COMPREHENSIVE BIOLOGY PRACTICALS

A STORY-DRIVEN, COMPETENCY-BASED GUIDE TO PRACTICAL MASTERY

With Real-Life Applications and Investigative Scenarios

Ngaiza Education Hub Organisation

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TABLE OF CONTENTS

Chapter 1: Dissection 1
Introduction 1
Dissection of a cockroach 1
Dissection of a frog or toad 6
Dissection of mouse or rat 11
Digestive system of a mouse 14
Experiments 18
Chapter 2: Food test 35
Introduction 35
Experiments 42
Chapter 3: Classification 53
Introduction 53
Kingdom Plantae 53
Kingdom Animalia 59
Kingdom Fungi 67
Experiments 74
Chapter 4: Additional practicals 91
Enzymology 91
Reproduction in flowering plants 100
Diffusion 103
Osmosis 104
Growth and development 107

PREFACE

Biology is often called the science of life — and for good reason. It unravels the secrets of cells and ecosystems, connects the smallest molecules to the largest biomes, and explains how living things survive, adapt, and evolve. From medicine to conservation, it fuels the discoveries that shape our world. But for many students, practical biology feels like a jungle of microscopes, dissections, and endless terminology. This book is here to clear the path.

What if every experiment was a story?

What if osmosis wasn't just water sneaking through a potato strip, but a secret negotiation between two sides of a cell, each fighting for balance? What if enzyme tests became high-speed races where catalase battles hydrogen peroxide, or dissections turned into detective missions, uncovering the hidden designs of living systems? In every practical, there's tension, drama, and the triumph of making the invisible processes of life visible — right in your hands.

Welcome to ***Comprehensive Biology Practicals*** — where real scientific skills meet **engaging narratives**, **critical thinking**, and **competency-based learning**.

Inside, you'll meet recurring characters like **Kipute**, *a curious and courageous student with a knack for uncovering biological truths*, and **Mr. Akilikubwa**, *the brilliant, slightly eccentric lab technician with wisdom (and warnings) to spare*. Through their stories, every experiment unfolds with purpose and imagination, while strengthening the practical skills, critical observations, and analytical reasoning needed to excel not only in exams but also in solving real-world biological challenges.

This book explores a broad spectrum of essential biology practicals, organized into four major chapters: dissection, food tests, classification, and additional investigations. Together, these chapters guide students through the hands-on skills, observations, and analytical thinking that bring biology to life.

Whether you're a form six student preparing for your final exams, a teacher looking to spice up your lab sessions, or just a biology lover who enjoys a good story, this book is your companion in mastering practical biology with confidence and joy.

So steady your hand, open your specimen tray, and trust your curiosity.

Let the dissections and tests begin — and may your conclusions always be sound!

Acknowledgements

This book would not have been possible without the constant encouragement and belief from the many students and teachers who urged us to bring it to life. Their trust in our organisation provided the driving force behind the long and demanding process of preparing this work.

I am deeply grateful to Mr. Faraji Liviga, Head of Biology at Premier Girls' Secondary School, and Mr. Julian Kagasheki, Biology expert at NEH, for their invaluable support and contributions to content development, which played a major role in the preparation of this book.

A special note of appreciation goes to my family for their unwavering support, patience, and understanding. Their quiet contributions behind the scenes made all the difference.

Finally, I sincerely thank the dedicated **NEH team** for their tireless work in typing, editing, and designing the final version of this book. Their professionalism helped turn a vision into a reality.

Ngaiza Lusima,
NEH-Executive Director.

Chapter one
DISSECTION

INTRODUCTION

Dissection is more than just cutting open a specimen; it is a chance to see how life is organized on the inside. In this book, you will explore three key examples: the **cockroach** as a representative invertebrate, the **frog/toad** as an amphibian vertebrate, and the **mouse/rat** as a mammalian vertebrate.

By carefully exposing and studying their internal organs, you will discover how digestive and reproductive systems are arranged, how different animals adapt to their way of life, and how these structures compare with human biology. Each practical is designed to build both your observation skills and your confidence in scientific drawing and explanation.

DISSECTION OF A COCKROACH

The cockroach is a common invertebrate that provides a simple model for studying insect anatomy. By dissecting it, students can locate and observe its internal organs, identify different tissues, and understand the major body systems such as the digestive, reproductive, and excretory systems. This exercise helps build a foundation for comparing invertebrate and vertebrate body plans.

Materials necessary for the dissection of a cockroach:

- Dissection kit
- Dissecting tray or body
- Pins (dissecting pins or office pins)
- Scissors
- Fine point forceps
- Gloves and chloroform

General Procedures for dissecting a cockroach:

1. Melt little wax in the centre of dissecting tray.
2. Cut the insect wings, antennae, and legs close to their base.
3. Place the cockroach in the melted wax or use dissecting pins to place the cockroach on its dorsal side while the closed side is facing upward.

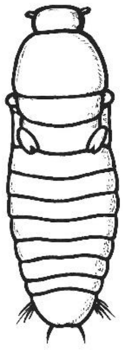


Figure 1: Cockroach fixed for dissection

4. Since the cockroach's heart is on its dorsal side and nervous system on its ventral side, when dissecting, cut either on its left or right lateral side from the last segment of the abdomen to the thorax.

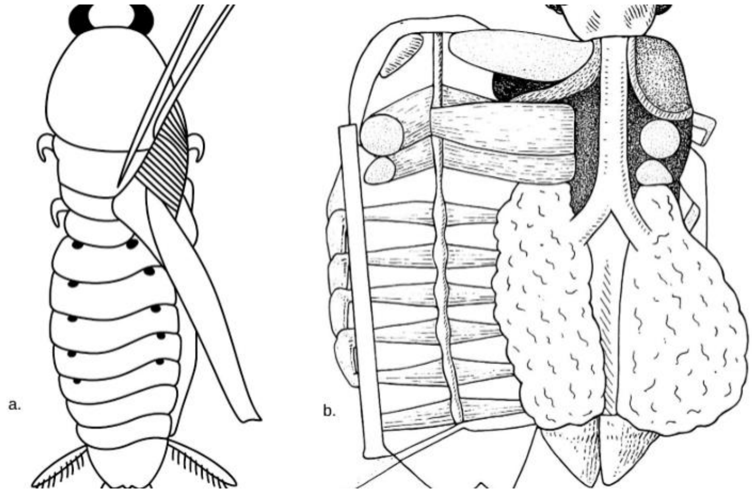


Figure 2: Fixed cockroach showing: a. lifted aside terga b. pinned terga

5. Carefully lift the last abdominal tergum with a pair of forceps, then make an incision along one side of the abdomen.
6. Place a pin to hold the terga aside.
7. Make sure the body wall is neatly pinned aside; the dissection is generally neat with all required features. Avoid damaging the organs and blocking the duct.
8. Remove fats to expose the gut and other organs in the body cavity.
9. Cover your dissection with water to bring the organs up, prevent them from drying up, and to enable them being seen clearly.
10. Loosen the gut, deflect to one side, and pin it to display all the systems.

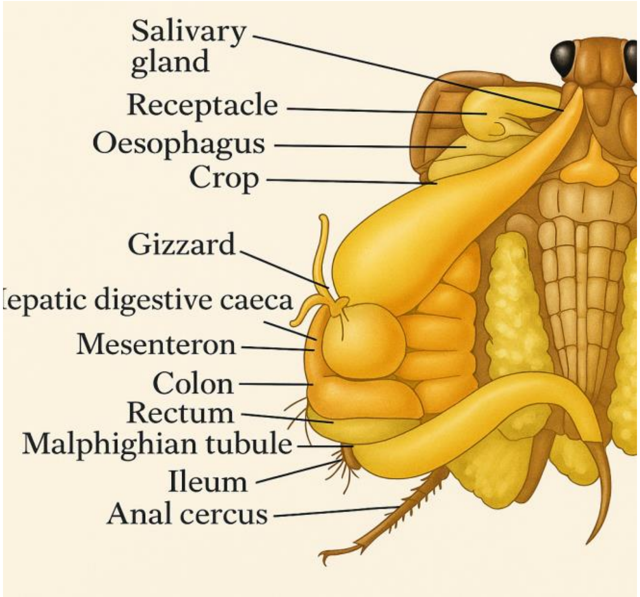


Figure 3: General view of the dissected cockroach

Systems to be Observed in Cockroach

Digestive System of a Cockroach

The alimentary canal of the cockroach is long and coiled, tubular structure starting at the mouth opening. It is divided into three main parts, namely:

1. **Foregut (Stomodaeum):**
   - The foregut is differentiated into five parts: buccal cavity, pharynx, oesophagus, crop, and gizzard.
   - The first two parts, buccal cavity and pharynx, are found inside the head capsule and will be visible in the dissected cockroach.
   - The other three parts (oesophagus, crop, and gizzard) are visible. The gizzard is muscular and internally provided with six cuticular pointed teeth for crushing food.
2. **Midgut (Mesenteron or Ventriculus):**
   - The midgut is short and tubular, lined with glandular endoderm. At the anterior end of the midgut, there are eight blind glandular hepatic caeca (digestive/ mucoproteic caeca), which increase the surface area for absorption.
   - The cells lining the mesenteron secrete digestive enzymes. Most nutrients are broken down here, and the resulting products are absorbed by the cells of the mesenteron and the digestive caeca.
   - The distal end of the midgut can be identified by the presence of Malpighian tubules, which serve an excretory function.
3. **The Hindgut (Proctodaeum):**
   - The hindgut comprises the ileum, colon, and rectum. The ileum is short and narrow and receives the openings of the Malpighian tubules.
   - The colon is wider and longer than the ileum. The wall of the rectum is provided with six rectal papillae, which help in the absorption of water and salts.

- The digestive system ends with the anal opening (anus), through which undigested materials are removed in the process known as egestion.

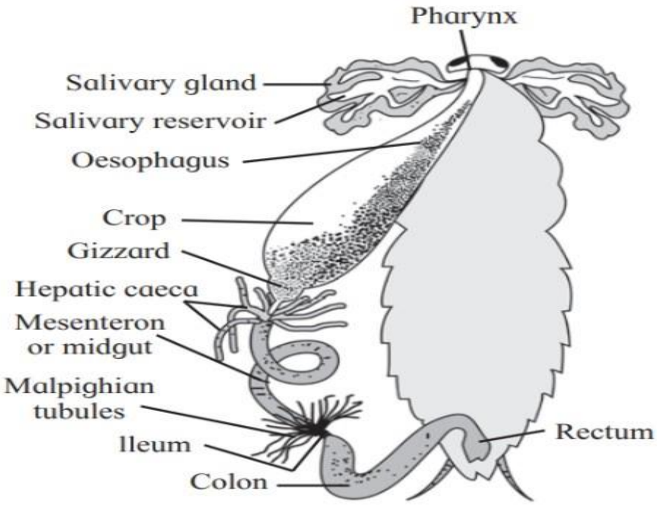


Figure 4: The digestive system of a female cockroach

Reproductive System of a Male Cockroach

External features: The male cockroach has a pair of genital styles, which are external structures used to distinguish it from the female.

