrons fall through the whole length of the chain and pass every point at which ATP is made, so three ATP are made from each NADH.

$FADH_2$ yields less because it delivers its electrons further along the chain, at a lower energy level. Entering lower down, its electrons skip the first ATP-making step and fall through only the rest of the chain, so only two ATP are made from each $FADH_2$.

Examiner's Note
The marks need NADH entering at the start, higher up, so its electrons pass all the ATP-making steps for three ATP, while $FADH_2$ enters lower, skipping the first step, for only two ATP.

Language Clinic
The connector so draws each yield from its cause. NADH enters at the top and passes every step, so three ATP; $FADH_2$ enters lower and skips one, so two: one word, two clean conclusions.

Question 60

When all four stages are added together, the complete oxidation of one glucose yields about 38 molecules of ATP. Set out the ATP balance sheet, showing where the 38 come from.

Model Answer

The 38 ATP are gathered across the four stages of respiration:

1) **Glycolysis:** a net 2 ATP made directly, and 2 NADH.
2) **The link reaction:** 2 NADH.
3) **The Krebs cycle:** 2 ATP made directly, and 6 NADH and 2 $FADH_2$.
4) **The electron transport chain:** here the 10 NADH give 3 ATP each (30 ATP) and the 2 $FADH_2$ give 2 ATP each (4 ATP), that is 34 ATP.

Adding the 4 ATP made directly, in glycolysis and the Krebs cycle, to the 34 made in the electron transport chain gives the 38 ATP from one glucose.

Examiner's Note
The marks need the four stages tallied: glycolysis and the Krebs cycle make 4 ATP directly, while the 10 NADH (30 ATP) and the 2 $FADH_2$ (4 ATP) are cashed in the electron transport chain for 34, giving 38 in all.

False Confidence Alert
Most students think the 38 ATP are made directly. Yet only 4 are; the other 34 come from the NADH and $FADH_2$ cashed in at the electron transport chain.

Question 61

When a cell runs short of oxygen, the pyruvate from glycolysis cannot enter the mitochondria, yet the cell can still make a little ATP. Explain what happens to the pyruvate, and why this lets glycolysis carry on.

Model Answer

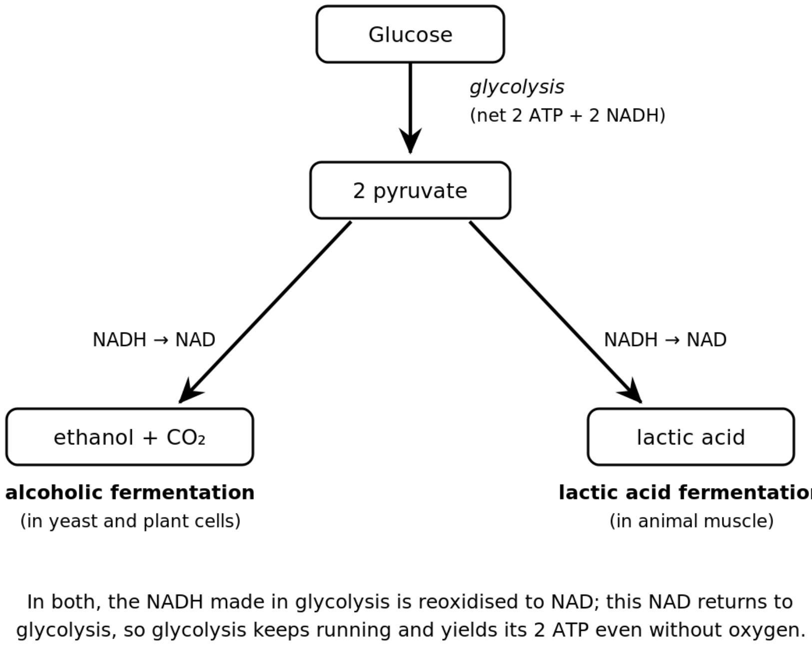


Figure 7.14: *the two kinds of fermentation, by which a cell respires without oxygen.*

Without oxygen, the pyruvate is turned into the products of fermentation: either ethanol and carbon dioxide, or lactic acid. It can no longer enter the mitochondria for the link reaction and the Krebs cycle, so instead it is changed, in the cytoplasm, into one of these fermentation products.

The real point of this is to reoxidise the NADH back to NAD, so that glycolysis can keep running. Glycolysis needs a steady supply of NAD to continue; by handing its hydrogen on to the pyruvate, the NADH turns back into NAD, which returns to glycolysis and lets it go on making its small yield of ATP.

Examiner's Note
The marks need the pyruvate, without oxygen, being turned into ethanol and carbon dioxide or into lactic acid in the cytoplasm, and the purpose being to reoxidise NADH to NAD so glycolysis can carry on.

Language Clinic
The connector so links the need to its solution. Glycolysis needs NAD, so the pyruvate is used to remake it: the word ties the fate of the pyruvate to the keeping-going of glycolysis.

Question 62

Some organisms are poisoned by oxygen, while others can switch between using it and doing without. Distinguish between an obligate anaerobe and a facultative anaerobe, and give an example of where each is found.

Model Answer

An obligate anaerobe can live only without oxygen, and oxygen is in fact poisonous to it. Such organisms respire only anaerobically, and live where there is no oxygen, as do the tetanus bacteria deep in a dirty wound or in the mud of a swamp.

A facultative anaerobe can live either with or without oxygen, using oxygen when it is there but turning to fermentation when it is not. Yeast is the familiar example, respiring aerobically in the air but fermenting sugar to alcohol once the oxygen has run out.

Examiner's Note
The marks need the obligate anaerobe living only without oxygen, to which oxygen is poisonous (e.g. tetanus bacteria), set against the facultative anaerobe that lives with or without it, switching as needed (e.g. yeast).

False Confidence Alert
Most students think every anaerobe just prefers no oxygen. Yet to an obligate anaerobe oxygen is actually poisonous, while a facultative anaerobe will use oxygen whenever it can get it.

Question 63

In a covered vat of fruit juice, yeast turns the sugar into alcohol. Explain what happens in alcoholic fermentation, and where it takes place.

Model Answer

In alcoholic fermentation, the pyruvate from glycolysis is turned into ethanol and carbon dioxide, in the cytoplasm of the yeast or plant cell. Each pyruvate first loses a carbon as carbon dioxide, and the part that is left is then reduced by the NADH to ethanol.

It is this reduction of the pyruvate that turns the NADH back into NAD. By giving up its hydrogen to make the ethanol, the NADH becomes NAD once more, so glycolysis can carry on and the yeast keeps making its small yield of ATP.

Examiner's Note
The marks need pyruvate losing carbon dioxide and being reduced by NADH to ethanol, in the cytoplasm of yeast or plant cells, with the NADH turned back into NAD.

Language Clinic
The word By names the means. By giving up its hydrogen to make the ethanol, the NADH is reoxidised: the connector shows that making the ethanol and remaking the NAD are one and the same step.

Question 64

When you sprint, your leg muscles soon run short of oxygen, yet they keep working for a while. Explain what happens in lactic acid fermentation, and why it is useful for a short, hard effort.

Model Answer

In lactic acid fermentation, the pyruvate from glycolysis is reduced straight to lactic acid, without losing any carbon. The NADH hands its hydrogen to the pyruvate, turning it into lactic acid and itself back into NAD, all in the cytoplasm of the muscle.

This is useful for a short, hard effort because it lets glycolysis keep making ATP quickly when oxygen cannot be delivered fast enough. It buys the muscle a little extra energy without oxygen, but only for a short while, since the lactic acid soon builds up and tires the muscle.

Examiner's Note
The marks need the pyruvate reduced by NADH to lactic acid (no carbon dioxide given off) in the muscle, the NAD regenerated, and glycolysis kept running for a quick burst of ATP without oxygen.

False Confidence Alert
Most students think the muscles get no energy once the oxygen runs out. Yet lactic acid fermentation keeps glycolysis going, buying a little ATP for a short, hard burst of effort.

Question 65

Anaerobic respiration gives a cell only two molecules of ATP from each glucose, while aerobic respiration gives far more. Explain why fermentation yields so little ATP.

Model Answer

Fermentation yields only the two ATP of glycolysis, because the glucose is never fully broken down. The only ATP made is the small net gain of glycolysis itself; no further ATP is made after the pyruvate is formed.

Most of the energy of the glucose stays locked up in the ethanol or the lactic acid, which are not broken down any further. Because the fuel is only partly oxidised and never reaches the Krebs cycle or the electron transport chain, the great bulk of its energy is never released, and so the yield stays at just two ATP.

Examiner's Note
The marks need the point that only the net two ATP of glycolysis are made, the glucose being only partly oxidised, with most of its energy left locked in the ethanol or lactic acid because the Krebs cycle and electron transport chain are not reached.

Question 66

Fermentation by microbes is put to use in homes and industries all over Tanzania. Outline the everyday uses of fermentation.

Model Answer

Fermentation is put to several everyday uses:

1) **Raising bread:** the carbon dioxide given off by yeast fermentation makes the dough rise, giving light, soft bread.
2) **Brewing drinks:** yeast ferments sugar into the alcohol of beer and wine and of local brews such as mbege.
3) **Souring milk:** bacteria ferment the sugar of milk into lactic acid, which thickens and sours it into yoghurt and mtindi.
4) **Making fuel:** sugar from crops is fermented into ethanol, which is burned as a fuel for stoves and vehicles.

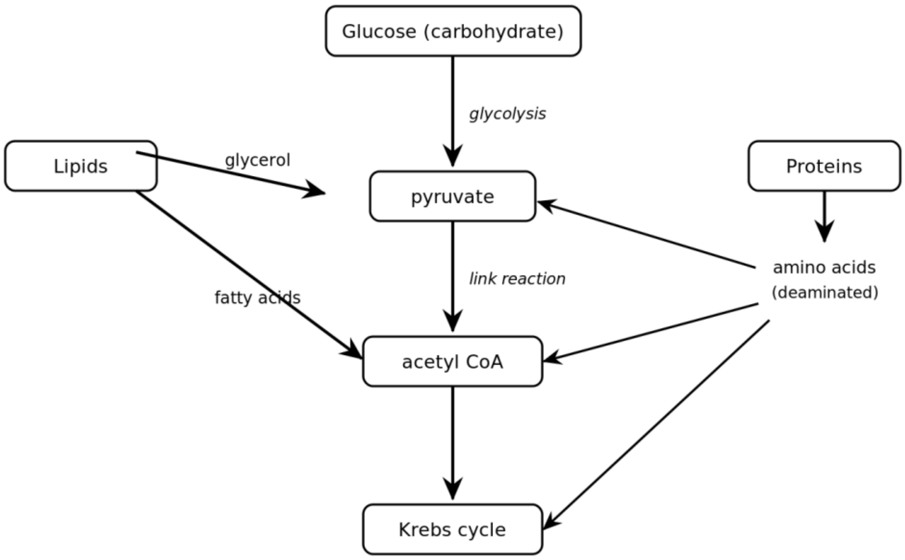
Examiner's Note
The marks need the uses tied to the products: the carbon dioxide for raising bread, the alcohol for brewing, the lactic acid for souring milk into yoghurt, and ethanol as a fuel.

False Confidence Alert
Most students name only beer and bread. Yet fermentation also sours milk into yoghurt and makes the ethanol that is burned as a fuel.

Question 67

A gram of fat releases more than twice the energy of a gram of carbohydrate, and the body can respire its fat stores when glucose runs low. Explain how a lipid is fed into the respiratory pathway.

Model Answer



The carbon skeletons of the amino acids enter as pyruvate, acetyl CoA or a Krebs intermediate.

Figure 7.15: *how lipids and proteins are fed into the respiratory pathway.*

A lipid is first split into its two parts, glycerol and fatty acids, and each is fed into the pathway at a different point. The glycerol is changed into a compound of glycolysis and enters there, while the long fatty-acid chains are broken into two-carbon units.

The two-carbon units from the fatty acids enter the pathway as acetyl coenzyme A. Because each fatty acid gives many such two-carbon units, and each unit feeds the Krebs cycle and loads the hydrogen carriers, a lipid yields a great deal of ATP.

Examiner's Note
The marks need the lipid split into glycerol, which enters glycolysis, and fatty acids, which are broken into two-carbon units entering as acetyl coenzyme A, the many units explaining the large ATP yield.

Language Clinic
The connector while sets the two halves of the lipid side by side. The glycerol enters glycolysis while the fatty acids are broken into two-carbon units: one word shows the two parts taking their two different routes.

Question 68

When the body has used up its carbohydrate and its fat, it can respire its proteins, but only after the proteins are treated in a particular way. Explain how a protein is fed into the respiratory pathway.

Model Answer

A protein is first broken down into its amino acids, and each amino acid must then be deaminated before it can be respired. Deamination removes the nitrogen-containing part of the amino acid, which is turned into urea and excreted, leaving behind a carbon skeleton that can be fed into the pathway.

The carbon skeletons then enter the respiratory pathway at whichever point suits them, as pyruvate, as acetyl coenzyme A, or as one of the compounds of the Krebs cycle. From there they are respired like any other fuel, so a protein too can be used to make ATP, once its nitrogen has been removed.

Examiner's Note
The marks need the protein broken to amino acids, each deaminated (the nitrogen removed as urea) to leave a carbon skeleton, which enters the pathway as pyruvate, acetyl coenzyme A or a Krebs intermediate.

False Confidence Alert
Most students think an amino acid can be respired just as it is. Yet its nitrogen must first be removed by deamination before the carbon skeleton that is left can enter the pathway.

Question 69

Even when you are lying still and doing nothing, your body is using up energy all the time. Explain what is meant by the basal metabolic rate, and why the body uses energy even at complete rest.

Model Answer

The basal metabolic rate is the rate at which the body uses energy when it is completely at rest, merely to stay alive. It is measured in a person who is lying still, warm and not digesting a meal, and it is the least energy the body needs to keep itself going.

The body uses energy even at rest because its many vital processes never stop. The heart keeps beating, the lungs keep breathing, the kidneys keep working and every cell keeps up its basic chemistry, and all of this calls for a steady supply of ATP from respiration.

Examiner's Note
The marks need the basal metabolic rate as the energy used at complete rest just to stay alive, and the reason that vital processes such as the heartbeat, breathing and the basic chemistry of the cells never stop.

Language Clinic
The pivot is because. The body spends energy at rest because its vital work never stops: the connector ties the unceasing heartbeat and breathing to the steady demand for ATP.

Question 70

By measuring the gases a living thing exchanges, we can tell which kind of food it is respiring. Explain what the respiratory quotient is, and how it is found.

Model Answer

The respiratory quotient, or RQ, is the ratio of the carbon dioxide a tissue gives out to the oxygen it takes in over the same time. It is written as RQ = carbon dioxide given out divided by oxygen taken in, and it has no units, being one volume divided by another.

It is found by measuring the volume of carbon dioxide produced and the volume of oxygen used, and dividing the first by the second. Because different foods need different amounts of oxygen for the carbon dioxide they yield, the value of the RQ tells us which substrate the tissue is respiring.

Examiner's Note
The marks need the RQ defined as the volume of carbon dioxide given out divided by the volume of oxygen taken in over the same time, found by measuring the two gas volumes, its value showing the substrate.

Language Clinic
The connector Because links the chemistry to the use. Because each food needs its own amount of oxygen, the RQ reveals the fuel: the word turns the measurement into a way of telling the substrates apart.

Question 71

The respiratory quotient can be worked out from the equation for respiring a fuel. Show how the RQ is calculated for a carbohydrate and for a fat, and explain what value the anaerobic case gives.

Model Answer

For a carbohydrate such as glucose, the RQ comes to exactly 1.0, because equal volumes of carbon dioxide and oxygen are exchanged. From the equation

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O,$$

6 volumes of carbon dioxide are given out for the 6 volumes of oxygen taken in, and 6 divided by 6 is 1.0.

For a fat the RQ is much lower, at about 0.7, because a fat needs far more oxygen for the carbon dioxide it makes. A fat holds little oxygen of its own but much hydrogen, so a great deal of oxygen must be taken in to burn it, while less carbon dioxide is given out for that oxygen, giving an RQ of roughly 0.7.

In anaerobic respiration the RQ rises very high, even to infinity. Here no oxygen is taken in at all, yet carbon dioxide may still be given off, as when yeast ferments sugar to alcohol; dividing the carbon dioxide by zero oxygen gives an extremely high, even infinite, value.

Examiner's Note
The marks need the carbohydrate worked as 6 carbon dioxide over 6 oxygen = 1.0, the fat as about 0.7 (it needs more oxygen), and the anaerobic case as very high or infinite (carbon dioxide given off with no oxygen taken in).

Language Clinic
The pivot is so. A fat is oxygen-poor, so much oxygen must be taken in for little carbon dioxide: the connector carries the make-up of the fat straight to its low RQ.

Question 72

The respiratory quotient of a pure carbohydrate should be exactly 1.0, yet a measurement on a real animal seldom gives so neat a value. Explain why the measured RQ is rarely exactly the theoretical figure.

Model Answer

The measured RQ is rarely exact because a living thing seldom respires one pure substrate at a time. In a real body, carbohydrate, fat and sometimes protein are all being respired together, so the measured RQ is a blend of their separate values and falls somewhere between them.

Other things, too, blur the figure, such as some of the carbon dioxide staying behind in the body. Not all the carbon dioxide made is breathed straight out, and a few processes other than respiration also use or release these gases, so the measured RQ drifts from the neat theoretical value.

Examiner's Note
The marks need the point that a real organism respires a mixture of carbohydrate, fat and protein, not one pure fuel, so its RQ lies between their values, with other factors such as retained carbon dioxide blurring it further.

False Confidence Alert
Most students expect a real RQ to land exactly on 1.0 or 0.7. Yet a body burns several fuels at once, so its measured RQ usually falls somewhere in between.

REAL QUESTIONS

The REAL questions take this biology out of the textbook and into the body, the farm and the examination room. They ask you to use what you have learnt, to explain a mechanism, to compare, to weigh a claim and to put a mistake right, in the way the examiner will. Read each one closely, for the marks lie in the reasoning.

Question 73

A fish breathes through gills, an earthworm through its skin, and a mammal through lungs, yet all three surfaces share the same features. Compare these respiratory surfaces, and say why each shared feature is necessary.

Model Answer

However different they look, the gill, the skin and the lung share the features of every good respiratory surface, and each feature is necessary:

1) **Thin:** each surface is only a short distance across, so the gases have only a tiny way to diffuse.
2) **Moist:** each is kept wet, so the gases dissolve in the film of moisture before passing through.
3) **Large in surface area:** the feathery gill, the broad skin and the millions of alveoli each give a great area, so many gas molecules cross at once.
4) **Well supplied with a transport medium:** blood in the capillaries that run close beneath the gill, the earthworm skin and the alveolus alike carries the gases away, keeping the concentration gradient steep.

In every case the same features serve the same end, so the gill, the skin and the lung are all built for the swift diffusion of gases down their gradients.

Examiner's Note
The marks need the shared features, thin, moist, large in area and well supplied with blood, each tied to faster diffusion, and shown across the gill, the skin and the lung alike.

Language Clinic
The connector so threads the answer together. Each feature is named and then, with so, joined to its purpose: thin, so the way is short; large, so much crosses at once. The marker rewards that link.

Question 74

By the time a breath of air reaches the alveoli it has been warmed, moistened and cleaned. Explain how the nose and the airway prepare the air in these three ways before it reaches the delicate alveoli.

Model Answer

As the air passes down, the nose and airway prepare it in three ways:

1) Warmed: the air is warmed towards body temperature by the blood in the warm lining of the nose and airway.
2) Moistened: water from the moist lining evaporates into the air, so the dry air does not dry out the thin alveolar walls.
3) Cleaned: sticky mucus from the goblet cells traps dust and microbes, and the beating cilia sweep this dirty mucus up and away from the lungs.

By the time the air reaches the alveoli it is warm, damp and clean, and so cannot harm the delicate gas-exchange surface.

Examiner's Note
The marks need the air warmed by the blood-rich lining, moistened by water from that lining, and cleaned by the mucus of the goblet cells with the sweeping cilia, all before it reaches the alveoli.

False Confidence Alert
Most students think the airway only carries the air to the lungs. Yet it also warms, moistens and cleans that air, guarding the delicate alveoli from cold, dryness and dirt.

Question 75

Breathing in and breathing out are brought about by muscles, not by the lungs themselves. Explain the mechanism of ventilation in a mammal, tracing the muscles, the pressure changes and the flow of air for both breathing in and breathing out.

Model Answer

During breathing in, the diaphragm contracts and flattens and the external intercostal muscles pull the ribs up and out, so the chest cavity grows larger. As the cavity enlarges, the pressure of the air in the lungs falls below the pressure outside the body, so air flows in through the airway until the two pressures are equal.

During breathing out, the diaphragm and the intercostal muscles relax, and the chest cavity becomes smaller again. The diaphragm domes upward and the ribs fall down and in, so the pressure in the lungs rises above the outside pressure, and the stale air is pushed out.

Examiner's Note
The marks need, for breathing in, the diaphragm and external intercostals enlarging the cavity so the pressure falls and air flows in; and for breathing out, the muscles relaxing so the cavity shrinks, the pressure rises and air is pushed out.

Language Clinic
The word As marks cause and effect at once. As the cavity enlarges, the pressure falls: the connector shows the pressure change is the direct result of the muscles moving, which is the heart of the answer.

Question 76

The alveoli are often called the most efficient gas-exchange surface in the body. Set out, feature by feature, why the alveoli are so efficient at exchanging gases.

Model Answer

The alveoli are efficient because of several features, each one speeding the exchange of gases:

1) **A very thin wall:** it is only one cell thick and lies against an equally thin capillary, so the gases cross only a tiny distance.
2) **An enormous total surface area:** the millions of alveoli give an area of about eighty square metres, so a great deal of gas can cross at once.
3) **A moist lining:** the gases dissolve in the film of moisture before they diffuse across.
4) **A rich blood supply:** the dense network of capillaries carries the gases away and brings more, keeping the diffusion gradients steep.
5) **Constant ventilation:** fresh air is brought in with every breath, keeping the alveolar air fresh and the gradients steep.

Examiner's Note
The marks need the features set out and each tied to fast exchange: the thin wall for a short distance, the huge area, the moist lining, the rich capillaries and the constant fresh air, all keeping the gradients steep.

False Confidence Alert
Most students stop at the large surface area. Yet the thin wall, the moist lining, the rich blood supply and the constant fresh air are all just as much a part of why the alveolus is so efficient.

Question 77

Kipanga says, *"The surfactant in the alveoli is useless; it is only a bit of slime*." Weigh his claim, and put it right.

Model Answer

Kipanga is wrong: the surfactant is far from useless, for without it the alveoli would collapse. Surfactant is a soapy substance that lowers the surface tension of the moist film lining each alveolus.

By lowering that surface tension, the surfactant stops the tiny alveoli from sticking shut as the air leaves them. Without it, the wet walls of a small alveolus would be drawn together and the alveolus would collapse, which is why a baby born with too little surfactant struggles to breathe; far from useless, the surfactant is vital.

Examiner's Note
The marks need the correction that surfactant lowers the surface tension of the alveolar film and so keeps the alveoli from collapsing, with the premature baby as proof that it is vital, not useless.

Language Clinic
The little word for carries the verdict. The surfactant is far from useless, for without it the alveoli would collapse: for works like because, giving the reason that overturns Kipanga.

Question 78

When you comment on the oxygen-haemoglobin dissociation curve, the examiner wants more than its S-shape. Comment on the shape of the curve, saying what it means for the loading of oxygen in the lungs and for its unloading in an active tissue.

Model Answer

The flat upper part of the S-shaped curve shows that haemoglobin loads up almost fully with oxygen in the lungs. Where the partial pressure of oxygen is high, as in the lungs, the haemoglobin is nearly completely saturated, so each red cell leaves the lungs carrying close to all the oxygen it can hold.

The steep middle part of the curve shows that haemoglobin unloads a great deal of oxygen in an active tissue. In a hard-working tissue the partial pressure of oxygen is low, and because the curve is steep there, a small fall in oxygen tension makes the haemoglobin give up a large share of its oxygen, exactly where it is needed most.

Examiner's Note
The marks need the flat top read as near-full loading in the lungs, and the steep middle read as a large unloading for only a small fall in oxygen tension in an active tissue.

Language Clinic
The connector because earns the mark. Because the curve is steep across the tissue range, a small fall in oxygen tension unloads a great deal of oxygen: it ties the shape of the curve to what it does.

Question 79

Carbon dioxide made in a respiring tissue must be carried in the blood all the way to the lungs. Explain the mechanism by which carbon dioxide is carried from the tissue to the lung.

Model Answer

Most of the carbon dioxide is carried as hydrogencarbonate ions formed inside the red blood cells. In the tissue the carbon dioxide diffuses into the red cells, where carbonic anhydrase quickly joins it with water to form carbonic acid, which splits into hydrogen ions and hydrogencarbonate ions; the hydrogencarbonate ions then pass out into the plasma and are carried to the lungs.

A smaller part of the carbon dioxide travels dissolved in the plasma or bound to the haemoglobin as carbaminohaemoglobin. At the lungs the whole process runs in reverse: the hydrogencarbonate ions are turned back into carbon dioxide, which diffuses out of the blood and is breathed out.

Examiner's Note
The marks need most carbon dioxide carried as hydrogencarbonate ions (made by carbonic anhydrase in the red cells, then passing to the plasma), a little dissolved or as carbaminohaemoglobin, and the reverse at the lungs so the carbon dioxide is breathed out.

False Confidence Alert
Most students think carbon dioxide is carried mainly as the gas dissolved in the blood. Yet much the largest share travels as hydrogencarbonate ions made inside the red cells.

Question 80

Every year people die in their sleep from a charcoal stove left burning in a closed room. Explain why this is so deadly, linking it both to carbon monoxide and to the using-up of the oxygen.

Model Answer

The burning charcoal gives off carbon monoxide, which seizes the haemoglobin and stops it from carrying oxygen. Carbon monoxide binds to haemoglobin far more tightly than oxygen does, forming carboxyhaemoglobin, so the blood can no longer carry oxygen to the body even while the person keeps breathing.

At the same time, the burning stove steadily uses up the oxygen in the closed room. With the door and windows shut, the flame burns the oxygen away and replaces it with carbon dioxide and carbon monoxide, so there is less and less oxygen to breathe; the two effects together overcome the sleeper before they wake.

Examiner's Note
The marks need both killers: the carbon monoxide binding the haemoglobin (as carboxyhaemoglobin) so the blood cannot carry oxygen, and the closed stove using up the oxygen of the room, the two together starving the body of oxygen.

Language Clinic
The answer leans on so, twice. The carbon monoxide binds tightly, so the blood cannot carry oxygen; the stove burns the air, so less is left to breathe: the two so-clauses build the double danger.

Question 81

A climber heading for a very high mountain must spend several days acclimatising on the way up, rather than rushing to the top. Explain why this acclimatisation is needed, relating it to the slow building of extra red blood cells.

Model Answer

High on the mountain the air is thin and its oxygen is at a low pressure, so the climber takes in less oxygen with each breath. To make up for this, the body must build more red blood cells, so that the blood can gather more oxygen from the thin air and still supply the tissues.

Building these extra red blood cells takes several days, and that is why the climber must go up slowly. The body cannot make them all at once, so a climber who rushes to the top before the extra red cells are ready would be starved of oxygen and fall dangerously ill.

Examiner's Note
The marks need the thin air at altitude (oxygen at a low pressure, less taken in per breath), the body answering by making extra red blood cells, and that this takes days, so the climber must acclimatise slowly.

False Confidence Alert
Most students think the air high up holds a smaller fraction of oxygen. Yet the fraction is the same; the air is merely thinner, so its oxygen is at a lower pressure, and the body needs days to build the extra red cells.

Question 82

A leaf has no lungs to pump air to its cells, yet a gas can reach even the cells deep in the middle of it. Explain how the leaf is built so that gases reach every mesophyll cell, reading the part played by the air spaces and the position of the stomata.

Model Answer

The leaf is filled with a network of air spaces that connect every mesophyll cell to the outside air. The spongy mesophyll is loosely packed, leaving large air spaces between its cells, and these spaces run right up to the stomata, so a continuous air path joins the outside air to each cell.

The stomata, set mostly in the lower surface, open these air spaces to the air outside. A gas diffuses in through a stoma, through the moist air spaces, and dissolves in the wet wall of a mesophyll cell before passing in; because the spaces reach every cell, no cell is too deep to be supplied.

Examiner's Note
The marks need the air spaces of the spongy mesophyll joining every cell to the outside, the stomata opening these spaces to the air, and a gas diffusing from a stoma through the spaces to dissolve in the wet wall of a mesophyll cell.

Language Clinic
The connector because seals the answer. Because the air spaces reach every cell, none is too deep to be supplied: the word turns the loose-packed structure of the leaf into the reason every cell is served.

Question 83

By day a green leaf takes in carbon dioxide and gives out oxygen overall, even though it never stops respiring. Explain how this can be so.

Model Answer

By day the leaf is both photosynthesising and respiring, but photosynthesis goes much the faster of the two. In good light the leaf photosynthesises far more quickly than it respires, so it uses up far more carbon dioxide than its respiration makes, and makes far more oxygen than its respiration uses.

The leaf therefore takes in carbon dioxide and gives out oxygen overall, the reverse of what it does in the dark. Its respiration carries on all the while, but the gases that respiration needs are more than supplied from within by photosynthesis, so only the surplus is traded with the air: carbon dioxide in and oxygen out.

Examiner's Note
The marks need both processes going on by day, with photosynthesis much faster than respiration, so more carbon dioxide is used and more oxygen made than respiration can match, giving the net intake of carbon dioxide and output of oxygen.

False Confidence Alert
Most students think a leaf stops respiring in the light. Yet it respires day and night; by day photosynthesis simply outpaces it, so the overall exchange is reversed.

Question 84

Gas exchange in a plant is driven entirely by diffusion, with no pump and no blood. Give a clear account of gas exchange in a plant, and say how the partial pressures of oxygen and carbon dioxide drive it.

Model Answer

A plant exchanges its gases by the simple diffusion of each gas through the stomata and the air spaces, from where its partial pressure is higher to where it is lower. There is no pump and no blood; a gas merely diffuses down the difference in its own partial pressure between the inside of the leaf and the air outside.

So the direction of the exchange depends on which way each partial-pressure gradient runs. In a photosynthesising leaf the cells use up carbon dioxide, lowering its partial pressure inside, so carbon dioxide diffuses in; and they make oxygen, raising its partial pressure inside, so oxygen diffuses out; in the dark, with only respiration, both gradients and both flows are reversed.

Examiner's Note
The marks need gas exchange by diffusion through the stomata and air spaces, each gas moving down its own partial-pressure gradient, with the cells using or making the gases to set those gradients, so the direction reverses between light and dark.

Language Clinic
The pivot is So. So the direction depends on the gradient, and then each gas is shown moving the way its gradient runs: the connector lifts the answer from what happens to why it happens.

Question 85

Glycolysis breaks one molecule of glucose down into two molecules of pyruvic acid in the cytoplasm, in a chain of small steps. Give a connected account of the stages of glycolysis, from glucose right through to pyruvic acid.

Model Answer

Glycolysis opens with an outlay, for the six-carbon glucose is first phosphorylated, using two molecules of ATP, to give a reactive six-carbon sugar bisphosphate. This early investment raises the energy of the otherwise sluggish glucose and readies it to be split; the stage goes on in the cytoplasm and needs no oxygen.

The six-carbon bisphosphate is then split into two three-carbon sugars, each one a triose phosphate. This splitting of the sugar is what gives glycolysis its name, and from here on every remaining step happens twice over, once for each of the two triose phosphates.

Each triose phosphate is then oxidised by the removal of hydrogen, which NAD takes up to become NADH, while phosphate is passed straight on to ADP to make ATP. This direct handing of phosphate from the substrate to ADP is substrate-level phosphorylation, and it leaves behind a three-carbon molecule of pyruvic acid.

The books are easily balanced, for four ATP are made while two were spent, leaving a net gain of two ATP together with two NADH and two molecules of pyruvic acid from each glucose. All of this is done in the cytoplasm without oxygen, which is why glycolysis is shared alike by aerobic and by anaerobic respiration.

Examiner's Note
The marks need the two ATP invested to phosphorylate glucose, the split into two triose phosphates, their oxidation with NAD reduced to NADH and ATP made by substrate-level phosphorylation, and the net tally of two ATP, two NADH and two pyruvic acid, all in the cytoplasm.

Language Clinic
The account is held together by then. The sugar is phosphorylated, then split, then oxidised: the one quiet word marches the reader down the pathway in the right order, step by step.

Question 86

It can seem wasteful that glycolysis spends two molecules of ATP before it has made any at all. Justify this early outlay of ATP, and say whether the cell loses out by it.

Model Answer

The two ATP are spent to phosphorylate the glucose, and a phosphorylated sugar is a reactive sugar. Glucose by itself is stable and slow to react; adding phosphate lifts its energy and makes it ready to be split and oxidised in the steps that follow, so the outlay is simply what sets the pathway going.

The added phosphate also carries a negative charge, and that charge traps the sugar inside the cell. The charged, phosphorylated sugar cannot slip back out through the membrane the way plain glucose can, so the fuel is held where it is needed; and by mopping up free glucose it keeps the inside concentration low, so yet more glucose diffuses in.

Far from losing out, the cell more than wins back its outlay, for four ATP are made later and only two were ever spent. The two invested ATP are therefore a priming investment and not a loss: they are repaid with a clear net profit of two ATP for every glucose.

Examiner's Note
The marks need the two ATP shown as a priming investment that phosphorylates glucose to make it reactive and to trap it in the cell, with the cell winning them back as a net gain of two ATP.

False Confidence Alert
Most students write off the early two ATP as wasted. In truth they are an investment that activates and traps the glucose, and the pathway pays it back twice over, for a net two ATP.

Question 87

At the end of glycolysis the pyruvic acid stands at a crossroads. Describe what becomes of it when oxygen is present and when oxygen is absent, and compare the two fates.

Model Answer

When oxygen is present, the pyruvic acid passes into the mitochondrion and is there broken down completely. The link reaction and the Krebs cycle strip away its carbon as carbon dioxide and its hydrogen onto carriers, and that hydrogen is in the end passed to oxygen to form water; the fuel is fully oxidised, so a great deal of energy is set free as ATP.

When oxygen is absent, the pyruvic acid stays in the cytoplasm and is merely reduced rather than broken down. In muscle it is reduced to lactic acid, and in yeast and in plants to ethanol and carbon dioxide; either way the real point of the step is to regenerate NAD so that glycolysis can keep running, for the fuel itself is scarcely broken at all.

The two fates therefore differ in place, in completeness and in yield. With oxygen the pyruvic acid is fully oxidised in the mitochondrion for a large harvest of ATP; without oxygen it is only converted in the cytoplasm, freeing almost no further energy and serving mainly to set the NAD loose for glycolysis to use again.

Examiner's Note
The marks need both fates: with oxygen, pyruvic acid enters the mitochondrion and is fully oxidised to carbon dioxide and water for much ATP; without oxygen it is reduced in the cytoplasm to lactic acid or to ethanol and carbon dioxide, regenerating NAD for very little energy.

Language Clinic
The two halves are balanced by the matched openings When oxygen is present and When oxygen is absent. The parallel wording sets the two fates side by side, so the contrast in place and in yield almost reads itself.

Question 88

Of the three respiratory substrates, protein is normally the last to be drawn upon for energy. Explain why the body holds its protein back, and say what must first happen to an amino acid before its carbon can be respired.

Model Answer

Protein is held back because it is the working material of the body and not its fuel store. Proteins build the muscles and the membranes and, above all, the enzymes that drive every reaction, so the body spares them for building and repair and turns to them for energy only when its carbohydrate and its fat are all but spent, as in prolonged starvation.

Before the carbon of an amino acid can be respired, its nitrogen must first be taken off by deamination in the liver. The amino group is removed as ammonia, which the body at once turns into the far less poisonous urea for excretion; only when the nitrogen is gone is the carbon skeleton left free to be used.

The carbon skeleton that is left then enters the respiratory pathway at whatever point fits it. Depending on the amino acid it joins in as pyruvic acid, as acetyl coenzyme A, or as one of the acids of the Krebs cycle, and from there it is oxidised exactly like the carbon that came from sugar or from fat.

Examiner's Note
The marks need protein spared as the body structural and enzyme material, used only once carbohydrate and lipid are exhausted, and deamination removing the amino group as ammonia (turned to urea) before the carbon skeleton enters as pyruvic acid, acetyl coenzyme A or a Krebs acid.

False Confidence Alert
Most students feed the whole amino acid, nitrogen and all, straight into respiration. The nitrogen must first be stripped off by deamination and got rid of as urea; only the carbon skeleton is ever respired.

Question 89

Trace the main steps of the Krebs cycle, and show how it is joined to glycolysis through the link reaction.

Model Answer

The Krebs cycle is joined to glycolysis by the link reaction, which turns the pyruvic acid that glycolysis makes into the acetyl coenzyme A that the cycle takes in. Each three-carbon pyruvic acid that leaves glycolysis passes into the mitochondrion, loses one carbon as carbon dioxide and a pair of hydrogens to NAD, and the two-carbon acetyl group that is left is carried in on coenzyme A; in this way the link reaction hands the cycle its fuel.

The cycle itself opens when the two-carbon acetyl group joins a four-carbon acceptor, oxaloacetic acid, to make the six-carbon citric acid. This is why the round is also called the citric acid cycle; the acetyl group is now committed to the chain of reactions that follows.

The six-carbon citric acid is then carried round the cycle in small steps, giving off two of its carbons as carbon dioxide and handing several pairs of hydrogen to NAD and to FAD. Each single turn gives off two molecules of carbon dioxide, makes three NADH and one $FADH_2$, and yields one ATP directly by substrate-level phosphorylation, while the four-carbon oxaloacetic acid is built up again at the end.

Because the oxaloacetic acid is remade at the close of every turn, the cycle is free to run round again and again, and since glycolysis sends in two pyruvic acids it turns twice for each glucose. Its great worth, even so, is less the single ATP than the loaded carriers, the NADH and the $FADH_2$, which carry their hydrogen on to the electron transport chain where the bulk of the ATP is made.

Examiner's Note
The marks need the link reaction turning pyruvic acid into acetyl coenzyme A (losing CO_2, reducing NAD), the acetyl joining oxaloacetic acid to form citric acid, the cycle giving off two CO_2 and making three NADH, one $FADH_2$ and one ATP per turn, and oxaloacetic acid regenerated so it turns twice per glucose.

Language Clinic
The turn of the cycle is explained by Because. Because the oxaloacetic acid is remade at the close of every turn, the cycle is free to run again: the word ties the rebuilding of the acceptor to the cycle being able to repeat.

Question 90

The Krebs cycle is far more than a maker of a little ATP. Explain its importance to the cell in two ways.

Model Answer

First and foremost, the Krebs cycle loads the hydrogen carriers that feed the electron transport chain, where the bulk of the cell energy is captured as ATP. Every turn reduces NAD and FAD to NADH and $FADH_2$, and these carry their hydrogen to the chain on the inner membrane; the single ATP made in the cycle itself is small beside the great yield these loaded carriers later make possible.

Second, the cycle is a crossroads that supplies carbon skeletons for building other molecules. Several of its acids can be drawn off to make amino acids, fats and other materials the cell needs, so it serves the building of the cell as well as its breathing, and it is the common meeting point at which the carbon from sugars, fats and proteins is all fed in and oxidised.

Examiner's Note
The marks need two distinct roles: the cycle reduces NAD and FAD to NADH and $FADH_2$ that feed the electron transport chain for most of the ATP, and it provides carbon-skeleton intermediates for making amino acids and other molecules, a meeting point for all three substrates.

False Confidence Alert
Most students think the Krebs cycle is where most of the ATP is made. Only one ATP comes from each turn; its real worth is the NADH and $FADH_2$ it hands to the electron transport chain, where most of the ATP is made.

Question 91

In the electron transport chain the electrons are passed from one carrier to the next, always from a higher to a lower energy level. Explain why they move this way, and say what is done with the energy they give up.

Model Answer

The electrons move from a higher to a lower energy level because each carrier in the chain holds them a little more tightly, that is at a lower energy, than the carrier before it. An electron always tends to fall to a lower energy level if it can, just as water runs downhill, so it passes of its own accord from carrier to carrier down the chain towards oxygen, which holds electrons most tightly of all and waits at the end as the final acceptor.

At each step down the chain a little energy is set free, and that energy is used to make ATP. Because the fall is broken into many small steps rather than one great drop, the energy comes off in small, handy amounts that the inner membrane can capture and use to drive the making of ATP; at the foot of the chain the spent electrons, together with hydrogen, are joined to oxygen to form water.

Examiner's Note
The marks need the electrons falling from higher to lower energy because each carrier holds them more tightly than the last, a spontaneous flow down to oxygen as final acceptor, the energy released in small steps used to make ATP, and water formed from hydrogen and oxygen at the end.

Question 92

Describe how the mitochondrion generates ATP during aerobic respiration, naming the parts of the mitochondrion where the work is done.

Model Answer

The work begins in the matrix, the fluid centre of the mitochondrion, where the link reaction and the Krebs cycle take place. Here the pyruvic acid that comes from glycolysis is broken down completely, its carbon driven off as carbon dioxide and its hydrogen loaded onto the carriers NAD and FAD to make NADH and $FADH_2$.

These loaded carriers then bring their hydrogen to the electron transport chain, which is built into the inner membrane and its folds, the cristae. The electrons are passed down the chain from a higher to a lower energy, oxygen waits at the end as the final acceptor and is joined to hydrogen to make water, and the energy given off as the electrons fall is used to make the great bulk of the cell ATP.

The inner membrane is thrown into many cristae so as to carry as many of these chains as it can, which is why the mitochondrion is so rich a source of ATP. All told, the complete aerobic breakdown of one glucose yields about thirty-eight ATP, the greater part of it made here on the inner membrane, far more than the small net gain that glycolysis makes by itself in the cytoplasm.

Examiner's Note
The marks need the matrix carrying the link reaction and the Krebs cycle (loading NADH and $FADH_2$), the inner membrane and its cristae carrying the electron transport chain where most ATP is made and oxygen forms water, the folding into cristae raising the yield, and the whole giving about thirty-eight ATP per glucose.

False Confidence Alert
Most students place the whole of respiration in the mitochondrion. Glycolysis comes first in the cytoplasm; only the link reaction, the Krebs cycle and the electron transport chain are housed in the mitochondrion.

Question 93

Yeast is used in making bread, in brewing beer and in making wine. Explain the part that fermentation plays in each, and say why the products are not the same.

Model Answer

In all three the yeast carries out the very same reaction, alcoholic fermentation, breaking sugar down without oxygen into ethanol and carbon dioxide. What differs between bread, beer and wine is not the chemistry at all but which of the two products is wanted and which is allowed to go.

In bread it is the carbon dioxide that is wanted. The gas the yeast gives off is trapped as bubbles in the dough, so the dough rises and the baked loaf is light and open; the small amount of ethanol made is driven off by the heat of the oven.

In beer and in wine it is the ethanol that is wanted. The yeast is left to ferment the sugars of malted barley for beer, or of grape juice for wine, and the alcohol is kept while the carbon dioxide is mostly let escape; so the one reaction serves the baker and the brewer in opposite ways.

Examiner's Note
The marks need the single reaction, alcoholic fermentation (sugar to ethanol and carbon dioxide, no oxygen), lying behind all three, with the carbon dioxide wanted to raise bread and the ethanol wanted in beer and wine.

Question 94

During a hard sprint a runner's leg muscles soon begin to ache and to tire. Explain why this happens, in terms of respiration, and what the body must do afterwards to put it right.

Model Answer

During a hard sprint the leg muscles work so fast that the blood cannot bring them oxygen quickly enough, so they are driven to respire anaerobically. With too little oxygen the muscles cannot use the full aerobic pathway, and they fall back on the anaerobic breakdown of glucose, which needs no oxygen but releases only a little energy.

The anaerobic pathway leaves lactic acid behind in the muscles, and it is this build-up that makes them ache and tire. The lactic acid gathers faster than the blood can carry it away, and as it does so the muscles grow sore and lose their power, which is why a sprinter cannot hold top speed for long.

Afterwards the body must take in extra oxygen to clear the lactic acid away, and this extra need is the oxygen debt. It is why the runner goes on breathing hard and deep for some minutes after stopping: the extra oxygen is used to deal with the lactic acid that built up, and only when it is cleared are the muscles back to normal.

Examiner's Note
The marks need oxygen failing to reach the muscle fast enough so it respires anaerobically, lactic acid building up and causing the ache and fatigue, and an oxygen debt repaid afterwards by hard breathing to clear the lactic acid.

False Confidence Alert
Most students say the tired muscle has simply run out of energy. In truth it has switched to anaerobic respiration, which still makes a little ATP; the ache comes from the lactic acid that this leaves behind.

Question 95

Aerobic and anaerobic respiration both begin in the same way but end very differently. Compare the two, bringing out the main points on which they differ.

Model Answer

Both begin by splitting glucose in glycolysis, but they part company after that, and they differ in several clear ways.

1) **Oxygen:** aerobic respiration needs oxygen, whereas anaerobic respiration goes on without it.
2) **Site:** aerobic respiration is completed in the mitochondrion, while anaerobic respiration takes place wholly in the cytoplasm.
3) **Completeness:** in aerobic respiration the glucose is broken down completely to carbon dioxide and water, whereas in anaerobic respiration it is only partly broken down.
4) **Products:** aerobic respiration gives carbon dioxide and water, while anaerobic respiration gives lactic acid in muscle, or ethanol and carbon dioxide in yeast and plants.
5) **Energy yield:** aerobic respiration releases a great deal of energy, about thirty-eight ATP for each glucose, whereas anaerobic respiration releases only a little, a net of two ATP.

Examiner's Note
The marks need the points of difference set out clearly: oxygen needed or not, mitochondrion against cytoplasm, complete against partial breakdown, the different products, and the large aerobic yield against the small anaerobic one.

False Confidence Alert
Most students think anaerobic respiration releases no energy at all. It does release a little, the net two ATP of glycolysis; what it cannot do is release the great amount that the complete aerobic breakdown gives.

Question 96

Fermentation carried out by microbes is of great value to people in many ways. Explain its importance, giving examples.

Model Answer

Fermentation gives people many of their everyday foods and drinks. Yeast raises bread and brews beer and wine, while other microbes turn milk into yoghurt and the soured milk mtindi and ferment cassava and other foods; these foods take on a flavour of their own and keep longer, because the acid and the alcohol that fermentation makes hold off the microbes that would otherwise spoil them.

Beyond food, fermentation both preserves and provides. The same souring that flavours fermented milk also preserves it, so food can be kept longer without a fridge; and on a larger scale yeast is set to ferment sugar into ethanol that is burned as a fuel, while other fermentations are put to work making medicines and other useful substances.

Examiner's Note
The marks need fermentation giving foods and drinks (bread, beer, wine, fermented milk such as mtindi and yoghurt), preserving food because the acid and alcohol hold off spoilage microbes, and providing fuel ethanol and other useful substances.

Language Clinic
The value is tied to its cause by because. The foods keep longer because the acid and alcohol hold off the spoiling microbes: the connector turns a plain fact into an explanation the examiner can reward.

Question 97

Lipid yields more than twice as much energy gram for gram as carbohydrate, and yet the body draws on carbohydrate first. Explain why lipid is not the first substrate to be respired.

Model Answer

The body burns carbohydrate first because it is the fuel that is quickest and easiest to use. Glucose is readily soluble, easily carried in the blood and quickly fed into respiration, so it is the natural first call for energy, above all when energy is wanted in a hurry.

Lipid, though it holds far more energy gram for gram, is the body store for the long term rather than its everyday fuel. It is insoluble and must first be broken down, carried to the cells and converted before its parts can enter the respiratory pathway, so it is drawn upon more slowly, as a reserve for when the carbohydrate begins to run low.

So the order in which the substrates are used follows how easily they can be respired, not how much energy they hold. Carbohydrate is spent first because it is the readiest to hand, lipid is held back as the rich reserve, and protein is spared until the last of all.

Examiner's Note
The marks need carbohydrate used first because it is soluble and quick to respire, lipid held back as an insoluble long-term store that must first be broken down and converted, so the order follows ease of use and not energy content.

Question 98

The respiratory quotient (RQ) of a small animal is found to be 1.0 on one day, 0.9 on a second and 0.7 on a third. Say what each value tells you about the substrate being respired.

Model Answer

The respiratory quotient, the carbon dioxide given out divided by the oxygen taken in, points to the substrate being respired, for each substrate has its own value.

1) **An RQ of 1.0:** carbohydrate is the substrate, for it gives out exactly as much carbon dioxide as the oxygen it uses.
2) **An RQ of 0.9:** protein is being respired, giving out a little less carbon dioxide than the oxygen taken in.
3) **An RQ of 0.7:** fat is the substrate, giving out much less carbon dioxide than oxygen, because fat is rich in hydrogen and needs a great deal of oxygen to burn.

Examiner's Note
The marks need each value read as its substrate: an RQ of 1.0 is carbohydrate, 0.9 is protein and 0.7 is fat, with fat low because it is hydrogen-rich and needs much oxygen to oxidise.

False Confidence Alert
Most students take a low RQ such as 0.7 to mean the animal is short of oxygen. The value is not about how much oxygen is available; it names the substrate, and 0.7 is simply the figure for fat, which needs much oxygen to burn.

HOT QUESTIONS

The HOT questions are the hardest in the chapter, but not because they hide rare facts. They ask you to put ideas together, to weigh the evidence and reach a verdict, and to reason your way through situations you have not met before. The facts are ones you already hold; the marks lie in how you use them. Take your time, think before you write, and let each answer show its reasoning.

Question 99

The gill, the leaf, the alveolus and the earthworm's skin look nothing alike, yet all share the same handful of features. Account for those shared features by reasoning from what diffusion requires, and explain why a large, active mammal could not survive on skin breathing alone.

Model Answer

All these surfaces share the same features because fast diffusion calls for the same things every time: a large area, a thin, moist barrier, and a gradient kept steep across it. A large area lets much gas cross at once; a thin, moist barrier gives the dissolved gas only a short way to travel; and a steep gradient, held up by ventilation on one side and a blood supply on the other, keeps the gas always moving the one way. Whatever the animal, its surface must meet these same demands, so gill, leaf, alveolus and skin all converge on the one plan.

A small, sluggish animal like the earthworm can breathe through its skin because its body is small and its needs are slight. A small body has a large surface set against its small volume, so the skin alone offers area enough for the little oxygen it uses, and its damp burrow keeps that skin moist.

A large, active mammal could not live so, and that is why it folds its exchange surface away inside the lungs. Its body is large, so its surface is small against its great volume, and its busy life demands oxygen far faster than any skin could pass it; on dry land a bare, moist skin would lose too much water as well. The surface must therefore be vast, internal and ventilated, which is exactly what the millions of alveoli provide.

Examiner's Note
The marks need the shared features traced to what diffusion demands (large, thin, moist, a steep gradient), and the large active mammal ruled out by its low surface-to-volume ratio, high oxygen need and water loss on land.

Question 100

A disease thickens the walls of the alveoli and floods some of the air sacs with fluid. Predict and explain how this would affect the person, reasoning from the features that make a healthy alveolus efficient.

Model Answer

Thickening the alveolar walls lengthens the path the gases must cross, so they diffuse across far more slowly. A healthy wall is exceedingly thin, giving oxygen the shortest of journeys into the blood; once it is thickened the same gradient drives much less gas across in a given time, and the blood leaves the lungs less fully loaded.

Flooding the air sacs with fluid both cuts down the area left for exchange and lays a layer of liquid in the gas's way. Fewer working sacs mean a smaller total surface, and now the gas must dissolve through the flooding fluid as well, so less oxygen still reaches the blood.

The upshot is that the person cannot take in oxygen fast enough and grows breathless, the more so on exertion. With the blood poorly loaded the tissues are starved of oxygen, so the person tires quickly and breathes faster to make up the shortfall; it shows how wholly the body depends on the thin, vast, ventilated surface the disease has spoiled.

Examiner's Note
The marks need the thickened wall lengthening the diffusion path and the flooding cutting the area and adding a liquid barrier, so less oxygen crosses, the blood is poorly loaded, and the person grows breathless.

False Confidence Alert
Most students blame the breathlessness on too little air getting in. The air still enters; the fault is at the surface, where a thick, fluid-filled wall lets far less oxygen cross into the blood.

Question 101

It is diffusion, not the breathing muscles, that actually moves a gas across the alveolus. Why, then, is ceaseless ventilation still vital? Reason it out.

Model Answer

Diffusion moves a gas only while there is a difference in its amount across the surface, and that difference would soon fade if it were not renewed. As oxygen diffuses from the alveolar air into the blood, the air left behind grows poorer in oxygen and richer in carbon dioxide; were the air to sit still, it would quickly come to match the blood, the gradient would vanish, and diffusion would stall.

Ventilation is vital because it keeps replacing the stale air with fresh, so the gradient is never let run down. Each breath sweeps out air that has given up its oxygen and taken on carbon dioxide and draws in fresh air, high in oxygen and low in carbon dioxide, so the alveolus always faces air very different from the blood beyond it.

Breathing and diffusion are therefore partners: the muscles never push the gas across, but they keep the conditions under which diffusion can keep going. The blood supply does the same work from the other side, bearing loaded blood away and bringing fresh, so that the gradient is held steep at the surface from both directions at once.

Examiner's Note
The marks need diffusion depending on a gradient that exchange itself would wipe out, and ventilation, with the blood flow, constantly renewing the air so the gradient stays steep and diffusion can go on.

Question 102

The shape of the oxygen dissociation curve and its shift in active tissue together make haemoglobin almost a perfect carrier. Justify this claim by reasoning from what the body needs.

Model Answer

The flat top of the curve means haemoglobin loads to nearly full in the lungs even if the oxygen there falls a little. Over the high range of oxygen found in the lungs the curve is all but level, so the blood leaves fully loaded whether the air is rich or merely adequate; the carrier is not easily caught short.

The steep middle means that where oxygen is low, in the active tissues, a small further fall makes haemoglobin give up a great deal of oxygen. Just where the cells are spending oxygen fastest the curve is at its steepest, so a slight drop unloads a large amount, delivering most where the need is greatest.

The Bohr shift then sharpens this further still, for the very carbon dioxide the busy tissue makes pushes haemoglobin to release yet more oxygen there. So the carrier loads fully where oxygen is plentiful and unloads generously, and more generously still, exactly where it is scarce; shape and shift together fit haemoglobin to the body's needs almost perfectly.

Examiner's Note
The marks need the flat top giving full loading in the lungs, the steep middle giving large unloading in active tissue, and the Bohr shift unloading still more where carbon dioxide is high.

Language Clinic
The link is made by for. Haemoglobin gives up more oxygen, for the carbon dioxide the tissue makes pushes it to: the small word for offers the reason in the same breath as the claim.

Question 103

Trace a molecule of carbon dioxide from a respiring muscle cell to the air in the alveolus, naming the changes it goes through, and explain how the blood can carry so much carbon dioxide without turning dangerously acid.

Model Answer

In the muscle the carbon dioxide diffuses into the red cells, where carbonic anhydrase speeds its joining with water to form carbonic acid, which at once splits into hydrogen ions and hydrogencarbonate ions. Most of the carbon dioxide travels on as these hydrogencarbonate ions, which pass out into the plasma while chloride ions move in to keep the charge in balance.

The blood does not turn dangerously acid because the hydrogen ions set free are at once mopped up by the haemoglobin. Haemoglobin takes up the hydrogen ions and holds them harmlessly, the more readily because it has just given up its oxygen, so the acid is buffered as fast as it forms and the blood's acidity barely stirs.

In the lungs the whole train of changes runs backwards. Where the carbon dioxide of the air is low, hydrogencarbonate and hydrogen ions join again into carbonic acid, carbonic anhydrase splits it back to water and carbon dioxide, and that carbon dioxide diffuses out into the alveolar air to be breathed away.

Examiner's Note
The marks need carbon dioxide carried mainly as hydrogencarbonate (made by carbonic anhydrase, with the chloride shift), the freed hydrogen ions buffered by haemoglobin so the blood stays near neutral, and the changes reversed in the lungs.

False Confidence Alert
Most students think carbon dioxide rides mostly as gas dissolved in the plasma. Only a little travels so; most is carried as hydrogencarbonate ions made inside the red cells.

Question 104

Carbon monoxide is deadly at amounts far too small to lower the oxygen of the air. Explain, by reasoning from how haemoglobin behaves, why so little can do so much harm.

Model Answer

Carbon monoxide does its harm not by crowding out the oxygen of the air but by seizing the very sites on haemoglobin that should carry oxygen, and gripping them far more tightly than oxygen can. It binds to the same iron sites, but with so much the stronger a hold that even a trace in the air locks up a large share of the haemoglobin, forming a stable carboxyhaemoglobin that will not let go.

Because each molecule it captures is taken out of service more or less for good, a very little carbon monoxide puts a great many carriers out of action. The blood may still meet air full of oxygen in the lungs, yet fewer and fewer of its carriers are free to take that oxygen up, so the amount carried to the tissues falls steeply though the air itself is barely touched.

This is why so small an amount is so deadly: the damage is done to the carrier, not to the air. A gas that merely thinned the oxygen of the air would have to be present in great quantity to matter; one that disables the carrier itself needs only a trace, and worse, it clings so fast that the victim cannot quickly breathe it off.

Examiner's Note
The marks need carbon monoxide binding the same haemoglobin sites as oxygen but far more tightly, so even a trace locks up many carriers as stable carboxyhaemoglobin, cutting oxygen delivery though the air is barely changed.

Language Clinic
The reason leads with Because. Because each captured molecule is lost for good, a little does great harm: putting the cause first makes the scale of the danger feel like a conclusion drawn.

Question 105

A baby before birth and a climber high on a mountain both face a shortage of oxygen, and in both the blood is altered to capture the scarce oxygen better. Identify the shared principle, and compare how it works in each.

Model Answer

In both cases the answer is the same in kind: since neither can change the oxygen of its surroundings, each instead changes its blood so as to lay better hold of what little oxygen there is. The shortage is met not by mending the supply but by improving the carrier.

The unborn baby must draw its oxygen across the placenta from its mother's blood, which has already given up much of its own, so its blood carries a haemoglobin of higher affinity than hers. Foetal haemoglobin holds oxygen the more strongly, so at the placenta it pulls oxygen from the mother's haemoglobin onto its own, winning the oxygen it needs from blood that is already partly spent.

The climber high on the mountain breathes air in which oxygen is thin, and over days his body answers by making more red cells and more haemoglobin. With more haemoglobin in his blood, each breath of thin air can be made to yield more oxygen to the tissues, so the same shortage is met by more carriers rather than by a tighter grip.

So the trick is one in principle but two in detail: where oxygen is scarce, improve the blood. The foetus is born ready with a haemoglobin of higher affinity, while the climber must build extra haemoglobin over time; one sharpens the grip, the other multiplies the carriers, but both fit the blood to a poor supply.

Examiner's Note
The marks need the shared principle (alter the blood to capture scarce oxygen), the foetus using a higher-affinity haemoglobin that pulls oxygen across the placenta, and the climber making more red cells and haemoglobin over days.

False Confidence Alert
Most students expect the climber, like the foetus, to grow a higher-affinity haemoglobin. He does not; he makes more red cells and haemoglobin, meeting the shortage by carrying more, not by gripping tighter.

Question 106

A land plant must open its stomata to take in carbon dioxide, yet open stomata also let water escape. Discuss the conflict this sets up, and explain how the plant manages it.

Model Answer

A land plant faces a real dilemma at its stomata, for the same pores that let carbon dioxide in let water vapour out. To photosynthesise it must open its stomata to admit carbon dioxide, yet for every moment they stand open water escapes from the moist air spaces within; the plant cannot have the one good without risking the other.

The plant meets this conflict by opening its stomata when the gain is worth the cost, and closing them when it is not. By day, when light allows photosynthesis, the stomata open so that carbon dioxide can enter; but in the fierce heat of midday, or when water runs short, the guard cells lose their turgor and the stomata close, saving water even at the price of pausing photosynthesis.

So the stoma is a compromise, opening enough to feed photosynthesis yet able to shut against drying out. Survival hangs on striking this balance, for a plant that held its stomata always open would feed well but soon wilt, while one that held them always shut would save its water but starve; the adjustable pore lets the plant lean whichever way the conditions demand.

Examiner's Note
The marks need the conflict (the stomata that admit carbon dioxide also lose water vapour) and the plant managing it by opening the stomata by day for photosynthesis but closing them in drought or fierce midday heat to save water.

Language Clinic
The tension is held in one word, yet. The stomata must open, yet open stomata lose water: the small word balances the gain against the cost in a single breath.

Question 107

A small animal and a green plant are sealed together in a glass jar standing in the light, and both stay alive far longer than the animal would on its own. Explain how the plant helps the animal, and say why this would fail in the dark.

Model Answer

In the light the plant and the animal supply each other with the very gases each one needs. The animal respires, using up oxygen and giving out carbon dioxide; the plant in the light photosynthesises faster than it respires, so it takes in that carbon dioxide and gives out oxygen, and between them they keep the air of the jar fit to breathe.

So the animal lasts far longer than it would alone, because the plant keeps renewing the oxygen the animal would otherwise use up. Instead of the oxygen running down and the carbon dioxide building up, as they would with the animal by itself, each gas is handed back almost as fast as it is taken, and the air stays breathable.

In the dark this help fails, for without light the plant cannot photosynthesise and can only respire. Now the plant and the animal alike are taking in oxygen and giving out carbon dioxide, so the oxygen of the jar falls and the carbon dioxide rises faster than before; far from saving the animal, the plant in the dark only adds to the demand on the air.

Examiner's Note
The marks need the light-time complement (the animal gives out carbon dioxide and takes oxygen, the photosynthesising plant does the reverse, so the air stays breathable) and the failure in the dark (the plant then only respires, so both use oxygen and the air worsens).

False Confidence Alert
Most students think a plant always cleans the air for an animal. Only in the light does it give out oxygen overall; in the dark it respires like the animal and makes the air worse, not better.

Question 108

Glycolysis goes on in almost every living thing, needs no oxygen, and runs in the cytoplasm with no special structures. Evaluate what these facts together suggest about the place of glycolysis in the living world.

Model Answer

Taken together, these facts mark glycolysis out as the most basic and the most widely shared of all the energy pathways. That it is found in almost every organism, from a bacterium to a human, suggests it is a very old and fundamental way of releasing energy, one inherited by nearly all living things alike.

That it needs no oxygen and no special structure means it can run in any cell, whatever its conditions. It goes on in the bare cytoplasm, so even an organism with no mitochondria, or a cell cut off from its oxygen, can still win some energy from glucose by this route; it is the one stage that never leans on air or on an organelle.

So glycolysis stands as the common foundation on which the rest of respiration is raised. Both the aerobic pathway and the anaerobic ones begin with it and add their later stages on top; it is the shared first step from which the others branch, which is why it is reckoned the most fundamental of them all.

Examiner's Note
The marks need the facts read as evidence: universal suggests ancient and shared; no oxygen and no organelle means it runs in any cell, even one without mitochondria; so glycolysis is the common foundation on which both aerobic and anaerobic respiration are built.

Language Clinic
The two pieces of evidence open alike: That it is found everywhere, and That it needs no oxygen. The matched openings let each fact lead straight on to what it shows, building the case point by point.

Question 109

A muscle cell short of oxygen falls back on a pathway that yields only two ATP from a glucose, against the thirty-eight it might gain with oxygen. Explain why this is still worth doing, and what the hidden cost is.

Model Answer

It is worth doing because a little energy at once is far better than none at all. When oxygen fails, the full aerobic pathway cannot run, and a cell that simply waited for oxygen would gain no ATP and soon die; by falling back on glycolysis alone the muscle still wins two ATP from each glucose and can keep working, at least for a while.

It is worth doing, too, because it regenerates the NAD that glycolysis must have if it is to continue. By passing its spare hydrogen on to pyruvic acid to make lactic acid, the cell frees its NAD to take up more hydrogen, so glycolysis and its small flow of ATP can carry on with no oxygen at all.

The hidden cost is twofold: the fuel is squandered and lactic acid builds up. Only a small part of the energy of the glucose is captured, the rest still locked in the lactic acid left behind, and that lactic acid gathers in the muscle, bringing the ache and fatigue that the body must later pay off as an oxygen debt.

Examiner's Note
The marks need anaerobic respiration justified as a little ATP being better than none and as regenerating NAD so glycolysis continues, with the hidden cost of squandered fuel (energy left in the lactic acid) and the lactic acid build-up, repaid later as an oxygen debt.

False Confidence Alert
Most students think a cell with no oxygen gets no energy at all. It still gains the net two ATP of glycolysis; what it loses is the great aerobic yield, and it pays for the shortfall in lactic acid.

Question 110

Respiration is often called the burning of food, yet no flame appears and the cell does not scorch. Explain how the cell releases the energy of glucose without the heat and light of a fire, and why this matters.

Model Answer

Burning and respiration bring about the very same overall change, turning glucose and oxygen into carbon dioxide and water, but they reach it by utterly different roads. A fire lets all the energy go at once, as heat and light; the cell instead breaks the glucose down in many small, enzyme-controlled steps, releasing the energy little by little.

Because the energy comes out in small amounts, the cell can capture much of it as ATP instead of losing it all as heat. At each step just enough energy is freed to make a molecule or two of ATP, so the energy is packed away in a form the cell can use; a single great release, as in a fire, could not be caught this way and would simply be lost.

This matters because a cell that let the energy of its fuel go all at once would cook itself. The sudden heat would destroy its enzymes and kill it; by letting the energy out gently, step by step, the cell holds itself at a safe, steady temperature and still saves much of the energy as ATP for its own work.

Examiner's Note
The marks need respiration and burning sharing the same overall change, but the cell using many small enzyme-controlled steps, so the energy is freed gradually and caught as ATP rather than lost as heat, keeping the cell from overheating.

Language Clinic
The contrast is carried by instead. The cell captures the energy as ATP instead of losing it as heat: the one word sets the living way of release against the way of a fire.

Question 111

A starving person, having used up the body's carbohydrate and then its fat, begins to waste away and to lose muscle. Explain this in terms of respiratory substrates, and why it is a sign of serious danger.

Model Answer

Once the carbohydrate and the fat are gone, the body has no choice but to turn to its protein for energy, and that protein is the very fabric of its tissues. Protein is the last substrate to be respired, spared as long as it can be because it builds the muscles and the enzymes; but when the other stores are spent there is nothing else left to burn, so the body starts to break down its own muscle for fuel.

So the person wastes away and loses muscle, because the body is now respiring the protein of its own flesh. The muscle proteins are broken down to amino acids, these are deaminated and their carbon skeletons fed into respiration, and as the muscle is consumed the limbs grow thin and weak.

This is a sign of serious danger because the body is now consuming the working parts it cannot do without. Once it is burning its own enzymes and muscle, in time even the muscle of the heart, the very machinery of life is being taken apart for fuel, and without food the wasting can end only one way.

Examiner's Note
The marks need the substrate order forcing the body to its protein once carbohydrate and fat are spent, the muscle protein broken to amino acids and deaminated for respiration so the body wastes, and the danger that it is now consuming its own essential tissues and enzymes.

False Confidence Alert
Most students think the wasting of starvation is just the loss of fat. By the time the muscle is going the fat is already gone, and the body has been driven to respire the protein of its own tissues, which is far more serious.

Question 112

A poison stops the very last carrier of the electron transport chain from passing its electrons to oxygen. Predict, with reasons, what would happen to the rest of respiration in that cell.

Model Answer

If the last carrier cannot pass its electrons to oxygen, the whole chain jams, for each carrier can pass its electrons on only when the one beyond it is free to take them. With oxygen no longer drawing the electrons off the end, they back up along the chain; every carrier stays loaded with electrons it cannot hand on, and the flow down the chain stops.

Because the jammed chain can no longer take their hydrogen, the NADH and $FADH_2$ cannot be unloaded, so they have no NAD or FAD to give back to the reactions that filled them. The link reaction and the Krebs cycle, robbed of the NAD and FAD they must have to keep turning, quickly grind to a halt; the mitochondrion, for all the oxygen around it, can make no more ATP.

All that is left to the cell is the small anaerobic yield of glycolysis, and that cannot keep it alive for long. A net two ATP from each glucose, with lactic acid piling up, is far too little for an active cell, so a poison that blocks the end of the chain is as deadly as cutting off the oxygen itself, and acts in just the same way.

Examiner's Note
The marks need the block backing up the whole chain (carriers stay reduced, no electrons reach oxygen), so NADH and $FADH_2$ cannot be reoxidised and the link reaction and Krebs cycle stall, leaving only the small anaerobic yield of glycolysis.

Question 113

Some of the ATP of respiration is made directly in glycolysis and the Krebs cycle, but far more is made on the electron transport chain. Compare these two ways of making ATP, and explain why the chain yields so much more.

Model Answer

ATP is made in respiration in two quite different ways, and they differ greatly in how much they yield. A little is made directly, by handing a phosphate straight from a substrate to ADP, as happens twice in glycolysis and once in each turn of the Krebs cycle; far more is made indirectly, on the electron transport chain, from the hydrogen the earlier stages collect.

The chain yields so much more because it does not draw its ATP from the fuel directly, but from the many hydrogen carriers the earlier stages have loaded. Every NADH and $FADH_2$ that glycolysis, the link reaction and the Krebs cycle send to the chain gives up its electrons down a long fall of energy, and that fall is tapped at several points to make ATP, so one glucose, which yields only four ATP directly, yields some thirty-four more along the chain.

The earlier stages matter most, then, not for the few ATP they make but for the loaded carriers they pass on. It is the chain, fed by those carriers and drained at its end by oxygen, that turns the greater part of the energy of glucose into ATP; the direct steps are only the small change of respiration, while the chain is where the real fortune is made.

Examiner's Note
The marks need the two routes named, substrate-level phosphorylation in glycolysis and Krebs giving a few ATP directly, and oxidative phosphorylation on the chain giving far more from the hydrogen carriers, with the chain yielding most because every NADH and $FADH_2$ is tapped for ATP.

Question 114

The cells of a hard-working tissue, such as heart muscle, are crowded with many large mitochondria, each with very many cristae. Explain this, reasoning from what the mitochondrion does and where.

Model Answer

A hard-working tissue needs a great deal of ATP without pause, and the mitochondrion is where the great bulk of a cell's ATP is made. It is in the mitochondrion that the link reaction, the Krebs cycle and, above all, the electron transport chain go on, so the more mitochondria a cell holds, the more ATP it can make at one time.

Each mitochondrion is packed with many cristae because the electron transport chain, which makes most of the ATP, is built into the inner membrane that the cristae fold up. The more the inner membrane is thrown into cristae, the greater the surface it offers and the more chains it can carry, so a mitochondrion rich in cristae is one that can make ATP fast.

So the crowd of large, many-folded mitochondria is simply the cell built to match its heavy and ceaseless need for energy. A heart that must beat without rest cannot afford to run short of ATP, and the answer is written into the very structure of its cells: many mitochondria, and within each all the membrane that can be folded in.

Examiner's Note
The marks need the tissue's high, ceaseless ATP demand met by many mitochondria (where the link reaction, Krebs and the chain run) and by many cristae (folding the inner membrane to carry more electron transport chains, so more ATP faster).

False Confidence Alert
Most students think more mitochondria simply store more energy. They do not store ATP, they make it; a busy cell needs many because ATP cannot be stockpiled and must be made as fast as it is spent.

Question 115

The Krebs cycle gives off carbon dioxide but takes in no oxygen at any of its steps, and yet it cannot keep running without oxygen. Resolve this apparent contradiction.

Model Answer

It is quite true that oxygen takes no direct part in the Krebs cycle, for nowhere in the round of reactions is oxygen itself used up. The whole business of the cycle is to strip carbon from its acids as carbon dioxide and to hand hydrogen to NAD and FAD; not one of those steps calls for oxygen.

Yet the cycle cannot keep turning unless its NAD and FAD are handed back to it, and they are set free only on the electron transport chain, which does need oxygen. Each turn loads NAD and FAD with hydrogen as NADH and $FADH_2$; these must be unloaded again on the chain before they can come back as empty NAD and FAD, and the chain can unload them only while oxygen waits at its end to take the spent electrons.

So the cycle needs oxygen not within itself but just beyond itself, to keep its carriers empty and ready. Take the oxygen away and the chain backs up, the NADH and $FADH_2$ stay loaded, no NAD or FAD returns, and the cycle, though it never once touched oxygen, is forced to stop; its dependence on oxygen is real, but it is indirect.

Examiner's Note
The marks need oxygen taking no direct part in the cycle, but the cycle depending on the chain to reoxidise its NADH and $FADH_2$ (returning NAD and FAD), and the chain needing oxygen as final acceptor, so without oxygen the carriers stay loaded and the cycle stops.

False Confidence Alert
Most students think the Krebs cycle uses oxygen directly to burn its acids. It uses none; its need for oxygen is indirect, through the chain that must reoxidise the carriers the cycle fills.

Question 116

Of all the energy held in a molecule of glucose, less than half is captured as ATP; the rest escapes as heat. Is respiration therefore wasteful? Weigh the question.

Model Answer

In one sense respiration is indeed wasteful, for much of the energy of the glucose never reaches ATP at all but leaves the cell as heat. At step after step a little energy slips away as heat rather than being caught, so the cell keeps only a part of what the glucose held, and by that measure the process falls well short of perfect.

Yet in a warm-blooded animal that escaping heat is far from wasted, for it is the very warmth that holds the body at its working temperature. A mammal or a bird uses the heat of its own respiration to keep itself warm, steady and active whatever the cold outside, so what looks like a loss to the single cell is a gain to the whole animal.

So whether respiration is wasteful depends on what one counts as waste. Judged only by the ATP it captures, it is far from complete; but judged by the whole animal, the heat that escapes does useful work of its own, and little is truly thrown away. A stepwise capture that also keeps the body warm is, on balance, no bad bargain.

Examiner's Note
The marks need both sides weighed: much of the glucose's energy is lost as heat rather than caught as ATP (wasteful by that measure), but in a warm-blooded animal that heat maintains body temperature, so it is not truly wasted; the verdict turns on the point of view.

Language Clinic
The answer turns on Yet. Much is lost as heat; Yet in a warm-blooded animal that heat is not wasted: the one word swings the argument from one side of the balance to the other.

Question 117

Yeast can live in a sugar solution whether or not air is present, but it grows and multiplies far faster when air is let in. Explain why.

Model Answer

Yeast is a facultative anaerobe, able to respire with oxygen when it is there and to ferment without it when it is not. So it gets along in the sugar solution either way: in air it breaks the sugar right down by aerobic respiration, and without air it falls back on alcoholic fermentation, making do on far less.

It grows and multiplies much faster in air because aerobic respiration draws far more energy from the same sugar than fermentation ever can. With oxygen each glucose is oxidised completely and gives about thirty-eight ATP, against the mere two of fermentation, so in air the yeast wins many times the energy and can build and divide all the faster.

In air, too, the yeast wastes far less of its sugar, for none of the energy is left locked away. In fermentation most of the energy of the glucose is left behind in the ethanol that is poured out, whereas in air that energy is captured as well, so the yeast needs far less sugar for the same growth; small wonder it thrives once air is let in.

Examiner's Note
The marks need yeast as a facultative anaerobe (respiring aerobically in air, fermenting without it), growing faster in air because aerobic respiration gives about thirty-eight ATP from a glucose against the two of fermentation, so far more energy for growth.

Language Clinic
The contrast is drawn by whereas. In fermentation the energy is left in the ethanol, whereas in air it is captured: the word sets the wasteful path against the thrifty one in a single line.

Question 118

A sprinter and a marathon runner draw on respiration in very different ways: the one leans on anaerobic respiration, the other burns mostly fat with plenty of oxygen. Explain why each way suits its event.

Model Answer

The sprinter needs a sudden, enormous burst of energy for a few seconds, faster than the blood could ever bring oxygen, so the muscles turn to anaerobic respiration. Anaerobic glycolysis needs no oxygen and can release its small store of energy at once, which is just what a short, explosive effort calls for; the price, the lactic acid and the tiny yield, scarcely matters over so brief a race.

The marathon runner works for hours at a steady pace that the oxygen supply can keep up with, so the muscles respire aerobically, and mostly on fat. At this gentler pace oxygen arrives fast enough to burn the fuel completely, and fat, though slow to call upon, holds far more energy than carbohydrate and lies ready in plenty, so it can power the long haul without draining the body's small sugar store too soon.

So each runner uses the pathway that fits the demand: quick but brief for the sprint, slow but lasting for the marathon. The sprinter trades thrift for speed, spending fuel wastefully to gain energy in an instant; the marathon runner trades speed for endurance, burning fat slowly and fully to keep going for hours. The event decides the pathway.

Examiner's Note
The marks need the sprinter using anaerobic respiration because the effort outruns the oxygen supply (quick energy, brief, lactic acid), and the marathon runner respiring aerobically and mostly on fat because the steady pace lets oxygen keep up and fat gives lasting energy.

False Confidence Alert
Most students think the marathon runner relies on sugar like the sprinter. The body's sugar would soon run out; the long race is fuelled mainly by fat, which is far more plentiful and far richer in energy.

Question 119

A germinating seed is found to have a respiratory quotient of about 1.0 at first, which then falls towards 0.7 as the days pass. Use the RQ to work out what is happening to the substrate the seed is respiring.

Model Answer

An RQ of about 1.0 at the start tells us the seed is respiring mainly carbohydrate. A quotient of one means the seed gives out as much carbon dioxide as the oxygen it takes in, and that is the mark of carbohydrate; so at first the seed is living on its store of sugar and starch.

As the RQ falls towards 0.7, it tells us the seed has turned to respiring mainly fat. A quotient near seven-tenths is the mark of fat, which gives out much less carbon dioxide than the oxygen it uses; so as the days pass the seed is moving from carbohydrate to its richer store of oil.

So the changing RQ traces the seed using up one store and turning to another. Many seeds keep a small, quickly-spent store of carbohydrate and a large store of oil; the seed burns the easy sugar first, giving an RQ near one, then draws on the oil as the sugar runs low, and the quotient drifts down towards the value for fat. The number is a window on what the seed is burning.

Examiner's Note
The marks need the RQ read as the substrate: about 1.0 = carbohydrate respired first, falling towards 0.7 = a turn to fat, so the changing value shows the seed spending its quick sugar store and then drawing on its richer oil store.

False Confidence Alert
Most students read the falling RQ as the seed running short of food or of air. It means only that the fuel has changed, from carbohydrate to fat; the RQ reports which store is being burned, not how much is left or how much oxygen there is.

Question 120

Trace the journey of a single molecule of oxygen from the air outside to the place where it finally does its work, say what that work is, and explain why, without that last step, nothing else in respiration could go on.

Model Answer

A molecule of oxygen begins its journey in the air drawn into the lungs, and crosses into the blood at the alveolus. Breathed into the millions of alveoli, it dissolves in their moist lining, diffuses across the thin wall into the blood, and is taken up there by the haemoglobin of a red cell, which carries it round the body to a tissue where oxygen is scarce.

Unloaded where it is needed, the oxygen diffuses into a cell and at last into a mitochondrion, where it does its one great work: it waits at the end of the electron transport chain as the final acceptor of the electrons. There it takes up the spent electrons and, joining with hydrogen, is made into water; this is the single step for which the whole long journey was made.

Without that last step nothing else in respiration could go on, for it is oxygen that keeps the whole chain, and all that feeds it, in motion. If no oxygen waited at the end, the electrons could not be passed on, the carriers could not be emptied, and the Krebs cycle and the link reaction that fill them would halt for want of NAD and FAD; the breathing, the blood and the carrying all exist to bring oxygen to this one place, so that the cell may win the great harvest of ATP that only the complete, oxygen-fed pathway can give.

Examiner's Note
The marks need the oxygen's path (alveolus, dissolves, diffuses into the blood, carried by haemoglobin, unloaded at the tissue, into the cell and mitochondrion), its work as the final electron acceptor forming water, and the point that without it the chain backs up and the whole of aerobic respiration stops.