Testes and ducts: The testes are small, lobed organs located on each side of the fourth and fifth abdominal segments. Each testis connects to a slender vas deferens, which leads into a wider ejaculatory duct.

Sperm storage: The testes produce sperm, which travel through the vas deferens into the seminal vesicles. Inside the vesicles, sperm are grouped into larger bundles called spermatophores (or germ pouches).

Copulatory structures: Three uneven chitinous structures, known as male gonopophyses or phallomeres, together with the pseudo-penis, form the copulatory organ. This organ is used to transfer spermatophores from the male to the female during mating.

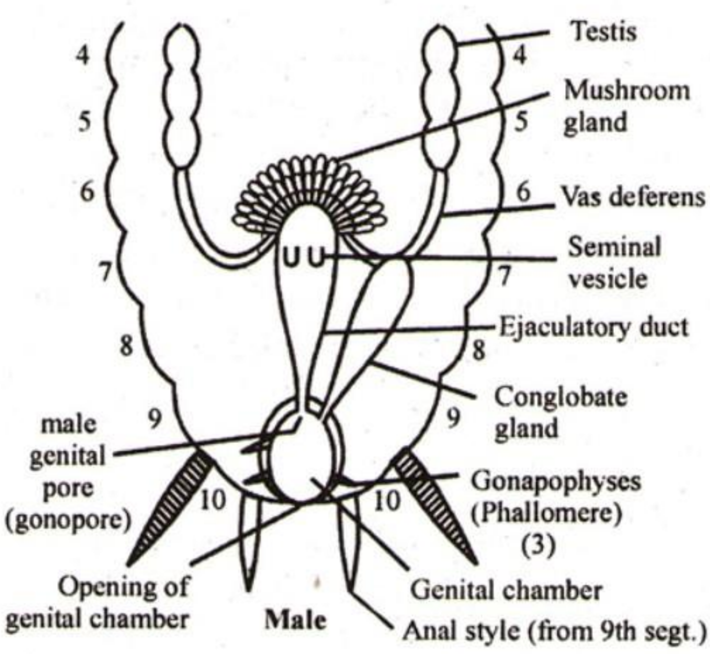


Figure 5: The reproductive system of a male cockroach

Reproductive System of a Female Cockroach

Organs included: The female reproductive system consists of the ovaries, oviducts, vagina, genital chamber, spermathecae (sperm-storage sacs), collateral glands, and female gonapophyses (ovipositor structures).

Ovaries: The ovaries are located on the sides of abdominal segments four, five, and six. Each ovary is made up of eight small units called ovarioles, where eggs are produced.

Genital chamber and ducts: From each ovary, an oviduct carries eggs into the genital chamber through a slit-like opening. A pair of collateral glands also open into this chamber.

Gonapophyses (ovipositor): Three pairs of chitinous rods, called female gonapophyses, hang from the roof of the oothecal chamber. These structures help in shaping the ootheca (egg case) and in depositing eggs.

Ootheca formation: The ootheca is a capsule containing sixteen fertilized eggs, coated with protein secretions from the collateral glands. The female carries the ootheca for several days, and after about six weeks, young cockroaches hatch and eventually develop into adults.

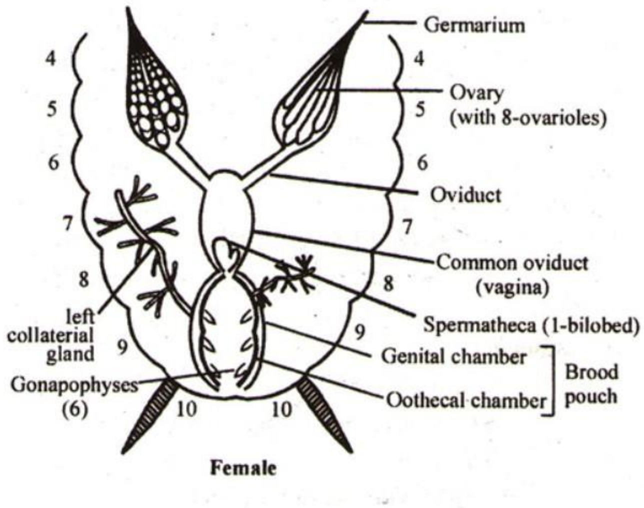


Figure 6: The reproductive system of a female cockroach

DISSECTION OF A FROG OR TOAD

The frog or toad is an amphibian vertebrate that represents the general body structure of many higher animals. Through dissection, students can explore its internal organs, study the arrangement of its digestive, circulatory, and reproductive systems, and recognize the special role of the cloaca as a common outlet. This practical provides valuable insights into vertebrate anatomy and how organs function together to support life.

General procedures for dissection of a frog/toad:

1. Wet a piece of cotton wool with chloroform and put it inside an airtight container such as a desiccator.
2. Put a live frog or toad inside the container containing wet cotton wool and leave it for about four to five minutes to anaesthetize it.
3. Take the frog or toad from the airtight container using forceps, place it on the dissecting tray and leave it for about 30 minutes to allow evaporation of chloroform.
4. Lay the frog or toad on its back leaving the ventral side (abdomen) facing upward.

Figure 7: Positioning the frog or toad for dissection

5. Pin the frog down on the tray through the fore and hind limbs.
6. Use forceps to lift the skin of the abdomen and use scissors to make a slit to the mid ventral line. Often insert one blade of the scissor into the slit.

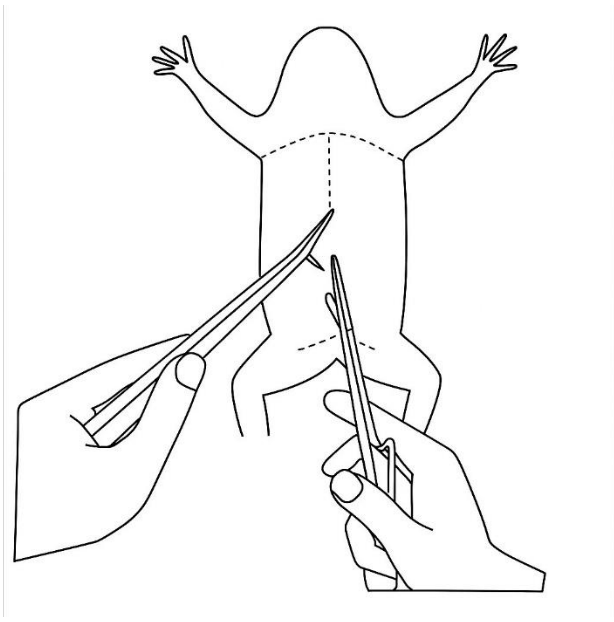


Figure 8: Opening the body cavity of an anesthetized frog

7. Hold the skin with forceps and loosen the skin from the underlying muscles, using the surgical blade, turn the skin flap back as in pin it.
8. Ligature the central abdominal vein at two sides. Use two scissors to make two small slits and insert a loop of thread through the slits by using forceps and grip it between their points. Pull the thread through the slits and cut the loop.

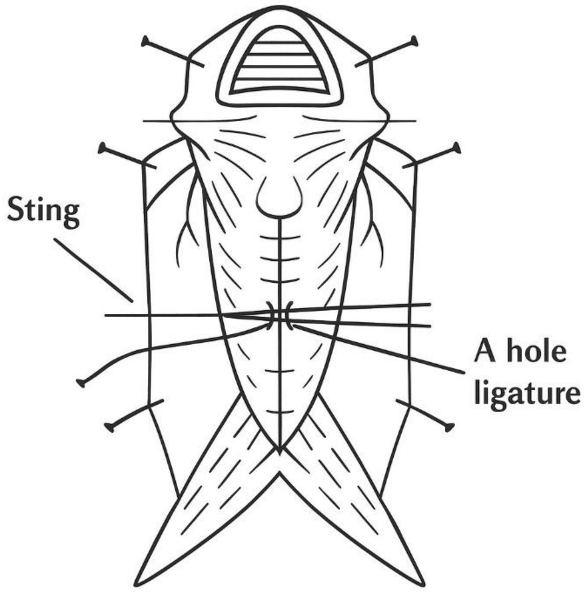


Figure 9: Ligaturing of the frog

9. Cut through the pectoral girdle on either side of the mid-line and remove the central piece of the girdle to expose the heart, and then cut the body wall transversely below the sternum.

10. Turn the trays so as legs face away from you, slit the body wall on either side of the midline to the pelvic area, remove the portion of the body wall. Cut the body wall transversely toward each leg. Pin across the belly wall.

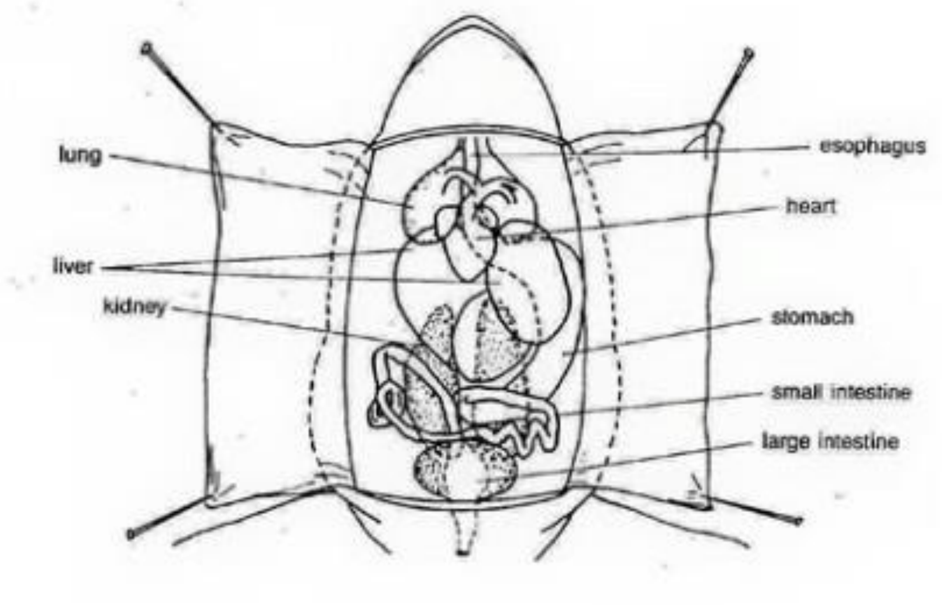


Figure 10: General view (visceral) of the dissected frog

11. To display the digestive system, pin out the stomach to either side of the animal. Pin out both lungs and turn the liver over. Pin out to turn in place with pin and grip the item. Rearrange the diaphragm and loosen the coils to expose the duodenum, duodenum in position, four right hand side to make all features visible.
12. In displaying the urogenital system, the cloaca should be opened by removing the ventral portion of pelvic girdles by inserting blade of the scissors through the girdle and then cut each side and remove the control portion of the girdle. Do not cut the blood vessels.
13. For the nervous system, remove the pins from the skin of the head and remove the floor of the mouth by cutting through an angle of the jaw to expose the first spinal nerve (the hypoglossal nerve).
14. Remove the flesh from both fore limbs around the shoulders and remove the pins from the lungs and stomach.
15. Cut through the oesophagus and remove lungs, the heart, stomach, and other parts of the alimentary canal. Remove the reproductive and excretory parts when removing the kidneys. Take care not to cut the aorta.
16. Remove any remaining membranes surrounding the abdominal lymph so as in order to expose the second spinal nerve called the brachial nerve and other third to tenth spinal nerve.
17. Trace the sympathetic nerve on either, the aorta, notice the sympathetic ganglia and identify the ramus communicans between the spinal nerves and the sympathetic ganglia.
18. Cut the flesh of the pelvic girdle through both thighs and trace the sciatic plexus and the sciatic nerve.