Chapter 8

REGULATION (HOMEOSTASIS)

BINDER QUESTIONS

Work through each question in order: attempt it on paper, then check the model answer beneath. The bold opening of every answer is the mark-bearing point; the notes in the boxes show how the marks are won and lost.

Question 1

Every cell of a mammal is bathed in tissue fluid whose temperature, acidity and glucose level scarcely change, even as the animal passes from the cold of the night to the heat of noon. Explain what is meant by homeostasis, and why an animal must hold its internal environment steady.

Model Answer

Homeostasis is the maintenance of a constant internal environment in the body in spite of changes in the external surroundings. The internal environment is the tissue fluid that bathes the cells, and its temperature, pH, water and solute levels are each held close to a fixed set point.

A steady internal environment keeps the conditions that the cells and their enzymes need in order to work. Because enzymes act only within a narrow range of temperature and pH, holding these conditions steady allows the body to stay active across many habitats, from the chill of the night to the heat of the day.

Examiner's Note
The mark is the idea of a constant internal environment held in spite of external change, joined to the reason: the enzymes of the cells work only within narrow limits of temperature and pH.

Language Clinic
Two connectors carry the sense. The phrase 'in spite of' sets the steady inside against the changing outside, and 'because' ties that steadiness to the needs of the enzymes.

Question 2

A dog fed richly on meat and sugar and a starving dog were found to have almost the same concentration of glucose in their blood. From observations like this the physiologist Claude Bernard reached a famous conclusion. Explain what he concluded, and how the steady blood glucose led him to it.

Model Answer

Claude Bernard concluded that a mammal keeps its own internal environment constant by an inner control of its own, independent of the world outside. The blood glucose stayed almost the same whether the dog was fed or starved, so its level could not be set simply by the food in the diet.

He reasoned that some mechanism inside the body must add glucose to the blood, or remove it, so as to hold the level steady. This constancy, he said, frees the animal from its surroundings and lets it live and stay active in a wide range of conditions.

Examiner's Note
Credit rests on the conclusion (an internal mechanism holds the internal environment constant) supported by the evidence (the fed dog and the starving dog share the same blood glucose).

False Confidence Alert
Most students say the diet sets the level of glucose in the blood. Yet the fed dog and the starving dog have the same level, which shows that the body, not the food, holds it steady.

Question 3

A good control system does not wait for a change to grow large; it senses a small drift from the norm and corrects it at once. Describe how a homeostatic control mechanism holds a variable steady through its set point, detector, regulator and effector.

Model Answer

A homeostatic mechanism works by comparing the actual value of a variable with a fixed set point, the norm at which the body is to be held. A detector, or receptor, senses any drift away from this set point and signals it to a regulator, the control centre that judges the size and the direction of the change.

The regulator then directs an effector to act in the way that reverses the change. The effector raises the value when it has fallen and lowers it when it has risen, so the variable is driven back to the set point and the correction stops.

Examiner's Note
The four parts must each appear with its job: the set point (the norm), the detector (senses the drift), the regulator (compares and decides), and the effector (reverses the change).

Language Clinic
The sequence words 'then' and 'so' carry the reader through the loop in order, from the sensing of the change to the correction that answers it.

Question 4

Although the body temperature or the blood glucose of a mammal is loosely called constant, the true value rises and falls a little all the while about its norm. Explain why homeostasis is better described as a dynamic equilibrium than as a fixed, unchanging state.

Model Answer

Homeostasis is a dynamic equilibrium because the controlled value is never perfectly still but drifts a little above and below the set point and is corrected again and again. The system makes small, continual adjustments rather than fixing the value rigidly at a single number.

It is therefore better called a steady state than a constant one. The variable is held within a narrow range around the norm, and the unceasing to-and-fro of correction is exactly what keeps it there.

Examiner's Note
The mark is that the value is held within a narrow range by continual correction, not pinned exactly in place; the term dynamic equilibrium, or steady state, carries it.

False Confidence Alert
Most students picture the value fixed exactly on the set point. In fact it swings a little to either side and is corrected each time, which is why homeostasis is a steady state and not a still one.

Question 5

The flow of control in every homeostatic system runs the same way, from the change that disturbs it to the response that puts it right. Draw a block diagram of the components of a homeostatic control mechanism, and state what each component does.

Model Answer

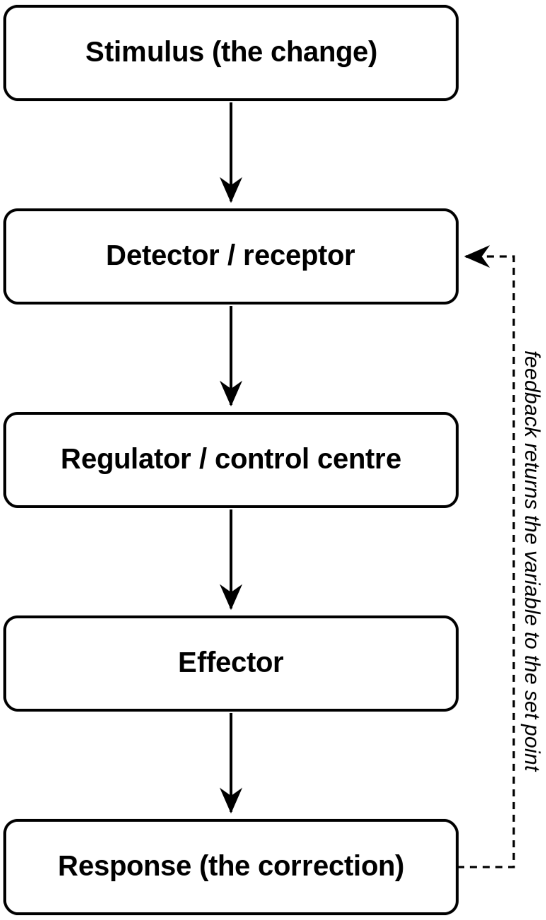


Figure 8.1: *the components of a homeostatic control mechanism*

The components are linked in the order shown, each passing its signal on to the next:

1) **Stimulus**: the change in the variable that disturbs the set point.

2) **Detector (receptor)**: senses the change and signals it to the control centre.

3) **Regulator (control centre)**: compares the value with the set point and decides on the response.

4) **Effector**: carries out the response that opposes the change.

5) **Response**: the corrective action that returns the variable to the set point.

Examiner's Note
A drawing earns its marks for the five blocks set in the right order and joined by arrows that show the one-way flow from stimulus to response, with a feedback arrow returning to the detector.

Question 6

Some homeostatic controls are run by an organ acting upon itself; others are directed from outside it by the nervous system or by hormones. Distinguish between intrinsic and extrinsic control in homeostasis.

Model Answer

Intrinsic control arises within the organ or tissue itself, which adjusts its own activity without any instruction from elsewhere. A working muscle, for instance, can widen its own blood vessels as its wastes build up.

Extrinsic control arises from outside the organ, the nervous system or the hormones of the body directing it from a distance. The signal therefore reaches the organ from beyond it in extrinsic control, whereas in intrinsic control the signal comes from within the organ itself.

Examiner's Note
The distinguishing point is the source of the signal: from within the organ in intrinsic control, from outside it, by nerves or hormones, in extrinsic control.

False Confidence Alert
Most students count a hormone as an intrinsic control because it comes from the body. Yet a hormone travels to the organ from a gland elsewhere, so its control is extrinsic, not intrinsic.

Question 7

The commonest control in the body answers a change by setting in motion the very events that cancel it out. Explain what negative feedback is, and how it returns a variable that has strayed back to its set point.

Model Answer

Negative feedback is a control in which a change in a variable triggers a response that opposes the change and restores the original state. The further the variable strays from the set point, the stronger the correcting response becomes.

When the variable rises above the set point the effectors act to bring it down, and when it falls below they act to raise it. Because the response always opposes the change that caused it, the variable is driven back towards the set point and there held steady.

Examiner's Note
The defining mark is that the response opposes the change and so returns the variable to the set point; an effector that reverses a rise and one that reverses a fall both earn credit.

Question 8

When a plate of *ugali* raises the glucose in the blood, the level is brought down again within the hour; when glucose runs low between meals, it is restored. Using blood glucose as your example, draw and explain how negative feedback holds the level steady.

Model Answer

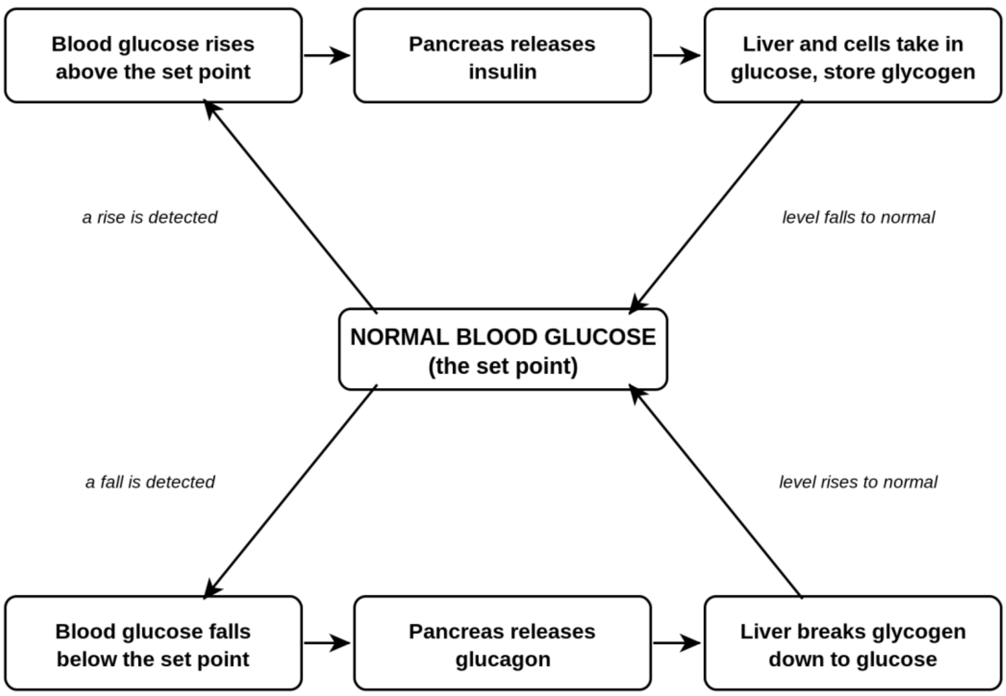


Figure 8.2: *negative feedback control of blood glucose by insulin and glucagon*

When blood glucose rises after a meal, the pancreas releases the hormone insulin, which makes the liver and the body cells take up glucose and store it as glycogen. The level therefore falls back towards the set point.

When blood glucose falls between meals, the pancreas releases glucagon, which makes the liver break glycogen down to glucose and release it into the blood. The level therefore rises again, and because each correction opposes the change, the loop is a negative feedback.

Examiner's Note
Both arms must be shown: insulin lowering a high level by storing glucose as glycogen, and glucagon raising a low level by breaking glycogen down, each returning the level to the set point.

False Confidence Alert
Most students name only insulin and the lowering of a high glucose. Yet without glucagon to raise a low level, the loop is only half a control; both hormones are needed to hold the level steady.

Question 9

A few processes in the body do the opposite of correcting a change: they build it up until the process is finished. Explain what positive feedback is, and why it is rare in the body.

Model Answer

Positive feedback is a control in which a change in a variable triggers a response that increases the change, driving the variable further from the set point instead of back to it. Each step makes the next step larger.

Because it amplifies a change rather than correcting it, positive feedback makes a system unstable. It is therefore used only in the few events that must be carried quickly through to completion, while almost all of the body's control is negative.

Examiner's Note
The mark is that the response increases the change and drives the variable away from the set point, and that this instability is the reason positive feedback is rare.

False Confidence Alert
Most students believe positive feedback never happens in a healthy body, or that it is always harmful. In fact it is a normal control used in a few events, such as the contractions of birth, that must run quickly to completion.

Question 10

During birth the contractions of the womb do not die away; each one makes the next one stronger until the baby is delivered. Explain how childbirth shows positive feedback.

Model Answer

In labour the hormone oxytocin makes the muscle of the uterus contract, and each contraction stimulates the release of still more oxytocin. The extra oxytocin then drives a contraction stronger than the one before.

Each contraction therefore builds a stronger one, and the cycle grows until the baby is born and the stimulus is removed. Because each change increases the next instead of opposing it, the control is a positive feedback.

Examiner's Note
Credit needs the self-building loop: oxytocin causes a contraction, the contraction causes more oxytocin, and the cycle ends only when the baby is delivered.

Question 11

A single ripe mango placed in a basket hastens the ripening of all the others around it. Explain how the ripening of fruit shows positive feedback.

Model Answer

A ripening fruit gives off the gas ethylene, and ethylene makes the unripe fruit around it ripen faster. Ripening is the softening and the change of colour and taste that ethylene brings on.

As more fruit ripens, more ethylene is released, which ripens still more fruit, so the change spreads and speeds up through the basket. Because each ripening fruit hastens the next instead of slowing it, this too is a positive feedback.

Examiner's Note
The mark is the self-spreading loop: ethylene from a ripe fruit ripens its neighbours, which then release more ethylene, so the ripening accelerates.

Question 12

Both kinds of feedback begin with a change in a variable, yet they finish in opposite places. Distinguish between negative and positive feedback, and say which of the two keeps the internal environment steady.

Model Answer

Negative feedback opposes a change and returns the variable to its set point, so it is the kind that keeps the internal environment steady. Almost all homeostatic control, from body temperature to blood glucose, works by negative feedback.

Positive feedback increases a change and drives the variable further from the set point, whereas negative feedback reverses it. Positive feedback does not maintain stability and serves only to push a process such as birth quickly to its end.

Examiner's Note
The distinguishing point is the direction of the response: negative feedback opposes the change and so holds homeostasis, while positive feedback amplifies it and does not.

False Confidence Alert
Most students read 'positive' as good and 'negative' as bad. In fact the words describe only the direction of the response: negative feedback opposes a change, positive feedback amplifies it.

Question 13

Most living things can stay active only within a narrow band of temperature, for their enzymes work fast enough only there. Explain what is meant by temperature regulation, and why an animal needs it.

Model Answer

Temperature regulation, or thermoregulation, is the keeping of the body temperature within a narrow range in spite of the changing temperature of the surroundings. The body does this by balancing the heat it gains against the heat it loses.

An animal needs this control because its enzymes work properly only within a narrow range of temperature. If the body grows too cold the reactions of life slow down, and if it grows too hot the enzymes are destroyed, so a steady temperature keeps the animal active and alive.

Examiner's Note
The mark is the balancing of heat gained against heat lost to hold the temperature steady, joined to the reason: the enzymes work only within narrow limits of temperature.

Language Clinic
The connector 'because' ties the need for control to the enzymes, and 'so' draws the conclusion that a steady temperature keeps the animal active.

Question 14

A lizard basking on a rock takes its warmth from the sun, while a goat in the same field makes its own from within. Distinguish between an ectotherm (poikilotherm) and an endotherm (homeotherm).

Model Answer

An ectotherm, or poikilotherm, takes most of its body heat from outside itself, so its body temperature rises and falls with the temperature of its surroundings. Reptiles, amphibians and most fish are ectotherms.

An endotherm, or homeotherm, makes its body heat within itself by its own metabolism and holds its temperature steady, whereas the ectotherm cannot. Birds and mammals are endotherms.

Examiner's Note
The distinguishing point is the source of the heat and the constancy: from outside and varying for the ectotherm, from within and steady for the endotherm.

False Confidence Alert
Most students think a 'cold-blooded' ectotherm always has cold blood. In fact a lizard basking in the sun may be hotter than a mammal; its temperature simply follows the surroundings instead of being held steady.

Question 15

An endotherm spends much of its food simply keeping warm, yet the strategy has spread to all the birds and mammals. Explain the advantage an animal gains from holding its body temperature constant.

Model Answer

A constant body temperature lets an endotherm stay active whatever the temperature around it. Because its enzymes are always kept near their best working temperature, the animal can hunt, escape and feed in the cold of the night or the heat of the day, when an ectotherm would be too sluggish to move.

It can therefore live and stay active in habitats that an ectotherm cannot, from cold mountains to cold nights. The cost is a large appetite, since the heat must be made from food, but the freedom from the surroundings is the gain.

Examiner's Note
The mark is that a steady temperature keeps the enzymes near their optimum, so the animal stays active across a wide range of surroundings and habitats.

Question 16

A bird in flight runs hotter than a resting mammal, and both are warmer than the air around them. Explain where an endotherm's body heat comes from, and how its body temperature is linked to its rate of metabolism.

Model Answer

An endotherm's body heat is made within it by its own metabolism, the heat released by the chemical reactions of respiration in its cells. Its body temperature is held between about 37°C and 44°C, well above that of the surroundings.

The faster the metabolism, the more heat is made and the higher the body temperature. A bird keeps a high metabolic rate to power flight, so its temperature, around 40°C, runs higher than that of most mammals.

Examiner's Note
Credit needs heat made within the body by metabolism (respiration), and the link that a higher metabolic rate yields more heat and a higher body temperature, as in the flying bird.

False Confidence Alert
Most students think a 'warm-blooded' animal sits at one fixed temperature. In fact endotherm temperatures range from about 37°C to 44°C, the bird running hotter than the mammal.

Question 17

The body's thermostat sits in the brain, in a region that watches the temperature of the blood flowing through it. Draw a diagram to show how the hypothalamus regulates body temperature by negative feedback, and name the two centres it contains.

Model Answer

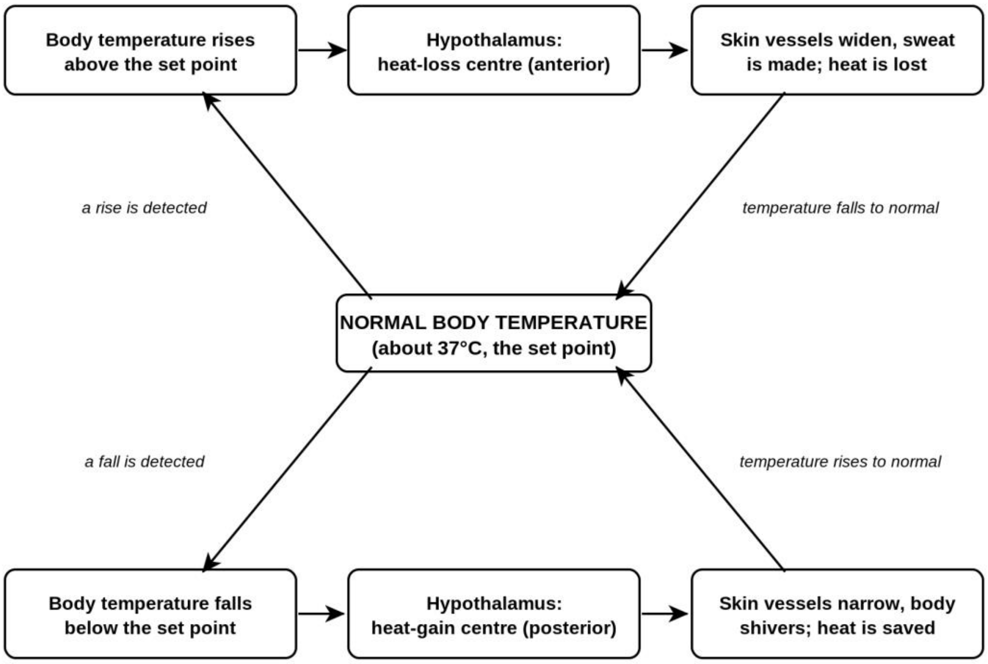


Figure 8.3: *negative feedback control of body temperature by the hypothalamus*

The hypothalamus is the control centre that holds the body temperature at its set point of about 37°C by negative feedback. It contains two centres: a heat-loss centre in the anterior part, roused when the blood grows too warm, and a heat-gain centre in the posterior part, roused when the blood grows too cold.

When the blood is too warm the heat-loss centre sets the effectors to lose heat, and when it is too cold the heat-gain centre sets them to save and make heat. Either way the temperature is brought back to the set point.

Examiner's Note
A drawing earns marks for the set point, the two named centres (heat-loss in the anterior, heat-gain in the posterior), the effectors, and arrows returning the temperature to normal.

False Confidence Alert
Most students put the heat-loss centre in the posterior hypothalamus. In fact the anterior hypothalamus holds the heat-loss centre, roused by a rise in blood temperature; the posterior holds the heat-gain centre.

Question 18

Some of the body's answers to heat and cold are automatic, while others, like moving into the shade or putting on a coat, are chosen. Explain how the control of skin temperature differs from the control of the deep core temperature.

Model Answer

The deep core temperature is held by an involuntary control: the hypothalamus reads the temperature of the blood and drives the automatic responses of the body, such as sweating and shivering. These happen without any decision being made.

The skin temperature is judged by the cortex of the brain from the skin's thermoreceptors and is answered by voluntary, behavioural action, whereas the core is answered automatically. Feeling too hot or too cold, a person chooses to move into the shade, add clothing or take other deliberate steps.

Examiner's Note
The distinguishing point is involuntary, hypothalamic control of the core (sweating and shivering) against voluntary, cortical, behavioural control of the skin (moving, clothing).

Language Clinic
The connector 'whereas' balances the two controls, setting the chosen, behavioural answer of the skin against the automatic answer of the core.

Question 19

On a hot day the skin of a light-skinned person flushes red, for more blood is being sent close to its surface. Explain how vasodilation of the skin helps an overheated mammal to lose heat.

Model Answer

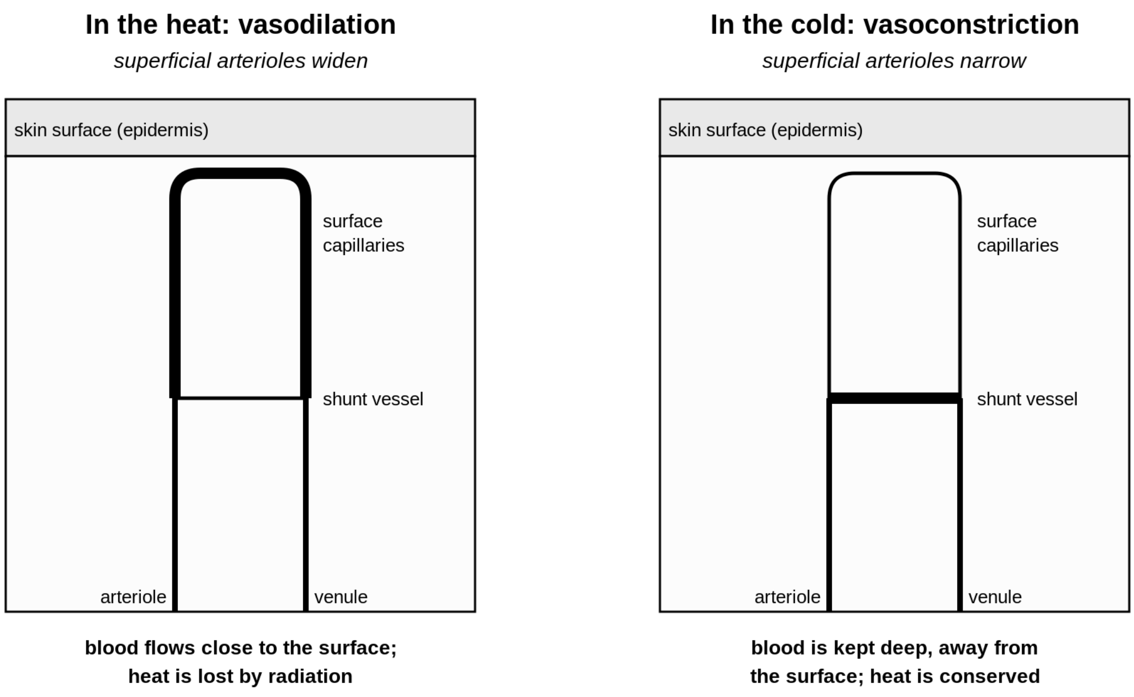


Figure 8.4: *the skin blood vessels in vasodilation and in vasoconstriction*

In vasodilation the small arterioles that supply the skin widen, so that more warm blood flows through the capillaries close to the surface. The blood is brought near the epidermis instead of being held deep in the body.

Heat then passes from this surface blood to the air by radiation, convection and conduction, and the body cools. The reddened, warm skin of a hot person is the blood that has been brought to the surface to give up its heat.

Examiner's Note
The mark is the widening of the skin arterioles bringing more blood to the surface, where heat is lost by radiation, convection and conduction.

False Confidence Alert
Most students say the blood vessels themselves move to the surface. They do not move; the superficial arterioles simply widen so that more blood flows through the vessels already lying near the surface.

Language Clinic
The connector 'so that' ties the widening of the arterioles to the blood reaching the surface, and 'then' carries the reader on to the heat being lost.

Question 20

A person working hard in the sun is soon wet with sweat, and feels cooler as it dries. Explain how sweating cools the body, and why a dog or a sheep cannot cool itself this way as well as a person can.

Model Answer

Sweat glands in the skin pour a watery sweat onto the surface, and as this water evaporates it takes its latent heat from the body, so the body is cooled. A person can lose about a litre of sweat in an hour on a hot day.

An animal covered in fur or feathers cannot cool by sweating as well as a bare-skinned person, because the coat traps the moisture and slows its evaporation. A dog has only a few sweat glands, in the pads of its feet, and a bird has none, so they must lose heat in other ways.

Examiner's Note
Credit needs the evaporation of sweat taking latent heat from the body, and the point that fur or feathers slow this evaporation, so furred and feathered animals sweat little.

Language Clinic
The connector 'as' marks the cooling happening while the sweat evaporates, and 'because' explains why a furred animal cannot cool this way.

Question 21

A dog that cannot sweat through its skin hangs out its tongue and breathes fast in the heat. Explain how panting and licking cool an animal that has few sweat glands.

Model Answer

In panting an animal breathes rapidly over the wet surfaces of its mouth, tongue and lungs, so that water evaporates from them and carries heat away. The dog hangs out its tongue to widen the moist surface from which the water can evaporate.

In licking an animal spreads saliva over its body, and the evaporation of this saliva cools the skin just as sweat would. A cat licking its paws and a rat licking itself are losing heat in the same way.

Examiner's Note
The mark is evaporative cooling from a moist surface: the breath over the mouth and tongue in panting, and the saliva on the body in licking.

Language Clinic
The connector 'so that' links the fast breathing to the evaporation, and 'just as' likens the cooling by saliva to the cooling by sweat.

Question 22

A desert fox has huge ears, while an arctic fox has small ones; and a mouse must eat far more for its size than an elephant. Explain how the body extremities and the surface-area-to-volume ratio affect the loss of heat.

Model Answer

Large, thin extremities such as the big ears of a desert fox carry many blood vessels close to the surface and so act as radiators that lose heat. An animal of a cold climate has small extremities instead, so as to keep its heat in.

A small animal has a large surface area for its volume, so it loses heat faster than a large animal and must feed more often to replace it. This is why a mouse eats far more for its size than an elephant, and why it often takes an energy-rich diet.

Examiner's Note
Two marks: large extremities act as heat radiators in a hot climate, and a large surface-area-to-volume ratio makes a small animal lose heat fast, so it must feed more.

Question 23

A desert rat is rarely seen by day; it comes out to feed only after the sun has set. Explain the behavioural ways by which a desert mammal keeps itself from overheating.

Model Answer

A desert mammal escapes the heat of the day chiefly by its behaviour, in the following ways:

1) **Being nocturnal**: it rests through the heat of the day and comes out to feed at night, when the air is far cooler.

2) **Burrowing**: it shelters in a burrow under the ground, where the soil stays cool and shaded.

3) **Seeking shade**: it keeps to the shade of rocks and plants, out of the direct sun.

4) **Aestivating**: in the hottest, driest season it may pass into a deep summer dormancy until the heat is over.

Examiner's Note
Credit needs behavioural means, not bodily ones: the nocturnal habit, burrowing, keeping to the shade, and aestivation in the worst of the heat.

False Confidence Alert
Most students call this summer dormancy 'hibernation'. Hibernation is the winter sleep that escapes the cold; the summer sleep that escapes the heat and drought is aestivation.

Question 24

On a cold morning the skin turns pale and feels cold to the touch, for the blood has been drawn away from it. Explain how vasoconstriction of the skin helps a mammal to keep warm in the cold.

Model Answer

In vasoconstriction the small arterioles that supply the skin narrow, so that less blood flows through the capillaries near the surface. Most of the blood is sent instead through deeper vessels, beneath the insulating layer of subcutaneous fat.

Because little warm blood now reaches the surface, little heat is carried there to be lost, and the body's heat is kept in. The pale, cold skin of a person in the cold is the skin from which the warm blood has been withdrawn.

Examiner's Note
The mark is the narrowing of the skin arterioles holding blood away from the surface, so that less heat is carried there and lost.

False Confidence Alert
Most students say vasoconstriction warms the skin. It does the opposite: it leaves the skin cold by keeping the warm blood deep, in order to save the heat of the body's core.

Question 25

A person who steps out into the cold soon begins to shiver, the muscles trembling without being told to. Explain how shivering helps to warm the body.

Model Answer

In shivering the skeletal muscles of the body contract and relax rapidly in small, involuntary movements. These contractions are not the work of moving a limb, and they happen without any decision.

The energy of these contractions is released as heat, which warms the body. Shivering is the body's way of making extra heat quickly when the surroundings turn cold.

Examiner's Note
Credit needs the rapid, involuntary contraction of the skeletal muscles releasing its energy as heat, which warms the body.

Question 26

A seal in the icy sea is wrapped in a thick layer of fat, and a cat in the cold fluffs up its fur. Explain how insulation reduces the heat a mammal loses in the cold.

Model Answer

Insulation is a layer that slows the escape of heat from the body: a coat of fur or feathers on the outside, or a layer of fat called blubber beneath the skin. A thick coat, or a thick layer of blubber, keeps the body's heat from passing out into the cold around it.

The fur traps a layer of still air, which is a poor conductor of heat, and the hair-erector muscles can raise the fur to trap a thicker layer when it is cold. A seal's blubber and an arctic animal's deep fur are both insulation against the cold.

Examiner's Note
The mark is a layer (fur, feathers or fat as blubber) that slows the loss of heat, with the trapped still air and the raising of the fur as the means.

False Confidence Alert
Most students think the fur itself keeps the animal warm. It is the still air trapped within the fur, a poor conductor of heat, that does the insulating; the raised fur simply traps a thicker layer of that air.

Question 27

An animal kept in the cold eats more than the same animal kept warm, even when it does no more work. Explain how raising the rate of metabolism helps a mammal to keep warm, and why it must then eat more.

Model Answer

In the cold the liver and other organs raise their rate of metabolism, and the hormones of the thyroid, adrenal and pituitary glands drive the cells to respire faster. This faster respiration releases more heat within the body, which helps to keep it warm.

Because this extra heat is made from the respiration of food, the animal must eat more to supply the fuel. This is why an animal in a cold climate feeds on a larger amount of food than one kept in the warmth.

Examiner's Note
Two marks: a raised metabolic rate, driven by the liver and the thyroid, adrenal and pituitary hormones, makes more heat, and the food eaten must rise to fuel it.

Language Clinic
The connector 'because' ties the extra eating to the heat made from food, and 'this is why' draws the everyday conclusion that a cold-climate animal eats more.

Question 28

A lizard cannot make enough heat of its own, yet on a cool morning it is often seen stretched out on a sunny rock. Explain how an ectotherm regulates its body temperature, and why it must rely on its behaviour to do so.

Model Answer

An ectotherm cannot raise its own heat production enough to hold a steady temperature, so it must take its warmth from outside and control its temperature mainly by its behaviour. It has no internal thermostat, as a mammal has, to make and hold its own heat.

It basks in the sun to warm up, spreading its body to catch the rays, and it moves into the shade or a burrow to cool down. In cold spells some ectotherms huddle or cluster together to share warmth, and some pass the worst of the heat or cold in aestivation or dormancy.

Examiner's Note
Credit needs the point that an ectotherm depends on outside heat and controls its temperature by behaviour, with examples such as basking, seeking shade, burrowing and huddling.

Language Clinic
The connector 'so' carries the reasoning from the ectotherm's weak heat production to its need to regulate by behaviour.

Question 29

The chemical reactions that keep a cell alive leave behind wastes that would poison it if they were left to pile up. Explain what is meant by excretion, and why it is necessary for life.

Model Answer

Excretion is the removal from the body of the toxic waste products of metabolism, the substances made by the chemical reactions within the cells. Wastes such as carbon dioxide and the nitrogen left over from protein would harm the body if they were allowed to build up.

Excretion is necessary because these wastes are poisonous and would halt the enzymes and the reactions of life if they gathered. In removing them the body also keeps the water and the pH of its fluids steady, so excretion is a part of homeostasis.

Examiner's Note
The mark is the removal of the TOXIC products of metabolism, joined to the reason they must go: they would poison the enzymes, and their removal also holds water and pH steady.

False Confidence Alert
Most students confuse excretion with egestion. Excretion removes the wastes the body's own reactions have made; egestion passes out the undigested food that never entered the cells.

Question 30

Different wastes leave a mammal's body, and each is the leftover of a particular process going on inside it. State the major excretory products of a mammal, and say where each one comes from.

Model Answer

The major excretory products of a mammal, with their sources, are:

1) **Carbon dioxide**: from the respiration of glucose and other fuels in every living cell.

2) **Urea and other nitrogenous waste**: from the breakdown of surplus amino acids and of nucleic acids.

3) **Bile pigments**: from the breakdown of the haemoglobin of worn-out red blood cells in the liver.

4) **Excess water and salts**: from the diet and from metabolism, removed to keep the body fluids balanced.

Examiner's Note
Credit needs each product paired with its source: carbon dioxide from respiration, urea from amino-acid breakdown, bile pigments from worn-out red cells, and excess water and salts.

Question 31

A mammal does not leave all its excretion to one organ; several share the task, each clearing a different waste. State the main excretory organs of a mammal, and the waste that each removes.

Model Answer

The excretory work of a mammal is shared among several organs:

1) **The kidneys**: remove urea, excess water and excess salts as urine.

2) **The lungs**: remove carbon dioxide and some water vapour in the breath.

3) **The skin**: removes water, salts and a little urea in the sweat.

4) **The liver**: makes urea from surplus amino acids and breaks worn-out red cells down to bile pigments.

Examiner's Note
The mark is each organ tied to its waste: the kidneys (urea, water, salts), the lungs (carbon dioxide), the skin (sweat), and the liver (making urea and bile pigments).

False Confidence Alert
Most students name only the kidney as an excretory organ. The lungs (carbon dioxide), the skin (sweat) and the liver (bile pigments) are excretory organs too.

Question 32

The body can store spare sugar as glycogen and spare energy as fat, but it cannot store spare protein. Explain how the body deals with surplus amino acids, and why this leaves a nitrogenous waste.

Model Answer

Surplus amino acids cannot be stored, so they are broken down in the liver by a process called deamination. In deamination the amino group is removed from each amino acid, leaving a part that can be respired for energy or turned into sugar or fat.

The amino group that is removed is turned into ammonia, a nitrogen-containing waste that is poisonous and must be excreted. Because the nitrogen of protein cannot be kept, every surplus amino acid leaves this nitrogenous waste behind.

Examiner's Note
The mark is deamination, the removal of the amino group in the liver leaving ammonia, while the rest of the molecule is respired for energy or turned to fat or sugar.

Question 33

A freshwater fish lets its nitrogen waste leave as ammonia, the most poisonous of the three forms, and is none the worse for it. Explain why an aquatic animal can afford to excrete ammonia.

Model Answer

Ammonia is the most toxic of the nitrogenous wastes and is very soluble, so it must be flushed away at once with a great deal of water. An animal that excretes ammonia is said to be ammonotelic.

An aquatic animal such as a bony fish can afford this because it is surrounded by water, which carries the ammonia away across its gills as fast as it is made. Living in water, it never has to save water, so the heavy water cost of ammonia does not trouble it.

Examiner's Note
The mark is that ammonia is very toxic and very soluble and so needs much water, which an aquatic, ammonotelic animal has in plenty and loses freely across its gills.

Question 34

A mammal lives on land and cannot spare water to flush away ammonia, yet it still makes plenty of nitrogen waste. Explain why a mammal excretes urea rather than ammonia.

Model Answer

A land mammal turns its ammonia into urea, which is far less toxic and less soluble, so it can be carried safely in the blood and excreted in only a moderate amount of water. An animal that excretes urea is said to be ureotelic.

Since urea is less poisonous, the body can let it build up a little and pass it out in a concentrated urine, which saves water. This water-saving is a great advantage for an animal that must find its water on land; sharks and adult amphibians are ureotelic too.

Examiner's Note
The mark is that urea is less toxic and less soluble than ammonia, so it can leave in a concentrated, water-saving urine, which suits a land mammal (ureotelic).

Question 35

A bird in the desert and an insect on a dry leaf save water at every turn, and they pay almost nothing in water to be rid of their nitrogen. Explain why insects, reptiles and birds excrete uric acid.

Model Answer

Uric acid is non-toxic and almost insoluble in water, so it can be excreted as a dry paste or as white crystals with hardly any water at all. An animal that excretes uric acid is said to be uricotelic.

This is the most water-saving of the three wastes, which suits the insects, reptiles and birds that must hold on to every drop. Because uric acid is harmless and nearly solid, it can even be stored safely inside a shelled egg, where waste cannot be flushed away.

Examiner's Note
The mark is that uric acid is non-toxic and insoluble and so needs least water, excreted as a paste; this suits the water-saving insects, reptiles and birds (uricotelic).

False Confidence Alert
Most students think a bird passes a white paste because it cannot make proper urine. In fact the bird makes uric acid on purpose, to save water; the white paste is its nitrogen waste.

Question 36

The three nitrogenous wastes can be set side by side, and the choice an animal makes among them turns on one thing above all. Compare ammonia, urea and uric acid, and explain how the form of waste an animal makes is matched to the water available to it.

Model Answer

Waste (group)	Toxicity	Solubility	Water to excrete	Excreted by
Ammonia (ammonotelic)	very toxic	very soluble	a great deal	bony fish, aquatic animals
Urea (ureotelic)	moderately toxic	fairly soluble	a moderate amount	mammals, sharks, adult amphibians
Uric acid (uricotelic)	non-toxic	almost insoluble	very little	insects, reptiles, birds

The form of nitrogen waste an animal makes is matched to the water it can spare. An animal living in water excretes the cheap but toxic ammonia, an animal on land with some water excretes urea, and an animal that must save every drop excretes uric acid. So the drier the life, the more water-sparing and the less soluble the waste.

Examiner's Note
The mark is the principle: the less water an animal can spare, the less soluble and less toxic its waste must be, passing from ammonia to urea to uric acid as water grows scarce.

Language Clinic
The connector 'so' draws the rule out of the table, and the pattern 'the drier... the more water-sparing' states it: the drier the habitat, the more water-sparing the waste.

Question 37

The two kidneys lie against the back wall of the abdomen, one on each side of the backbone, where they filter the blood that the heart drives through them. Draw the human urinary system, label its main parts, and state where the kidneys lie.

Model Answer

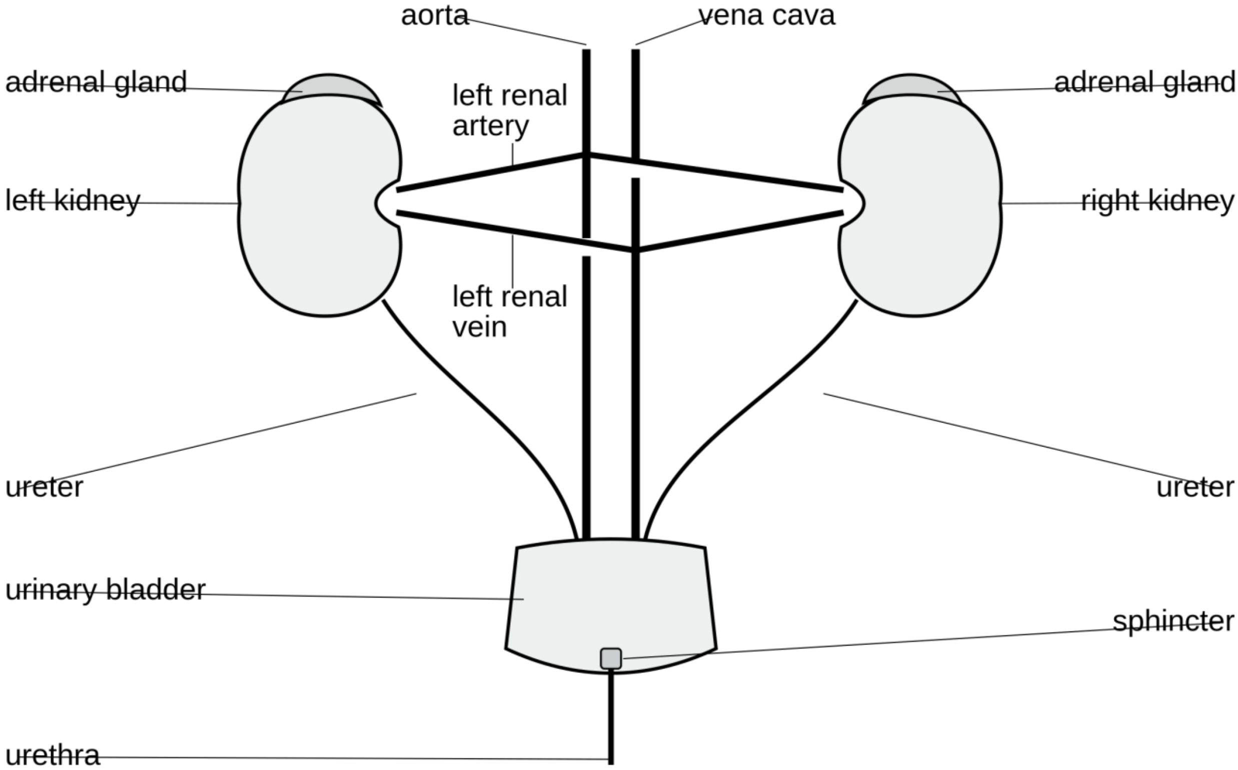


Figure 8.5: *the human urinary system*

The kidneys are a pair of bean-shaped organs lying against the back wall of the abdomen, one on each side of the spine, with the larger left kidney sitting a little higher than the right. They lie behind the lining of the abdominal cavity, so they are described as retroperitoneal, and an adrenal gland caps each one.

Blood reaches each kidney by a renal artery and leaves by a renal vein, while the urine that is made passes down a ureter to the bladder and out through the urethra. A ring of muscle, the sphincter, holds the urine in the bladder until it is released.

Examiner's Note
The labelled diagram should show the two kidneys, the two ureters, the bladder, the urethra and the renal vessels; stating that the kidney is retroperitoneal and that the left lies higher earns the position marks.

False Confidence Alert
Most students draw the two kidneys exactly level. In fact the left kidney is the larger of the two, and it sits a little higher than the right.

Question 38

Cut a kidney down its length and two regions show at once, an outer and an inner, with a space where the urine gathers. Draw a section through the kidney and label the cortex, the medulla, a pyramid and the pelvis.

Model Answer

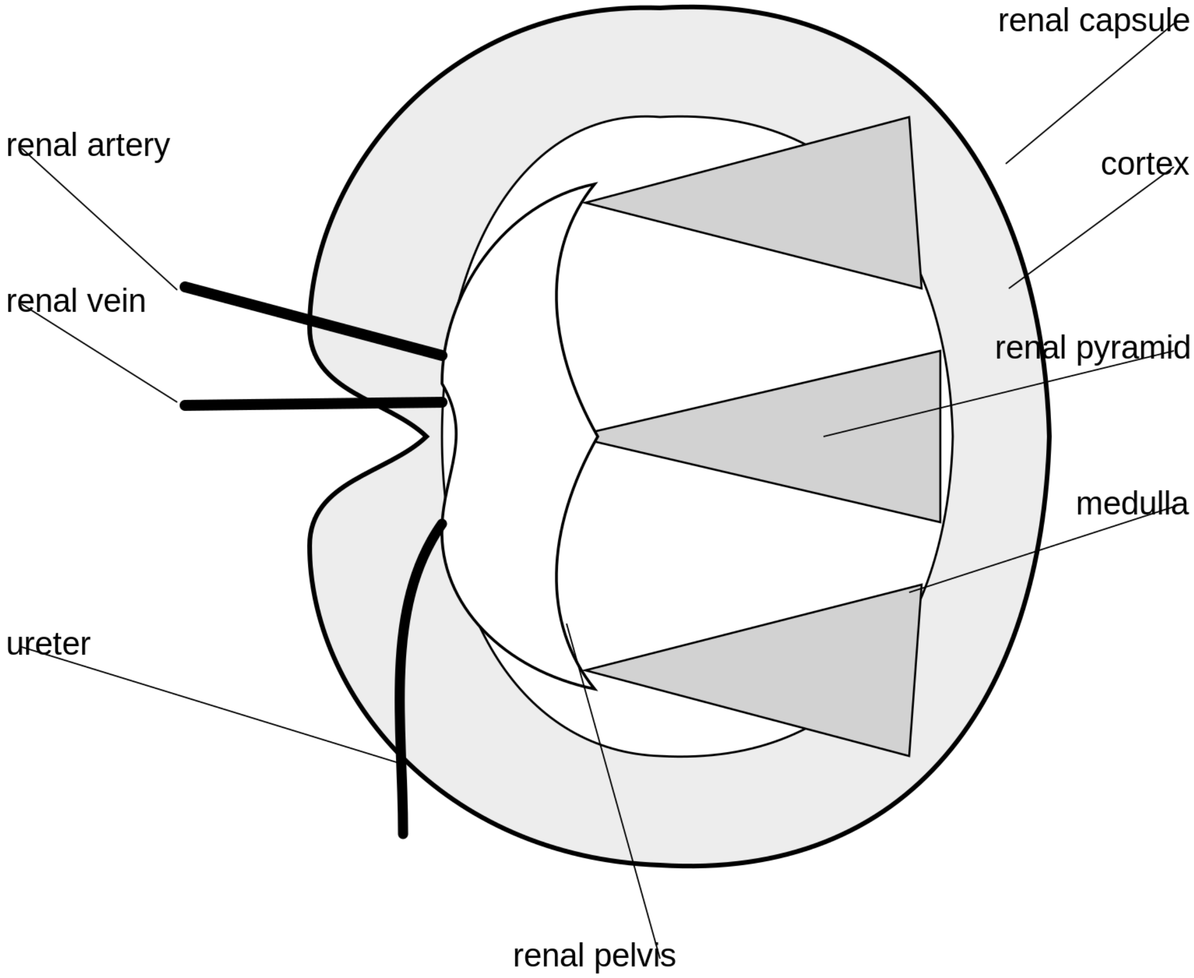


Figure 8.6: *a longitudinal section through the kidney*

A section through the kidney shows an outer, darker region, the cortex, and an inner region, the medulla, which is made up of cone-shaped pyramids. A tough fibrous capsule covers the whole kidney and keeps its shape.

The tips of the pyramids point inward to a funnel-shaped space, the renal pelvis, which gathers the urine and leads it into the ureter. The renal artery and the renal vein enter and leave at the hilus, the notch on the inner side of the kidney.

Examiner's Note
Marks come from the cortex (outer), the medulla with its pyramids (inner), the renal pelvis (the collecting funnel) and the capsule, each drawn in its right place.

Question 39

The two regions seen in a cut kidney are not merely an outer and an inner ring; each one holds a different part of the kidney's working tubes. Distinguish between the cortex and the medulla of the kidney.

Model Answer

The cortex is the outer region of the kidney, and it holds the renal corpuscles, that is the glomeruli with their Bowman's capsules, together with the convoluted tubules of the nephrons. It has a granular look because the corpuscles are packed within it.

The medulla is the inner region, made up of the pyramids, and it holds the loops of Henle and the collecting ducts, whereas the cortex holds the corpuscles. Its striped look comes from these straight tubules running down through the pyramids.

Examiner's Note
The distinguishing point is what each region contains: the cortex the renal corpuscles and convoluted tubules, the medulla the loops of Henle and the collecting ducts within its pyramids.

Question 40

Making urine is not the kidney's only work; it also helps to hold the blood itself in good order. Apart from excretion, explain how the kidney helps to regulate the body's water, its blood pressure and its red blood cells.

Model Answer

Besides removing waste, the kidney keeps the blood in order in several ways:

1) **Water balance**: it adjusts the water it returns to the blood from minute to minute, removing more when there is a surplus and saving more when the body runs short.

2) **Blood pressure**: when the pressure falls too low, the kidney releases renin, which leads to angiotensin and so to the narrowing of vessels and the holding back of salt and water, raising the pressure again.

3) **Red blood cells**: when the blood is short of oxygen, the kidney releases erythropoietin, a hormone that drives the bone marrow to make more red blood cells.

Examiner's Note
Credit needs each role with its means: water balance by adjusting the water returned, blood-pressure control through renin and angiotensin, and red-cell production through erythropoietin.

False Confidence Alert
Most students think the kidney only makes urine. It also controls the blood's water, its pressure (through renin) and its red-cell count (through erythropoietin), as well as its pH and salts.

Question 41

The kidney also keeps watch over the acid balance of the blood, the salts dissolved in it, and even helps to finish a vitamin. Explain how the kidney regulates the pH and the ions of the blood, and its part in making vitamin D active.

Model Answer

The kidney holds the pH of the blood steady by excreting hydrogen ions into the urine and keeping back the hydrogencarbonate ions that buffer the blood. In this way it stops the blood from turning too acid or too alkaline.

It also sets the amounts of the ions in the blood, such as sodium, potassium, calcium, chloride and phosphate, passing out any excess, and it carries out the last step that turns vitamin D into its active form. So the kidney guards the blood's acidity, its salts and even a vitamin, as well as clearing its waste.

Examiner's Note
Credit needs the pH control (excreting hydrogen ions, keeping back hydrogencarbonate), the regulation of the ions (sodium, potassium, calcium, chloride and phosphate), and the activation of vitamin D.

Language Clinic
The phrase 'in this way' ties the buffering to the steady pH, and 'so' gathers the kidney's several guardianships into one closing point.

Question 42

Two streams run through the kidney and leave it changed: the blood that is cleaned, and the urine that is made. Trace the path of the blood, and the path of the urine, through the kidney.

Model Answer

Blood enters the kidney under high pressure through the renal artery, which branches again and again until it reaches the nephrons, where the blood is filtered and its useful substances are taken back. The cleaned blood, now poorer in waste, leaves the kidney by the renal vein.

The urine made in the nephrons drains through the collecting ducts into the pyramids, and from their tips into the renal pelvis. From the pelvis it passes down the ureter to the bladder, where it is stored until it leaves through the urethra.

Examiner's Note
The mark is the two paths kept apart: blood in by the renal artery, filtered, out by the renal vein; urine from the nephrons to the pelvis, then by the ureter to the bladder.

Language Clinic
The connector 'where' marks the place the blood is filtered, and 'until' carries the urine to the moment it leaves the bladder.

Question 43

The kidney does its work not as one great filter but as a million tiny ones, each a coiled tube with its own blood supply. Draw a nephron, label its parts, and name the two kinds of nephron.

Model Answer

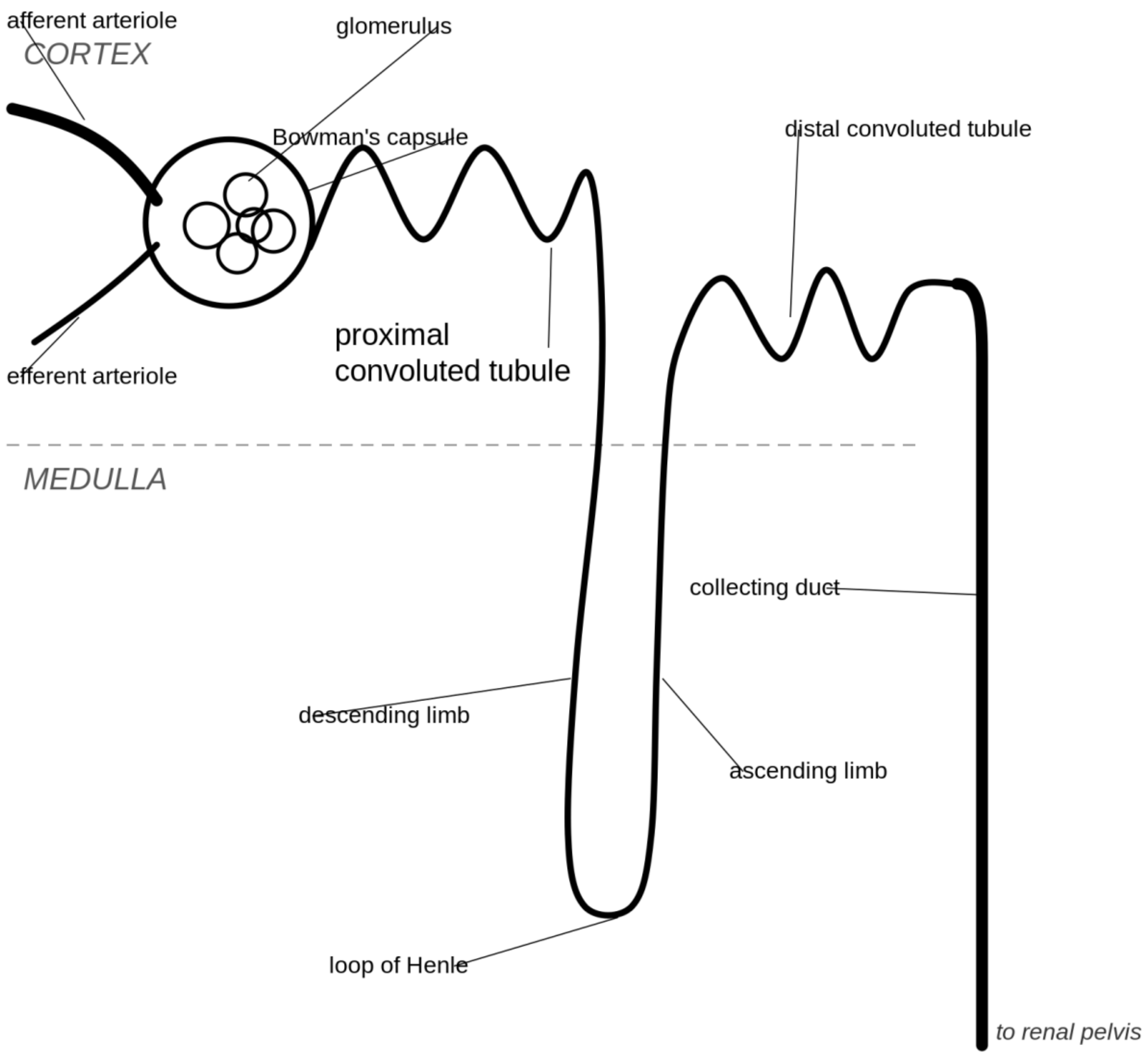


Figure 8.7: *the structure of a nephron*

A nephron is the working unit of the kidney, a long tubule that begins at a cup-shaped Bowman's capsule and runs through the proximal convoluted tubule, the loop of Henle and the distal convoluted tubule to a collecting duct. Each kidney holds about a million nephrons.

The two kinds of nephron are the cortical nephrons, lying mostly in the cortex with a short loop, and the juxtamedullary nephrons, lying next to the medulla with a long loop that dips deep into it. The long-looped juxtamedullary nephrons are the ones that make a concentrated urine.

Examiner's Note
Marks come from the Bowman's capsule, the proximal convoluted tubule, the loop of Henle with its descending and ascending limbs, the distal convoluted tubule and the collecting duct, drawn in order, with the corpuscle in the cortex and the loop dipping into the medulla.

Question 44

At the head of every nephron sits a knot of capillaries cupped in a hollow ball, and the way the blood enters and leaves it is the secret of filtration. Describe the renal corpuscle, and explain why the blood in the glomerulus is under such high pressure.

Model Answer

The renal corpuscle is the filtering head of the nephron, made of a glomerulus, a knot of capillaries, cupped inside a hollow Bowman's capsule. Blood is brought to the glomerulus by an afferent arteriole and carried away by an efferent arteriole.

The blood in the glomerulus is under high pressure because the afferent arteriole that brings blood in is wider than the efferent arteriole that takes it out. Blood enters faster than it can leave, so it dams up and builds the high pressure that drives the filtration.

Examiner's Note
The mark is the glomerulus (a capillary knot) within the Bowman's capsule, and the reason for the high pressure: the afferent arteriole is wider than the efferent, so the blood dams up.

False Confidence Alert
Most students credit the heart's pumping alone for the glomerular pressure. The key is that the efferent arteriole is narrower than the afferent, which dams the blood and raises the pressure within the glomerulus.

Question 45

Under this high pressure the blood is not pumped onward but squeezed, so that part of its liquid is pushed out through the capillary wall. Explain how ultrafiltration forms the filtrate in the Bowman's capsule.

Model Answer

Ultrafiltration is filtration under pressure: the high hydrostatic pressure of the blood in the glomerulus forces the plasma and its small dissolved molecules out through the capillary wall into the Bowman's capsule. Water, glucose, salts, amino acids and urea all pass through to form the filtrate.

The blood cells and the large plasma proteins are too big to pass through and so stay behind in the capillary. The filtrate that gathers in the capsule is therefore like blood plasma but without its cells and its proteins.

Examiner's Note
The mark is filtration driven by the high hydrostatic pressure, with the small molecules (water, glucose, salts, urea) passing into the capsule while the cells and proteins stay in the blood.

Question 46

Between the blood and the capsule lie three thin layers, and together they act as a sieve that lets the small through and holds the large back. Describe the three layers of the filtration barrier, and how each helps the filtering.

Model Answer

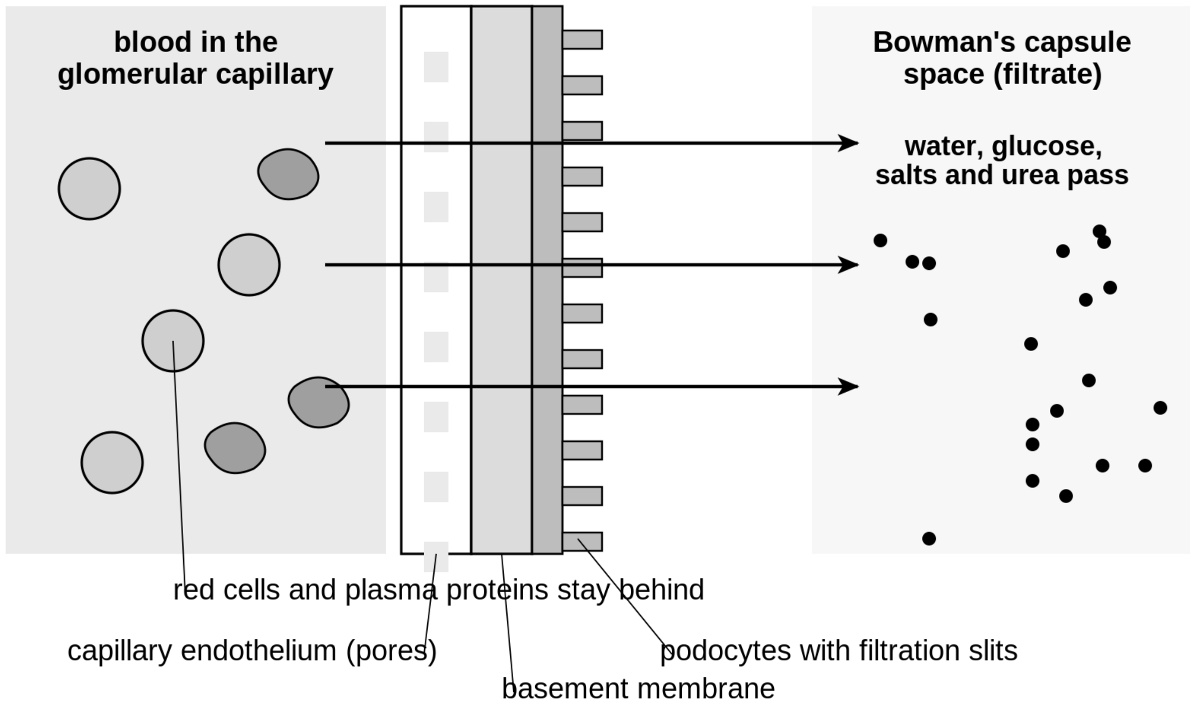


Figure 8.8: *the filtration barrier of the renal corpuscle*

The filtrate passes through three layers, which together make the filtration barrier:

1) **The capillary endothelium**: the wall of the glomerular capillary, full of tiny pores that let the plasma through but hold back the blood cells.

2) **The basement membrane**: a meshwork of fibres between the layers, which is the true sieve, letting small molecules through but stopping the large plasma proteins.

3) **The podocytes**: the cells of the inner wall of the Bowman's capsule, whose foot processes interlock to leave narrow filtration slits for the filtrate to pass.

Examiner's Note
Credit needs the three layers each with its job: the pored capillary endothelium, the sieve-like basement membrane that stops the proteins, and the podocytes with their filtration slits.

False Confidence Alert
Most students think the capillary wall alone does the filtering. It is the basement membrane between the layers that is the true sieve, holding back the large plasma proteins.

Question 47

The filtrate is not yet urine; much of it is far too precious to throw away, and most is taken straight back. Explain what happens to the filtrate in the proximal convoluted tubule, and why it is called selective reabsorption.

Model Answer

In the proximal convoluted tubule the useful substances of the filtrate are reabsorbed, taken back out of the tubule into the blood of the capillaries that surround it. All of the glucose and the amino acids, most of the salts, and much of the water are returned to the body.

It is called selective reabsorption because only the useful substances are taken back, while the waste, such as urea, is left in the tubule to pass on as urine. The body in this way keeps what it needs and lets the waste go.

Examiner's Note
The mark is the taking back of the useful substances (all the glucose and amino acids, most of the salts and water) into the blood, while urea is left behind; this selectivity is the point.

Question 48

The cells that line the proximal tubule are among the busiest in the body, for they must haul a great load of dissolved substances back into the blood. Explain how the cells of the proximal convoluted tubule are adapted for reabsorption.

Model Answer

The cells of the proximal convoluted tubule are built for reabsorption in several ways:

1) **Microvilli**: their inner surface is folded into many microvilli, giving a large surface area for taking substances back.
2) **Many mitochondria**: they are packed with mitochondria to supply the ATP needed for the active uptake of substances.
3) **Close capillaries**: blood capillaries lie very close to the cells, so the reabsorbed substances are carried away quickly into the blood.
4) **Carrier proteins**: their membranes hold channel and carrier proteins that move glucose, amino acids and ions across.
5) **Pinocytosis**: they take in small proteins from the filtrate by pinocytosis and break them down within the cell.

Examiner's Note
Credit needs the adaptations tied to reabsorption: microvilli for surface area, many mitochondria for the ATP of active transport, close capillaries, carrier proteins, and the pinocytosis of small proteins.

Question 49

The loop of Henle dips from the cortex deep into the medulla and back, and in doing so it leaves the medulla around it heavy with salt. Explain how the loop of Henle makes the medulla salty.

Model Answer

The ascending limb of the loop of Henle pumps salt, sodium and chloride, out into the medulla around it, and this limb is impermeable to water, so the water cannot follow the salt out. Salt therefore builds up in the medulla while the water stays inside the tubule.

The descending limb, in contrast, is permeable to water, so water passes out of it into the salty medulla as the fluid runs down. Between them the two limbs make the deep medulla very salty, saltiest of all at the bottom of the loop.

Examiner's Note
The mark is the ascending limb pumping salt out into the medulla while staying impermeable to water, so the medulla grows salty, saltiest at the tip of the loop.

False Confidence Alert
Most students think the loop of Henle reabsorbs the body's water itself. Its task is to make the medulla salty; the water is drawn out later, from the collecting duct, as it passes through that salty medulla.

Question 50

The collecting duct carries the forming urine down through the very medulla that the loop has made salty, and there the last of the water is won back. Explain how the salty medulla lets the kidney make a concentrated urine.

Model Answer

As the urine passes down the collecting duct it runs through the salty medulla, and water is drawn out of the duct by osmosis into those salty surroundings. The water passes from the dilute urine into the medulla and is carried back to the blood.

Losing this water, the urine left in the duct becomes concentrated, holding the same waste in far less water. The longer the loop of Henle, the saltier the medulla can be made, and the more concentrated the urine the kidney can produce.

Examiner's Note
The mark is water leaving the collecting duct by osmosis into the salty medulla, so the urine is concentrated; a longer loop makes a saltier medulla and so a more concentrated urine.

Language Clinic
The connector 'as' marks the water leaving while the urine flows down, and the pattern 'the longer, the more' ties the length of the loop to the concentration of the urine.

Question 51

How much water finally leaves the body is not fixed; it is set to the body's need, more on a dry day and less after a long drink. Explain how the distal convoluted tubule and the collecting duct adjust the water the body keeps.

Model Answer

The distal convoluted tubule and the collecting duct carry out osmoregulation, the fine adjustment of how much water is reabsorbed from the urine back into the blood. This sets the final volume and concentration of the urine.

When the body is short of water, more is reabsorbed here and the urine is scant and concentrated; when there is plenty, less is reabsorbed and the urine is copious and dilute. In this way the body holds the water of its blood steady whatever a person drinks.

Examiner's Note
The mark is that the distal tubule and collecting duct adjust the water reabsorbed (osmoregulation), making the urine scant and concentrated when water is short, copious and dilute when it is plentiful.

Question 52

The fluid that enters the nephron at the top and the urine that leaves at the bottom are very different things, though the one is made from the other. Compare the glomerular filtrate with the urine, and say what has happened between them.

Model Answer

The glomerular filtrate is like blood plasma without its cells and proteins, holding water, glucose, amino acids, salts and urea. It is large in volume and dilute.

The urine holds urea, excess salts and water only, for the glucose, the amino acids and most of the salts and water have been reabsorbed along the tubule. So the urine is small in volume and concentrated, and a healthy urine holds no glucose at all.

Examiner's Note
The mark is the difference: the filtrate carries glucose, amino acids, salts, water and urea; the urine carries only urea, excess salts and water, the useful substances having been reabsorbed.

False Confidence Alert
Most students expect glucose in the urine because it was in the filtrate. In a healthy person all of the glucose is reabsorbed in the proximal tubule, so none should appear in the urine.

Question 53

The kidney is the organ that puts urea out of the body, yet the urea is not made there at all. Explain where and why urea is made, and how it reaches the kidney.

Model Answer

Urea is made in the liver, not the kidney, where surplus amino acids are deaminated and their amino groups are turned first into ammonia. Ammonia is very poisonous, so the liver at once joins it with carbon dioxide to make the far less toxic urea.

The urea then passes into the blood, which carries it to the kidney, where it is filtered out and excreted in the urine. The liver therefore makes the nitrogen waste safe, and the kidney removes it from the body.

Examiner's Note
The mark is that the liver makes the urea, deaminating amino acids and turning the toxic ammonia into urea, while the kidney only excretes the urea the blood brings to it.

Question 54

The liver makes urea not in a single step but in a short cycle that takes in two molecules of waste nitrogen and a molecule of carbon dioxide and hands back urea. Trace the ornithine cycle, and show where the urea comes from.

Model Answer

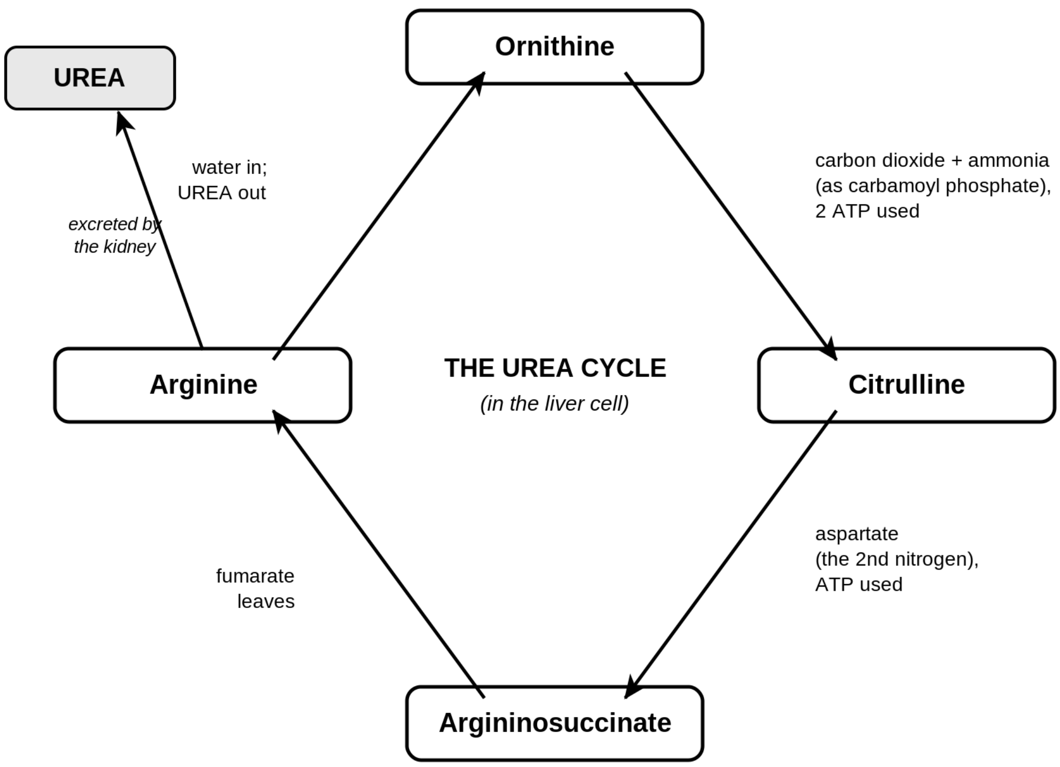


Figure 8.9: *the ornithine (urea) cycle in the liver*

In the ornithine cycle, ornithine takes up carbon dioxide and a first ammonia (as carbamoyl phosphate) to become citrulline, which then takes up a second nitrogen from aspartate to become arginine. Each of these steps costs ATP.

Arginine is then split by water into urea and ornithine: the urea is the waste that leaves, and the ornithine is freed to begin the cycle again. So one turn of the cycle brings two amino groups and a carbon dioxide together into a single molecule of urea.

Examiner's Note
Credit needs the cycle making urea from two amino groups and a carbon dioxide, with ornithine regenerated at the end to start again; the urea then travels to the kidney to be excreted.

Question 55

When the kidneys begin to fail, the urea they should be clearing from the blood is left to gather there instead. Explain what is meant by uraemia, and why it is dangerous.

Model Answer

Uraemia is the condition in which urea and other nitrogenous wastes build up in the blood because the kidneys are no longer removing them properly. It is a sign that the kidneys are failing in their work of cleaning the blood.

Uraemia is dangerous because urea is toxic, and a high level of it poisons the body, upsets the balance of water and salts, and brings on vomiting, drowsiness and, if untreated, coma and death. The blood can be made safe again only by treating the failing kidneys or by dialysis.

Examiner's Note
The mark is urea and other nitrogenous waste gathering in the blood because the kidneys have failed to remove it, joined to the point that this build-up is poisonous.

False Confidence Alert
Most students think uraemia means urine has leaked into the blood. It is not urine but the waste urea, left in the blood because filtration has failed.

Question 56

A person whose kidneys have stopped working can still be kept alive by a machine that takes over the cleaning of the blood. Explain how dialysis removes wastes from such a patient's blood.

Model Answer

In dialysis the patient's blood is led out of the body and made to flow along one side of a partially permeable membrane, while a special dialysis fluid flows along the other side. The membrane has fine pores that let small waste molecules through but hold back the blood cells and the proteins.

Wastes such as urea pass by diffusion from the blood, where they are concentrated, across the membrane into the dialysis fluid, which holds none of them, so the blood is cleaned. The fluid is made with glucose and salts at their normal blood levels, so these needed substances do not diffuse out, and the cleaned blood is returned to the patient.

Examiner's Note
The mark is diffusion of wastes down their concentration gradient across a partially permeable membrane into the dialysis fluid, while glucose and salts are held at normal levels so they are not lost.

Language Clinic
The connector 'while' sets the blood and the fluid flowing on opposite sides, and 'so' draws out both the cleaning of the blood and the keeping of the glucose and salts.

Question 57

Sometimes a kidney stops working all at once, and sometimes it fails little by little over many years. Explain what is meant by renal failure, and describe what happens to the output of urine.

Model Answer

Renal failure is the condition in which the kidneys can no longer filter the blood and form urine properly. It may be acute, coming on suddenly from causes such as heavy blood loss, poisoning or a blockage, or chronic, a slow loss of working over months or years from long-standing disease.

As the kidneys fail, the output of urine falls; a reduced output, under 250 ml a day, is called oliguria, and a fall to almost nothing, under 50 ml a day, is called anuria. The wastes that should have left in the urine, chiefly urea, then build up in the blood and bring on uraemia.

Examiner's Note
The mark is the kidneys failing to filter the blood, set out as acute (sudden) or chronic (gradual), with the fall in urine named: oliguria for a scanty output (under 250 ml a day) and anuria for almost none (under 50 ml a day).

False Confidence Alert
Most students use anuria for any small amount of urine. Oliguria is a scanty output, under 250 ml a day, while anuria is a fall to almost none, under 50 ml a day.

Question 58

Some of the substances dissolved in urine can settle out and harden into solid lumps inside the kidney. Explain how kidney stones form, and the trouble they bring.

Model Answer

Kidney stones, or renal calculi, form when salts that are normally dissolved in the urine, such as calcium oxalate, grow too concentrated and crystallise, building slowly into hard stones in the kidney or its pelvis. Drinking too little water, or carrying too much of these salts in the urine, makes the stones more likely to form.

A stone brings severe pain, especially when it moves into the ureter and blocks it, and it can hold back the flow of urine and let infection take hold. Small stones may be passed out in the urine, but large ones may have to be broken up or removed.

False Confidence Alert
Most students picture kidney stones as little pieces of bone. They are not bone but crystals of salt that have settled out of the urine.

Language Clinic
The phrase 'especially when' marks the moment a stone hurts most, as it enters the ureter, and the connector 'but' sets the small stones that pass against the large ones that must be removed.

Question 59

Germs can travel up the tube that carries urine to the outside and settle in the bladder, where they multiply. Explain what a urinary tract infection is, and why it troubles women more often than men.

Model Answer

A urinary tract infection is an infection of the urinary tract by bacteria; when it settles in the bladder it is called cystitis, and in the urethra, urethritis. It brings a burning pain on passing urine, a frequent and urgent need to urinate, and sometimes blood or cloudiness in the urine.

It troubles women more often because a woman's urethra is much shorter than a man's and opens close to the anus, so the bacteria have only a short distance to travel up to reach the bladder. Drinking plenty of water and keeping clean help to keep the infection away.

Examiner's Note
The mark is a bacterial infection of the urinary tract, named cystitis in the bladder and urethritis in the urethra, with the short female urethra, which opens close to the anus, given as the reason women are affected more often.

Language Clinic
The connector 'because' opens the reason women are more often affected, and 'so' carries it through to the shorter journey the bacteria must make to the bladder.

Question 60

If anything blocks the path that urine must take to leave the body, the urine cannot escape and begins to back up behind the block. Explain what happens when the urinary tract is obstructed.

Model Answer

An obstruction is anything that blocks the flow of urine, such as a stone, a tumour or a narrowing of the tube, and when the urine cannot pass it backs up behind the block and the pressure rises. The fault may lie anywhere along the path, from the pelvis of the kidney down to the urethra.

The back-pressure drives urine into the kidney and makes it swell, a condition called hydronephrosis, so if the block is not cleared the rising pressure presses on the kidney tissue and in time destroys its working. Clearing the obstruction early is what saves the kidney.

Examiner's Note
The mark is a block stopping the flow of urine so that it backs up under pressure, swelling the kidney (hydronephrosis) and, if it is not relieved, damaging the kidney tissue.

Question 61

A person may pass great volumes of pale, watery urine and feel a thirst that cannot be quenched, and yet their urine holds no sugar at all. Explain what causes diabetes insipidus.

Model Answer

Diabetes insipidus is caused by a lack of antidiuretic hormone (ADH), the hormone that makes the distal tubule and the collecting ducts of the kidney reabsorb water back into the blood. ADH is normally released from the posterior pituitary gland when the blood is short of water.

Without ADH the collecting ducts cannot reabsorb the water, so a large volume of dilute, watery urine is lost, and the person grows very thirsty and tired and must drink a great deal to make up for it. The urine is plentiful and pale, but it carries no sugar, for the fault lies in the handling of water, not of glucose.

Examiner's Note
The mark is the lack of ADH leaving the tubule and collecting ducts unable to reabsorb water, so that a large volume of dilute urine is passed, with great thirst and tiredness.

Question 62

Two different illnesses carry the name 'diabetes' because both make a person pass a great deal of urine, yet their causes lie far apart. Compare diabetes insipidus and diabetes mellitus.

Model Answer

Feature	Diabetes insipidus	Diabetes mellitus
Cause	a lack of ADH	a lack of insulin
Sugar in the urine	none	present
Volume of urine	large and watery	large and watery
Underlying fault	water is not reabsorbed	blood sugar is not controlled
Simple test	no sugar in the urine	sugar in the urine

Both illnesses make a person pass much urine and feel a great thirst, but their causes are quite separate. Diabetes insipidus comes from a lack of ADH, so water is not reabsorbed, whereas diabetes mellitus comes from a lack of insulin, so sugar builds up in the blood and spills into the urine.

Examiner's Note
The mark is that both cause much urine and thirst, set apart by their cause: insipidus from a lack of ADH with sugar-free urine, mellitus from a lack of insulin with sugar in the urine.

False Confidence Alert
Most students think every 'diabetes' is a disease of sugar. Diabetes insipidus has nothing to do with sugar; the shared name points only to the large flow of urine.

Question 63

The blood of a mammal must hold its water and its dissolved salts within narrow limits, however much the animal drinks or sweats. Explain what is meant by osmoregulation, and why it matters.

Model Answer

Osmoregulation is the control of the water and the dissolved-solute content of the body fluids, so that their osmotic concentration is held steady. In a mammal it keeps the blood and the tissue fluid neither too dilute nor too concentrated, whatever the animal takes in or loses.

It matters because the cells can work properly only when the fluid around them is at the right osmotic concentration. If the blood grew too dilute, water would swell the cells and burst them; if it grew too concentrated, water would be drawn out and shrink them. So osmoregulation is a part of homeostasis.

Examiner's Note
The mark is the control of water and solute so that the osmotic concentration of the body fluids is held steady, neither too dilute nor too concentrated.

False Confidence Alert
Most students treat osmoregulation and excretion as one thing. Osmoregulation balances the water and salts; excretion removes the toxic wastes. The kidney happens to do both.

Language Clinic
The connector 'so' draws the conclusion that osmoregulation belongs to homeostasis, and the paired 'if... if...' sets the danger of dilute blood against that of concentrated blood.

Question 64

Of all the organs that help to keep the body steady, one does most of the work of holding the water balance. Explain how the kidney acts as the chief organ of osmoregulation.

Model Answer

The kidney osmoregulates by adjusting how much water it returns to the blood and how much it lets pass out in the urine. When the blood is too concentrated it reabsorbs more water and makes a small amount of concentrated urine; when the blood is too dilute it reabsorbs less and makes a large amount of dilute urine.

In this way the kidney holds the osmotic concentration of the blood steady, whatever the animal drinks or loses. The fine control rests on the loop of Henle, which makes the medulla salty, and on the hormone ADH, which sets how much water the collecting duct reabsorbs.

Examiner's Note
The mark is that the kidney varies the water it reabsorbs against the water it passes out, making concentrated urine when the blood is concentrated and dilute urine when the blood is dilute, so holding the blood steady.

Question 65

The loop of Henle dips deep into the medulla and sets up the salty conditions that let the kidney save water. Draw and label the loop of Henle and the collecting duct, and explain how the counter-current multiplier makes the medulla salty.