Systems to be observed in frog body

1. Digestive System of a Frog

The alimentary canal of a frog includes the mouth, buccal cavity, pharynx, oesophagus, duodenum, ileum, and rectum, all of which open into the cloaca.

Mouth and buccal cavity: The wide mouth allows ingestion of large pieces of food. The buccal cavity is flattened and continuous with the pharynx. It contains small, sharp, conical teeth used for cutting and crushing food.

Additional structures: Near the angles of the jaws are two Eustachian tube openings, which balance air pressure in the inner ear during swimming. The short oesophagus closes to prevent air from entering the stomach but can dilate during swallowing.

Swallowing aid: The buccal cavity, pharynx, and oesophagus are lined with cilia. These move mucus and food particles backward into the stomach, ensuring smooth swallowing and preventing food from returning forward.

Duodenum and ileum: The duodenum lies alongside the stomach and receives bile and pancreatic secretions through the hepato-pancreatic duct. Its folded inner surface increases surface area for secretion and absorption. The duodenum connects to the ileum, where most nutrient absorption takes place.

Rectum and cloaca: The alimentary canal ends in the rectum, where faeces collect before being passed through the anal sphincter into the cloaca, the common outlet for waste.

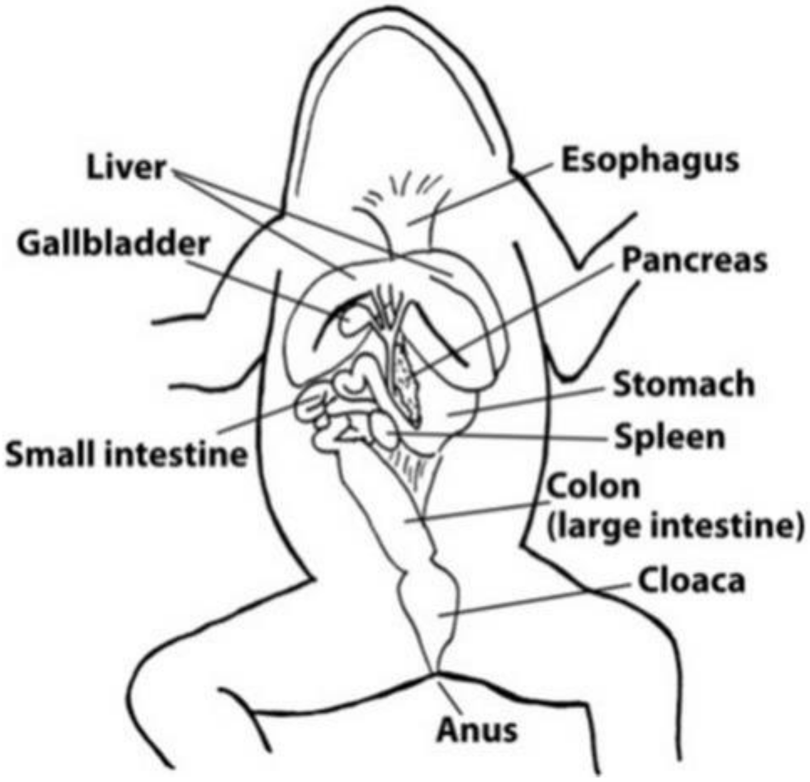


Figure 11: The digestive system of a frog

2. Urogenital System of a Male Frog

External feature: The male frog is generally slender and can be identified by the nuptial pads on its first fingers, which help in gripping the female during mating.

Kidneys and ureters: It has two dark red, oval, and slightly flattened kidneys located near the testes, beneath the ureters. Each ureter runs along the outer edge of a kidney and opens into the cloaca.

Cloaca: The cloaca serves as a common outlet for the digestive, reproductive, and urinary systems.

Testes and sperm ducts: The frog has two testes, each suspended by a fold of tissue called the mesorchium. From each testis, tiny tubes called vasa efferentia pass through the mesorchium and deliver sperm into the ureters.

Sperm storage: On both ureters, near the urinary bladder, are pouch-like glands called vesicula seminalis, which store sperm until the breeding season.

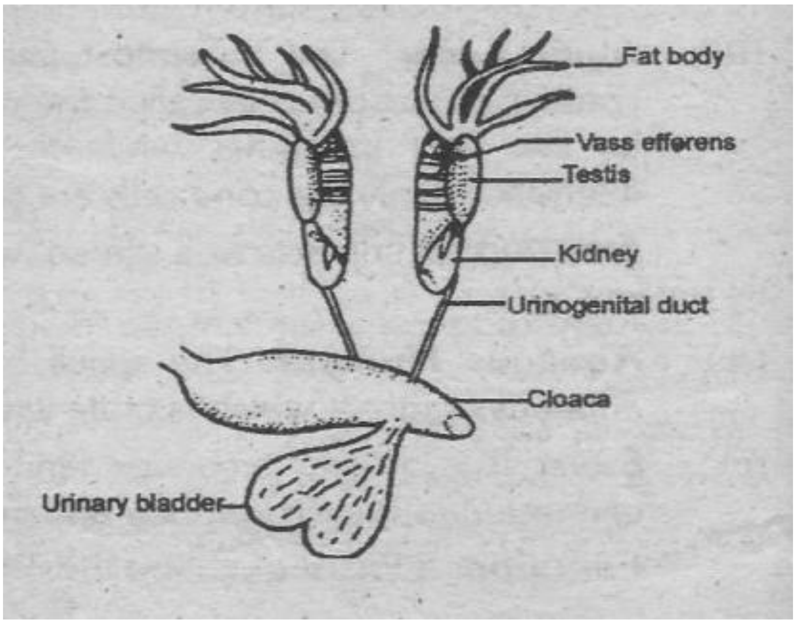


Figure 12: The urinogenital system of a male frog

3. Urogenital System of a Female Frog

Ovaries: The female frog has a pair of ovaries located in the same position as the testes in males. Each ovary is supported by a mesovarium and lies above the kidneys. The ovaries contain numerous eggs that appear half black and half white, visible through their thin covering.

Oviducts and oviducal sacs: Each ovary is connected to a long, thin tube called the oviduct. At the posterior end, the oviduct enlarges into an oviducal sac, which temporarily stores eggs before laying.

Excretory connection: The kidneys are connected to tubes called ureters. In females, the ureters carry only urine, while in males they carry both urine and sperm.

Common outlet: Both the oviducts and ureters open into the cloaca, which serves as the common passage for the reproductive and excretory systems.

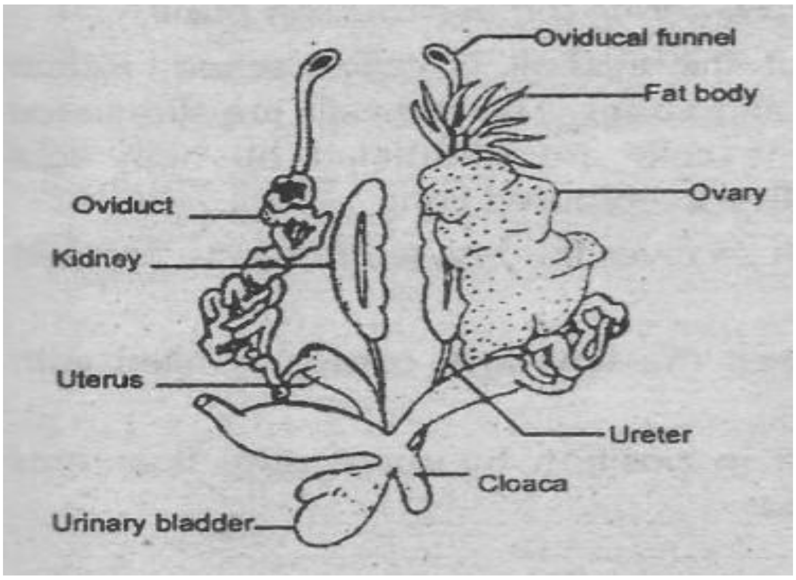


Figure 13: The urinogenital system of a female frog

DISSECTION OF MOUSE OR RAT

A mouse or rat is a typical vertebrate whose body organization closely resembles that of other mammals, including humans. By studying its anatomy, physiology, and metabolism, scientists gain useful insights into how the human body works. Although mice and rats differ from humans in size and appearance, they share a strong genetic similarity. The purpose of dissecting a rat or mouse is to observe its internal organs and systems, providing a clear understanding of basic mammalian anatomy.

General procedures of dissection of a mouse or rat

1. Place a live mouse or rat in a closed container with an anesthetic, such as chloroform applied to a piece of cotton wool, and leave it for about five minutes.
2. Lay the anesthetized animal on its back (ventral side facing upward) on the dissecting tray. Pin the forelimbs and hindlimbs securely, with the pins pointing outward for stability.

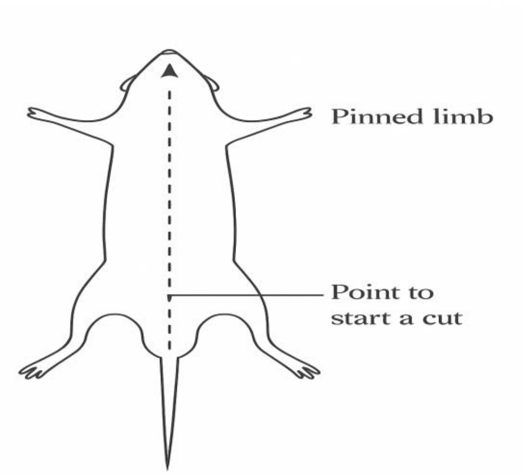


Figure 14: Positioning the mouse or rat for dissection

3. Lift the skin along the mid-ventral line with forceps and make a small slit. Extend the cut upward toward the lower lip. For a male specimen, cut backward around the penis and between the scrotum; for a female specimen, cut backward as far as the anus, passing on either side of the urinary and genital openings.

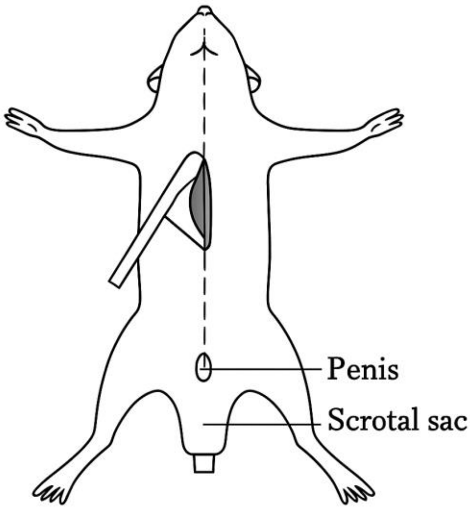


Figure 15: Opening the body cavity of an anaesthetized mouse or rat

4. Use your fingers to gently pull the skin aside, separate it from the body wall, stretch it, and pin it back.
5. Lift the abdominal wall with forceps, make an incision, and cut upward to the xiphoid cartilage and sideways toward the left and right ribs. Stretch the body wall and pin it aside.