Model Answer

The loop of Henle works as a counter-current multiplier because its two limbs carry the fluid in opposite directions and treat salt and water differently.

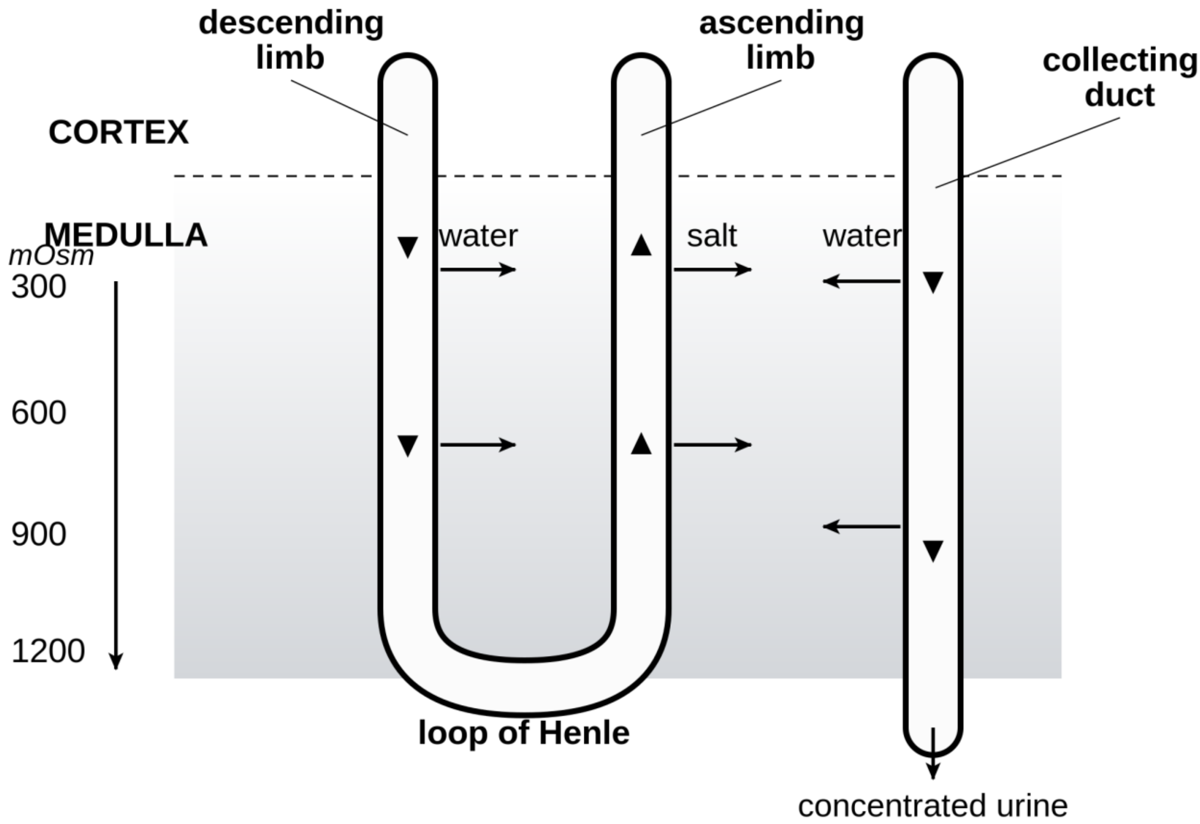


Figure 8.10: *the loop of Henle and the collecting duct as a counter-current multiplier; the ascending limb pumps salt into the medulla, the descending limb and the collecting duct lose water to it, and so the medulla grows saltier with depth*

The ascending limb pumps salt (sodium and chloride) out into the medulla but is impermeable to water, so the medulla around it grows salty. The descending limb, by contrast, is permeable to water, so water passes out of it into the salty medulla and the fluid left inside grows more and more concentrated as it sinks towards the tip.

Because the two limbs lie side by side and flow in opposite directions, the small difference made at each level is added to the next and multiplied down the loop. This builds a steep gradient that is most concentrated at the tip, leaving the medulla very salty, ready to draw water from the collecting duct.

Language Clinic
The connector 'because' opens the reason the loop multiplies, and 'so' carries each step through: salt out so the medulla turns salty, water out so the fluid grows concentrated.

Question 66

Making the medulla salty would be of no use unless the kidney could turn that saltiness into water saved. Explain how the salty medulla is used to make a concentrated urine.

Model Answer

The collecting duct carries the urine down through the salty medulla on its way to the renal pelvis. Because the medulla outside is saltier than the fluid inside the duct, water passes out of the collecting duct by osmosis into the medulla, and the blood carries it away.

As the water leaves, the urine left behind grows more and more concentrated, so the body saves water. The longer the loop of Henle, the saltier the medulla it can build, and so the more concentrated the urine the animal can make; this is why desert mammals have very long loops.

> **False Confidence Alert**
> Most students say the collecting duct pumps out salt to concentrate the urine. It is the loop that makes the medulla salty; the collecting duct only loses water to that salty medulla.

Question 67

If ordinary blood vessels ran straight through the medulla, they would wash its salt away as fast as the loop built it up. Explain how the vasa recta keep the medulla salty.

Model Answer

The vasa recta are the long, hairpin blood vessels that run beside the loop of Henle, dipping down into the medulla and back up again. Because they too run in opposite directions, they act as a counter-current exchanger.

As the blood flows down into the medulla it picks up salt and loses water, and as it flows back up it gives the salt back and takes the water up again, so it leaves the medulla almost as salty as it found it. In this way the vasa recta bring the medulla its blood supply without washing away the salt gradient that the loop has built.

Question 68

The body can change how much water it saves from one minute to the next, and it does so with a single hormone. Explain where antidiuretic hormone comes from, what triggers its release, and what it does.

Model Answer

Antidiuretic hormone (ADH) is made in the hypothalamus and released into the blood from the posterior pituitary gland. It is released when osmoreceptors in the hypothalamus detect that the blood has grown too concentrated, its osmotic pressure has risen, as happens when the body is short of water.

ADH travels in the blood to the kidney, where it makes the walls of the distal tubule and the collecting ducts more permeable to water. More water is then reabsorbed back into the blood, so a small amount of concentrated urine is passed and the blood is brought back to its proper concentration.

Question 69

The control of the body's water turns on a loop that corrects itself, raising and lowering the hormone as the blood demands. Explain how ADH controls the water content of the blood by negative feedback.

Model Answer

When the blood becomes too concentrated, the osmoreceptors detect it and more ADH is released, so the kidney reabsorbs more water and passes a small, concentrated urine, and the blood is diluted back to normal. The correction removes the very change that caused it.

When the blood becomes too dilute, less ADH is released, so the kidney reabsorbs less water and passes a large, dilute urine, and the blood is concentrated back to normal. Because each change is reversed and the blood is brought back towards its set level, the control is by negative feedback.

> **False Confidence Alert**
> Most students think more ADH means more urine. It is the opposite: more ADH saves water, so it makes less urine, and that urine is concentrated.

Question 70

Besides saving water, the kidney also helps to hold the blood pressure and the salt of the blood steady, and it does this with a chain of three substances. Explain how the renin-angiotensin-aldosterone system works.

Model Answer

When the blood pressure or the sodium level of the blood falls, special cells of the kidney, the juxtaglomerular apparatus, release an enzyme called renin into the blood. Renin begins a chain: it turns a blood protein into angiotensin, which is then changed into its active form.

Angiotensin narrows the blood vessels, which by itself raises the blood pressure, and it makes the adrenal glands release the hormone aldosterone. Aldosterone then makes the distal tubule and the collecting duct reabsorb more sodium, and water follows the sodium, so the blood volume and pressure are brought back up.

> **False Confidence Alert**
>
> Most students confuse this with ADH. ADH controls how much water is reabsorbed directly; aldosterone controls how much sodium is reabsorbed, and the water then follows the sodium.

Question 71

A shark lives in the sea, whose water is saltier than its blood would otherwise be, and yet it does not lose its water to the sea and shrivel. Explain how a marine cartilaginous fish such as a shark osmoregulates.

Model Answer

A shark holds a high level of urea, together with a substance called trimethylamine oxide (TMAO), in its blood, and this raises the blood's osmotic concentration until it equals, or a little passes, that of the sea water around it. Because its blood is no longer more dilute than the sea, the shark does not lose its water to the sea by osmosis.

The salt that leaks in, and the salt in its food, is removed by a special rectal gland and by the kidney, which excrete the excess sodium chloride. So the shark holds its water and its salt steady even in salty sea water.

> **False Confidence Alert**
> Most students think urea is only a poison to be thrown out. In the shark, urea is kept in the blood on purpose, to hold its water against the sea.

Question 72

A desert rat may live its whole life without ever taking a drink, and the secret lies in the kidney it carries. Explain how a desert mammal such as the kangaroo rat saves water through the structure of its kidney.

Model Answer

The kangaroo rat has very long loops of Henle that dip far down into a thick medulla. The longer the loop, the saltier it can make the medulla, and the saltier the medulla, the more water can be drawn out of the collecting duct.

So the kangaroo rat can pass a urine far more concentrated than its blood, a hypertonic urine about twenty times as concentrated as its blood plasma, losing only a tiny amount of water in ridding itself of its wastes. This lets it live on the little water it gets from its food alone.

Language Clinic
The pattern 'the longer... the saltier...' builds the chain of cause, and 'so' delivers its result: a hypertonic urine that saves water.

Question 73

An animal that never drinks must still get its water from somewhere, for nothing can live without it. Explain where a desert mammal gets the water it needs.

Model Answer

A desert mammal gets most of its water from its food and from its own metabolism. The water held in the seeds and plants it eats is one source; the other is metabolic water, the water made when food, especially fat, is respired in the cells.

It drinks little or nothing, and so it must hold on to the water it has by every means. In a desert rodent as much as nine-tenths of the water may come from its metabolism and only about one-tenth from its food, yet together these are just enough to replace the small amounts it loses.

Examiner's Note
The mark is the two sources: the water held in the food, and the metabolic water made when food, especially fat, is respired in the cells; the animal drinks little or nothing.

Question 74

Having found its water, the desert mammal must then lose as little of it as possible, saving water both in its kidney and in its gut. Explain how a desert mammal cuts down the water it loses in its urine and its faeces.

Model Answer

In the kidney, the very long loops of Henle let it pass a very concentrated urine, so it loses very little water in getting rid of its urea. The more concentrated the urine it can make, the less water it must spend on its nitrogen waste.

In the gut, water is reabsorbed thoroughly from the food remains before they are passed, so the faeces come out very dry. By saving water in both the urine and the faeces, the animal keeps its total water loss to the least possible.

Question 75

Beyond its kidney and its gut, a desert mammal also saves water by the way it behaves and, in the worst heat, by slowing its whole body down. Explain the behavioural ways in which a desert mammal saves water.

Model Answer

A desert mammal saves water by its habits as much as by its body:

1) **Coming out only at night**: it feeds in the cool dark and rests by day, so it sweats and evaporates far less water.
2) **Sheltering in a burrow**: the air deep in a burrow is cool and damp, so little water evaporates from its body.
3) **Keeping out of the midday sun**: by resting in shade it stays cool without spending water on sweat.
4) **Entering torpor or aestivation**: in the driest times the body slows right down, the metabolism falls, and water is spent very slowly until the rains return.

By these habits the animal loses far less water than it would out in the open sun. Its behaviour guards the water that its kidney and gut have worked to save.

REAL QUESTIONS

These questions take the same biology into real situations and into the traps an examiner sets, to test whether you can use what you have learned and not only recite it. Attempt each on paper first; the bold opening of every answer is the mark-bearing point, and the boxes show how the marks are won and lost.

Question 76

A Form Five student eats a large plate of rice and beans, and a blood test shows her blood glucose rising soon afterwards, then falling back to its normal level within two hours. Trace this correction through the stages of a negative-feedback loop, naming the detector, the corrective response and the effectors that bring her blood glucose back to normal.

Model Answer

Her blood glucose is returned to normal by a negative-feedback loop with these stages:

1) **The change**: the meal raises the blood glucose above its set point.
2) **The detector**: the islet cells of the pancreas detect the rise in the blood glucose.
3) **The corrective response**: these cells secrete the hormone insulin into the blood.
4) **The effectors**: the liver and the body cells answer the insulin by taking glucose out of the blood, the liver storing it as glycogen and the cells respiring more of it.
5) **The return to normal**: as the glucose is removed the blood level falls back to the set point, so the insulin slows and the correction switches itself off.

Because the response reverses the very rise that set it off, the control is by negative feedback.

Examiner's Note
The stage most often dropped is the last one, that the loop switches itself off as the glucose returns to the set point. Name the effectors, the liver and the body cells, and not the hormone alone, to take every mark.

False Confidence Alert
Most students say insulin destroys or burns up the extra glucose. Insulin destroys nothing; it makes the body cells take the glucose in and the liver store it as glycogen.

Question 77

Three everyday events are these: first, blood glucose returning to normal after a meal; second, the contractions of the womb growing stronger and stronger during birth until the baby is born; third, sweating that cools the body when it overheats. State for each whether it is controlled by negative or by positive feedback, and justify your answer.

Model Answer

Taking each event in turn:

Blood glucose returning to normal: negative feedback, because the rise in glucose triggers insulin, which removes the glucose and reverses the rise.

The contractions growing stronger until birth: positive feedback, because each contraction triggers more of the hormone oxytocin and a stronger contraction, adding to the change until the baby is born.

Sweating that cools an overheated body: negative feedback, because the rise in temperature triggers sweating, which cools the body and reverses the rise.

The test in every case is the direction of the response. Where the response reverses the change, as in the first and third events, it is negative feedback; whereas where it adds to the change, as in the second, it is positive feedback.

Examiner's Note
A bare 'negative' or 'positive' earns little; the credit is in the reason. Say in each case whether the response reverses the change or adds to it, and the answer defends itself.

Language Clinic
The connector 'because' carries the reason in each line, and 'whereas' sets the two reversing events against the one that builds, marking the difference for the examiner.

Question 78

Kipanga writes in his exercise book: *'Positive feedback is the good kind that keeps the body healthy, and negative feedback is the harmful kind that the body tries to avoid.'* Identify the mistake in Kipanga's statement, and correct it.

Model Answer

Kipanga's mistake is to read 'positive' and 'negative' as though they meant 'good' and 'bad'. In biology the two words describe the direction of the response, not whether it helps or harms the body.

Negative feedback means the response reverses the change that caused it and returns the body to its set point, so it is the common control that keeps the internal environment steady. Positive feedback works the other way: whereas negative feedback reverses a change, positive feedback adds to it and drives it further, so it is the rarer kind, kept for events that must run quickly to completion, such as birth. Both are useful, and neither is in itself good or bad.

Examiner's Note
Simply swapping Kipanga's labels round wins nothing; the examiner wants the ground of the distinction. The words name the direction of the response, reversing or amplifying, never its benefit or harm.

Language Clinic
The connector 'whereas' sets the reversing of negative feedback against the amplifying of positive feedback, and 'so' draws the use of each kind from its direction.

Question 79

The French scientist Claude Bernard wrote that the constancy of the internal environment is the condition for a free and independent life. Using examples, explain what he meant, and why a steady internal environment is an advantage to an animal.

Model Answer

Bernard meant that an animal whose internal environment, the tissue fluid around its cells, is held constant can stay active whatever its surroundings do, instead of being ruled by them. Its cells are kept at their best conditions of temperature, pH and glucose, and so go on working steadily.

For example, a mammal that holds its temperature and blood glucose steady can feed and move on a cold night or under the noon sun alike, whereas an animal that cannot regulate must grow sluggish when the cold comes. So a constant internal environment frees the animal from its surroundings and lets it live in places and at times that would otherwise stop it.

Examiner's Note
Two things must show for full credit: that it is the internal environment, not the animal, held constant, and the pay-off that follows, freedom from the surroundings. An example, active by cold night and hot noon alike, seals it.

False Confidence Alert
Most students take a constant internal environment to mean that the animal itself never changes. It is the internal environment, the tissue fluid, that is held steady; the animal stays free to move, feed and grow.

Question 80

A farmer hoes his field under the midday sun in Dodoma and is soon sweating, his skin flushed and red. Explain the changes taking place in his skin and body that keep his temperature from rising, and how each one cools him.

Model Answer

The small arteries supplying his skin widen, a change called vasodilation, so that more warm blood flows through the capillaries near the surface and the skin flushes red. As this blood passes close to the surface it gives up its heat to the cooler air, and the cooled blood returns to carry away more.

At the same time his sweat glands pour sweat onto the skin, and as the sweat evaporates it draws its latent heat from the body, cooling it. The harder he works and the hotter he grows, the more he sweats, and so the more heat is carried away.

Examiner's Note
Examiners want the heat actually leaving the body, not blood merely 'coming to the surface'. Say that the surface blood gives its heat to the air, and that it is the evaporation of the sweat, not the sweat itself, that cools.

False Confidence Alert
Most students say the blood vessels move up to the skin. The vessels do not move; the arterioles widen so that more blood flows through capillaries that are already near the surface.

Language Clinic
The connector 'as' carries the cooling in both changes, 'as this blood passes close to the surface' and 'as the sweat evaporates', tying each loss of heat to the moment it happens.

Question 81

A herdsboy spends a cold night watching cattle in the southern highlands, and begins to shiver, his skin pale and the hairs on his arms standing up. Explain the changes that keep his body warm, and how each one works.

Model Answer

Several changes work together to hold his warmth:

1) **Vasoconstriction**: the arterioles to the skin narrow, so less warm blood flows near the surface and less heat is lost; this is why his skin looks pale.
2) **Shivering**: the muscles contract and relax fast, and the extra respiration in them releases heat that warms the body.
3) **Raised hairs**: tiny muscles pull the hairs upright, trapping a layer of still air against the skin that slows the loss of heat.
4) **A faster metabolism**: the body lifts its rate of respiration, especially in the liver, so that more heat is given out.

Together these cut the heat he loses and raise the heat he makes, holding his temperature steady through the cold.

Examiner's Note
Easy marks are lost by naming the pale skin and the raised hairs without their cause. Give the narrowed vessels and the trapped air, and for shivering credit the heat from the extra muscle respiration, not the shaking itself.

False Confidence Alert
Most students think standing hairs warm a person as well as they warm a cat. A furry animal traps a thick layer of air, but a human has too little hair for it to help much; in us it is a leftover response.

Question 82

Early in the morning a lizard lies still on a sun-warmed rock, while a goat nearby is already grazing. Explain why the lizard must bask in the sun before it can become active, but the goat need not.

Model Answer

The lizard is an ectotherm: it cannot make enough heat of its own, so its body takes the temperature of its surroundings. On a cold morning it is cold and sluggish, and it must bask to soak up the sun's heat until its muscles are warm enough to work.

The goat is an endotherm: it makes its own heat from a high rate of respiration and holds its body at a steady warm temperature all through the night. So it is already warm at dawn and can graze at once, without waiting for the sun to warm it.

> **Examiner's Note**
> A contrast that names only 'ectotherm' and 'endotherm' scores little; the marks lie in the source of the heat, the lizard taking it from the sun while the goat makes its own by respiration.

Question 83

Kipanga explains to a friend that *sweat cools you down because the sweat that comes out of your skin is cold.* Identify the mistake in what Kipanga says, and give the correct explanation.

Model Answer

Kipanga is wrong to think the sweat is cold. The sweat leaves the body at body temperature; it is not cold when it reaches the skin.

Sweat cools the body because it evaporates: to change from liquid into vapour it must take in heat, its latent heat, and it draws that heat from the skin, so the body is cooled as the sweat dries. This is why a person feels little relief on a humid day, when the air is already so moist that the sweat cannot easily evaporate.

> **Examiner's Note**
> Everything turns on the evaporation drawing latent heat from the skin; an answer that stops at 'sweat cools you' wins nothing. The humid-day point is the surest proof the idea is understood.

Question 84

A mouse must eat almost its own weight in food each day, while an elephant eats only a small fraction of its weight. Explain, in terms of surface area and volume, why a small mammal must eat so much more for its size to keep warm.

Model Answer

A small animal has a large surface area compared with its volume, while a large animal has only a small surface for its volume. Heat is made throughout the volume of the body but lost through its surface, so the mouse loses heat far faster, for its size, than the elephant does.

To replace the heat it loses so quickly, the mouse must respire fast, and so it must eat a great deal of food for its size to fuel that respiration. The elephant, losing heat slowly for its size, needs proportionally far less food to stay warm.

> **Examiner's Note**
> State the ratio the right way round, a large surface for a small volume in the little animal, and link it to heat made in the volume but lost from the surface. 'Small animals lose heat faster' on its own is half the marks.

> **False Confidence Alert**
> Most students say a mouse loses more heat than an elephant. In plain amount the elephant loses more; it is the loss compared with the body's size that is greater in the mouse.

Question 85

A frog excretes its nitrogen as ammonia while it is a tadpole swimming in the pond, but as urea once it has grown into an adult living on land. Explain why its nitrogenous waste changes as it grows up.

Model Answer

As a tadpole the frog is surrounded by water that can carry its waste away at once. Ammonia is very toxic and needs a great deal of water to flush it out safely, but the tadpole has water all around it, so it can afford to excrete the cheap, poisonous ammonia and is ammonotelic.

As an adult on land the frog can no longer spare so much water, so it turns its ammonia into urea. Urea is far less toxic and can be carried in the blood and passed out in only a little water, which saves water for life on land; the adult is therefore ureotelic. So the change of waste simply follows the change of home from water to land.

Examiner's Note
Each waste must be tied to the water on hand: ammonia where water is everywhere, urea where it must be hoarded. The words 'ammonotelic' and 'ureotelic' on their own, without the water reason, carry few marks.

False Confidence Alert
Most students say the waste changes because the adult frog is bigger or stronger. The size is not the reason; the move from water to land, and the new need to save water, is what changes the waste.

Question 86

On a hot day a person sweats a great deal but passes only a little urine, while on a cold day they sweat little but pass much more urine. Explain why, linking the work of the skin and the kidney.

Model Answer

On a hot day the skin loses a great deal of water as sweat in cooling the body. To stop the blood growing too concentrated, the kidney then saves water by reabsorbing more of it, so it passes only a little, concentrated urine.

On a cold day the person sweats little, so little water is lost through the skin. The body now has water to spare, so the kidney reabsorbs less and passes a larger amount of dilute urine to be rid of it. In this way the skin and the kidney share the one task of holding the body's water steady.

Examiner's Note
Credit hangs on the link, not on the two halves kept apart. Show that the water the skin loses in sweat is the water the kidney then holds back, so the urine falls; an answer that treats skin and kidney separately misses the point.

Language Clinic
The connector 'so' carries each cause to its effect: much sweat, so little urine; little sweat, so much urine, the two organs answering each other.

Question 87

A student argues that *the kidney is the body's only excretory organ, since the lungs merely breathe and the skin merely sweats.* Judge whether the student is right, giving your reasons.

Model Answer

The student is wrong. Excretion is the removal of the toxic wastes of metabolism, and several organs share in it, not the kidney alone.

The lungs excrete carbon dioxide, the waste of respiration, in the breath; the skin excretes water, salts and a little urea in the sweat; and the liver makes the urea and breaks worn-out red cells down to the bile pigments it passes into the gut. So the kidney is the chief excretory organ, but it is far from the only one.

Examiner's Note
A verdict with no organ-and-waste pairs earns nothing. Open from the definition, that excretion removes the waste of metabolism, then give the lungs (carbon dioxide), the skin (sweat) and the liver (bile pigments) to show the kidney is not alone.

False Confidence Alert
Most students rule the lungs and skin out because they have other jobs. An organ may do more than one thing: the lungs breathe and also excrete carbon dioxide; the skin cools the body and also passes out salts and urea.

Question 88

A doctor tests a patient's urine and finds protein in it. Explain what this finding tells her about the patient's kidney, using what you know of how the filter of the nephron works.

Model Answer

In a healthy kidney the filtration barrier of the renal corpuscle lets only small molecules pass from the blood into the nephron, the water, glucose, salts and urea. The blood cells and the large plasma proteins are too big to cross the barrier, while these small molecules pass, and so the proteins are normally kept in the blood.

So protein in the urine tells the doctor that this barrier is damaged and is leaking, letting through proteins that it should hold back. It is a sign that the glomerulus, or the filtering membrane around it, is no longer working as it should.

Examiner's Note
Full credit links the normal barrier, proteins too big to pass, to the verdict that a leak means damage. 'The kidney is damaged' on its own, without the barrier reasoning, earns little.

False Confidence Alert
Most students think a little protein in urine is normal because the filtrate carries 'everything from the blood'. The proteins are too large to be filtered, so a healthy urine has none.

Question 89

The filtrate made in a healthy person's kidney contains glucose, yet their urine contains none. In a person with untreated diabetes, however, glucose appears in the urine. Explain both observations.

Model Answer

In a healthy person the glucose that is filtered into the nephron is all taken back into the blood by selective reabsorption in the proximal tubule, so none is left to appear in the urine. The tubule is able to recover every bit of the glucose the filtrate carries.

In untreated diabetes the blood glucose is so high that the filtrate carries far more glucose than the tubule can reabsorb. The tubule takes back all it can, but the excess is left behind and passes out in the urine. So glucose in the urine is a sign that the blood glucose has risen beyond what the kidney can recover.

Examiner's Note
The healthy case must name selective reabsorption taking all the glucose back; the diabetes case must say the tubule is overwhelmed by the excess, not that the kidney is damaged. Miss either and the answer is half done.

False Confidence Alert
Most students say diabetes lets glucose through because it has damaged the filter. The filter always passes glucose; the difference is that the tubule cannot reabsorb so large an amount.

Question 90

Trace the journey of a molecule of glucose from the blood in the glomerulus, through the nephron, and back into the blood, naming each part it passes and what happens to it there.

Model Answer

A glucose molecule makes this journey:

1) **The glomerulus**: being small, it is forced out of the blood with the filtrate, through the filtration barrier, under the high blood pressure there.
2) **The Bowman's capsule**: it collects in the capsule as part of the filtrate and enters the start of the nephron.
3) **The proximal convoluted tubule**: here it is reabsorbed, carried out of the filtrate and back through the tubule wall.
4) **The blood capillary**: it passes into the blood of the capillary network around the tubule and is carried away in the renal vein.

A glucose molecule is therefore filtered out and then wholly reabsorbed, so a healthy urine holds none of it.

Examiner's Note
Marks are for the parts named in order, glomerulus, capsule, proximal tubule, blood, and for the glucose being reabsorbed at the proximal tubule. A trace that halts at the filtrate forgets the journey home.

Language Clinic
The connector 'so' closes the trace by drawing its lesson: filtered out and then wholly reabsorbed, so the urine holds no glucose.

Question 91

The blood entering the glomerulus is kept under high pressure. Explain why this high pressure is needed, and what would happen to the making of urine if a person's blood pressure fell very low.

Model Answer

The high pressure in the glomerulus is what drives ultrafiltration, forcing the water and the small molecules out of the blood, through the filtration barrier, and into the nephron. It is kept high because the wide afferent arteriole that brings the blood narrows into the fine glomerular capillaries, and because the vessel leaving the glomerulus is narrower still than the one entering it, so the blood is dammed back.

So if the blood pressure fell very low, the filtering pressure in the glomerulus would fall with it, and far less filtrate, or none at all, would be formed. The making of urine would slow or stop, and the wastes the kidney should remove would begin to build up in the blood.

Examiner's Note
Tie the pressure to driving the filtration, and the wide arteriole narrowing into fine capillaries wins the extra mark. The low-pressure half is unfinished until it reaches the slowing of urine and the build-up of wastes.

Question 92

Kipanga writes that *the kidney makes urine in a single step, working like a sieve that lets the wastes pass through into the urine while keeping all the useful substances back in the blood.* Identify the mistake, and give the correct account.

Model Answer

Kipanga's mistake is to think the kidney sorts the useful from the waste in one step. The filter of the glomerulus cannot tell useful from waste; it lets through everything small enough to pass, the water, glucose and salts just as much as the urea.

The kidney works in two stages, not one. First, ultrafiltration forces all the small molecules, useful and waste alike, out of the blood into the nephron; then selective reabsorption takes the useful ones, the glucose and much of the water and salts, back into the blood, leaving the wastes to pass out as urine. So it is this second stage, not the filter, that saves what is useful.

Examiner's Note
The correction must carry both stages and stress that the filter cannot pick and choose. 'Two stages' on its own, without saying the filter is blind to useful against waste, misses the heart of it.

Language Clinic
The connector 'then' sets the second stage after the first, and 'so' draws the conclusion that it is reabsorption, not the filter, that saves the useful substances.

Question 93

A student claims that, *because urine is made from the blood, urine and blood plasma must contain the same substances*. Judge whether the student is right, giving your reasons.

Model Answer

The student is wrong. Urine and blood plasma are not the same, even though the urine is made from the plasma.

The plasma holds proteins, which never cross the filter, so the urine has none; the plasma holds glucose, which is all reabsorbed, so a healthy urine has none of that either. And the urine is far richer in urea and far more concentrated than the plasma, because the water and the useful salts have been taken back while the urea has been left behind. So selective reabsorption makes the urine quite unlike the plasma it came from.

Examiner's Note
The verdict needs the differences named, no protein, no glucose, concentrated urea, each tied to filtration or to reabsorption. A bare 'they are different' earns almost nothing.

False Confidence Alert
Most students picture urine as blood with the wastes simply filtered out. Reabsorption changes it greatly: the useful substances are taken back, so the urine that remains is quite unlike the plasma.

Question 94

Renal failure does more than stop the making of urine; it disturbs the whole body. Outline the main causes of renal failure, and explain the effects it has on the body.

Model Answer

Renal failure may be brought on suddenly or slowly:

1) **Sudden (acute) causes**: a heavy loss of blood, a sharp fall in blood pressure, poisoning, or a blockage of the urinary tract.
2) **Slow (chronic) causes**: long-standing high blood pressure, diabetes, repeated infection or inflammation of the kidney, or kidney stones.

Because the failing kidney can no longer do its work, several effects follow, each from a lost task:

1) **Wastes build up**: urea and other nitrogen wastes gather in the blood, the state called uraemia, and poison the body.
2) **The legs swell**: the body cannot remove enough water, so fluid collects in the tissues and causes swelling, called oedema.
3) **Salts rise**: salts such as potassium climb to dangerous levels in the blood.
4) **Anaemia sets in**: the kidney makes less of the hormone erythropoietin, so fewer red cells are formed and the patient grows anaemic.

So renal failure is dangerous not only because urine is not made, but because the blood is poisoned, waterlogged and short of red cells.

Examiner's Note
Each effect must be pinned to the kidney task that has failed, waste removal, water balance, salt balance and the making of red cells. A list of symptoms with no lost task behind them earns far less.

Question 95

A woman goes to the clinic with a burning pain when she passes urine and a frequent, urgent need to go. Explain what is most likely wrong, why women suffer this more often than men, and what may happen if it is left untreated.

Model Answer

She most likely has a urinary tract infection, an infection of the bladder by bacteria, called cystitis. The burning pain on passing urine and the frequent, urgent need to go are its usual signs.

Women suffer it more often because a woman's urethra is short and opens close to the anus, so bacteria reach the bladder over only a short distance. A man's longer urethra gives the bacteria a far longer journey.

If it is left untreated, the bacteria may climb from the bladder up to the kidney itself, causing a more serious kidney infection and, in time, lasting damage to the kidney. So an early infection should be treated, with plenty of fluids and clean habits, before it can spread.

Examiner's Note
Three things are wanted, and the last is the one dropped: name the infection, give the short-urethra reason, and carry it through to the spread to the kidney if it is left untreated.

False Confidence Alert
Most students think a burning pain on passing urine must mean a sexually transmitted disease. Most cystitis is caused by ordinary gut bacteria reaching the bladder, not by an STD.

Question 96

Two patients each pass large volumes of urine and are very thirsty. A simple test shows sugar in the urine of the first patient but none in the urine of the second. Explain which patient has diabetes mellitus and which has diabetes insipidus, and how the test tells them apart.

Model Answer

The first patient, whose urine holds sugar, has diabetes mellitus. It comes from a lack of insulin, so the blood glucose climbs so high that the kidney cannot reabsorb it all and sugar spills into the urine; that sugar drags water with it, which is why so much urine is passed.

The second patient, whose urine has no sugar, has diabetes insipidus. It comes from a lack of ADH, so the collecting ducts cannot reabsorb water and a large volume of dilute, sugar-free urine is lost. So the test for sugar tells the two apart: sugar in the urine means mellitus, no sugar means insipidus.

Examiner's Note
Each diagnosis must rest on its cause, a lack of insulin with sugar in the urine against a lack of ADH without, and the test be tied to that cause. Naming the two diseases without the sugar-and-ADH reasoning scores little.

False Confidence Alert
Most students think both kinds of diabetes are diseases of sugar. Only diabetes mellitus involves sugar; diabetes insipidus is a fault in handling water, through the lack of ADH, with no sugar in the urine at all.

Question 97

A freshwater fish and a marine bony fish face opposite water problems, yet each holds its salt and water steady. Explain the problem each one faces and how it solves it.

Model Answer

A freshwater fish has blood saltier than the water around it, so water floods into its body by osmosis, mostly across the gills, and it is in danger of swelling and of its blood growing too dilute. To cope, it never drinks; it passes a large amount of very dilute urine to throw out the surplus water, and it takes up salts actively through its gills to replace those it loses.

A marine bony fish has blood less salty than the sea, so water is drawn out of its body into the sea by osmosis, and it is in danger of drying out. To cope, it drinks sea water to make good the loss; it passes only a little, concentrated urine, and it pumps the extra salt it swallows out actively through its gills.

So the two fish are mirror images of each other. The freshwater fish must bail out water and gather salt, whereas the marine fish must hoard water and shed salt.

Examiner's Note
Credit comes from matching each problem to its remedies and from seeing the two fish as mirror images. Give one fish only, or muddle which way the water moves, and the answer falls apart.

False Confidence Alert
Most students say a freshwater fish drinks a great deal of water. It does not drink at all; water floods in through its surface by osmosis, and its task is to pass the surplus out as dilute urine.

Question 98

A runner finishes a long race on a hot day, having lost a great deal of water in sweat. Explain what happens to her ADH and to her urine, and why.

Model Answer

Losing so much water in sweat has made her blood more concentrated, and the osmoreceptors in her hypothalamus detect this. So more ADH is released from the posterior pituitary into her blood.

The extra ADH makes the collecting ducts of her kidneys reabsorb more water back into the blood, so she passes only a small amount of dark, concentrated urine. In this way the water is saved and her blood is brought back to its proper concentration; when she later drinks and her blood turns dilute again, less ADH is released and she passes more, paler urine.

Examiner's Note
The chain must run in full: concentrated blood, osmoreceptors, more ADH, more water reabsorbed, little concentrated urine. Jumping straight to 'little urine' skips the marks in the middle.

Question 99

A desert rat may pass its whole life without ever taking a drink. Drawing together what its kidney, its gut and its habits do, explain how it survives on so little water.

Model Answer

The desert rat saves and finds water in several ways at once:

1) **Its kidney**: very long loops of Henle let it pass a tiny amount of very concentrated urine, so almost no water is lost there.
2) **Its gut**: water is reabsorbed thoroughly from the food remains, so its faeces come out very dry.
3) **Its habits**: it shelters in a cool, damp burrow by day and feeds at night, so it sweats and evaporates very little.
4) **Its water supply**: it draws the water it needs from its food and from the metabolic water made when that food, especially fat, is respired.

With its losses cut to so little and its needs met from food alone, the desert rat has no need ever to drink.

Examiner's Note
A full answer gathers all three savings, the kidney, the gut and the habits, and then names where the water comes from. Stopping at the concentrated urine leaves most of the marks on the table.

Question 100

Kipanga says that *a person who drinks a great deal of water has weak kidneys, because they keep having to run to pass urine.* Identify the mistake, and give the correct explanation.

Model Answer

Kipanga has it backwards: passing plenty of urine after drinking a great deal is a sign of healthy kidneys, not weak ones. It is exactly what good osmoregulation should do.

When a person drinks a great deal, the blood turns dilute, so less ADH is released and the collecting ducts reabsorb less water. The kidneys then pass the surplus as a large amount of dilute urine, keeping the blood from growing too watery. So the frequent, pale urine shows the kidneys working well, ridding the body of water it does not need.

Examiner's Note
The correction must turn on the ADH response to dilute blood, not merely 'the kidneys are fine'. Show that low ADH leads to less reabsorption and so to much dilute urine.

False Confidence Alert
Most students think much urine is a sign of weak or diseased kidneys. In a healthy person it is the correct answer to drinking; it is too little urine, or wrong things in it, that points to trouble.

Question 101

A shipwrecked sailor adrift at sea is warned never to drink the sea water, however thirsty he grows. Explain, using osmoregulation, why drinking sea water would make his thirst worse, not better.

Model Answer

Sea water is far saltier than the sailor's blood, so when he drinks it the salt enters his blood and makes it more concentrated still, drawing water out of his cells and sharpening his thirst.

To be rid of all that extra salt his kidneys must make urine, but they cannot make urine concentrated enough to shed so much salt without spending more water than the sea water gave him. So he loses more water than he gains, and grows more dehydrated with every mouthful.

Examiner's Note
Everything hangs on one fact: the kidney cannot make urine as salty as sea water, so shedding the salt costs more water than the drink supplied. Stop at 'sea water is salty' and the marks are lost.

False Confidence Alert
Most students assume any drink must quench thirst. Sea water is the exception: the salt in it takes more water to flush out than the drink itself provides, so it leaves the body drier.

HOT QUESTIONS

These questions go further than recall. They ask you to connect ideas from across the chapter, to weigh claims and evidence, and to reason about situations you have not met before. Take your time; the bold opening of each answer carries the heart of the reasoning, and the boxes show how the strongest answers are built.

Question 102

Most of the body's controls work by negative feedback, while positive feedback is rare and is always switched off in the end. Explain why an unchecked positive feedback would be dangerous to the body, and why negative feedback suits the work of homeostasis far better.

Model Answer

Positive feedback drives a change further and further, the way each contraction in birth brings on a stronger one. If such a loop were never switched off, it would carry the body further and further from its set point without limit; a small rise in temperature, say, could feed upon itself into a deadly fever.

Negative feedback does the opposite: it reverses every change and so always pulls the body back towards its set point. This is exactly what homeostasis needs, a steady internal environment, so the body keeps positive feedback only for events that must be driven quickly to an end, like birth, and trusts everything that must be held steady to negative feedback.

Examiner's Note
The danger must be tied to the runaway away from the set point, and the fitness of negative feedback to restoring it. Defining the two kinds without that contrast of direction leaves the question half answered.

False Confidence Alert
Most students treat positive feedback as a faster kind of negative feedback. It is the opposite in direction: it drives the body away from the set point, not back towards it.

Question 103

When a person has a fever, the body holds its temperature at a higher level than usual, and may even shiver to reach it though the skin already feels hot. Using the idea of a set point and negative feedback, explain this puzzling behaviour.

Model Answer

In a fever the thermostat in the hypothalamus has been re-set to a higher set point than the usual 37 degrees. The negative-feedback system has not broken; it is simply working to reach and hold this new, higher target instead of the old one.

So while the body is still below the new set point it behaves as though it were cold, shivering and narrowing its skin vessels to raise its temperature, even though it feels hot to the touch. When the fever later breaks and the set point drops back, the same system sweats to shed the extra heat. The behaviour is strange only until you see that it is the set point, not the machinery, that has moved.

Examiner's Note
Everything turns on the raised set point: the feedback machinery is unchanged and still chases its target. An answer that says only 'the body is fighting infection', without the moved set point, never explains the shivering.

Question 104

A student says that homeostasis means the internal environment never changes at all. Evaluate this claim, using the idea of dynamic equilibrium.

Model Answer

The claim is not quite right. The internal environment is not fixed and still; its values rise and fall a little all the time as the body feeds, works and rests.

What homeostasis holds steady is the average, by correcting each small departure as it arises; this is dynamic equilibrium, a balance kept in constant motion rather than a frozen stillness. So a truer statement is that the internal environment is held within narrow limits about a set point, not that it never changes at all.