Observe the abdominal organs in their natural (undisturbed) position which is known as the visceral general view.

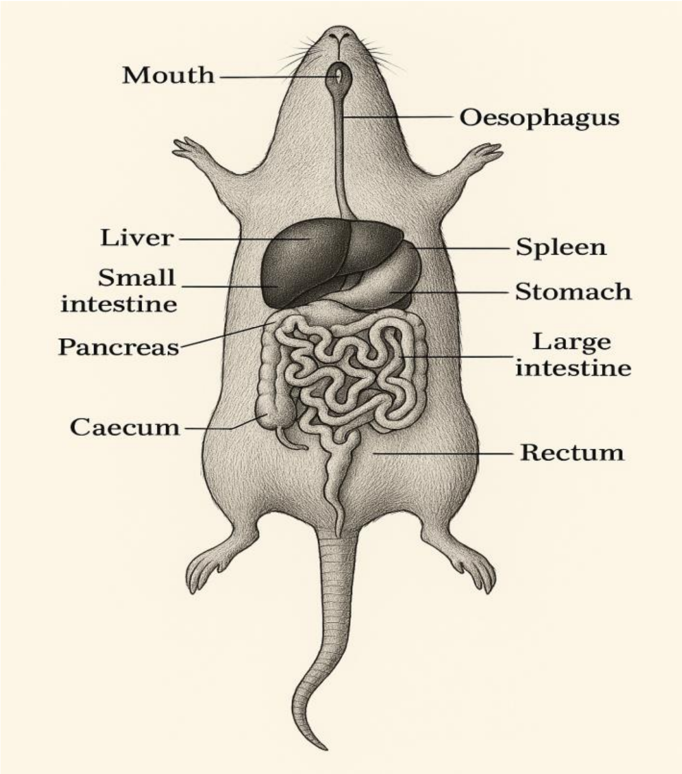


Figure 16: General view of the dissected mouse/rat

6. To display the digestive system, move most of the intestine to the left side of the specimen to expose the duodenum and colon.
7. Gently separate the duodenum and colon, pull them apart to reveal the hepatic portal vein, then turn the intestines to untwist them. Rearrange the digestive organs neatly and draw a well-labeled diagram.
8. To display the urinogenital system, first remove the alimentary canal. Then, carefully remove fat from the kidneys with blunt forceps and expose the ureters.
9. In a male specimen, open the scrotal sac by cutting through its ventral wall to expose the testes, epididymis (caput and cauda), and vas deferens. Lay the bladder, seminal vesicles, coagulating glands, and prostate glands to one side.
10. In a female specimen, hold the clitoris gently to lift the ureter away from the pelvis, then cut through the ventral part of the pelvic girdle.

- Lift the cut portion and remove the mesovarium to expose the ureters on both sides. Remove fat bodies from the kidneys and ureters but leave those around the ovaries.

- Note that the ovaries are enclosed within a thin ovarian sac and connected to small, coiled fallopian tubes.

Systems to be observed in mouse/rat

1. Digestive System of a Mouse

The alimentary canal of a mouse extends from the mouth to the anus. The mouth has sixteen teeth: twelve molars and four incisors. The lower incisors are longer, sharper, and more pointed than the others, and are used for cutting food into chewable pieces.

Beyond the mouth lie the oesophagus, stomach, pancreas, and small intestine. The small intestine is divided into three parts: duodenum, jejunum, and ileum, followed by the large intestine, which consists of the caecum, colon, rectum, and anus. The stomach is a pouch-like organ in the ventral abdomen, partly covered by the liver, where food is digested and stored before passing to the small intestine.

The liver has four lobes (one left, two right, and one central). Although it produces bile, the mouse has no gall bladder. Instead, bile from the liver lobes flows directly to the duodenum through cystic ducts. The hepatic portal vein collects nutrients absorbed from the intestines and delivers them to the liver. The intestines are supported by mesenteries—thin tissue sheets that attach them to the body wall and carry blood vessels, lymphatics, and nerves.

The pancreas lies near the stomach and secretes digestive enzymes through many small ducts into the duodenum. The duodenum receives food from the stomach and mixes it with bile and pancreatic secretions, while the jejunum and ileum continue digestion and absorb nutrients. The large intestine completes absorption of water, produces some vitamins, forms faeces, and passes waste to the anus. The caecum plays a special role in reabsorbing water and salts after small-intestine digestion, while also secreting mucus to lubricate food remains. The rectum temporarily stores faeces before elimination.

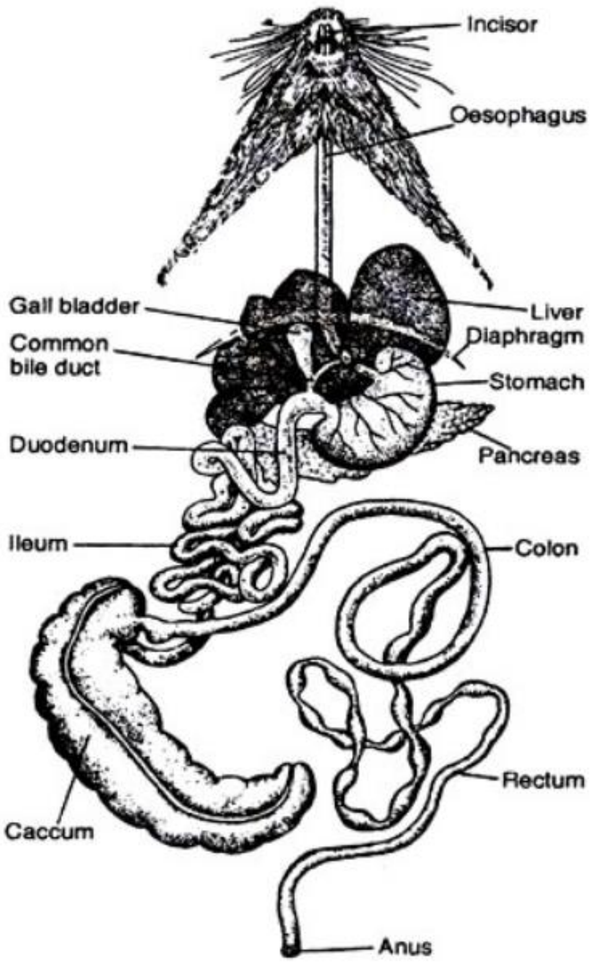


Figure 17: The digestive system of mouse

2. Urinogenital System of a Male Mouse

The urinary and reproductive systems of a male mouse are closely linked, so they are studied together as the urinogenital system.

Kidneys and urinary system: The mouse has two bean-shaped kidneys located at the back of the abdominal cavity. Each kidney has a small adrenal gland on top. From each kidney, a thin tube called the ureter carries urine to the urinary bladder. The bladder connects to the urethra, which passes urine out of the body through the penis.

Reproductive system: The scrotal sacs (scrotum) protect the testes, which produce sperm. Each testis is attached to a coiled tube called the epididymis, which temporarily stores sperm. The epididymis has three parts: caput, corpus, and cauda. From the epididymis, sperm travel through the vas deferens into the urethra. The urethra serves as a common passage for both urine and sperm, carrying them out through the penis.

Accessory glands: Alongside the bladder are the seminal vesicles, which secrete fluid that nourishes sperm. Additional glands include the prostate glands on each side of the urethra and Cowper's glands at the base of the penis, all of which contribute to seminal fluid.

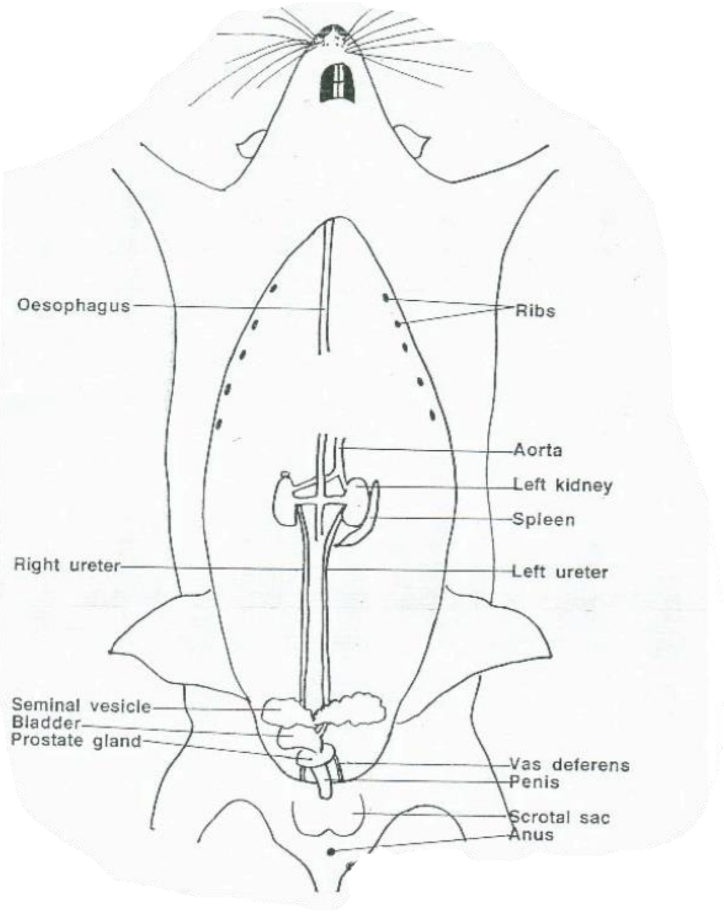


Figure 18: Urinogenital system of a male mouse

3. Urinogenital System of a Female Mouse

Pelvic openings: The female pelvic region has three openings: the anal opening, the genital (vaginal) opening, and the urethral opening. As in males, the kidneys and ureters filter and transport urine, but in females the bladder passes only urine, which exits through the urethra.

Reproductive system: The vaginal opening leads to a pair of long tubes called the uterus, which can accommodate multiple developing fetuses. At the tip of each uterus is an ovary, enclosed in a thin ovarian sac, responsible for producing eggs.

Connections: Each ovary is linked to the uterus by a small, coiled tube known as a fallopian tube, which transports the eggs from the ovary to the uterus.