> **Examiner's Note**
> A real evaluation does not just agree or reject; it replaces 'never changes' with the dynamic-equilibrium picture of small swings corrected about a set point. Stop at 'the student is wrong' and the marks are not earned.

> **False Confidence Alert**
> Most students imagine homeostasis as a flat, unmoving line. It is really a small wobble held closely about the set point, each drift away being pulled back.

Question 105

Predict what would happen to the control of blood glucose if the pancreas still sensed the glucose and released insulin correctly, but the liver no longer answered the insulin. What does this tell you about a control system?

Model Answer

The blood glucose would stay high after a meal even though the pancreas worked and insulin was present, because the liver would not take the glucose up and store it. The detector senses and signals as it should, but with no effector to act on the signal, nothing is put right.

This shows that a control system needs every part working together, the detector, the control centre and the effector, and is only as good as its weakest link. A signal that no part acts upon changes nothing; the correction depends on the effector actually carrying it out.

> **Examiner's Note**
> The prediction must reach the key result, glucose staying high despite a working detector and real insulin, and the lesson must be the whole loop's dependence on its effector. Naming the parts without that consequence misses the point.

Question 106

An ectotherm needs far less food than an endotherm of the same size, yet it is the endotherms that live in the coldest places on Earth. Weigh the advantages and the disadvantages of being an endotherm.

Model Answer

An endotherm makes its own heat and holds a steady warm body, so it can stay active in the cold, feed by night, and live where an ectotherm could not, from polar ice to cold mountains, with its enzymes always near their best temperature. This freedom from the temperature of its surroundings is the great advantage.

But making heat without rest costs a great deal of energy, so an endotherm must eat far more food, and far more often, than an ectotherm of its size. Where food is scarce or the air is already warm, the cheap, slow ectotherm does better. So neither way of life is best everywhere; each is suited to its own conditions.

> **Examiner's Note**
> A true weighing gives both sides and lands on 'it depends on the conditions'. Listing only the advantages of endothermy, or only its costs, earns half the marks at most.

Question 107

On a very hot, dry day a mammal must do two things at once: keep cool and save water. Yet its chief way of keeping cool, sweating, is also its chief way of wasting water. Explain this conflict, and how a desert mammal escapes it.

Model Answer

Sweating cools the body because water evaporates from the skin and carries the heat away, but that same water is then lost from the body for good. So in a hot, dry place the two needs pull against each other: an animal that sweats freely to stay cool soon runs short of water, while one that hoards its water cannot use sweating to keep cool.

A desert mammal escapes the conflict by not relying on sweating at all. Instead it dodges the heat, resting in a cool burrow by day and coming out at night, so it never has to cool itself by evaporation and its water is saved. By avoiding the heat rather than fighting it, the animal keeps cool and keeps its water together.

Examiner's Note
The conflict must be put as a genuine trade-off, the same water both cooling the body and being lost, and the escape must be behavioural avoidance, not 'drinking more'. Miss the trade-off and the rest of the answer has nothing to resolve.

False Confidence Alert
Most students say the animal simply drinks more to replace the sweat. In the desert there is little or nothing to drink; the animal avoids the heat so that it need not sweat in the first place.

Question 108

A desert fox has very large, thin ears that are richly supplied with blood. Suggest how these ears help it to survive the desert heat, and why this serves it better than sweating would.

Model Answer

The large, thin ears work as radiators of heat. Warm blood is brought close to the wide, thin surface of the ear, where its heat passes out into the air, and the cooled blood then returns to the body; the larger the ear, the more surface there is from which to lose heat.

This serves the fox better than sweating because it sheds heat without losing water. The ear loses heat by radiation into the air, not by evaporating the body's water, so in a desert, where water is scarce, cooling by the ears saves the very water that sweating would have spent.

Examiner's Note
The reasoning must reach the decisive point, that the ears lose heat without losing water, which is everything in a desert. Describing them as radiators but never making that comparison with sweating stops one step short.

Question 109

A newborn baby loses heat much faster than an adult, which is why a cold ward is dangerous for it. Explain why, and say what this shares with the problem faced by a mouse.

Model Answer

A baby is small, so it has a large surface area compared with its volume. Heat is made in the volume of the body but lost through its surface, so a baby loses heat quickly for its size, faster than a large adult whose surface is small for its volume, and in a cold ward it can chill dangerously fast.

This is exactly the mouse's problem. The mouse too is small, with a large surface-area-to-volume ratio, so it also loses heat fast for its size and must eat almost without stopping to replace it. Baby and mouse meet the same geometry; only their answers differ, the baby wrapped and kept warm, the mouse eating and sheltering.

Examiner's Note
Both cases must rest on the one surface-area-to-volume idea, and the parallel must be drawn out plainly. Explaining the baby alone, without naming what it shares with the mouse, leaves the 'what they share' mark unclaimed.

Language Clinic
The connector 'so' ties the baby's large surface to its fast heat loss, and the word 'exactly' binds its plight to the mouse's.

Question 110

There is no single best nitrogenous waste; each one suits the life of the animal that makes it. Evaluate this statement, comparing ammonia, urea and uric acid against where and how their animals live.

Model Answer

The statement is sound, because the worth of each waste turns on the water the animal can spare. Ammonia is very toxic but cheap to make, and it suits an animal that lives in water and can flush it away at once, like a bony fish; urea is less toxic and needs less water, suiting a land animal with some water to spare, like a mammal.

Uric acid is almost non-toxic and needs least water of all, suiting an animal that must save every drop or that grows in a shelled egg, like an insect, reptile or bird. So no one waste is best in itself: the cheap ammonia would kill a land animal that could not spare the water to flush it, while the water-saving uric acid would be needless trouble for a fish. Each is best only for its own way of life.

Examiner's Note
A real evaluation judges each waste against its animal's water supply and shows why it would fail elsewhere. Listing the three wastes with their properties, but never reaching 'best only in context', is description, not evaluation.

Question 111

A small reptile lays shelled eggs in dry desert sand, and the young develop sealed inside until they hatch. Predict which nitrogenous waste the developing embryo makes inside the egg, and explain your reasoning.

Model Answer

The embryo will make uric acid. Sealed inside a shelled egg, the waste cannot be flushed away, and there is only a little water, so the waste must be one that is both safe to store and needs almost none of that water.

Ammonia would poison the embryo, and urea would need water the egg cannot spare; only uric acid, being nearly non-toxic and almost insoluble, can be laid down as a harmless solid inside the shell until the young hatches. So the sealed, dry egg all but forces the embryo to be uricotelic.

Examiner's Note
The prediction must be reasoned from the sealed egg itself, that the waste cannot leave and little water is to hand, ruling out ammonia and urea in turn. 'Uric acid because reptiles use it' states the answer but skips the reasoning the question asks for.

False Confidence Alert
Most students choose the waste by habit, naming ammonia or urea. The sealed, dry egg rules both out: ammonia would poison the embryo it cannot escape, and urea would cost water the egg has not got.

Question 112

The liver makes urea but the kidney removes it; neither organ alone could rid the body of its nitrogen. Explain how the two share the task, and predict what would happen to the blood if the liver failed but the kidneys still worked.

Model Answer

The two organs do different halves of one job. The liver takes the poisonous ammonia made from surplus amino acids and turns it into urea, which is far less toxic; the blood then carries that urea to the kidney, which filters it out and passes it from the body in the urine.

If the liver failed but the kidneys still worked, the body could no longer turn its ammonia into urea. The kidneys would now have little urea to remove, yet the ammonia itself would gather in the blood and poison it, because the kidneys cannot do the liver's work of making it safe. So the two organs lean on each other: the kidney can remove only what the liver has first made safe.

> **Examiner's Note**
> The prediction must reach the sharp result, ammonia building up in the blood despite healthy kidneys, which shows the kidney cannot stand in for the liver. A vague 'wastes build up' names neither the waste nor the reason.

Question 113

The kidney filters out almost everything useful from the blood and then takes most of it back, which seems a wasteful way to work. Evaluate why this two-stage design is in fact better than a filter that picked out and removed only the wastes.

Model Answer

A filter that removed only the wastes would have to recognise every kind of waste molecule, and would need a separate carrier for each one, including new poisons and drugs the body had never met. Faced with a waste it had no carrier for, such a filter would simply let it stay in the blood.

The kidney's way is simpler and safer: it filters out everything small by size alone, useful and waste together, and then reabsorbs the short list of things it wants to keep. Because the body knows exactly what to save but cannot know every waste it must lose, it is far easier to take back the few useful substances than to recognise the endless list of wastes. So the two-stage design clears even unfamiliar poisons, which a selective filter never could.

> **Examiner's Note**
> The evaluation must reach why filter-then-reabsorb is the more robust design, that it copes with unknown wastes by saving a known short list rather than recognising an endless one. Calling it 'two stages' without that argument does not weigh the design.

> **False Confidence Alert**
> Most students agree the two-stage way is wasteful. It is in truth the cleverer design: saving a known handful of useful substances is easier and safer than building a separate carrier to recognise every possible waste.

Question 114

Predict the effects on the rest of the body if the filtration barrier of a person's kidneys slowly became leaky to protein over many months.

Model Answer

Protein would be lost from the blood into the urine month after month, so the amount of protein in the blood plasma would steadily fall. What began as a fault in the filter would slowly empty the blood of its proteins.

The plasma proteins help to hold water in the blood by drawing it back from the tissues; with fewer of them, water would stay in the tissues instead of returning to the blood, and the body would swell with fluid, an oedema. The person would also grow short of the very proteins being lost. So a leak that seems to concern the kidney alone would, in time, waterlog the whole body.

Examiner's Note
The prediction must follow the chain to a body-level effect, low plasma protein leading to water held in the tissues and so to oedema. Stopping at 'protein in the urine' never answers 'effects on the rest of the body'.

Question 115

A poison stops the cells lining the proximal tubule from making or using ATP. Predict what would then appear in the urine, and explain why.

Model Answer

Glucose and salts would appear in the urine, which a healthy urine never holds. They are normally taken back from the filtrate into the blood at the proximal tubule, leaving none behind.

That reabsorption is active: it needs energy from ATP to pump the glucose and the salts against their concentration gradient, out of the tubule and into the blood. With no ATP the pumps stop, so the glucose and salts are left in the filtrate and carried out in the urine. The poison shows that reabsorption is an active, energy-using process, not a passive leak.

Examiner's Note
The prediction must name glucose and salts and tie their loss to the failure of active, ATP-driven reabsorption. 'The kidney stops working' is too loose to earn the marks the question offers.

Question 116

A dialysis machine can clean the wastes from a patient's blood, yet a kidney transplant is still far better. Using all the things a kidney does, evaluate why a machine is not a full replacement for a living kidney.

Model Answer

A dialysis machine does only one of the kidney's jobs well: it clears the wastes such as urea and helps balance the water and salts, but only in sessions every few days, not minute by minute as a living kidney does. For waste removal alone it is a fair stand-in, though a rougher one.

A living kidney does more than clean the blood: it makes the hormone erythropoietin that tells the marrow to form red cells, and it helps turn vitamin D into its active form for healthy bones, while the machine does neither. So a dialysis patient may still grow anaemic and weak-boned, and never has the constant fine control a real kidney gives. The machine can save a life, but only a transplant restores all the kidney's work.

Examiner's Note
A full evaluation goes past 'it cleans the blood' to the jobs dialysis cannot do, the erythropoietin, the vitamin D and the minute-by-minute control. An answer that praises only the waste-clearing misses why the transplant wins.

False Confidence Alert
Most students think dialysis fully replaces a kidney because it cleans the blood. It misses the kidney's hormone work, so patients on dialysis may still become anaemic and suffer weak bones.

Question 117

Explain why the nephron must carry out its work in the order ultrafiltration, then reabsorption, then concentration, and why this order could not sensibly be reversed.

Model Answer

Each step depends on the one before it. Ultrafiltration must come first, to force the water and small molecules out of the blood into the nephron; until that filtrate has been made, the later steps have nothing to work upon.

Reabsorption must follow, taking back the glucose, salts and much of the water as the filtrate flows along the tubule; only then, with the useful things saved, can the last step concentrate what is left by drawing yet more water out in the collecting duct. The order could not be reversed: you cannot reabsorb from a filtrate not yet made, nor sensibly concentrate a urine before its glucose and salts have been recovered. So the sequence simply follows the logic of the job itself.

Examiner's Note
What is rewarded is showing each step needs the one before, not listing them in order. The 'could not be reversed' point must be earned: there is nothing to reabsorb until filtration has made the filtrate.

Language Clinic
The phrase 'only then' fixes concentration after reabsorption, and 'so' closes the answer on the sequence following the logic of the work.

Question 118

Kidney failure can leave a person swollen, anaemic, poisoned and weak in the bones, all at once. Explain how the failure of a single organ can cause such different troubles.

Model Answer

The kidney is not a one-task organ; it does several different jobs, and failure stops them all together. Because it can no longer remove the wastes, urea gathers in the blood and poisons the body; and because it can no longer balance the water, fluid collects in the tissues and the person swells with oedema.

The kidney also makes two things the body needs for itself. It makes the hormone erythropoietin, which tells the marrow to form red cells, so without it the person grows anaemic; and it activates vitamin D, which the body needs to take up calcium, so without it the bones grow weak. One failed organ brings many troubles because that one organ did many jobs.

Examiner's Note
Each trouble must be pinned to a separate kidney job, waste removal, water balance, erythropoietin and vitamin D. A general 'the kidney is important' never reaches the one-organ-many-jobs point the question turns on.

Question 119

A patient with diabetes insipidus is given ADH and recovers, while a patient with diabetes mellitus is given the same ADH and is not helped at all. Explain why, and say what this shows about the two diseases.

Model Answer

Diabetes insipidus is caused by a lack of ADH, so giving the patient ADH simply replaces what was missing. The collecting ducts can reabsorb water once more, the flood of dilute urine stops, and the patient recovers.

Diabetes mellitus is not a fault of ADH at all, but of insulin, so adding ADH does nothing for the real trouble; the blood sugar stays high and still spills into the urine. This shows that the two diseases, alike in causing much urine and thirst, are quite different in cause: one is a fault in handling water, the other in handling sugar, and each needs its own missing hormone, not the other's.

Examiner's Note
The contrast must rest on which hormone is missing: ADH replaces ADH, but it cannot mend a fault of insulin. An answer that never names the two different missing hormones cannot explain the two different results.

> **False Confidence Alert**
> Most students expect both kinds of diabetes to answer to one treatment, because they share the name and the symptom of much urine. The cure must match the cause, not the symptom; the missing hormone differs in each.

Question 120

Two mammals are alike in every way but one: the first has much longer loops of Henle than the second. Predict which makes the more concentrated urine, and explain fully why, linking the loop's length to survival on dry land.

Model Answer

The first mammal, with the longer loops, makes the more concentrated urine. A longer loop of Henle reaches deeper into the medulla and pumps out salt along a greater length, so it builds a saltier medulla than a short loop ever could.

The saltier the medulla, the more water can be drawn out of the collecting duct by osmosis as the urine passes down through it, so the longer-looped mammal can pass a urine far more concentrated than its blood. On dry land this is a great advantage: losing less water in getting rid of its wastes, the long-looped animal can live where water is scarce, while the short-looped one could not.

> **Examiner's Note**
> The prediction must be carried through the whole chain, longer loop to saltier medulla to more water drawn from the collecting duct to more concentrated urine to survival where water is scarce. 'Longer loop, more concentrated urine' without the medulla in between is only the ends without the middle.

Question 121

The kidney is controlled by two different hormone systems: ADH, and the renin-angiotensin-aldosterone system. Explain how the two differ in what they sense and in what they control, and why the body needs both.

Model Answer

ADH answers to the concentration of the blood. When the blood grows too concentrated, ADH is released and makes the kidney reabsorb more water, so it controls the body's water and the concentration of its fluids.

The renin-angiotensin-aldosterone system answers instead to the blood pressure and the level of sodium. When these fall, the kidney releases renin, which through angiotensin brings out aldosterone, and the kidney then reabsorbs more sodium, with water following, so it controls the body's salt and its blood pressure. The body needs both because water balance and salt-and-pressure balance are two separate things to hold steady: one system watches the concentration of the blood, the other its pressure and salt, and between them they keep the whole balance.

> **Examiner's Note**
> Tell the two apart by both what each senses and what each controls: ADH, concentration to water; the renin system, pressure and sodium to salt and pressure. Blur the two, or give only ADH, and the reason the body needs both is lost.

Question 122

A sea bird may drink sea water and yet not grow dehydrated, because a salt gland in its head pours out drops far saltier than its blood. Explain how this lets the bird do what a shipwrecked sailor cannot.

Model Answer

The sailor cannot drink sea water because his kidneys cannot make urine as salty as the sea. To shed the salt he swallows he must spend more of his own water than the sea water gave him, so he ends up drier with every drink.

The sea bird escapes this trap because its salt gland can pour out a fluid far saltier than sea water, saltier than any kidney could make. It can therefore be rid of all the swallowed salt in only a little water, less than the sea water brought in, so it keeps a net gain of water from each drink. Where the sailor loses water by drinking the sea, the bird gains it, because it carries an organ that can out-salt the sea.

Examiner's Note
Everything turns on the salt gland making a fluid more concentrated than sea water, which the human kidney cannot. The bird gains water and the sailor loses it; an answer that says only 'the bird has a salt gland', without that comparison, never explains the difference.

False Confidence Alert
Most students think the bird's kidneys do the work, or that the sailor too could survive by passing salty urine. The human kidney cannot beat sea water; only the bird's special gland can make a fluid saltier than the sea.

Question 123

Temperature regulation, excretion and osmoregulation are taught as separate topics, yet all three are the same idea at work. Explain the single principle that unites them, using one example from each.

Model Answer

The one principle is homeostasis by negative feedback: the body holds each condition of its internal environment steady about a set point, sensing any change and acting to reverse it, so the same loop of detector, control centre and effector lies under all three. Different conditions are held steady, but the way they are held steady is the same.

In temperature regulation, the body senses a rise in temperature and reverses it by sweating and vasodilation, holding the temperature near 37 degrees. In excretion, it senses the build-up of wastes such as urea and removes them, holding their level low; in osmoregulation, it senses the blood growing too concentrated and reverses it by releasing ADH to save water, holding the water balance steady. Three topics, one idea: each is the body keeping its internal environment constant by correcting every change.

Examiner's Note
The uniting idea must be named, negative feedback holding the internal environment about a set point, and then shown at work in each of the three, not merely the three topics described side by side. The marks are in the single thread, not in the examples alone.

Language Clinic
The connector 'so' ties the negative-feedback principle to the one loop beneath all three, and the matching openings 'In temperature regulation... In excretion... In osmoregulation' show the single idea at work in each.

PART TWO
EXAMINATIONS

GENERAL INSTRUCTIONS

These instructions apply to all five Form Five examination papers (Papers 1 to 5). Read them once, before you begin; they are not repeated on the individual papers.

1. Each paper consists of three sections: A, B and C, with a total of ten (10) questions.
2. Answer seven (7) questions in all: three (3) from Section A, two (2) from Section B and two (2) from Section C.
3. Section A carries 30 marks, Section B carries 30 marks and Section C carries 40 marks; each paper totals 100 marks.
4. The marks for each question, or part of a question, are shown in brackets beside it.
5. Each paper is to be completed in three (3) hours.
6. All diagrams must be drawn in pencil and clearly labelled; non-programmable calculators may be used.
7. Cellular phones and any other unauthorised materials are not allowed in the examination room.

How each paper is built

Section	Question type	Printed	Answer	Each	Section marks
A	Short-answer	4	3	10	30
B	Structured	3	2	15	30
C	Essay	3	2	20	40
Total		**10**	**7**		**100**

Two ways to use a paper. To sit it as a timed examination, answer the seven questions above in three hours for 100 marks. To revise the whole syllabus instead, answer all ten questions, untimed; the solutions cover every question.

Paper 1

FORM FIVE EXAMINATION

Biology **Time: 3 Hours**

SECTION A (30 Marks)

Answer THREE (3) questions from this section. Each question carries 10 marks.

Question 1

A Form Five student examines onion cells under a light microscope and turns it to its highest power. The nucleus comes into clear view, but the tiny mitochondria in the cytoplasm never become sharp, however much the image is enlarged.

(a) Explain why increasing the magnification cannot make the mitochondria appear sharp. ***(04 marks)***
(b) The actual length of a chloroplast is 5 µm. In an electron micrograph it appears 40 mm long. Calculate the magnification of the image. ***(03 marks)***
(c) Give three reasons why the electron microscope reveals finer detail than the light microscope. ***(03 marks)***

Question 2

Ugali pounded from maize flour, the sweet juice of ripe sugarcane, and the tough fibres of the cane stalk are all built from carbohydrate, yet the body treats each one very differently.

(a) With one example of each, describe the three classes of carbohydrate according to the number of sugar units they contain. ***(06 marks)***
(b) Explain why cellulose, although it is a carbohydrate, passes through the human gut undigested. ***(04 marks)***

Question 3

An early naturalist grouped the fruit bat, the swallow and the butterfly together, reasoning that anything able to fly belonged in one group. A modern biologist places each of the three in a completely different group.

(a) Name the type of classification the naturalist was using, and explain why grouping organisms by the ability to fly alone is unsatisfactory. ***(04 marks)***
(b) The whale lives in the sea and is shaped like a fish, yet it is classified with the mammals. Use this example to explain the basis of the natural system of classification. ***(03 marks)***
(c) Give three reasons why biologists prefer the natural system. ***(03 marks)***

Question 4

When a person treads on a sharp stone the foot is snatched up almost at once, but the pounding heart and uneasy feeling that follow a sudden fright die away only slowly.

(a) Explain how this everyday experience reflects the work of two different coordinating systems in the body. ***(02 marks)***
(b) Distinguish between nervous and hormonal (endocrine) coordination, using four points. ***(08 marks)***

SECTION B (30 Marks)

Answer TWO (2) questions from this section. Each question carries 15 marks.

Question 5

On a bright afternoon, streams of gas bubbles rise from the cut stem of a water plant in a pond. The gas collected relights a glowing splint, showing it to be oxygen, which is set free in the first stage of photosynthesis.

(a) Write the overall balanced equation for photosynthesis, and name the sources of the carbon dioxide and the water that the plant uses. ***(03 marks)***

(b) Name the precise site of the light-dependent reaction within the chloroplast. ***(01 mark)***

(c) Describe what happens during the light-dependent reaction with reference to: ***(09 marks)***

(i) the absorption of light by chlorophyll;

(ii) the photolysis of water;

(iii) the formation of ATP and reduced NADP.

(d) State the two products of this stage that pass to the Calvin cycle, and explain why the Calvin cycle would soon stop if the light-dependent reaction failed. ***(02 marks)***

Question 6

A labourer digging his field on a hot afternoon breathes deeply and quickly. Each breath carries air down to millions of tiny air sacs, the alveoli, where oxygen crosses into the blood.

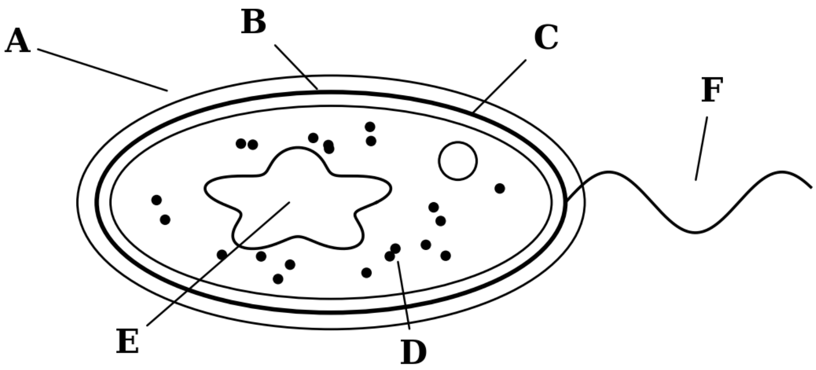
(a) State four features of an efficient respiratory surface, and explain how each one speeds up the exchange of gases. ***(08 marks)***

(b) Trace the path taken by a molecule of oxygen from the air in an alveolus to the haemoglobin in a red blood cell, and explain what keeps it moving in that direction. ***(05 marks)***

(c) Explain why the rate and depth of breathing increase while the labourer is working hard. ***(02 marks)***

Question 7

The diagram below shows the structure of a generalised bacterial cell as revealed by the electron microscope.



(a) Name the parts labelled A to F. ***(06 marks)***

(b) State the function of each of the following: ***(03 marks)***

(i) the cell wall;

(ii) the capsule;

(iii) the flagellum.

(c) With a named example in each case, describe three ways in which bacteria are important in the daily life and economy of Tanzania. ***(06 marks)***

SECTION C (40 Marks)

Answer TWO (2) questions from this section. Each question carries 20 marks.

Question 8

Far more of Tanzania's animals are invertebrates than vertebrates. They reach from the simple Hydra of a pond, through the flatworms and the segmented earthworm of the soil, to the countless insects of the air.

(a) Giving a named example in each case, write an account of the distinctive features of any four invertebrate phyla. ***(16 marks)***

(b) Explain two reasons for the great success of the invertebrates. ***(04 marks)***

Question 9

A cattle herder walks all day under the hot sun of central Tanzania. He drinks little and sweats heavily, and by evening he passes only a small quantity of dark, concentrated urine.

(a) With the help of a large labelled diagram, describe the structure of a single nephron (kidney tubule). ***(08 marks)***

(b) Explain how the kidney increases the amount of water it returns to the blood on a day like this, and so keeps the water content of the body constant. ***(12 marks)***

Question 10

When a child's hand touches a hot cooking pot, the message races from the skin along a nerve fibre to the spinal cord and back to the arm muscle in a fraction of a second. Where one nerve cell meets the next, the message must also cross a tiny gap.

(a) Describe how a nerve impulse is transmitted along an axon. ***(12 marks)***

(b) Explain how a nerve impulse is transmitted across a synapse from one neurone to the next. ***(08 marks)***

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Paper 2

FORM FIVE EXAMINATION

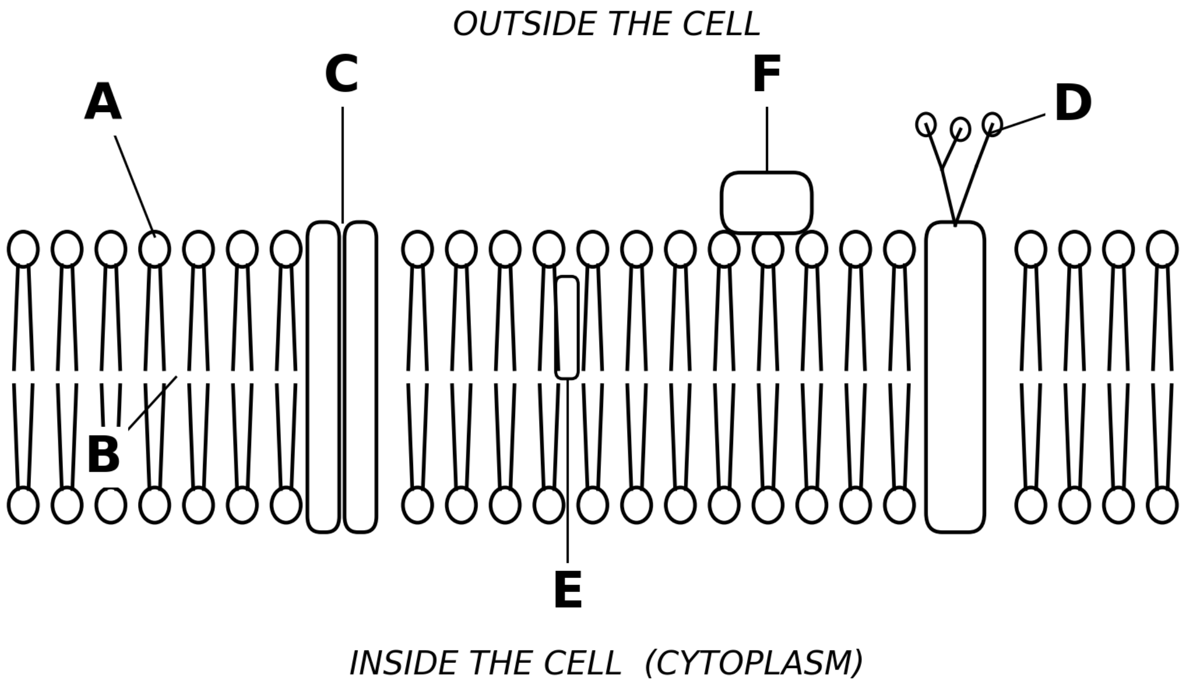
Biology Time: 3 Hours

SECTION A (30 Marks)

Answer THREE (3) questions from this section. Each question carries 10 marks.

Question 1

Every living cell is wrapped in a thin plasma membrane that decides what may enter and leave it. The diagram below shows the currently accepted fluid-mosaic model of this membrane.



(a) Name the parts labelled A to F. ***(06 marks)***

(b) Explain why the model is described as both "fluid" and a "mosaic". ***(02 marks)***

(c) Give one reason why oxygen passes through the membrane easily while most ions cannot cross it on their own. ***(02 marks)***

Question 2

A groundnut seed stores its energy chiefly as oil, and an animal stores its long-term energy reserve as fat beneath the skin, rather than as carbohydrate. Fat is the body's most concentrated energy store.

(a) Giving two points, explain why fat is a better long-term energy store than carbohydrate. ***(04 marks)***

(b) With one example of each, classify lipids as simple, compound and derived. ***(03 marks)***

(c) Apart from energy storage, state three other roles of lipids in living organisms. ***(03 marks)***

Question 3

Throughout the world the leopard is known by one scientific name, *Panthera pardus*, whatever local language is spoken. Biologists also place it in a series of ever-larger groups.

(a) Arrange the following groups in the correct order, from the largest to the smallest: family, kingdom, genus, order, species, class, phylum. ***(03 marks)***

(b) State two rules that are followed when writing the scientific name of an organism. ***(02 marks)***

(c) Explain why one internationally agreed scientific name is more useful to biologists than local common names. ***(03 marks)***

(d) Name the genus and the species to which the leopard *Panthera pardus* belongs. ***(02 marks)***

Question 4

If a finger touches a flame, it is snatched back before the person has consciously felt the pain or decided to move. This automatic, protective response is a reflex action.

(a) Name, in the correct order, the parts of the reflex arc through which the impulse passes. ***(05 marks)***

(b) Explain why a reflex action is faster than a voluntary action. ***(03 marks)***

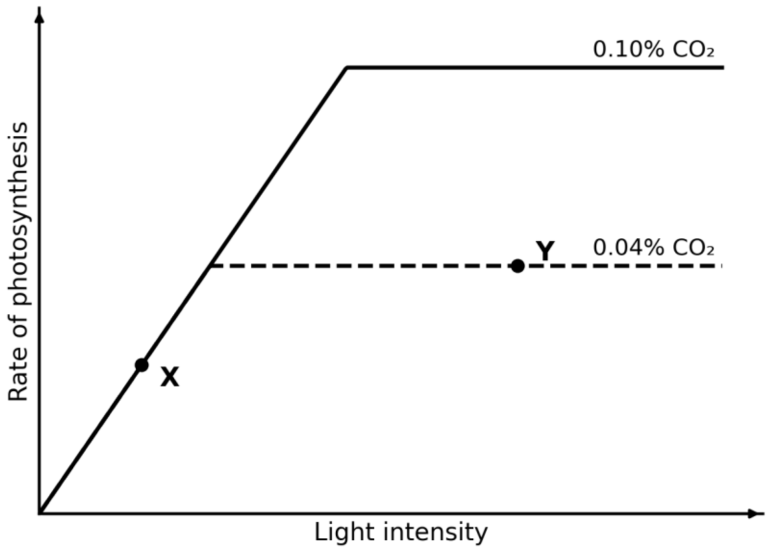
(c) State two examples of protective reflex actions in human beings. ***(02 marks)***

SECTION B (30 Marks)

Answer TWO (2) questions from this section. Each question carries 15 marks.

Question 5

A maize plant builds its sugars in the second stage of photosynthesis, the Calvin cycle, using the ATP and reduced NADP made in the light. The graph below shows how the rate of photosynthesis changes with light intensity at two different carbon dioxide concentrations.



(a) Describe the main events of the Calvin cycle (the light-independent reaction), naming the principal substances involved. ***(07 marks)***

(b) Using the graph, explain how a limiting factor controls the rate of photosynthesis, and state which factor is limiting the rate at point X and at point Y. ***(06 marks)***

(c) Explain how a farmer growing vegetables in a greenhouse could use this knowledge to raise the yield. ***(02 marks)***

Question 6

Whether a grain of glucose is broken down in a runner's muscle or in the yeast used to brew mbege, the first stage is the same: glycolysis. What happens to the product afterwards depends on whether oxygen is present.

(a) Outline the main events of glycolysis, and state its net yield of ATP. ***(06 marks)***

(b) Describe the fate of pyruvate (pyruvic acid) in the presence of oxygen, in a muscle without oxygen, and in yeast without oxygen. ***(06 marks)***

(c) Explain why anaerobic respiration releases far less energy than aerobic respiration. ***(03 marks)***

Question 7

A single drop of water from a Tanzanian pond, placed under the microscope, may hold hundreds of single-celled organisms of the kingdom Protoctista, among them *Amoeba*, *Euglena* and *Paramecium*.

(a) State the structure used for movement by each of *Amoeba*, *Euglena* and *Paramecium*. ***(03 marks)***

(b) *Euglena* is claimed by botanists as a plant and by zoologists as an animal. Giving its plant-like features and its animal-like features, explain why it is difficult to place in a single kingdom. ***(06 marks)***

(c) Name one disease of human beings caused by a member of the Protoctista, and outline how it is spread and how it affects the people of Tanzania. ***(06 marks)***

SECTION C (40 Marks)

Answer TWO (2) questions from this section. Each question carries 20 marks.

Question 8

No other group of animals is as numerous or as widespread as the arthropods. In Tanzania alone they include the malaria mosquito, the honey-bee, the cattle tick, the freshwater crab and the millipede of the forest floor.

(a) Describe the distinguishing features of any four classes of the phylum Arthropoda, giving a named example of each. ***(12 marks)***

(b) Explain four reasons for the great success of the arthropods. ***(08 marks)***

Question 9

After a meal rich in protein, such as meat or beans, the body takes in more amino acids than it can use. They cannot be stored, yet they must not be wasted, and the work of dealing with them falls to the liver.

(a) Describe the process of deamination, and explain how the liver makes the resulting waste safe for excretion. ***(10 marks)***

(b) Describe four other roles of the liver in maintaining a constant internal environment. ***(10 marks)***

Question 10

A farmer notices that his bean shoots bend towards the light of the window, that green bananas ripen faster when one ripe banana is placed among them, and that leaves fall in the dry season. All these are controlled by plant hormones (phytohormones).

(a) Describe the main effects of any three named plant hormones. ***(12 marks)***

(b) Using an example of each, explain how two plant hormones may act synergistically, and how two may act antagonistically. ***(08 marks)***

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Paper 3

FORM FIVE EXAMINATION

Biology Time: 3 Hours

SECTION A (30 Marks)

Answer THREE (3) questions from this section. Each question carries 10 marks.

Question 1

Under the electron microscope a bacterial cell and a human cheek cell look utterly different: the bacterium has no nucleus and few internal structures, while the cheek cell has a true nucleus and many membrane-bound organelles.

(a) Giving four points, describe how a prokaryotic cell differs from a eukaryotic cell. ***(08 marks)***

(b) Name two structures that are found in both a prokaryotic and a eukaryotic cell. ***(02 marks)***

Question 2

From the haemoglobin in your blood to the keratin in your hair and the enzymes in your gut, proteins do more different jobs than any other kind of molecule, yet all are built from the same set of about twenty amino acids.

(a) Draw and label the general structure of an amino acid, showing its three important groups. ***(04 marks)***

(b) Describe the four levels of structure of a protein, naming the type of bond that holds each one in place. ***(06 marks)***

Question 3

A pupil collects four small animals from a Tanzanian garden: a housefly, a spider, a millipede and an earthworm. To identify an unknown specimen, biologists use a dichotomous key, a series of paired, contrasting statements.

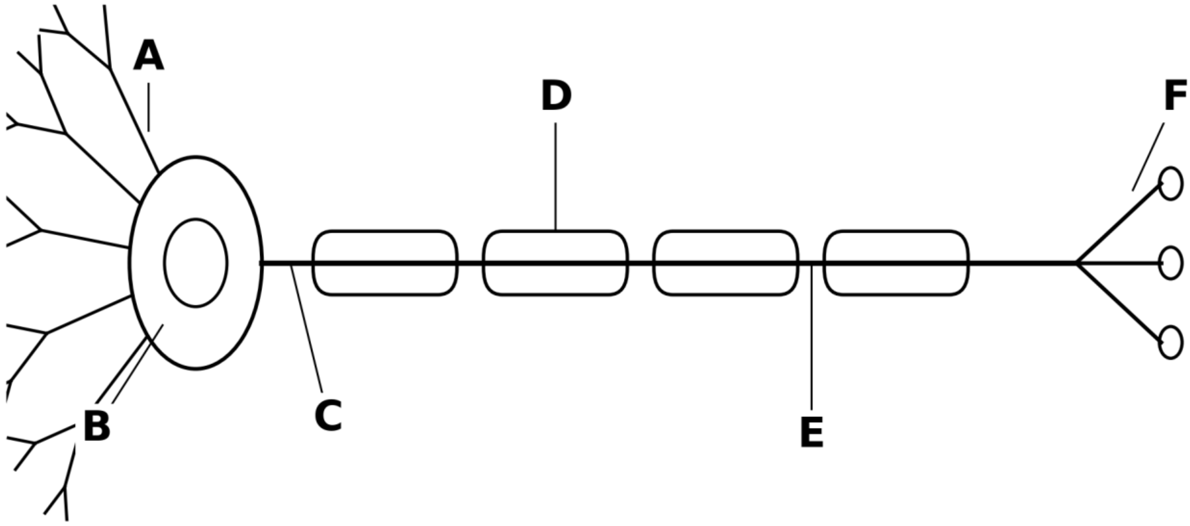
(a) Explain how a dichotomous key is used to identify an organism. ***(02 marks)***

(b) Construct a dichotomous key to separate the four animals named above. ***(06 marks)***

(c) State two qualities that make a feature suitable for use in such a key. ***(02 marks)***

Question 4

The nervous system is built of nerve cells, called neurones, which are specialised to carry electrical impulses at high speed. The following diagram shows a motor neurone.



(a) Name the parts labelled A to F. ***(06 marks)***

(b) Explain how the resting potential is maintained across the membrane of a resting neurone.***(04 marks)***

SECTION B (30 Marks)

Answer TWO (2) questions from this section. Each question carries 15 marks.

Question 5

A plate of *ugali* and beans eaten at lunch is a mixture of starch and protein. The body can use neither until it has been broken down into small, soluble molecules that can pass into the blood.

(a) Explain why large food molecules must be digested before the body can use them. ***(03 marks)***

(b) Name the enzymes that bring about the complete digestion of starch and of protein, and state the final product into which each food is broken down. ***(06 marks)***

(c) Describe how the soluble products of digestion are absorbed into the blood in the small intestine.***(06 marks)***

Question 6

After glycolysis, when oxygen is available, the real harvest of energy begins inside the mitochondrion, where most of a cell's ATP is finally made.

(a) State the precise site, within the mitochondrion, of the Krebs cycle and of the electron transport chain. ***(02 marks)***

(b) Outline what happens to pyruvate in the link reaction and the Krebs cycle. ***(07 marks)***

(c) Explain the part played by oxygen in the electron transport chain, and state the total number of ATP molecules formed from the complete breakdown of one glucose molecule. ***(06 marks)***

Question 7

Fungi are found wherever there is dead matter to feed on: the grey mould *Rhizopus* spreading over a loaf of bread, the yeast that raises dough and ferments mbege, and the mushrooms that push up after the rains.

(a) State three features that are common to all fungi. ***(03 marks)***

(b) Describe how *Rhizopus* obtains its food from the bread on which it grows. ***(05 marks)***

(c) Describe the importance of fungi to the people of Tanzania, giving examples of the several ways in which they are both useful and harmful. ***(07 marks)***

SECTION C (40 Marks)

Answer TWO (2) questions from this section. Each question carries 20 marks.

Question 8

Tanzania's lakes, forests and plains are home to all five classes of vertebrate animals: the tilapia in Lake Victoria, the frog by the pond, the lizard on a sunlit wall, the weaver bird in the acacia, and the elephant on the plain.

(a) Giving a named example of each, give an account of the distinguishing features of the five classes of vertebrates. ***(15 marks)***

(b) Explain three features that allowed the reptiles, birds and mammals to live on dry land, unlike the amphibians. ***(05 marks)***

Question 9

Whether at noon under the blazing sun or in the chill before dawn, the body of a person stays close to 37 degrees Celsius. This steady temperature is held by the skin and the brain working together.

(a) Explain why it is important for a mammal to keep its body temperature constant. ***(04 marks)***

(b) Describe how the body loses heat and cools down when it becomes too hot. ***(08 marks)***

(c) Explain how the body conserves and produces heat when it becomes too cold. ***(08 marks)***

Question 10

Every movement, thought, heartbeat and memory is governed by the brain. Though it weighs little more than a kilogram, it is the most complex organ in the body, and its different regions do very different work.

(a) With the help of a labelled diagram, name the main parts of the mammalian brain. ***(08 marks)***

(b) Describe the function of each of the following: the cerebrum, the cerebellum, the medulla oblongata and the hypothalamus. ***(12 marks)***

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Paper 4

FORM FIVE EXAMINATION

Biology Time: 3 Hours

SECTION A (30 Marks)

Answer THREE (3) questions from this section. Each question carries 10 marks.

Question 1

Two organelles power the living world: the chloroplast, which captures the energy of sunlight, and the mitochondrion, which releases energy from food. Both carry deeply folded inner membranes that greatly increase their working surface.

(a) Draw and label a diagram of a mitochondrion. ***(04 marks)***

(b) Draw and label a diagram of a chloroplast. ***(04 marks)***

(c) State one way in which the structure of each of these organelles is suited to its work. ***(02 marks)***

Question 2

Many enzymes cannot work alone but need a non-protein helper, and some poisons kill by blocking enzymes altogether. Both facts are put to use in medicine and in farming.

(a) Giving an example of each, explain the part played by a cofactor and by a coenzyme in the working of an enzyme. ***(04 marks)***

(b) Describe how a competitive inhibitor and a non-competitive inhibitor each slow down an enzyme-controlled reaction. ***(06 marks)***

Question 3

When biologists sort all living things into five great kingdoms, they go not by size or by habitat but by a few deep features of the cell and of the way each organism feeds.

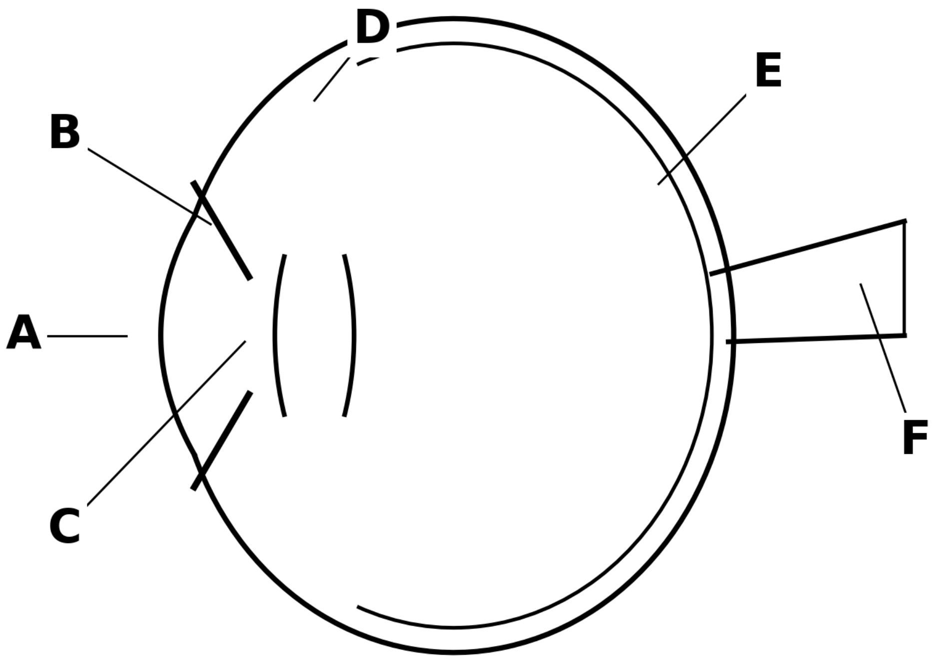
(a) State four features that are used to decide in which kingdom an organism is placed. ***(04 marks)***

(b) Explain why the fungi were taken out of the plant kingdom and given a kingdom of their own. ***(03 marks)***

(c) Explain why the five-kingdom system is preferred to the older two-kingdom system. ***(03 marks)***

Question 4

The eye works much like a camera, bending light to form a small, sharp picture on a screen of light-sensitive cells at the back. The diagram below shows a section through the human eye.



(a) Name the parts labelled A to F. ***(06 marks)***

(b) Explain how the eye adjusts so as to form a clear image first of a distant object and then of a near object. ***(04 marks)***

SECTION B (30 Marks)

Answer TWO (2) questions from this section. Each question carries 15 marks.

Question 5

Not all organisms feed in the same way. A person chews and digests solid food, a tapeworm bathes in the already-digested food of its host, and a mushroom feeds on the dead matter in which it grows.

(a) Describe what happens in holozoic, parasitic and saprophytic nutrition, giving a named example of each. ***(09 marks)***

(b) Explain three ways in which a tapeworm is adapted to its parasitic way of life. ***(06 marks)***

Question 6

A green plant must exchange gases with the air just as an animal does, taking in carbon dioxide for photosynthesis and oxygen for respiration and releasing the gases each process makes. It does all this without any lungs.

(a) Explain how the structure of a leaf allows gases to be exchanged between the air and the photosynthesising cells. ***(06 marks)***

(b) Describe how the guard cells open and close a stoma. ***(05 marks)***

(c) Explain the part played by lenticels in the gas exchange of a woody stem. ***(04 marks)***

Question 7

On a walk through a Tanzanian forest you pass mosses carpeting a damp rock, ferns uncurling in the shade, and flowering plants from the grasses underfoot to the great trees overhead. These three groups show the main steps by which plants conquered the land.

(a) State three features that are common to all members of the kingdom Plantae. ***(03 marks)***

(b) Compare a moss, a fern and a flowering plant with respect to: ***(06 marks)***

(i) the presence of vascular (conducting) tissue;

(ii) the presence of true roots;

(iii) whether they reproduce by spores or by seeds.

(c) Explain why the flowering plants (angiosperms) are the most successful and widespread of all plants. ***(06 marks)***

SECTION C (40 Marks)

Answer TWO (2) questions from this section. Each question carries 20 marks.

Question 8

Every living thing in Tanzania, from the bacteria in a spoonful of soil to the baobab tree and the lion, belongs to one of the five kingdoms of life. Each kingdom is set apart by the structure of its cells and the way its members feed.

(a) Giving a named example of each, describe the distinguishing features of the five kingdoms of living things. ***(15 marks)***

(b) Explain why viruses are not placed in any of the five kingdoms. ***(05 marks)***

Question 9

After a meal of *ugali* the sugar level of the blood rises sharply, yet within an hour or two it is back to normal; during a long day's work without food it falls, yet it does not crash. The body holds it within narrow limits.

(a) Explain why the level of glucose in the blood must be kept within narrow limits. ***(04 marks)***

(b) Describe how the body brings the blood glucose level down when it has risen too high after a meal. ***(08 marks)***

(c) Describe how the body brings the blood glucose level up when it has fallen too low. ***(08 marks)***

Question 10

Besides the swift messages of the nerves, the body is also controlled by slower chemical messengers, the hormones, which are made by ductless glands and carried in the blood to wherever they are needed.

(a) Explain how a hormone reaches the organ on which it acts, and why endocrine glands are described as ductless. ***(04 marks)***

(b) For any four named endocrine glands, state one hormone that each produces and the effect of that hormone in the body. ***(12 marks)***

(c) Explain why hormonal control is well suited to bringing about slow, long-term changes such as growth and the changes of puberty. ***(04 marks)***

ENJOY & MASTER ADVANCED BIOLOGY

Paper 5

FORM FIVE EXAMINATION

Biology Time: 3 Hours

SECTION A (30 Marks)

Answer THREE (3) questions from this section. Each question carries 10 marks.

Question 1

A cell that makes and exports a product, such as a gland cell secreting an enzyme, works like a factory in which each organelle has its own job in making, packing and dispatching the goods.

(a) State the function of each of the following organelles: ***(08 marks)***

(i) the nucleus;

(ii) the rough endoplasmic reticulum;

(iii) the Golgi body;

(iv) the lysosome.

(b) Name the organelle that would be especially plentiful in a cell that secretes large amounts of protein, and give a reason for your answer. ***(02 marks)***

Question 2

Two molecules are central to all life: water, which fills and surrounds every living cell, and ATP, the small molecule in which a cell carries its ready energy.

(a) Explain how two named properties of water make it important to living things. ***(04 marks)***

(b) Explain why ATP is described as the energy currency of the cell. ***(03 marks)***

(c) Name the three components from which a molecule of ATP is built. ***(03 marks)***

Question 3

To decide how organisms are related and how they should be grouped, a biologist looks not at one feature alone but at many: the form of the body, the way it develops, the structure of its cells, and even its chemistry.

(a) Outline four kinds of character (feature) that biologists use when classifying organisms. ***(04 marks)***

(b) Explain why evidence from DNA has made classification more reliable than the use of outward appearance alone. ***(03 marks)***

(c) Give three reasons why the classification of living things is important. ***(03 marks)***

Question 4

A bean shoot bends towards the light at the window, while the leaves of a touched mimosa fold up at once. Both are responses of plants to their surroundings, but they are of two different kinds.

(a) Distinguish between a tropism and a nastic movement. ***(04 marks)***

(b) Name the tropism shown, and state whether it is positive or negative, in each of the following: ***(04 marks)***

(i) a shoot growing towards light;

(ii) a root growing down into the soil.

(c) Explain how being positively phototropic helps a shoot to survive. ***(02 marks)***

SECTION B (30 Marks)

Answer TWO (2) questions from this section. Each question carries 15 marks.

Question 5

Besides making sugars by photosynthesis, a green plant must also take in mineral salts from the soil. A few plants, growing where the soil is too poor in nitrogen, have taken instead to trapping and digesting insects.

(a) Name two mineral elements that a plant needs, and state what each is used for. ***(04 marks)***

(b) Describe the symptoms shown by a plant that is short of: ***(04 marks)***

(i) nitrogen;

(ii) magnesium.

(c) Explain how an insectivorous plant, such as the sundew, traps and digests insects, and how this benefits the plant. ***(07 marks)***

Question 6

Air is drawn into the lungs and forced out again by the movements of the ribs and the diaphragm, and the kind of food a body is respiring can even be told from the gases it gives out.

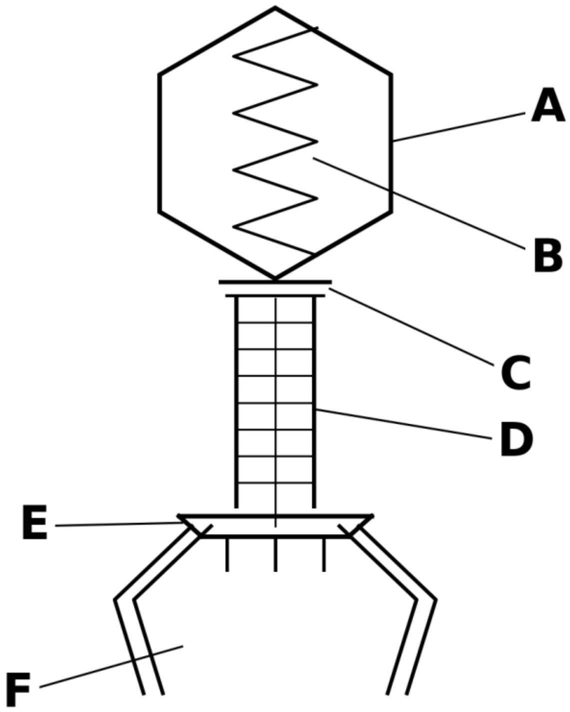
(a) Describe what happens in the chest to draw air into the lungs during inspiration (breathing in). ***(06 marks)***

(b) State three ways in which expired (breathed-out) air differs from inspired (breathed-in) air. ***(03 marks)***

(c) The respiratory quotient (RQ) is the ratio of the carbon dioxide given out to the oxygen taken in. State the RQ of a carbohydrate, and explain what an RQ of about 0.7 tells you about the food being respired. ***(06 marks)***

Question 7

Viruses sit on the very borderline of life: outside a cell they are as lifeless as a chemical crystal, yet inside one they multiply and cause disease. The diagram below shows a bacteriophage, a virus that attacks bacteria.



(a) Name the parts labelled A to F. ***(06 marks)***

(b) Give two features of viruses that suggest they are living, and two that suggest they are non-living. ***(06 marks)***

(c) Name one viral disease of human beings in Tanzania, and state how it is spread from person to person. ***(03 marks)***

SECTION C (40 Marks)

Answer TWO (2) questions from this section. Each question carries 20 marks.

Question 8

Malaria is the most deadly of all the diseases of Tanzania, and the parasite that causes it, *Plasmodium*, is wonderfully fitted to its life inside two different hosts, the human being and the mosquito.

(a) Describe the ways in which the malaria parasite, *Plasmodium*, is adapted to its life as a parasite. ***(12 marks)***

(b) Giving four points, explain why malaria is so difficult to control in Tanzania. ***(08 marks)***

Question 9

The body keeps its internal conditions steady by a method called negative feedback, and no organ shows this better than the skin, which is also the largest organ of the body and its first line of defence.

(a) Explain how negative feedback keeps a condition such as the body temperature steady. ***(08 marks)***

(b) Describe four functions of the skin, other than the sense of touch. ***(08 marks)***

(c) Apart from temperature, give two other conditions in the body that are kept steady by negative feedback, naming the organ chiefly responsible for each. ***(04 marks)***

Question 10

A person who suddenly comes face to face with a snake reacts in an instant, the heart pounding, the breathing quick, the body ready to run. This single response to danger is the work of the nervous system and the hormone system together.

(a) Describe the part played by the nervous system in the body's immediate response to the sight of sudden danger. ***(06 marks)***

(b) Describe how the hormone adrenaline brings about and keeps up the body's readiness for action. ***(08 marks)***

(c) Explain why both a nervous and a hormonal response are needed, rather than just one. ***(06 marks)***

PART THREE
MODEL SOLUTIONS TO THE EXAMINATIONS

How to use these solutions. *Each answer is written exactly as it should be set down in the examination room. It opens with the mark-bearing point stated plainly and in bold, and then develops that point in connected scientific English, in which one idea is joined to the next by linking words such as because, which in turn, consequently, as a result of which, leading to and whereas. Read every answer not only for what it states, but for the way its statements are reasoned into a single chain of cause and effect; notice, too, how each answer keeps strictly to what its question asks, and matches its length to the marks.*

ENJOY & MASTER ADVANCED BIOLOGY

Paper 1

FORM FIVE EXAMINATION

Solutions

SECTION A

Question 1

(a) **The difficulty lies in resolution, not in magnification.** Resolution is the ability to show two points that lie close together as two separate points, and it is this, rather than the size of the image, that decides how much detail can be seen. **The light microscope cannot resolve anything smaller than about 200 nm,** because it uses light, whose wavelength is relatively long; consequently the fine detail inside a mitochondrion, which lies closer together than this limit, merges into one and cannot be separated. **Greater magnification therefore only enlarges the blur,** because once the resolution limit has been reached, magnifying further merely spreads the same unresolved detail over a wider area, so that the image grows bigger without becoming any clearer.

(b) Magnification = size of image ÷ actual size of object.

Both lengths must be in the same unit, so 40 mm is written as 40 000 µm.

Magnification = 40 000 µm ÷ 5 µm = **×8000.**

(c) The electron microscope reveals finer detail for three reasons:

1) **It uses electrons in place of light:** a beam of electrons has a far shorter wavelength than light, so that it can separate structures lying extremely close together.
2) **Its resolving power is therefore far greater:** it resolves down to about 0.2 nm, whereas the light microscope manages only about 200 nm, consequently it shows as two separate points what the light microscope shows as one.
3) **It reaches a far higher useful magnification:** because the fine detail is resolved, the image can be enlarged to display ultrastructure such as ribosomes and membranes, which remain altogether invisible under the light microscope.

Question 2

(a) Carbohydrates fall into three classes according to the number of sugar units they contain:

1) **Monosaccharides are single sugar units, the simplest carbohydrates,** for example glucose; because they are small they are soluble and sweet, and they serve as the immediate source of energy in respiration.
2) **Disaccharides are formed when two monosaccharide units join by a glycosidic bond, with the loss of a water molecule,** for example sucrose, the sugar of sugarcane, which is built from glucose and fructose.
3) **Polysaccharides are very large molecules of many monosaccharide units joined by glycosidic bonds,** for example starch, the food store of maize and cassava; because they are large they are insoluble, which suits them to storage and to structural roles.

(b) **Cellulose is built of glucose units joined by β-1,4 glycosidic bonds,** which give a straight, rigid chain quite unlike the coiled α-linked chain of starch. **Humans, however, secrete no enzyme that can break this β bond:** the gut produces amylase, which splits the α bonds of starch, but it makes no cellulase, so that the cellulose chain is never cut into absorbable sugars and it passes out of the gut undigested, as roughage (dietary fibre).

Question 3

(a) **The naturalist was using an artificial system of classification,** one that groups organisms by a single, easily seen feature, here the ability to fly, rather than by their whole make-up. **Such a system brings together organisms that are not truly related:** the bat is a mammal, the swallow a bird and the butterfly an insect, so that the group mixes three very different kinds of animal which share only the habit of flight. **It also separates close relatives,** because a flightless bird such as the ostrich would be placed far from the swallow, even though the two are in truth closely related.

(b) **The whale is placed with the mammals because it shares the deep, defining features of mammals:** it breathes air with lungs, it is warm-blooded, and it suckles its young on milk. **Its fish-like shape is only a surface resemblance,** brought about by life in water; consequently the natural system looks past this outward likeness to the many internal features which show that the whale is descended from mammal ancestors. The natural system thus groups organisms by their many shared characters, which reveal true relationship, and not by a single habit or habitat.

(c) Biologists prefer the natural system for three reasons:

1) **It reflects true evolutionary relationships,** grouping together organisms that share a common ancestor, so that it shows how living things are really related to one another.
2) **It is stable and predictive,** because the members of a natural group share many characters, consequently an organism placed in the group can be expected to show further features typical of that group.
3) **It organises biological knowledge usefully,** so that what is known of one member becomes a reliable guide to its relatives, which helps in study, in agriculture and in medicine.

Question 4

(a) **The instant lifting of the foot is the work of nervous coordination,** an electrical impulse carried swiftly along nerves to the muscle, so that the response is immediate and brief. **The slow, lingering effect of fright is the work of hormonal coordination,** brought about by the hormone adrenaline carried in the blood, which acts more slowly and lasts much longer.

(b) Nervous and endocrine coordination differ in four main ways:

1) **Nature of the message:** in nervous coordination the message is an electrical impulse carried along neurones, whereas in endocrine coordination it is a chemical, the hormone, carried dissolved in the blood.
2) **Speed of action:** the nerve impulse travels very fast and brings an almost instant response, whereas a hormone travels slowly and acts only after a delay.
3) **Duration of the effect:** the effect of a nerve impulse is brief and stops quickly, whereas that of a hormone is much longer lasting.
4) **Area affected:** a nerve impulse is delivered to one particular effector and gives a localised response, whereas a hormone is carried throughout the body and may act on several organs at once.

SECTION B

Question 5

(a) The overall equation for photosynthesis is:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \quad \text{(in light, catalysed by chlorophyll)}$$

The carbon dioxide is taken from the surrounding air, entering the leaf through the stomata, **whereas the water is absorbed from the soil by the roots** and carried up to the leaf in the xylem.

(b) **The light-dependent reaction takes place on the thylakoid membranes,** the flattened sacs that are stacked to form the grana of the chloroplast.

(c)

(i) **Absorption of light by chlorophyll:** the chlorophyll in the thylakoid membrane absorbs light energy, which raises (excites) its electrons to a higher energy level, so that these high-energy electrons leave the chlorophyll and are passed to a chain of electron carriers.

(ii) **Photolysis of water:** some of the trapped energy is used to split water, $2H_2O \rightarrow 4H^+ + 4e^- + O_2$, whereby oxygen is set free as a by-product while the hydrogen ions and electrons are held back for the next step.

(iii) **Formation of ATP and reduced NADP:** as the excited electrons pass along the carriers they release energy, which is used to add phosphate to ADP and so build ATP; at the end of the chain the electrons and the hydrogen ions are joined to NADP to form reduced NADP.

(d) **The two products passed on to the Calvin cycle are ATP and reduced NADP.** The Calvin cycle draws on the ATP for energy and on the reduced NADP for the hydrogen needed to reduce carbon dioxide to sugar; consequently, if the light-dependent reaction failed, neither would be supplied, and the Calvin cycle would soon stop.

Question 6

(a) An efficient respiratory surface, such as the lining of the alveoli, has four features, each of which speeds up diffusion:

1) **A large surface area:** the millions of alveoli together give an enormous area, so that a great volume of gas can diffuse across at the same time.
2) **A very thin surface:** each alveolar wall is only one cell thick, so that the distance the gases must diffuse is extremely short, which in turn makes the exchange rapid.
3) **A moist surface:** the lining is covered by a thin film of moisture in which the gases dissolve, because they can cross the surface only in solution.
4) **A rich blood supply and good ventilation:** a dense network of capillaries carries the gases away while breathing renews the air, whereby a steep diffusion gradient is kept across the surface and diffusion continues quickly.

(b) Oxygen reaches the haemoglobin in the following way:

1) **It first dissolves** in the film of moisture that lines the alveolus.
2) **It then diffuses across two thin walls:** it passes through the single-celled wall of the alveolus and the single-celled wall of the capillary, and so into the blood plasma.
3) **It is taken up by a red blood cell:** on entering the cell it combines with haemoglobin to form oxyhaemoglobin.
4) **What keeps it moving in that direction is the diffusion gradient:** the oxygen is more concentrated in the alveolar air than in the blood, so it diffuses down the gradient, which is kept steep because breathing constantly renews the air while the circulation carries the oxygenated blood away.

(c) **The hard-working muscles respire faster and so release more carbon dioxide into the blood.** This rise in carbon dioxide is detected by the brain, which consequently quickens and deepens the breathing, both to bring in the extra oxygen the muscles need and to carry away the additional carbon dioxide.

Question 7

(a) The labelled parts are:

A: the capsule.

B: the cell wall.

C: the cell membrane (plasma membrane).

D: the cytoplasm, containing the ribosomes.

E: the nucleoid, the circular DNA.

F: the flagellum.

(b)

(i) **The cell wall** gives the bacterium a definite shape and protects it, so that the cell does not burst when water enters it by osmosis.

(ii) **The capsule** forms a protective slimy layer that helps the cell to resist drying and to withstand the defences of a host.

(iii) **The flagellum** rotates like a propeller to drive the bacterium through its liquid surroundings, and so brings about movement.

(c) Bacteria are important in daily life and the economy in three main ways:

1) **Making food and medicines:** useful bacteria are put to work in food and industry, for example *Lactobacillus* ferments milk into mtindi, whereas *Streptomyces* is used to make antibiotics such as streptomycin.

2) **Decay and soil fertility:** saprophytic bacteria rot dead plants and animals and so return nutrients to the soil, while nitrogen-fixing bacteria such as *Rhizobium*, in the root nodules of beans, enrich the soil for crops; such bacteria are also used in the treatment of sewage.

3) **Causing disease:** some bacteria cause disease in people, livestock and crops, for example *Vibrio cholerae* causes cholera and *Mycobacterium tuberculosis* causes tuberculosis, bringing heavy costs to health and to farming.

SECTION C

Question 8

(a) Four invertebrate phyla, each with a named example and its distinctive features, may be described as follows:

1) **Phylum Cnidaria (example: *Hydra*):** the body shows radial symmetry and is built of only two cell layers, so that the animal is diploblastic. It has a single body cavity, the enteron, with one opening that serves as both mouth and anus, and it bears tentacles armed with stinging cells (nematocysts) for capturing prey, while its nervous system is a simple nerve net.

2) **Phylum Platyhelminthes (example: the tapeworm):** these are flatworms with a flattened, bilaterally symmetrical body of three cell layers, so that they are triploblastic; they have no body cavity, however, and so are acoelomate. In the parasitic tapeworm the gut is altogether absent, consequently the digested food of the host is absorbed over the whole body surface.

3) **Phylum Annelida (example: the earthworm):** the body is bilaterally symmetrical and divided into many similar true segments. There is a true fluid-filled body cavity, the coelom, and a closed blood system, while small bristles called chaetae project from the segments and grip the soil during movement.

4) **Phylum Arthropoda (example: the housefly):** the body is segmented and bears jointed appendages, from which the phylum takes its name. It is covered by a hard chitin exoskeleton, which is moulted from time to time so that the animal can grow, and the body cavity is a blood-filled haemocoel.

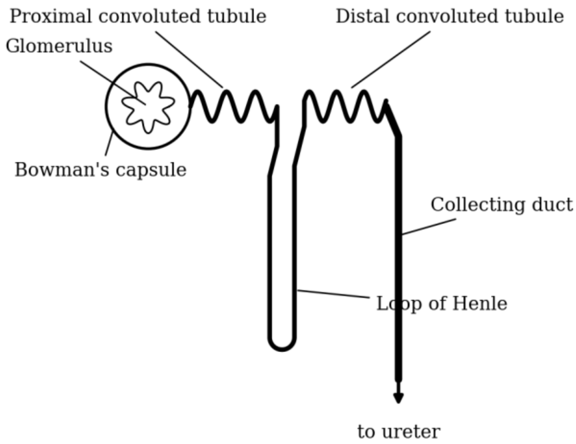
(b) The invertebrates are so successful for two main reasons:

1) **A very wide range of body forms:** their great structural diversity has fitted them to almost every habitat, on land, in fresh water and in the sea.

2) **A protective exoskeleton or cuticle:** in many groups this supports the body, greatly reduces the loss of water and guards against injury, which has been especially important in allowing the arthropods to colonise dry land.

Question 9

(a) The nephron is the working unit of the kidney; its structure is shown in the diagram below.



Its parts, in the order in which the fluid passes through them, are:

1) **The Bowman's (renal) capsule:** a cup that encloses a knot of capillaries called the glomerulus, and it is here that the blood is filtered.
2) **The proximal convoluted tubule:** the first coiled region beyond the capsule, where much of the useful filtrate, such as glucose, salts and water, is reabsorbed.
3) **The loop of Henle:** a long hairpin loop, with a descending and an ascending limb, that dips down into the medulla and helps to conserve water.
4) **The distal convoluted tubule:** the second coiled region, where the amounts of salt and water reabsorbed are finely adjusted.
5) **The collecting duct:** the tube into which the nephron empties, carrying the urine away towards the ureter.

(b) On a hot day much water is lost in sweat, so the kidney must conserve water by adjusting how much it reabsorbs, under hormonal control:

1) **The blood is monitored:** osmoreceptors in the hypothalamus of the brain constantly detect the concentration of the blood.
2) **A concentrated blood is detected:** after heavy sweating the blood becomes more concentrated, that is, its water potential falls, and this stimulates the osmoreceptors.
3) **ADH is released:** the hypothalamus then causes the posterior pituitary gland to release more antidiuretic hormone (ADH) into the blood.
4) **The tubule is made permeable:** the ADH makes the walls of the distal convoluted tubule and the collecting duct more permeable to water.
5) **Water is reabsorbed:** consequently more water passes back from the filtrate into the blood, so that only a small volume of concentrated urine is formed, as in the herder's dark urine, and water is conserved.
6) **Balance is restored by negative feedback:** as the blood returns to normal the osmoreceptors are no longer stimulated and less ADH is released; had the blood instead become too dilute, little ADH would be released and a large volume of dilute urine would be passed.

Question 10

(a) An impulse travels along an axon as a moving change in the electrical charge across the membrane, in the following stages:

1) **The resting potential:** when no impulse is passing, the inside of the axon is negative compared with the outside, at about minus seventy millivolts; this is maintained by the sodium-potassium pump, which pumps sodium ions out and potassium ions in.
2) **A stimulus reaches the threshold:** a stimulus strong enough to reach the threshold value opens the voltage-gated sodium channels in the membrane.
3) **Depolarisation:** sodium ions rush into the axon, so that the inside briefly becomes positive compared with the outside, at about plus forty millivolts; this reversal of charge is the action potential.
4) **Repolarisation:** the sodium channels then close and potassium channels open, so that potassium ions move out and the inside becomes negative once more, restoring the resting potential.
5) **The refractory period:** for a brief moment the region cannot be stimulated again, which ensures that the impulse passes in one direction only.
6) **Propagation:** the action potential at one point sets up local currents that depolarise the next region to its threshold, so that a fresh action potential arises there and the impulse moves along the axon; in a myelinated fibre it leaps from one node of Ranvier to the next, whereby conduction is made much faster.

(b) At a synapse the two neurones do not touch, so the impulse is carried across the gap by a chemical transmitter, in four steps:

1) **Arrival of the impulse:** when the action potential reaches the synaptic knob at the end of the axon, it opens calcium-ion channels, so that calcium ions diffuse into the knob.
2) **Release of the transmitter:** the calcium ions cause the synaptic vesicles to fuse with the presynaptic membrane and release a chemical transmitter, for example acetylcholine, into the synaptic cleft.
3) **Action on the next neurone:** the transmitter diffuses across the narrow cleft and binds to receptors on the postsynaptic membrane, making it permeable to sodium ions, consequently this membrane depolarises and a new impulse begins in the next neurone.
4) **Removal of the transmitter:** the transmitter is at once broken down by an enzyme, for example cholinesterase, and reabsorbed, whereby the synapse is reset and the impulse can pass in one direction only.

ENJOY & MASTER ADVANCED BIOLOGY

Paper 2

FORM FIVE EXAMINATION

Solutions

SECTION A

Question 1

(a) The labelled parts are:

A: phospholipid (hydrophilic) head.

B: fatty acid (hydrophobic) tails.

C: channel protein.

D: glycoprotein, a protein with a carbohydrate chain.

E: cholesterol.

F: peripheral (surface) protein.

(b) **The membrane is called fluid because its phospholipids and many of its proteins are not fixed but drift sideways within the layer,** so that the membrane can bend and change shape; and it is called a mosaic because the scattered proteins set in the phospholipid sheet resemble the many pieces of a mosaic picture.

(c) **Oxygen crosses easily because it is a small, uncharged molecule that dissolves in the oily (hydrophobic) core of the bilayer,** whereas ions carry an electric charge and are repelled by that oily core; consequently the ions cannot slip through on their own, but must instead pass through special channel proteins.

Question 2

(a) Fat is the better long-term store for two reasons:

1) **Fat releases more energy for its mass:** a gram of fat yields about twice as much energy as a gram of carbohydrate when it is respired, so that the same store of energy is held in a smaller and lighter mass.
2) **Fat is insoluble in water:** because it does not dissolve, it has no effect on the water potential of the cell and draws in no water by osmosis, consequently large amounts can be stored without upsetting the cell's water balance.

(b) Lipids are classified into three groups:

1) **Simple lipids:** esters of fatty acids with an alcohol, for example a triglyceride (a fat or an oil).
2) **Compound lipids:** a lipid joined to another group, for example a phospholipid, which contains a phosphate group.
3) **Derived lipids:** substances formed from lipids, for example cholesterol, which is a steroid.

(c) Besides storing energy, lipids have three other roles:

1) **Forming membranes:** the phospholipids make up the bilayer of every cell membrane.
2) **Insulation and protection:** a layer of fat beneath the skin reduces the loss of heat and cushions the delicate organs.
3) **Waterproofing:** waxy lipids on leaves, on fur and on the cuticle of insects cut down the loss of water.

Question 3

(a) **The correct order, from the largest group to the smallest, is:** Kingdom, then Phylum, then Class, then Order, then Family, then Genus, and finally Species.

(b) Two rules are followed:

1) **The genus name begins with a capital letter and the species name with a small letter,** for example *Panthera pardus*.
2) **The whole name is printed in italics, or underlined in handwriting,** and after the first use the genus may be shortened to its initial, for example *P. pardus*.

(c) **A common name varies from place to place and from one language to another,** so that the same animal may carry many different names, while one name may be used for several different animals, which leads to confusion. **A scientific name, in contrast, is unique and is the same everywhere,** consequently a biologist in Tanzania and one in Japan know at once that they are speaking of exactly the same organism, which makes communication between scientists both exact and worldwide.

(d) **The leopard belongs to the genus *Panthera* and to the species *Panthera pardus*,** its specific name being *pardus*; the genus *Panthera* is the group of closely related big cats, whereas the species name marks out the leopard within that genus.

Question 4

(a) The impulse passes through five parts, in this order:

1) **Receptor:** the sense organ, such as a pain receptor in the skin, which detects the stimulus.
2) **Sensory neurone:** it carries the impulse from the receptor to the spinal cord.
3) **Relay (intermediate) neurone:** lying within the spinal cord, it passes the impulse from the sensory neurone to the motor neurone.
4) **Motor neurone:** it carries the impulse from the spinal cord out to the effector.
5) **Effector:** the muscle or gland that carries out the response, for example the muscle that pulls the finger away.

(b) **A reflex follows a short, fixed pathway that runs through the spinal cord and not through the conscious brain,** so that the impulse need not travel all the way up to the brain and back before the response is made. **The pathway also crosses very few synapses,** and because each synapse causes a slight delay, having few of them makes the response extremely rapid, which matters when the action is protecting the body from harm.

(c) **Two protective reflexes are the blinking of the eyelid when an object suddenly approaches the eye, and the narrowing of the pupil in bright light;** each happens automatically and so guards a delicate part of the body.

SECTION B

Question 5

(a) The Calvin cycle proceeds as follows:

1) **It takes place in the stroma of the chloroplast,** the fluid that surrounds the grana.
2) **Carbon dioxide is fixed:** each carbon dioxide molecule combines with a five-carbon acceptor, ribulose bisphosphate (RuBP), in a reaction catalysed by the enzyme rubisco.
3) **An unstable six-carbon compound forms and at once splits** into two molecules of a three-carbon compound, glycerate-3-phosphate (GP).
4) **GP is reduced to triose phosphate (TP),** using the ATP for energy and the reduced NADP for hydrogen, both brought from the light-dependent reaction.

5) **The triose phosphate is then used in two ways:** some is built up into glucose and other foods, whereas most is used to regenerate the RuBP, so that the cycle can turn again.

(b) **A limiting factor is the one factor, among all those a process needs, that is in shortest supply and so holds the rate back;** when that factor is increased the rate rises, whereas increasing the others has no effect. **At point X the rate is limited by the light intensity:** the line is still rising and the two carbon dioxide curves lie together, which shows that more light would raise the rate, so light is in short supply here. **At point Y the rate is limited by the carbon dioxide concentration:** the lower-carbon-dioxide curve has levelled off even though the light is still increasing, consequently light is no longer limiting, and only more carbon dioxide would raise the rate.

(c) **The grower should increase whichever factor is limiting the rate at the time.** In a greenhouse this means supplying extra light, burning a fuel to raise the carbon dioxide, and keeping the air warm, so that no single factor holds photosynthesis back and the crop consequently grows faster and yields more.

Question 6

(a) Glycolysis proceeds as follows:

1) **It takes place in the cytoplasm of the cell** and does not require oxygen.
2) **Each glucose molecule (six carbons) is first phosphorylated** by two molecules of ATP, which activates it.
3) **The six-carbon sugar is then split into two three-carbon molecules,** each of which is converted into pyruvate (pyruvic acid).
4) **Hydrogen is removed and taken up by NAD** to form reduced NAD, while four molecules of ATP are produced.
5) **The net yield is therefore two ATP for each glucose,** since two were used at the start and four were made, together with two molecules of pyruvate and two of reduced NAD.

(b) The fate of the pyruvate depends on the conditions:

1) **In the presence of oxygen:** the pyruvate passes into the mitochondrion, where it is broken down completely to carbon dioxide and water, releasing a large amount of energy.
2) **In a muscle without oxygen:** the pyruvate is converted into lactic acid (lactate), which builds up and causes muscle fatigue until oxygen becomes available once more.
3) **In yeast without oxygen:** the pyruvate is converted into ethanol and carbon dioxide, which is the basis both of brewing mbege and of making bread rise.

(c) **In anaerobic respiration the glucose is only partly broken down, so that most of its energy stays locked up in the lactic acid or the ethanol that is formed.** Because the pyruvate does not enter the oxygen-requiring stages in the mitochondrion, where most of the ATP is made, only the two ATP from glycolysis are gained, whereas the full aerobic breakdown of the same glucose releases far more energy.

Question 7

(a) ***Amoeba* moves by pseudopodia (false feet),** flowing extensions of its own cytoplasm. ***Euglena* moves by beating a single long flagellum** at its front end. ***Paramecium* moves by the beating of the many short, hair-like cilia** that cover its body.

(b) ***Euglena* shows several plant-like features:** it contains chloroplasts, it carries out photosynthesis in the light to make its own food, and it stores carbohydrate, just as a green plant does. **Yet it also shows several animal-like features:** it has no cellulose cell wall, it swims actively by beating a flagellum, it bears a sensitive eyespot that responds to light, and in the dark it can take in ready-made food like an animal. **Because it combines both sets of features it fits neither the plant kingdom nor the animal kingdom neatly,** and it is for this reason placed in a separate kingdom, the Protoctista.

(c) **Malaria is caused by the protoctistan *Plasmodium*,** a single-celled parasite of the blood. **It is spread from an infected person to a healthy one by the bite of the female *Anopheles* mosquito,** which breeds in still pools and ponds and takes up the parasite when it sucks blood. **Inside the body the parasite destroys the red blood cells,** consequently bringing on repeated bouts of fever, shivering and anaemia, and in severe cases it can kill. **Malaria remains one of the leading causes of illness and death in Tanzania, especially among young children and pregnant women,** placing a heavy burden on families, on farm work and on the health service, which is why mosquito nets and the draining of stagnant water matter so much.

SECTION C

Question 8

(a) Four classes of the phylum Arthropoda, each with a named example, are described below:

1) **Class Insecta (example: the housefly):** the body has three parts, a head, a thorax and an abdomen; there are three pairs of legs, usually two pairs of wings and one pair of antennae, and gas exchange is by air tubes called tracheae.
2) **Class Arachnida (example: the cattle tick):** the body has two parts, a cephalothorax and an abdomen; there are four pairs of legs, and neither antennae nor wings.
3) **Class Crustacea (example: the crab):** the body has two parts and bears two pairs of antennae and many legs; gas exchange is by gills, and a hard carapace covers the head and thorax.
4) **Class Myriapoda (example: the millipede):** the body is made of many similar segments, each bearing legs, with one pair of antennae; the millipede has two pairs of legs on each segment, whereas the centipede has one.

(b) The arthropods are so successful for four reasons:

1) **A hard chitin exoskeleton:** it supports the body, protects the soft parts within, and gives firm anchorage against which the muscles can pull.
2) **A waterproof cuticle:** it greatly reduces the loss of water from the body surface, which is what allowed the arthropods to colonise dry land.
3) **Jointed appendages:** the jointed legs and mouthparts can be specialised for walking, swimming, digging, flying and for feeding on many kinds of food.
4) **Wings in the insects:** the power of flight lets them escape enemies, find food and mates, and spread into new habitats, while metamorphosis lets the young and the adults use different foods and so avoid competing with one another.