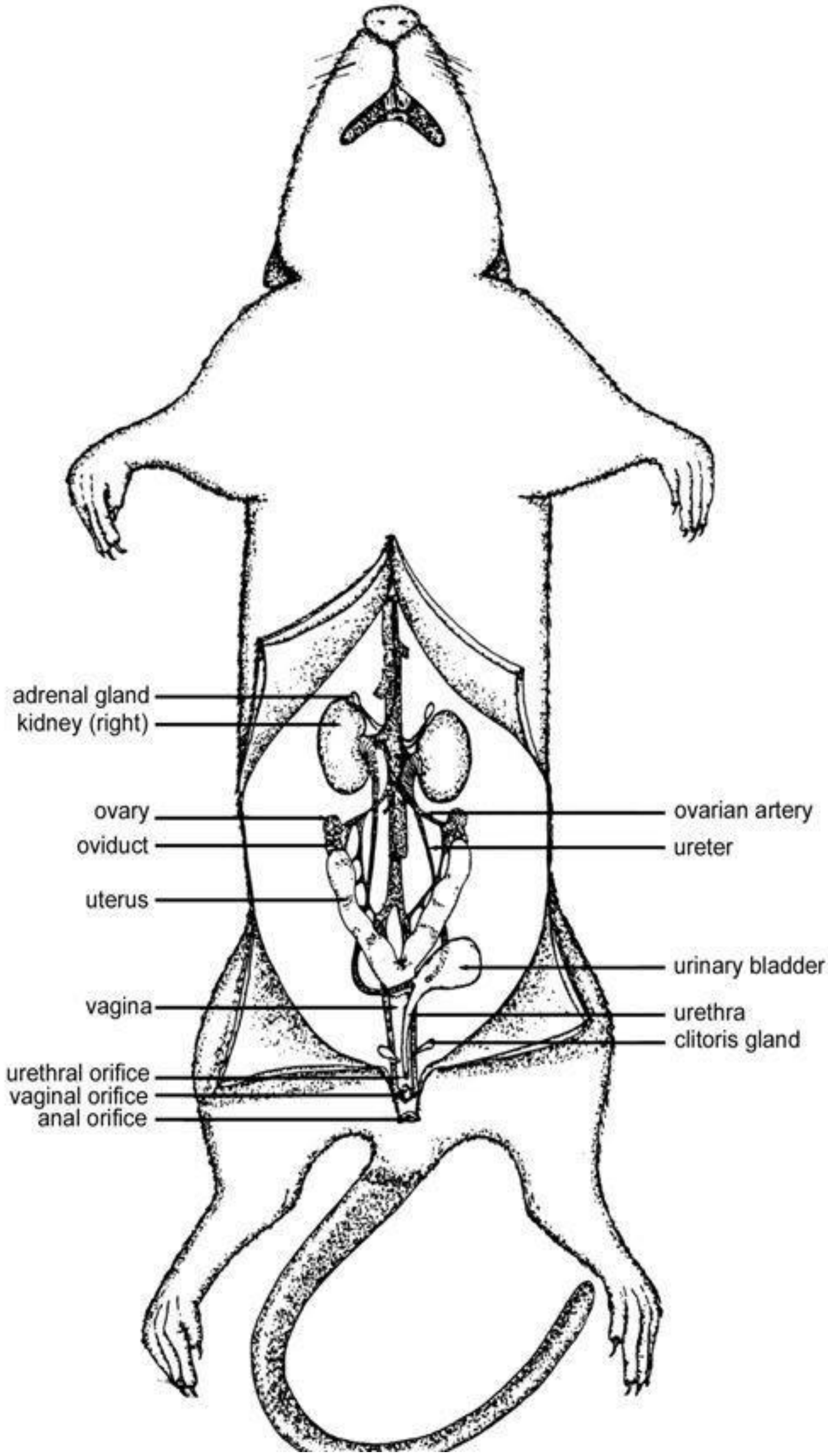


Figure 19: Urinogenital system of a female mouse

EXPERIMENTS

Experiment 1

Kipute tugged at her gloves with a sigh. *"Too tight,"* she muttered, *"but every surgeon has to suffer a little."* She lifted the scalpel like a professional about to perform her first big operation. The lab was quiet, the faint smell of disinfectant hanging in the air. With her classmates watching, she gently placed **Specimen C1** on the dissection tray.

"Operation: digestive system exposure," she announced half-jokingly, making a few of her classmates laugh. Slowly, she made the first incision, careful not to damage the internal organs. With each pin she placed, she felt like a detective gathering evidence. The stomach, intestines, liver—all neatly spread out like pieces of a mystery puzzle.

She leaned in and whispered to herself: *"So this is how food makes its journey—quite the adventure."* Kipute grinned. Today, she wasn't just a student; she was part surgeon, part investigator, uncovering the secrets of life hidden inside her specimen.

Now, as a student following in Kipute's steps, perform the task below:

Task:

Dissect specimen C1 in the usual way, expose its digestive system, and pin it neatly on your right-hand side.

Questions

(a) Draw a large, neat diagram of your dissected specimen and label at least **twelve (12)** parts.

(b) What are the roles played by digestive parts you have labelled in (a)? Give five points.

(c) Why do medical students and veterinarians often begin their training with animal dissections like this one?

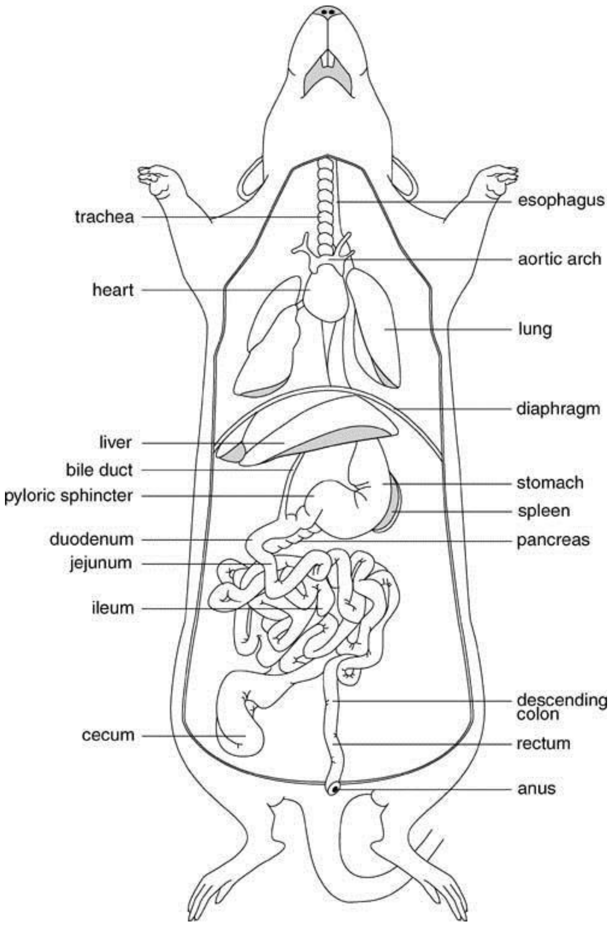
(d) Compare the digestive system of Specimen C1 with that of a human. Which major organ is well developed in the specimen but reduced in humans, and what role does it play?

(e) Imagine a child skips breakfast before school. Based on your dissection, explain why the small intestine would have very little activity compared to after a meal.

(f) Farmers often dissect young animals during veterinary checks. How does this practice help in maintaining livestock health?

Response to Questions

(a) Diagram of dissected mouse showing parts.



(b) Roles played by digestive parts:

1) **Mouth:** Responsible for mechanical digestion through chewing and chemical digestion through salivary amylase.
2) **Stomach:** It stores food and secretes gastric juice for breaking down proteins.
3) **Small intestine:** Main site of digestion and absorption of nutrients**.**
4) **Liver:** Produces bile which helps in emulsification of fats.
5) **Pancreas:** Produces digestive enzymes and bicarbonates to neutralize stomach acid.

(c) Because the structure and function of mammalian organs (such as those in mice and rats) closely resemble those of humans, they provide an essential foundation for understanding human anatomy and physiology.

(d) The specimen has a well-developed caecum, which houses bacteria that aid in cellulose digestion. In humans, this structure is reduced to a vestigial appendix with little or no digestive function.

(e) Without food intake, there is limited nutrient flow into the small intestine, so enzyme activity and absorption processes are minimal.

(f) It allows farmers to detect parasites, infections, or organ abnormalities early, ensuring better food quality and reducing economic losses.

Experiment 2

Kipute snapped on her gloves and looked at the class with a grin. *"Today, I'm the chief surgeon,"* she declared, holding up her scalpel as though it were a royal scepter. Her classmates chuckled, but when she placed **Specimen B** on the tray, she whispered dramatically, *"Patient admitted... condition: unknown."*

The bright lab lights and the silence that followed made it feel like an anatomy theatre. With a careful incision, she opened the specimen and exposed its digestive system. She pinned each part neatly, as though preparing it for a medical textbook.

"There we go," she thought, *"stomach stable, small intestine in place, caecum oversized—hmm, must be a herbivore case."* She chuckled quietly at her own diagnosis. It wasn't just dissection; it was like solving a medical mystery. Every cut, every pin, every organ was a clue to how this tiny creature survived on its diet.

Now, step into Kipute's operating room and perform the task below.

Task

Dissect specimen B in the usual way to fully display the digestive system.

Questions

(a) Draw a large diagram of your dissection and label ten parts. Leave your dissection properly displayed for assessment.

(b) Explain five adaptations of the digestive system to its role in specimen B.

(c) (i) Identify two structures of digestive system which are more developed in specimen than in human being.

(i) What effect will specimen B face if the structure you have mentioned at (c)(i) will fail to function normally?

(d) Suppose the liver of Specimen B becomes diseased and fails to produce bile. What specific digestive difficulties would arise, and how might this affect the animal's survival?

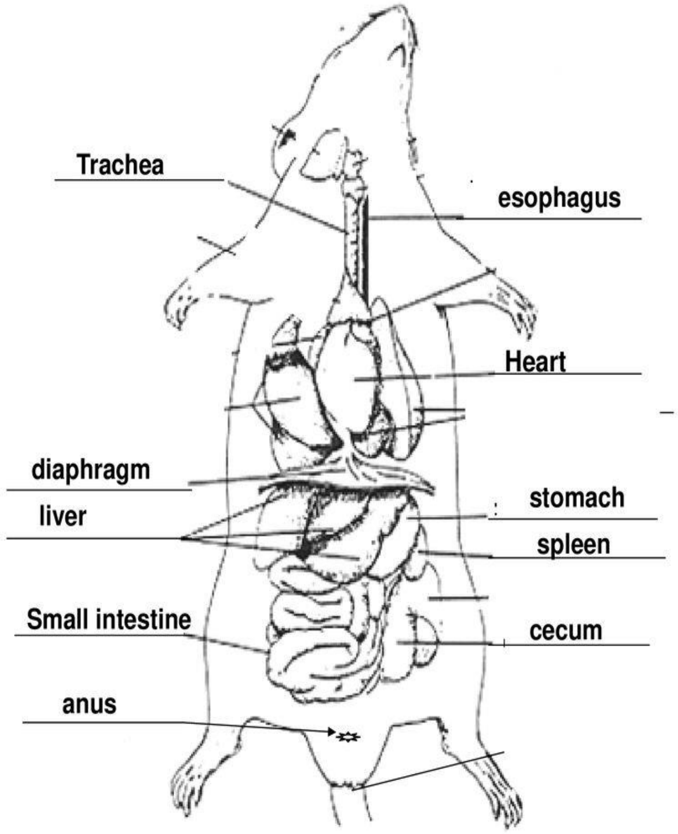
(e) In many rural areas, farmers use external observations like dull fur, weakness, or reduced weight to suspect digestive problems in small mammals. Based on your dissection, which internal organs should a veterinarian pay special attention to when confirming such cases?