Question 9

(a) The liver deals with the excess amino acids as follows:

1) **Deamination is the removal of the amino group from an amino acid,** and it is carried out in the liver because surplus amino acids cannot be stored in the body.
2) **The amino group (NH_2) that is removed forms ammonia,** whereas the remainder of the amino acid is an organic acid that can be respired for energy or changed into carbohydrate or fat.
3) **Ammonia is extremely poisonous,** so that it cannot be allowed to accumulate, nor to be carried far through the body in that form.
4) **The liver therefore at once combines the ammonia with carbon dioxide to form urea,** a far less poisonous substance, in a series of reactions called the ornithine cycle.
5) **The urea then passes into the blood and is carried to the kidneys,** which filter it out and remove it from the body in the urine.

(b) The liver has four other homeostatic roles:

1) **Regulating blood glucose:** under the hormone insulin the liver stores excess glucose as glycogen, and under glucagon it breaks the glycogen back into glucose, so keeping the blood sugar steady.

2) **Detoxification:** the liver breaks down poisons such as alcohol and drugs and inactivates worn-out hormones, changing them into harmless substances that can be excreted.

3) **Storage:** it stores the iron recovered from worn-out red blood cells, together with glycogen and the vitamins A and D, releasing them as the body needs them.

4) **Heat production:** the very many chemical reactions of the liver release a great deal of heat, which the blood then carries round the body, whereby it helps to keep the body temperature constant.

Question 10

(a) The main effects of three named plant hormones are these:

Auxin (for example indole-acetic acid) makes the cells just behind a shoot tip elongate, thereby bringing about growth and the bending of shoots towards light and of roots towards gravity, and it also keeps the side buds from sprouting (apical dominance).

Gibberellin promotes the lengthening of stems, causing rapid elongation, and it breaks the dormancy of seeds and buds, so that they germinate and grow.

Ethylene (a gas) hastens the ripening of fruit, which is why one ripe banana ripens the green ones beside it, and it promotes the fall (abscission) of leaves and of fruit.

(b) **Two hormones act synergistically when they work in the same direction, so that their combined effect is greater than either alone:** for example, auxin and gibberellin together both promote the elongation of the stem, consequently giving more growth than either would give by itself. **Two hormones act antagonistically when they have opposite effects:** for example, auxin and gibberellin promote growth and the sprouting of buds, whereas abscisic acid opposes them, holding back growth and bringing on dormancy and the closing of the stomata.

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Paper 3

FORM FIVE EXAMINATION

Solutions

SECTION A

Question 1

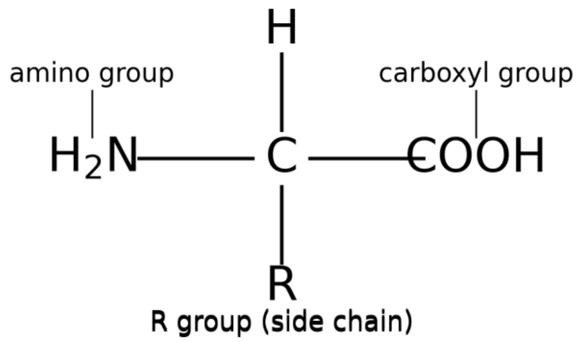
(a) A prokaryotic cell differs from a eukaryotic cell in four main ways:

1) **Nucleus:** a prokaryotic cell has no true nucleus, its DNA lying free in the cytoplasm as a single circular strand, whereas a eukaryotic cell has a true nucleus enclosed by a nuclear membrane.
2) **Membrane-bound organelles:** a prokaryotic cell has none, so that there are no mitochondria, no endoplasmic reticulum and no Golgi body, whereas a eukaryotic cell has many such organelles.
3) **Size:** a prokaryotic cell is very small, about one to ten micrometres across, whereas a eukaryotic cell is much larger, commonly ten to a hundred micrometres.
4) **Cell wall and ribosomes:** a prokaryotic wall, where present, is made of peptidoglycan and the ribosomes are small, whereas a plant or fungal eukaryotic wall is of cellulose or chitin and the ribosomes are larger.

(b) **Two structures present in both kinds of cell are the cell (plasma) membrane and the ribosomes;** both kinds of cell also contain cytoplasm and carry their genetic information as DNA.

Question 2

(a) The general structure of an amino acid is shown in the diagram below.



Every amino acid has a central carbon atom joined to four groups: an amino group, a carboxyl group, a hydrogen atom and a variable side chain (the R group); it is the R group that differs from one amino acid to another.

(b) A protein has four levels of structure:

1) **Primary structure:** the particular sequence and number of amino acids in the polypeptide chain, held together by peptide bonds.
2) **Secondary structure:** the coiling of the chain into an alpha-helix, or its folding into a beta-pleated sheet, held in shape by hydrogen bonds.
3) **Tertiary structure:** the further folding of the whole chain into a precise three-dimensional shape, held by hydrogen bonds, ionic bonds, disulphide bridges and hydrophobic forces.
4) **Quaternary structure:** the joining of two or more polypeptide chains into one working protein, as in haemoglobin, which is built of four chains.

Question 3

(a) **A dichotomous key is used by working through a series of paired statements and, at each step, choosing the one that fits the specimen.** Each choice either names the organism or directs the user on to the next pair of statements, so that the specimen is identified step by step, by a process of elimination.

(b) A suitable dichotomous key for the four animals is:

1 (a) Body with no legs, made of many similar ring-like segments ...... earthworm

1 (b) Body with jointed legs ...... go to 2

2 (a) Three pairs of legs ...... housefly

2 (b) More than three pairs of legs ...... go to 3

3 (a) Four pairs of legs ...... spider

3 (b) Many pairs of legs, two pairs on most segments ...... millipede

(c) Two qualities make a feature suitable for use in a key:

1) **It must be clear-cut, giving an obvious either-or choice,** such as the number of legs or whether the body is segmented, so that there is no doubt which half of the couplet fits the specimen.

2) **It must be a constant feature, present at all times,** and not one that changes with the age, the sex or the season of the organism, such as size or colour, which could mislead.

Question 4

(a) The labelled parts are:

A: dendrites.

B: cell body (centron).

C: axon.

D: myelin sheath.

E: node of Ranvier.

F: axon terminals (motor end plates).

(b) **The resting potential is the difference in charge across the membrane when no impulse is passing,** the inside of the axon being negative compared with the outside, at about minus seventy millivolts. **It is set up mainly by the sodium-potassium pump,** which actively pumps three sodium ions out of the axon for every two potassium ions it pumps in, so that positive charge is carried out faster than it is brought in. **The membrane is also more permeable to potassium than to sodium,** consequently potassium tends to leak back out, which helps to keep the inside of the axon negative and ready to carry an impulse.

SECTION B

Question 5

(a) **Large food molecules such as starch and protein are too big and too insoluble to pass through the wall of the gut into the blood.** Digestion breaks them into small, soluble molecules, such as glucose and amino acids, which can then be absorbed through the gut wall and carried in the blood to the cells, where they are used for energy and growth.

(b) **Starch is digested by amylase,** made in the salivary glands and the pancreas; the amylase first breaks the starch to maltose, and maltase then completes the work, so that the final product is glucose. **Protein is digested by proteases,** such as pepsin in the stomach and trypsin from the pancreas; these break the protein to peptides, and peptidases then complete the work, so that the final product is amino acids.

(c) The soluble products are absorbed at the small intestine in the following way:

Absorption takes place through the villi, the many tiny finger-like projections of the lining of the ileum, which together give a very large surface area. **Each villus has a wall only one cell thick and a dense network of blood capillaries,** so that the diffusion distance is short and the absorbed food is carried away quickly, whereby a steep concentration gradient is kept up. **The glucose and the amino acids pass into the blood capillaries** and are carried in the hepatic portal vein to the liver, **whereas the fatty acids and glycerol pass into the lacteal,** a small lymph vessel in the centre of the villus, and so enter the lymph.

Question 6

(a) **The Krebs cycle takes place in the matrix,** the central fluid of the mitochondrion, whereas the electron transport chain is located on the inner membrane, which is folded into cristae.

(b) The pyruvate passes through two stages, the link reaction and then the Krebs cycle:

1) **The link reaction:** in the matrix of the mitochondrion each pyruvate (three carbons) loses one carbon as carbon dioxide and is joined to coenzyme A to form acetyl coenzyme A (two carbons), whereby reduced NAD is also formed.
2) **The Krebs cycle:** the two-carbon acetyl group combines with a four-carbon acceptor to form the six-carbon compound citrate; as the cycle turns, this is broken down step by step, so that two molecules of carbon dioxide are given off, hydrogen is removed onto NAD and FAD to form reduced NAD and reduced FAD, a little ATP is made directly, and the four-carbon acceptor is regenerated, consequently the cycle can continue.

(c) **The reduced NAD and reduced FAD carry hydrogen to the electron transport chain on the inner membrane,** where the electrons are passed from carrier to carrier, releasing the energy that is used to make most of the cell's ATP. **Oxygen is the final acceptor of the electrons:** at the end of the chain it combines with the electrons and the hydrogen ions to form water, so that without oxygen the chain backs up and stops. The complete breakdown of one glucose molecule yields about 38 molecules of ATP.

Question 7

(a) Three features common to all fungi are:

1) **They are eukaryotic, with bodies built of thread-like hyphae** that together form a mesh called a mycelium.
2) **Their cell walls are made of chitin,** and not of cellulose as in plants.
3) **They have no chlorophyll,** so that they cannot photosynthesise; they feed instead as saprophytes or as parasites, and they reproduce by spores.

(b) *Rhizopus* feeds saprophytically on the bread in the following way:

The hyphae grow into the bread, spreading through it and anchoring the mould. **The hyphae then secrete digestive enzymes onto the bread,** which break down the starch and the other large molecules outside the fungus, in what is called extracellular digestion. **The soluble products are then absorbed** back through the walls of the hyphae into the fungus, where they are used for energy and growth.

(c) Fungi are useful to the people of Tanzania in several ways:

1) **Making food and drink:** the yeast *Saccharomyces* ferments sugars to raise bread and to brew local drinks such as mbege.
2) **A food in themselves:** edible mushrooms are gathered and eaten as a valued food.
3) **Medicine:** the mould *Penicillium* gives us the antibiotic penicillin.
4) **Decay and soil fertility:** as decomposers, fungi rot dead matter and return its nutrients to the soil, whereby the soil is kept fertile.

But some fungi are harmful:

1) **Spoiling stored food:** moulds spoil stored food, and *Aspergillus* growing on damp maize and groundnuts produces poisonous aflatoxins.

2) **Crop diseases:** fungi such as the rusts and the smuts attack maize and other crops, consequently reducing the harvest.

3) **Diseases of people:** some fungi cause human diseases, such as ringworm and thrush.

SECTION C

Question 8

(a) The five classes of vertebrates, each with a named example, are described below:

1) **Class Pisces, the fishes (example: the tilapia):** the streamlined body is covered with wet scales; the animal breathes by gills, moves by fins and is cold-blooded, and its eggs are fertilised externally in water.

2) **Class Amphibia (example: the frog):** the skin is moist and without scales; the tadpole breathes by gills in water, whereas the adult breathes by lungs and through the skin on land; they are cold-blooded and lay jelly-covered eggs in water.

3) **Class Reptilia (example: the lizard):** the skin is dry and covered with horny scales; they breathe by lungs, are cold-blooded, and lay leathery-shelled eggs on land.

4) **Class Aves, the birds (example: the weaver bird):** the body is covered with feathers, the forelimbs are wings and the jaws form a beak; they are warm-blooded and lay hard-shelled eggs.

5) **Class Mammalia (example: the elephant):** the body is covered with hair or fur; they are warm-blooded, the females feed their young on milk from mammary glands, and most give birth to live young.

(b) Three features fitted the reptiles, birds and mammals for life on dry land:

1) **A waterproof body covering:** the dry scales of reptiles, the feathers of birds and the hair of mammals all greatly reduce the loss of water from the body, so that the animal does not dry out on land.

2) **Lungs for breathing air:** all three breathe entirely by lungs, consequently they do not depend on water, or on a moist skin, for gas exchange, as the amphibian still partly does.

3) **Reproduction freed from water:** reptiles and birds lay shelled eggs that carry their own water supply, whereas mammals develop the young inside the body, so that breeding no longer depends on water as it does for the frog.

Question 9

(a) **A constant temperature keeps the body's enzymes working at their best,** because the enzymes control all the reactions of the body and each works fastest at its optimum temperature, close to 37 degrees Celsius in a mammal. **If the body grew too hot the enzymes would be denatured and would stop working, whereas if it grew too cold the reactions would become far too slow;** consequently holding a steady temperature keeps the body's chemistry running properly whatever the weather outside.

(b) When the body becomes too hot, the hypothalamus brings about the loss of heat:

Sweating increases: the sweat glands pour out more sweat, and as it evaporates from the skin it draws heat from the body and so cools it.

Vasodilation: the small arterioles supplying the skin widen, so that more warm blood flows close to the surface and more heat is lost to the air.

The hairs lie flat: the hair-erector muscles relax so that the hairs lie down, trapping less air and letting heat escape more easily.

Behaviour: the animal rests in the shade, spreads itself out and drinks water, all of which help it to lose heat.

(c) When the body becomes too cold, the hypothalamus brings about the saving and the making of heat:

Vasoconstriction: the small arterioles to the skin narrow, so that less warm blood flows near the surface and less heat is lost.

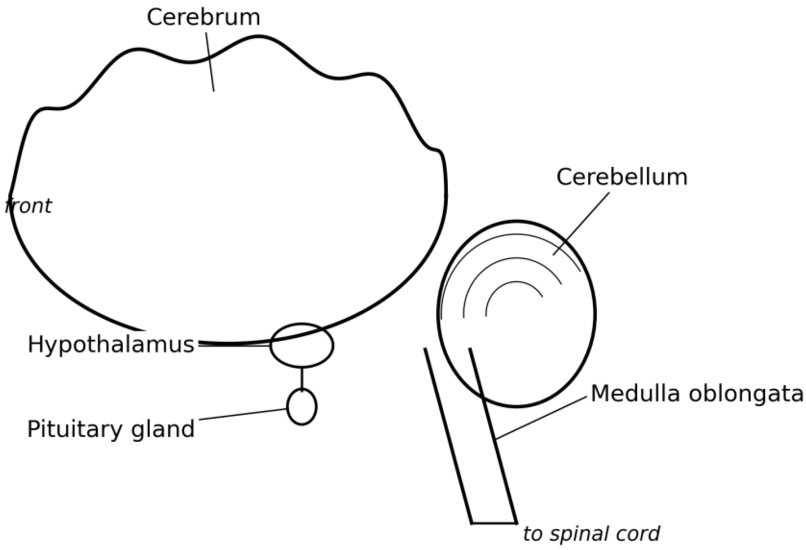
Shivering: the muscles contract and relax rapidly, and the extra respiration that this needs releases heat which warms the body.

The hairs stand up: the hair-erector muscles contract so that the hairs are raised, trapping a layer of still air that insulates the body.

Less sweating and a faster metabolism: sweating almost stops, so that little heat is lost by evaporation, while the liver and other organs respire faster to generate more heat; the animal may also curl up or seek the sun.

Question 10

(a) The main parts of the mammalian brain are shown in the diagram below.



They are the cerebrum, the cerebellum, the medulla oblongata, the hypothalamus and the pituitary gland.

(b) The functions of the four parts are these:

The cerebrum is the centre of intelligence, memory, reasoning and will; it receives and interprets the sensations from the sense organs and controls all the voluntary (conscious) actions of the body.

The cerebellum controls balance and posture and coordinates the contraction of the muscles, so that the movements of the body are smooth and accurate.

The medulla oblongata controls the involuntary actions of the body, such as the heartbeat, the breathing, the blood pressure and swallowing.

The hypothalamus regulates the internal environment, controlling the body temperature, the water content of the blood, and hunger and thirst, and it links the nervous system to the endocrine system through the pituitary gland.

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Paper 4

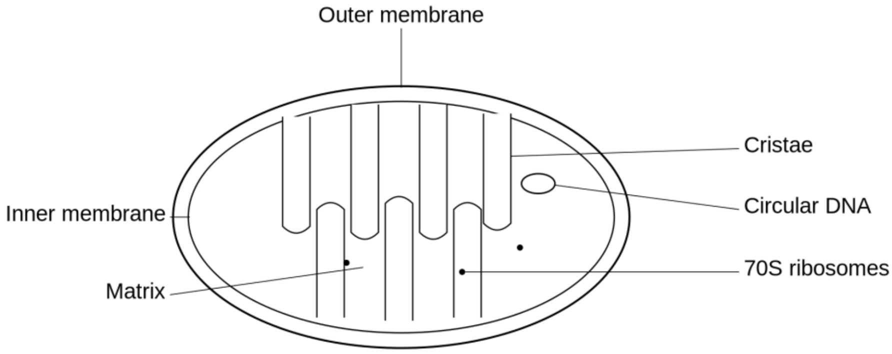
FORM FIVE EXAMINATION

Solutions

SECTION A

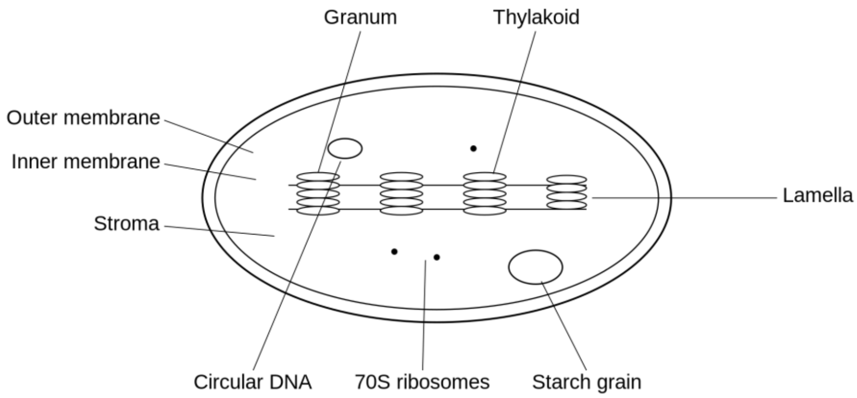
Question 1

(a) A mitochondrion is drawn and labelled below.



The mitochondrion is bounded by a smooth outer membrane and a folded inner membrane; the folds of the inner membrane are the cristae, and the inner space they enclose is the matrix.

(b) A chloroplast is drawn and labelled below.



The chloroplast is bounded by an outer and an inner membrane and is filled with a fluid called the stroma; within the stroma are stacks of disc-like thylakoids, each stack forming a granum.

(c) **In the mitochondrion the inner membrane is folded into cristae, which give a large surface area to carry the enzymes and electron carriers of respiration;** in the chloroplast, likewise, the thylakoid membranes are stacked into grana, which give a large surface area to hold the chlorophyll that traps the light.

Question 2

(a) **A cofactor is a non-protein substance that an enzyme must have in order to work,** very often a metal ion; for example, chloride ions are needed by the enzyme amylase, and zinc ions by certain other enzymes. **A coenzyme is an organic (carbon-containing) cofactor, usually made from a vitamin, that carries chemical groups or hydrogen from one reaction to another;** for example NAD, which is made from a B vitamin, carries hydrogen during respiration.

(b) **A competitive inhibitor has a shape similar to that of the substrate,** so that it competes with the substrate for the active site and blocks it; because the two compete, the effect of the inhibitor can be lessened by adding more substrate. **A non-competitive inhibitor binds to the enzyme at a different place, away from the active site,** and thereby changes the shape of the active site, so that the substrate can no longer fit; adding more substrate does not relieve this, because the two are not competing for the same place.

Question 3

(a) Four features are used to place an organism in its kingdom:

1) **The kind of cell:** whether the organism is prokaryotic (no true nucleus) or eukaryotic (with a true nucleus).
2) **The number of cells:** whether the organism is unicellular (one cell) or multicellular (many cells).
3) **The way it feeds:** whether it is autotrophic (makes its own food) or heterotrophic (takes in ready-made food).
4) **The cell wall:** whether a cell wall is present and, if so, what it is made of, for example cellulose, chitin or peptidoglycan.

(b) **Fungi were once grouped with plants because they do not move about and they have cell walls,** yet they differ from plants in several deep ways. **They have no chlorophyll and so cannot photosynthesise;** instead they feed as saprophytes or as parasites on ready-made food, and their cell walls are made of chitin and not of cellulose, consequently they are too different from plants to belong in the plant kingdom.

(c) **The five-kingdom system gives a separate kingdom to organisms that are neither true plants nor true animals, such as the bacteria, the protoctists and the fungi.** It therefore groups living things by their real differences in cell structure and in the way they feed, whereas the old two-kingdom system of plants and animals could not do so.

Question 4

(a) The labelled parts are:

A: cornea.

B: iris.

C: pupil.

D: lens.

E: retina.

F: optic nerve.

(b) **To focus on a distant object the lens is made thin:** the ciliary muscles relax, which lets the suspensory ligaments pull tight and stretch the lens into a less curved (thinner) shape, so that the light is bent only a little and the distant rays are brought to a focus on the retina. **To focus on a near object the lens is made fat:** the ciliary muscles contract, the suspensory ligaments slacken, and the lens springs back into a more rounded (thicker) shape, consequently the light is bent more strongly and the near rays are focused on the retina. This adjusting of the lens is called accommodation.

SECTION B

Question 5

(a) The three modes of nutrition are:

1) **Holozoic nutrition:** the organism takes in solid food, digests it inside its body, absorbs the products and gets rid of the waste; this is the way of most animals, for example a human being.

2) **Parasitic nutrition:** the organism lives on or inside another living organism, the host, and takes its food from it, harming the host in the process, for example the tapeworm in the human gut.

3) **Saprophytic nutrition:** the organism feeds on dead and decaying matter, pouring enzymes onto it and absorbing the soluble products, for example a mushroom or the bread mould *Rhizopus*.

(b) The tapeworm is adapted to its parasitic way of life in three ways:

1) **Hooks and suckers:** its head bears hooks and suckers that grip the wall of the host's gut, so that the worm is not swept away.

2) **A protective cuticle:** its body is covered by a cuticle that resists the host's digestive enzymes, so that the worm itself is not digested.

3) **No gut and a flat, segmented body:** having no gut of its own, it absorbs the host's already-digested food over its whole flat surface, and it makes very large numbers of eggs, so that some survive to reach a new host.

Question 6

(a) The leaf is built for gas exchange in several ways:

1) **Stomata:** the surface of the leaf, mainly the lower surface, is dotted with tiny pores called stomata, through which gases pass between the outside air and the inside of the leaf.

2) **Air spaces:** the spongy mesophyll within the leaf has large, connected air spaces, so that the gases can move freely up to every cell.

3) **A large, thin, moist surface:** the mesophyll cells present a large, moist surface over which the gases dissolve and diffuse, and because the leaf is thin and flat, the distance the gases must travel is short.

(b) The guard cells work the stoma by changes in their turgor:

1) **To open the stoma the guard cells take in water and become turgid:** because the inner wall, next to the pore, is thicker and less stretchy than the outer wall, each guard cell curves outwards as it swells, whereby the pore between the two is pulled open.

2) **To close the stoma the guard cells lose water and become flaccid:** they straighten and sag back together, so that the pore between them closes.

(c) **A woody stem is covered by bark, which is corky and waterproof and would otherwise cut the living cells inside off from the air. Lenticels are small pores in this bark, made of loosely packed cells with air spaces between them,** through which oxygen and carbon dioxide can diffuse between the outside air and the living cells of the stem, so that these cells can go on respiring.

Question 7

(a) Three features common to all plants are:

1) **They are eukaryotic and multicellular,** their bodies being built of many cells.

2) **Their cells have walls made of cellulose.**

3) **They contain chlorophyll and are autotrophic,** making their own food by photosynthesis.

(b)

(i) **Vascular tissue:** the moss has none, so that it stays small and low, whereas the fern and the flowering plant both have vascular tissue (xylem and phloem), which carries water and food and supports a taller body.

(ii) **True roots:** the moss has only thread-like rhizoids, whereas the fern and the flowering plant both have true roots, which anchor the plant and absorb water from the soil.

(iii) **Spores or seeds:** the moss and the fern both reproduce by spores and need a film of water for fertilisation, whereas the flowering plant reproduces by seeds and does not depend on water for fertilisation.

(c) The flowering plants are the most successful for several reasons:

1) **Vascular tissue and true roots** let them grow large and stand upright on dry land, drawing water from deep in the soil.

2) **The seed** encloses and protects the tiny embryo and stores food for it, so that the young plant has a good start and can survive harsh conditions before it grows.

3) **Flowers, pollination and fruits:** the flower allows fertilisation without water, often using insects or the wind, while the fruit helps to scatter the seeds widely, consequently the flowering plants have spread into almost every habitat on land.

SECTION C

Question 8

(a) The five kingdoms, each with a named example, are distinguished as follows:

1) **Kingdom Monera (example: a bacterium):** the organisms are prokaryotic, having no true nucleus and no membrane-bound organelles; they are unicellular and feed in a variety of ways.

2) **Kingdom Protoctista (example: *Amoeba*):** the organisms are eukaryotic and mostly unicellular; some feed like animals while others photosynthesise like plants, so that they form a varied group fitting neither plants nor animals.

3) **Kingdom Fungi (example: the mushroom):** the organisms are eukaryotic, with bodies of thread-like hyphae and cell walls of chitin; they have no chlorophyll and feed as saprophytes or parasites.

4) **Kingdom Plantae (example: the maize plant):** the organisms are eukaryotic and multicellular, with cellulose cell walls and chlorophyll, and they make their own food by photosynthesis.

5) **Kingdom Animalia (example: the elephant):** the organisms are eukaryotic and multicellular, have no cell wall, and feed on ready-made food, most of them being able to move about.

(b) **Viruses are not made of cells:** they have no cytoplasm, no nucleus and no organelles, but consist only of a coat of protein around a strand of genetic material, so that they lack the cell structure on which the five kingdoms are based. **They also show no life processes of their own and cannot reproduce by themselves:** a virus can multiply only inside a living host cell, which it forces to make new viruses, whereas outside a host it is as lifeless as a chemical; for these reasons it cannot be placed in any of the kingdoms of living things.

Question 9

(a) **Glucose is the main fuel that the cells, and especially the brain, break down in respiration to release energy,** so that a steady supply must always be available in the blood. **If the level falls too low the brain is starved of energy and the person may faint, whereas if it rises too high water is drawn out of the cells by osmosis and glucose is lost in the urine;** consequently the level must be held within narrow limits for the body to work properly, and a lasting failure of this control is the disease diabetes.

(b) When the blood glucose rises too high it is brought down as follows:

1) **The rise is detected by the pancreas,** in particular by the islets of Langerhans within it.

2) **The pancreas releases the hormone insulin into the blood.**

3) **Insulin makes the liver and the muscle cells take glucose out of the blood and store it as glycogen,** and it makes the cells respire glucose faster.

4) **Consequently the blood glucose level falls back to normal,** after which less insulin is released; this control by negative feedback keeps the level steady.

(c) When the blood glucose falls too low it is brought up as follows:

1) **The fall is detected by the pancreas.**
2) **The pancreas releases the hormone glucagon into the blood.**
3) **Glucagon makes the liver break its stored glycogen back down into glucose** (and form glucose from other substances) and release it into the blood.
4) **Consequently the blood glucose level rises back to normal,** after which less glucagon is released; again the control works by negative feedback.

Question 10

(a) **Endocrine glands are described as ductless because they have no tubes to carry away what they make;** instead they pass their hormones straight into the blood flowing through them. **The blood then carries the hormone all over the body, but only the target organ, whose cells bear the right receptors for that hormone, responds to it,** whereas the other organs take no notice.

(b) Four endocrine glands, with a hormone and its effect, are:

1) **Pancreas:** it produces insulin, which lowers the level of glucose in the blood.
2) **Thyroid gland:** it produces thyroxine, which raises the metabolic rate of the body; because thyroxine contains iodine, a shortage of iodine in the diet makes the thyroid swell as a goitre.
3) **Adrenal glands:** they produce adrenaline, which prepares the body for action, raising the heartbeat and the breathing rate and releasing glucose for energy.
4) **Pituitary gland:** it produces growth hormone, which controls the growth of the body, and antidiuretic hormone, which controls the reabsorption of water in the kidney.

(c) **Hormones travel in the blood and act slowly, and their effects last a long time,** so that they are well suited to controlling changes that take place gradually over weeks, months or years. **A hormone is also carried to every part of the body and can act on several organs at once,** which is just what is needed for whole-body changes such as steady growth and the many changes of puberty, rather than the swift, brief and local responses that the nerves bring about.

ENJOY & MASTER ADVANCED BIOLOGY

Paper 5

FORM FIVE EXAMINATION

Solutions

SECTION A

Question 1

(a)

(i) **The nucleus:** it holds the DNA and so controls all the activities of the cell, directing the making of proteins and passing on the hereditary information when the cell divides.

(ii) **The rough endoplasmic reticulum:** it is studded with ribosomes and carries the proteins they make through the cell, whereby it gives a large surface for the making and the transport of protein.

(iii) **The Golgi body:** it receives, modifies, packages and dispatches proteins and other substances, wrapping them in vesicles ready to be secreted from the cell.

(iv) **The lysosome:** it holds digestive enzymes that break down worn-out structures and material taken into the cell, and it can destroy the cell itself when the cell is no longer needed.

(b) **The rough endoplasmic reticulum, together with many ribosomes, would be especially plentiful.** This is because the ribosomes upon it are the site where proteins are made, and the reticulum then carries those proteins through the cell, so that a cell which exports a great deal of protein needs a large amount of it.

Question 2

(a) Two properties of water that make it important are:

1) **It is an excellent solvent:** because its molecules are polar, water dissolves salts, sugars and gases, consequently substances can be carried about in the blood and the xylem, and reactions can take place in solution within the cell.

2) **It has a high heat capacity:** water must gain or lose a great deal of heat before its own temperature changes much, so that it keeps the temperature of cells and of lakes steady and shields living things from sudden changes.

(b) **ATP releases its energy in small, usable amounts:** when it loses its end phosphate group to become ADP and phosphate, a little energy is set free, just enough to drive a single task in the cell, so that none is wasted. **It is also spent and remade over and over again:** ATP is built up during respiration and broken down wherever energy is needed, then at once rebuilt, consequently it is used like money rather than kept as a long-term store. For these reasons it is called the energy currency of the cell.

(c) A molecule of ATP is built from three components:

1) **A nitrogenous base, adenine.**

2) **A five-carbon sugar, ribose.**

3) **Three phosphate groups.**

Question 3

(a) Biologists use several kinds of character:

1) **Morphological characters:** the external form and structure of the body, such as the number of limbs or the shape of the leaves and flowers.

2) **Anatomical characters:** the internal structure, such as the plan of the skeleton or the arrangement of the tissues in a stem.

3) **Cytological characters:** the structure of the cells and the number and form of the chromosomes.

4) **Biochemical characters:** the make-up of important molecules, above all the DNA and the proteins, which show how closely organisms are related.

(b) **The DNA carries the hereditary information, so that closely related organisms have very similar DNA, whereas distant ones differ more;** comparing the DNA therefore measures true relationship directly. **Outward appearance, in contrast, can mislead, because unrelated organisms may come to look alike when they live in the same way:** a whale looks like a fish, yet its DNA shows it to be a mammal, consequently the DNA evidence sees past such surface resemblances to the real ancestry.

(c) Classification is important for three reasons:

1) **It brings order to the great variety of living things,** so that the millions of different kinds can be studied and understood, instead of remaining a confused mass.

2) **It shows how organisms are related and how they have evolved,** grouping together those that share a common ancestor.

3) **It gives every organism one agreed scientific name,** so that scientists everywhere can communicate exactly, which helps in agriculture, in medicine and in conservation.

Question 4

(a) A tropism and a nastic movement differ in two main ways:

1) **Direction:** in a tropism the direction of the response is decided by the direction of the stimulus, as when a shoot grows towards the light, whereas in a nastic movement the direction is not related to the direction of the stimulus, as when a mimosa leaf folds the same way whichever side is touched.

2) **Nature and speed:** a tropism is a growth movement, and so it is slow and usually permanent, whereas a nastic movement is not due to growth and is usually quick and reversible.

(b)

(i) **Phototropism, and it is positive,** because the shoot grows towards the light.

(ii) **Geotropism (gravitropism), and it is positive,** because the root grows in the direction of gravity, down into the soil.

(c) **By growing towards the light, the shoot brings its leaves into the brightest position,** where they can absorb the most light for photosynthesis; consequently the plant makes more of the food it needs to live and to grow.

SECTION B

Question 5

(a) A plant needs several mineral elements, for example:

1) **Nitrogen** (taken up as nitrate): it is needed to make amino acids, and so proteins, and also chlorophyll, so that it is essential for healthy growth.

2) **Magnesium:** it is needed to make chlorophyll, the green pigment that traps the light for photosynthesis.

(b)

(i) **Shortage of nitrogen:** the plant is stunted and grows poorly, and its older leaves turn pale and yellow, because without nitrogen it cannot make enough protein or chlorophyll.

(ii) **Shortage of magnesium:** the leaves turn yellow between the veins (chlorosis), because without magnesium the plant cannot make chlorophyll.

(c) The insectivorous plant feeds on insects in the following way:

1) **It grows where the soil is very poor in nitrogen,** such as a bog or an acid marsh, where ordinary plants cannot get enough.
2) **Its leaves are turned into traps:** the sundew bears leaves covered with sticky hairs that hold fast any insect landing on them.
3) **The insect is gripped and held** as the sticky hairs bend over and close around it.
4) **The leaf then pours digestive enzymes onto the trapped insect,** which break down its body, and especially its proteins.
5) **The soluble products, rich in nitrogen, are then absorbed** into the leaf.
6) **In this way the plant gains the nitrogen that the soil cannot supply,** for the making of its own proteins, consequently it can live and thrive where other plants would starve.

Question 6

(a) Air is drawn into the lungs during inspiration as follows:

1) **The diaphragm contracts and flattens,** moving downwards and so deepening the chest cavity.
2) **The external intercostal muscles contract and pull the rib cage upwards and outwards,** which widens the chest cavity.
3) **The volume of the chest cavity therefore increases,** so that the pressure of the air inside the lungs falls below the pressure of the air outside.
4) **Because the pressure inside is now lower than that outside, air is pushed in through the nose and the trachea into the lungs,** which expand to fill the larger space.

(b) Expired air differs from inspired air in three ways:

1) **It contains less oxygen,** about sixteen parts in a hundred instead of about twenty-one, because some oxygen has been used up in respiration.
2) **It contains much more carbon dioxide,** several parts in a hundred instead of the very small amount in fresh air, because carbon dioxide is produced in respiration.
3) **It contains more water vapour and is warmer,** having picked up moisture and heat from the warm, moist lining of the lungs.

(c) **The RQ of a carbohydrate is 1.0,** because when a carbohydrate is respired the volume of carbon dioxide given out is equal to the volume of oxygen taken in. **An RQ of about 0.7, in contrast, shows that fat is being respired:** a fat contains very little oxygen of its own, so that a great deal of oxygen must be taken in to oxidise it, far more than the carbon dioxide it gives out, consequently the ratio falls well below one.

Question 7

(a) The labelled parts are:

A: head (capsid).

B: DNA (the genetic material).

C: collar.

D: sheath (tail sheath).

E: base plate (end plate).

F: tail fibres.

(b) As living:

1) **They can reproduce, which is a sign of life:** inside a host cell a virus multiplies to make many new viruses.
2) **They carry genetic material, as living things do:** each virus contains DNA or RNA, which can mutate, so that viruses show variation and heredity.

As non-living:

1) **Yet they are not made of cells:** a virus has no cytoplasm, no nucleus and no organelles, but only a coat of protein around its genetic material.
2) **And they cannot live on their own:** outside a host a virus carries out no life processes, neither feeding nor respiring, and it can even be crystallised like a lifeless chemical.

(c) **Measles is a viral disease common in Tanzania, especially among young children.** It is spread through the air, in the tiny droplets that an infected person coughs or sneezes out and that other people then breathe in.

SECTION C

Question 8

(a) The malaria parasite, *Plasmodium*, is adapted to its parasitic life in several ways:

1) **It is carried from host to host by the bite of the female *Anopheles* mosquito,** so that it passes straight from one bloodstream into another and never has to survive in the open air.
2) **It lives in two hosts, the human being and the mosquito,** the mosquito carrying it from place to place and letting it complete its life cycle.
3) **It multiplies in enormous numbers,** first in the cells of the liver and then in the red blood cells, so that vast numbers of parasites grow from a single infection.
4) **It lives hidden inside the host's own cells,** the liver cells and the red blood cells, where it is sheltered from the body's defences and feeds on the contents of the cell.
5) **It forms special stages ready to be taken up by a mosquito** when the insect next sucks blood, whereby the parasite is passed on to a new host.
6) **Its repeated bursting out of the red cells is what brings on the bouts of fever,** and the timing of its life cycle is fitted to the feeding of the mosquito, which ensures its spread.

(b) Malaria is hard to control for four main reasons:

1) **The mosquito breeds very easily:** the warm climate and the many pools of still water in which the *Anopheles* mosquito lays its eggs let it breed all the year round.
2) **The parasite hides inside the cells,** in the liver and in the red blood cells, where it is hard for the body's defences, and for some drugs, to reach it.
3) **The parasite has become resistant to several anti-malarial drugs,** so that medicines which once worked now often fail.
4) **The mosquito has become resistant to some insecticides,** and because the mosquitoes are so many, a person who recovers is soon bitten and infected once more.

Question 9

(a) Negative feedback holds a condition steady in the following way:

1) **Every controlled condition has a normal level, or set point,** about which it is held; for the body temperature this is close to 37 degrees Celsius.
2) **A change away from the normal level is detected by receptors:** a rise in temperature, for example, is detected by the hypothalamus of the brain and by the skin.

3) **The information is passed to a control centre,** which determines what must be done to correct the change.

4) **Effectors are then brought into action that reverse the change and bring the condition back towards normal:** when the body is too hot, sweating and the widening of the skin's blood vessels lose heat and cool it.

5) **As the normal level is restored, the correction is switched off;** because the response always opposes the change, the condition is held steady, swinging only narrowly about its set point.

(b) Besides the sense of touch, the skin has four other functions:

1) **Protection:** the skin is a tough, waterproof covering that keeps out germs and dirt, shields the body from injury and from the sun's rays, and prevents the loss of water.

2) **Regulating body temperature:** by sweating and by widening or narrowing the blood vessels of the skin, it loses or conserves heat, and so helps to keep the body temperature steady.

3) **Excretion:** in the sweat the skin removes from the body a little water, salt and urea.

4) **Making vitamin D:** in sunlight the skin makes vitamin D, which the body needs for the healthy growth of the bones.

(c) Two other conditions kept steady by negative feedback are:

1) **The level of glucose in the blood,** kept steady chiefly by the pancreas, working together with the liver.

2) **The water and salt content of the blood,** kept steady chiefly by the kidneys.

Question 10

(a) The nervous system brings about the immediate response:

1) **The danger is detected by the sense organs,** above all the eyes, which send impulses to the brain.

2) **The brain at once sends impulses out along the motor nerves to the muscles,** so that the body reacts within a fraction of a second, freezing, jumping back or getting ready to run.

3) **Because the message travels as an electrical impulse along the nerves, the response is extremely fast, though brief,** giving the instant reaction that may save the person's life.

(b) The hormone adrenaline brings about and sustains the readiness for action:

1) **The brain causes the adrenal glands to pour the hormone adrenaline into the blood,** which carries it all over the body.

2) **Adrenaline makes the heart beat faster and harder and the breathing become deeper and quicker,** so that more oxygen and glucose are carried to the muscles.

3) **It causes the liver to release glucose into the blood,** giving the muscles extra fuel for action.

4) **It sends more blood to the muscles and less to the gut and the skin, widens the pupils and raises the hairs,** all of which prepare the body to fight or to flee.

5) **Because the hormone travels in the blood, its effects come on a little more slowly but last much longer,** keeping the body ready for as long as the danger remains.

(c) **The nervous response is needed for its speed:** danger calls for an instant reaction, and only the swift electrical impulses of the nerves can move the body quickly enough to escape. **The hormonal response is needed for its staying power:** adrenaline keeps the heart, the lungs and the muscles ready, and supplied with energy, for as long as the danger lasts, which the brief nerve impulses by themselves could not do. **Working together, then, the fast nerves and the lasting hormone give a complete response,** an immediate reaction backed up by a sustained readiness for action.

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