(f) Herbivores like Specimen B eat frequently throughout the day, while carnivores may eat once and survive long. How does the design of the digestive system explain this difference?

(g) Humans possess only a vestigial appendix, while Specimen B has a large caecum. Why do some humans suffer from appendicitis, and why is it often treated by surgical removal without major long-term digestive issues?

Response to Questions

(a) Diagram of dissected mouse showing general parts



(b) Adaptations of digestive system:

1) The oesophagus is muscular and capable of peristalsis, allowing smooth transport of food.
2) The stomach is large with strong muscles and acidic secretion for breaking down food.
3) The small intestine is long with villi to increase surface area for absorption.
4) The liver produces bile which helps in the emulsification of fats, aiding digestion.
5) The large intestine reabsorbs water and form faeces for elimination, conserving body water.

(c) (i) Caecum and incisors.

(ii)

- Without a functional caecum, cellulose digestion would be inefficient, leading to reduced energy from fibrous root food.
- Failure of incisors would hinder cutting and processing of food, leading to feeding difficulty and poor digestion.

(d) Without bile, fats cannot be emulsified into small droplets, making it difficult for lipase to act effectively. As a result, fat digestion and absorption of fat-soluble vitamins (A, D, E, and K) would be impaired. This would lead to malnutrition, weakness, and reduced survival, especially if the animal relies on seeds or fatty plant material in its diet.

(e) A veterinarian should closely examine the **stomach**, **intestines**, **liver**, and **caecum**. These organs play key roles in nutrition and energy supply, so any dysfunction would explain external symptoms.

(f) Herbivores consume plant material that is rich in cellulose but low in readily available energy. Their **long digestive tracts, large caeca, and microbial fermentation chambers** slowly extract nutrients, requiring frequent feeding to meet energy demands. Carnivores, on the other hand, eat protein and fat-rich diets that are energy-dense and digested faster, so they can survive long intervals between meals.

(g) Appendicitis occurs when the human appendix becomes blocked and infected because of its narrow, tube-like structure. In ancestral humans, the appendix was part of a larger caecum that played a vital role in digesting cellulose-rich plant material. Over time, as humans shifted to a more varied diet that includes cooked and easily digestible foods, the appendix lost its digestive function and became vestigial. Since it no longer contributes significantly to digestion or nutrient absorption, its surgical removal (appendectomy) does not affect survival. Other digestive organs, such as the small intestine, fully handle nutrient breakdown and absorption.

Experiment 3

Kipute tightened her gloves and gave a little laugh, *"Well, today I'm a surgeon!"* she whispered to herself as she placed Specimen **S1** on the tray. The lab lights reflected off the shiny scalpel, making her feel as though she were in a miniature operating theatre.

Her classmates teased her for being so serious, but she replied, *"If I mess this up, my patient won't complain but my teacher will!"* Everyone chuckled. With steady hands, she made the first incision, carefully exposing the vascular system and the associated digestive organs.

There they were: the **liver, pancreas, and gall bladder**—looking less glamorous than the diagrams in her biology textbook but far more real. Kipute thought of how, in a human surgery, doctors would talk about liver transplants, insulin injections, or gall stones. Here, in this tiny specimen, she saw the same principles of life written in flesh and blood.

As she pinned the organs neatly in place, she felt like both an investigator and a trainee doctor. Each pin was a clue, each organ a witness, and the story they told was one of digestion, energy balance, and survival.

Now, as a student stepping into Kipute's "operating room," perform the dissection and respond to the questions below.

Questions

(a) Draw a neat diagram of your dissection and label parts. Leave your dissection properly displayed for assessment.

(b) (i) What are the associated organs of the digestive system present in the specimen?

(ii) Which digestive role is played by each of the associated organs identified in (b)(i)?

(iii) How does each of the associated organs identified in (b)(i) adapt to perform its digestive role in the specimen?

(c) How does each of associated organ identified in (b)(i) adapt to regulate sugar in the body of the specimen?

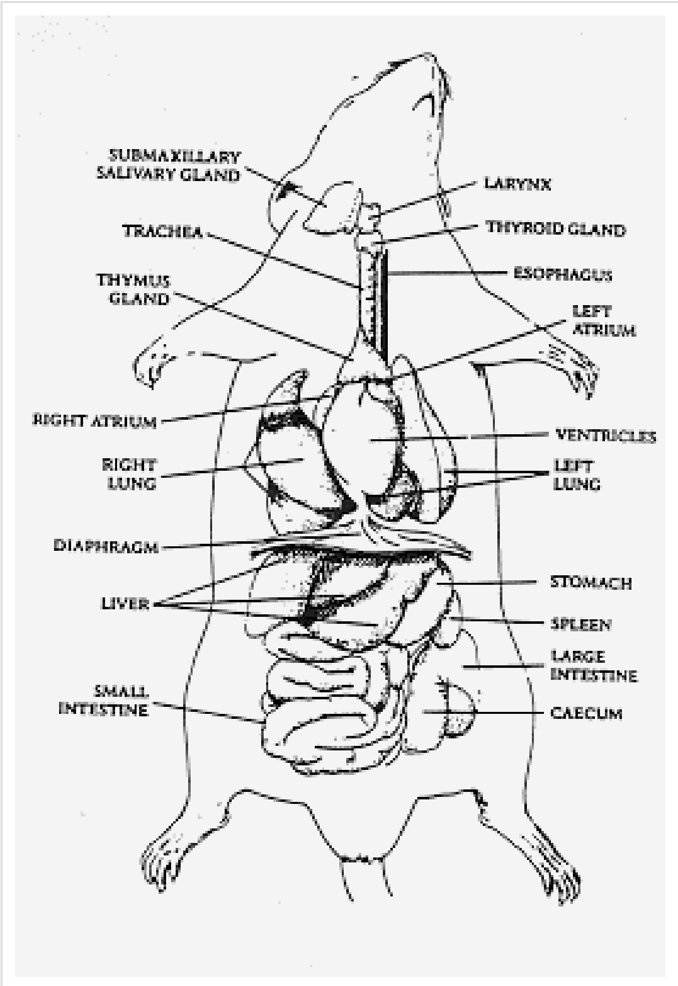
(d) If the liver could not store glycogen properly, how would this affect the specimen's ability to survive periods of fasting?

(e) Gall bladder stones (gallstones) are common in humans. If a similar condition occurred in specimen S1, what difficulties in digestion would result, and why?

(f) Imagine specimen S1 eats a meal rich in fat. Which associated organ would immediately become active, and how would it contribute to efficient digestion of the meal?

Response to Questions

(a) Diagram of dissected mouse showing general parts



(b)

(i) Parts:

- Liver
- Pancreas

- Gall bladder

(ii) **Digestive roles:**

Liver: Produces bile for emulsification of fats.

Pancreases: Secretes digestive enzymes and bicarbonates to aid digestion in small intestine.

Gall bladder: Stores and releases bile into the duodenum when needed.

(iii)**Adaptations for digestive roles:**

Liver: Has many lobes which supply blood for efficient processing and storage of glycogen.

Pancreas: Contains enzyme-producing cells and ducts that deliver secretions into the duodenum

Gall bladder: Muscular walls allow contraction for rapid release of bile.

(c) **Adaptations for sugar regulation:**

Liver: Stores glucose as glycogen and breaks it down when needed to regulate blood sugar.

Pancreas: Contains islets of Langerhans which produce insulin and glucagon to regulate sugar level.

Gall bladder: Not directly involved in sugar regulation.

(d) Without glycogen storage, the specimen would lack an energy reserve to release glucose during fasting. Blood sugar would drop quickly, leading to weakness, reduced activity, and possibly death if food is not constantly available.

(e) Gallstones would block the release of bile into the duodenum. Without bile, fats would not be properly emulsified, making it difficult for lipase enzymes to act effectively. This would lead to poor fat digestion, oily or fatty stools, and reduced absorption of fat-soluble vitamins (A, D, E, K).

(f) The **gall bladder** would contract and release bile into the duodenum. Bile breaks down large fat globules into smaller droplets (emulsification), increasing the surface area for lipase enzymes from the pancreas to act on. This ensures efficient digestion and absorption of fats.

Experiment 4

Mr. Akilikubwa adjusted his lab coat, cleared his throat, and said in his usual dramatic tone: *"Ladies and gentlemen, today we open a very special case—Specimen K. Think of me not just as your technician, but as your chief surgeon in charge of intestines."*

The students chuckled as he carefully placed the specimen on the tray. With steady hands, he made a clean incision and revealed the **viscera** inside. The organs unfolded like a hidden map, each curve and fold telling its story.

He leaned in and tapped the small intestine with his forceps. *"Here is where the real magic happens—nutrients, energy, life itself. If this fails, no creature stands a chance."* He smiled and added, *"And remember, these structures are not just squiggly tubes—they are biochemical factories working overtime."*

As he pinned the duodenum and ileum neatly, Mr. Akilikubwa looked around the lab like a proud surgeon showing off his patient. *"Alright young doctors,"* he said, *"your job is to take over the operation—observe, dissect, and record. Let's see if you can trace the story these intestines tell."*

Task

Dissect specimen K to fully display the visceral general.

Questions

(a) Draw a larger neat and well labelled diagram of your dissection. Leave your dissection properly displayed for assessment.

(b) (i) Identify two structures in specimen K which form the small intestine.

(ii) How do the structures you identified in 2(i) adapt to their function? Give three points for each.

(c) The ileum in Specimen K shows clusters of lymphoid tissue. Why is this feature essential for the specimen's survival in its natural environment, where exposure to pathogens from food is common?

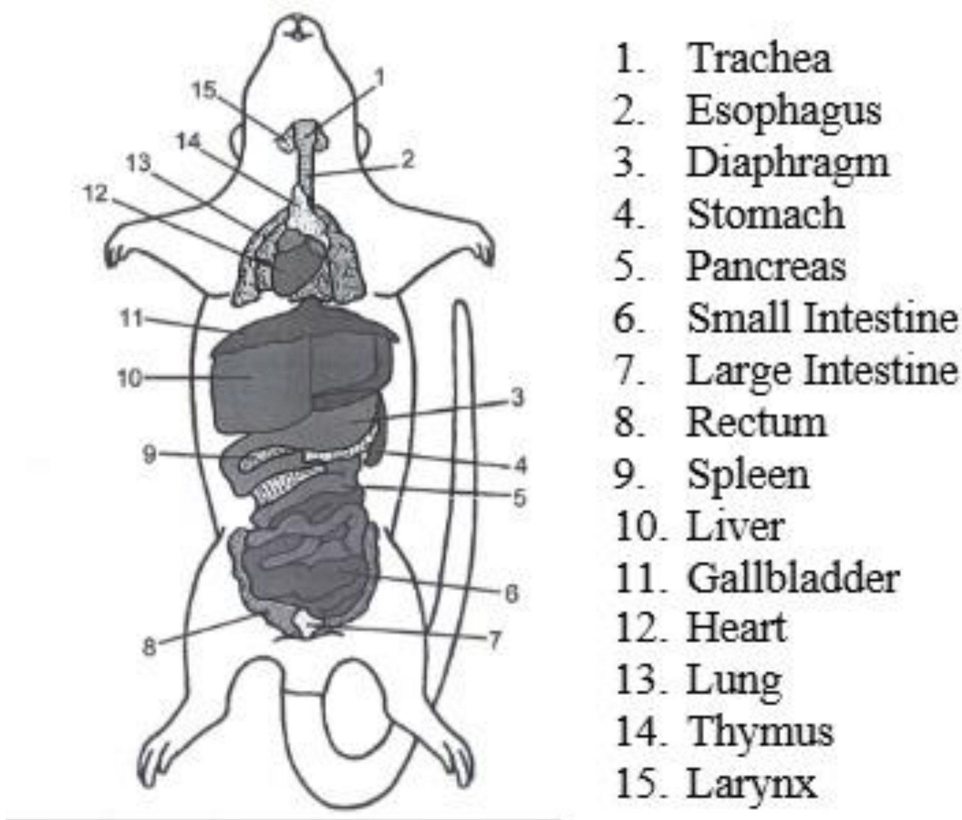
(d) Suppose Specimen K had part of its small intestine surgically removed. From your dissection, which structure (duodenum or ileum) would cause more severe nutritional problems if removed, and why?

(e) During an outbreak of cholera in a community, patients suffer severe dehydration. Based on your dissection of Specimen K, explain why damage to the small intestine (especially the ileum) results in rapid water loss.

(f) Suppose Specimen K's duodenum is surgically removed. What immediate digestive problems would occur, and why?

Response to Questions

(a) Diagram of dissected mouse showing general parts



(b) (i)

- Duodenum
- Ileum

(ii) **Duodenum**

- Receives bile and pancreatic juices which aid in digestion of different food nutrients.
- Has Brunner's gland that secrete mucus to protect the lining of the duodenum.
- Has villi to increase surface area for absorption of digested nutrients.

Ileum

- Contains numerous villi and microvilli for maximum absorption.
- Has a rich blood supply for efficient transport of absorbed nutrients.
- Contains lymphoid tissue for immune defense.

(c) The lymphoid tissue in the ileum (Peyer's patches) acts as a frontline defense against pathogens entering with food. These tissues contain immune cells that detect and neutralize harmful bacteria and viruses before they spread through the bloodstream. In the specimen's natural environment, where food may carry microbes, this adaptation reduces the risk of infections and ensures safe absorption of nutrients. Without it, the specimen would be more vulnerable to intestinal diseases.

(d) Removal of the **ileum** would cause more severe nutritional problems. This is because the ileum is specialized for maximum absorption of nutrients, including amino acids, glucose, fatty acids, vitamins, and minerals. It also absorbs vitamin B12 and bile salts, both vital for energy metabolism. While the duodenum is important for receiving bile and pancreatic juices, much of the actual nutrient absorption takes place in the ileum. Therefore, loss of the ileum would lead to malnutrition and serious digestive complications in the specimen.

(e) The ileum normally reabsorbs large amounts of water and electrolytes along with nutrients. If it is damaged, water cannot be absorbed efficiently, leading to watery stools and dehydration.

(f) The duodenum receives bile and pancreatic enzymes. Without it, fats, proteins, and carbohydrates would not be properly broken down before absorption. This would lead to incomplete digestion, malnutrition, and undigested food passing into the large intestine, often causing diarrhea.

Experiment 5

Kipute stood nervously over Specimen J, scalpel in hand. Today she wasn't alone—Mr. Akilikubwa was watching closely, arms folded, as if he were supervising a real surgical operation.

"Remember, Kipute," he said with a grin, *"steady hands, clear eyes. Pretend you're a surgeon on a million-dollar patient… except this one won't sue you if you slip."* The class burst into laughter, breaking the tension.

Kipute giggled, then made her first incision. She carefully traced along the specimen's abdomen and gently exposed the digestive organs. Mr. Akilikubwa leaned in and pointed with his forceps. *"Now, pin at the ileum—yes, that's the correct spot. Excellent. This is how surgeons learn: one pin at a time."*

As the gall bladder, liver lobes, and stomach came into view, Kipute thought of how doctors talk about gallstones, ulcers, and digestion problems in real hospitals. Here, in this small specimen, the same principles were visible. It was dissection class, surgery theatre, and detective investigation rolled into one.

"Very good," Mr. Akilikubwa finally said, smiling. *"Now, let's see if you can answer the questions this patient has left for us."*

Now, as a student following in Kipute's and Mr. Akilikubwa's steps, perform the task below:

Task

Dissect specimen J in the usual way to fully display the digestive system. Pin at the ileum to your right-hand side.

Questions

(a) Draw a large, neat diagram of your dissection and label nine parts. Leave your dissection properly displayed for assessment.

(b) Use handle lens to observe your dissection carefully.

(i) What is the name of a transparent overleaf structure lying between the main lobes of the liver in the specimen J?

(ii) State the role of the structure named in (b)(i).

(iii) Enumerate three main digestive juices secreted into the duodenum.

(c) (i) Identify two structures in the specimen J which are responsible for the storage of the excess absorbed food and state the food type stored in each structure.

(ii) What is the name of a ring muscle like structure which is situated immediately between the far end of the stomach and the duodenum in specimen J?

(ii) State the role of the structure named in (c)(ii)

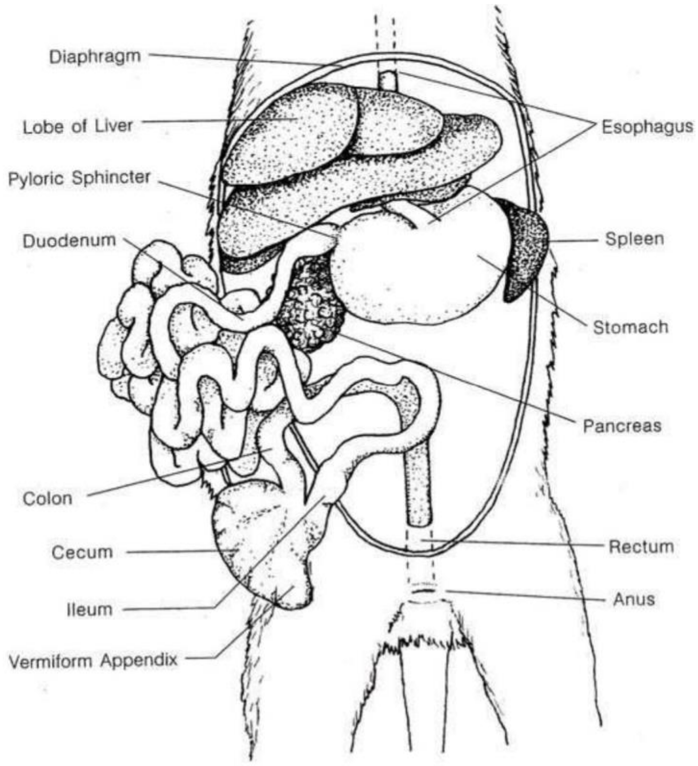
(d) If the pyloric sphincter in Specimen J failed to close properly, what problems would you expect in the digestive process?

(e) Based on your dissection, explain why the liver's ability to store glycogen is critical during fasting periods in Specimen J.

(f) In humans, fatty liver disease occurs when excess fat accumulates in the liver. Based on what you observed in Specimen J, predict how this condition would affect its normal digestive and storage roles.

Response to Questions

(a) Diagram of dissected mouse showing digestive system with ileum pinned on left hand side of the specimen (your right hand side).



(b) (i) Gall bladder

(ii) It stores and concentrates bile produced by the liver and releases it into the duodenum to aid fat digestion.

(iii)

1) Pancreatic juice
2) Intestinal juice
3) Bile

(c) (i) **Structures and stored food types:**

Liver: Stores glucose in the form of glycogen.

Fat tissue: Stores excess lipids (fats).

(ii) Pyloric sphincter

(iii) It controls the passage of partially digested food (chime) from the stomach into the duodenum and prevents backflow.

(d) Partially digested food could flow backward from the duodenum into the stomach, causing irritation and poor digestion. The stomach might also empty too quickly, reducing efficiency of nutrient breakdown before reaching the small intestine.

(e) The liver releases stored glycogen as glucose when no food is available. This maintains steady blood sugar levels and ensures continuous energy supply. Without this function, the specimen would become weak and unable to survive between meals.

(f) Excess fat in the liver would interfere with glycogen storage and bile production. This would impair blood sugar regulation and fat digestion, leading to malnutrition and energy imbalance.

Experiment 6

Mr. Akilikubwa rolled up his sleeves and announced:

*"Today's patient is back—**Specimen S1**. But don't panic, this operation is strictly educational. No malpractice lawsuits here."* The class chuckled as he placed the specimen on the tray.

He adjusted the overhead lamp like a real surgeon preparing for theatre. *"Scalpel,"* he said, and Kipute quickly handed it over, pretending to be his nurse. *"Ah, thank you, Dr. Kipute. You may scrub in one day."* The students burst out laughing.

With practiced care, he made an incision and slowly exposed the digestive system. Each organ unfolded like a mystery clue: the mouth leading to the oesophagus, the stomach neatly tucked, the intestines winding like hidden tunnels. He pinned the specimen carefully to the right-hand side, nodding with approval.

"Class," he said, tapping the stomach with his forceps, *"the foregut and midgut are more than just pipes—they are life's kitchen. One prepares the meal, the other serves it to the bloodstream. Now let's see if you can decode their story."*

Now, as a student following in Mr. Akilikubwa's steps, perform the task below:

Task

Dissect specimen S1 in the usual way and display the digestive system on the right-hand side of the animal.

Questions

(a) Draw a large, neat, well labelled diagram of your dissection.

(b) State the role played by each part which makes up the following:

(i) Foregut

(ii) Midgut.

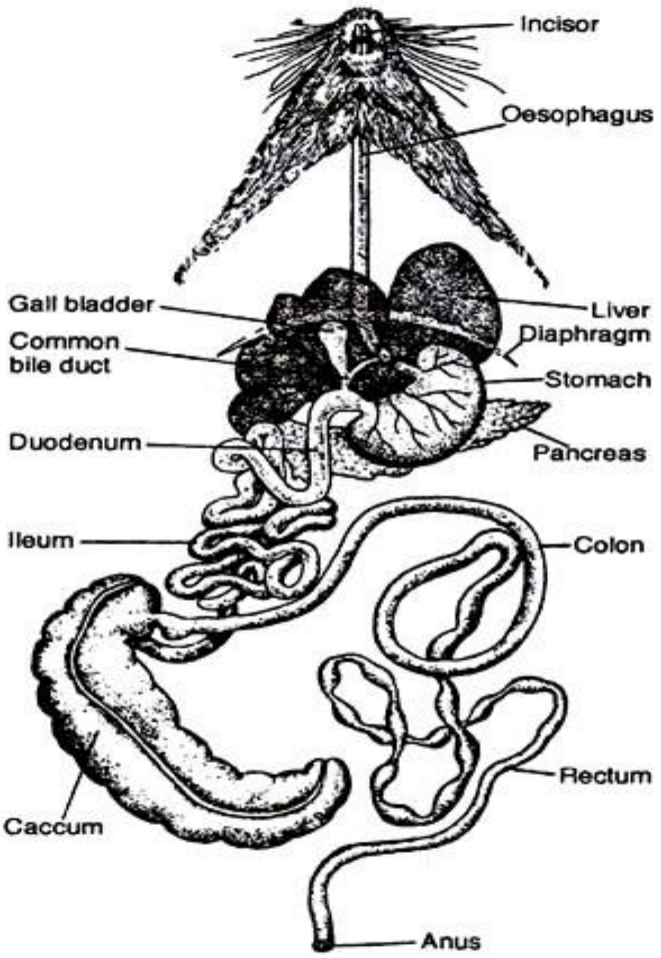
(c) If the stomach lining in Specimen S1 became damaged by excess acid, what condition would develop, and how would it affect digestion?

(d) If the midgut (small intestine) failed to function properly, which nutrients would be most affected, and what symptoms would appear in Specimen S1?

(e) During your dissection of **Specimen S1**, you observed that the midgut includes the duodenum and ileum. Why would a veterinarian carefully examine this region when an animal shows persistent diarrhea?

Response to Questions

(a) Diagram of dissected rat/mouse showing digestive system.



(b) (i) Foregut:

- The foregut includes the mouth, oesophagus, and stomach.
- Its role in digestion includes mechanical digestion and initial breakdown of food using enzymes and gastric acid.

(ii) Midgut:

- The midgut includes the small intestine (duodenum and ileum).
- Its role is chemical digestion using enzymes and absorption of nutrients into the bloodstream.

(c) An ulcer would form, causing pain and reduced ability to digest proteins. Food would pass to the small intestine only partially digested, lowering nutrient absorption.

(d) Carbohydrates, proteins, fats, vitamins, and minerals would not be absorbed effectively. The specimen would show weight loss, weakness, stunted growth, and possibly anemia or bone weakness.

(e) In Specimen S1, the midgut is the main site of nutrient and water absorption. If it is damaged or infected, absorption fails, leading to persistent diarrhea, (and of course, dehydration, and weakness).

Experiment 7

Mr. Akilikubwa placed a cockroach labeled **Specimen Q** on the dissection tray. Kipute wrinkled her nose and muttered, *"Of all the creatures in the lab…why this one?"* Her deskmate laughed, reminding her that cockroaches are survivors, masters of adaptation, and fascinating creatures to study.

"Don't just think of it as an insect," Mr. Akilikubwa encouraged the class. *"Think of it as a lesson in evolution. Its nervous system, its senses, and its resilience can teach us how life is designed to thrive even in the toughest conditions."*

As Kipute adjusted her scalpel, she turned to you and whispered: *"Alright, partner, let's do this together. You'll help me with the labeling while I steady my hand for the cut."*

As Kipute's lab partner, cooperate with her to carry out the following:

Task

Dissect Specimen Q in the usual way to fully expose the nervous system.

Questions

(a) Draw a large, neat, and well-labeled diagram of your dissection.

(b) Propose the sex of Specimen Q and give one external feature you considered in making your conclusion.

(c) Enumerate five features that help Specimen Q adapt to its life.

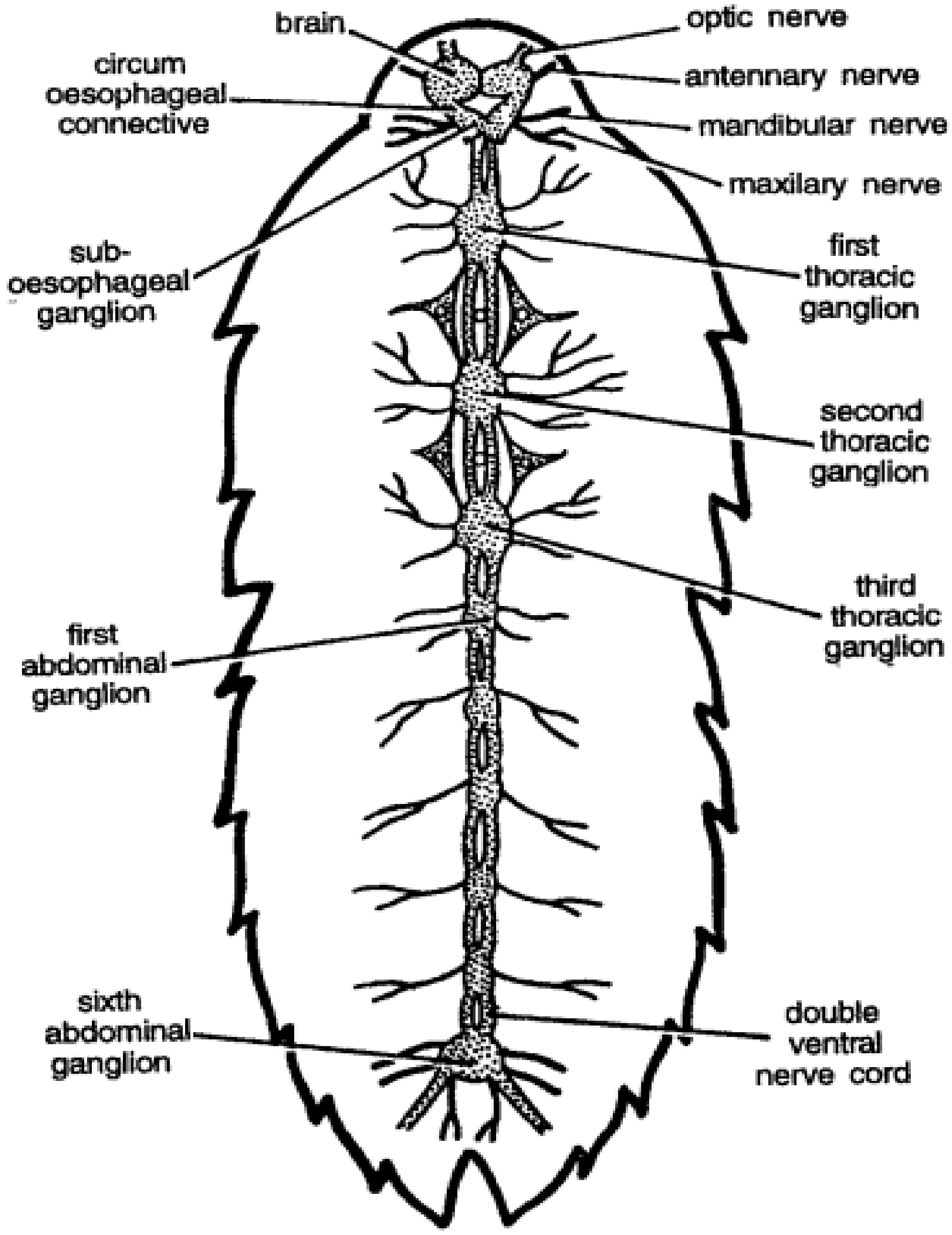
(d) Why are cockroaches often used in biology dissection practicals despite being considered pests?

(e) Why do cockroaches survive in harsh conditions better than many other insects?

(f) Imagine urban pest control scientists are studying cockroaches. Which adaptations from part (c) make them especially difficult to eliminate?

Response to Questions

(a)



Cockroach nervous system

(b) **Sex:** Male
External feature: Presence of **anal styles** (C-shaped paired structures near the anus), found only in males.

(c) Adaptive features of cockroach:

1. Strong **chitinous exoskeleton** for protection and support.
2. **Jointed antennae** for detecting chemical stimuli in the environment.

3. **Compound eyes** for wide-angle vision and motion detection.
4. **Wings and jointed legs** for quick escape, dispersal, and mobility.
5. **Spiracles and tracheal system** for efficient gaseous exchange.

(d) Their anatomy (nervous system, digestive system, and respiratory structures) is simple yet representative of insects, making them excellent study specimens.

(e) Their tough exoskeleton, ability to feed on diverse foods, and efficient respiratory system make them resilient to environmental changes.

(f)

1) Quick mobility from jointed legs and wings,
2) Resistance provided by the exoskeleton, and
3) Their ability to detect chemical stimuli make them hard to control.

Chapter 2

FOOD TEST

INTRODUCTION

Food tests are simple biochemical experiments that help us identify which nutrients are present in different food samples. In biology, these tests focus mainly on **carbohydrates, proteins, and lipids**—the essential components of most diets. Each nutrient reacts in a unique way with certain reagents, producing colour changes or visible precipitates that reveal its presence.

For example, iodine solution turns blue-black in the presence of starch, Benedict's solution produces a brick-red precipitate with reducing sugars, the Biuret reagent forms a violet colour with proteins, while Sudan III or the emulsion test confirms the presence of lipids. These tests are not just classroom exercises, they are the same principles used in **food industries, hospitals, and research laboratories** to check food quality, diagnose health conditions, and ensure nutritional value.

Through food tests, students strengthen their skills in observation, inference, and laboratory technique, while also seeing how biological theory connects to real life. Just as nutritionists, doctors, and food scientists test meals and drinks, you too will act as a food detective, uncovering the hidden nutrients in everyday substances.

Biochemical Test for Carbohydrates

Carbohydrates are vital energy-giving compounds found in most foods. They are made up of carbon, hydrogen, and oxygen, and include sugars, starches, and cellulose. Depending on their structure, carbohydrates may occur as single sugar molecules or as long chains linked together, and they can exist alone or be combined with other molecules.

In biochemical testing, the detection of carbohydrates relies on their chemical groups, (especially aldehydes or ketones) which give them reducing properties. Because of these features, different reagents can be used to identify various forms of carbohydrates.

The three main types of carbohydrate tests in the laboratory are:

- **Starch test** (using iodine solution),
- **Reducing sugar test** (using Benedict's solution), and
- **Non-reducing sugar test** (using acid hydrolysis followed by Benedict's test).

These tests help us distinguish simple sugars from complex ones and reveal how carbohydrates are broken down and used by living organisms.

1. Biochemical Test for Starch

Starch is a complex carbohydrate and one of the main storage forms of energy in plants. Since it is only slightly soluble in water, starch usually occurs as a suspension or in solid form. Testing for starch is one of the simplest and most common biochemical experiments in the laboratory.

Principle: Iodine solution (a mixture of iodine and potassium iodide in water) has a light orange-brown colour. When it comes into contact with starch, the iodine molecules fit into the helical structure of amylose, forming a polyiodide complex that appears dark blue or blue-black.

Procedure: Add a few drops of iodine solution to a food sample in suspension or to a small solid piece (such as a slice of potato or cabbage).

Result: A **blue-black colour** confirms the presence of starch, while an **orange-brown colour** indicates starch is absent (the orange-brown color of the aqueous solution is retained in the absence of starch).

Test	Observation
Add 2cm^3 of starch to a test tube.	A blue-black coloration.(A mixture solution changes to blue-black coloration.)
Add three (3) drops of iodine solution or potassium iodide solution.	
Alternatively:	
Add three drops of iodine solution to the solid form of starch (e.g., to a piece of cabbage).	

2. Biochemical Test for Reducing Sugars

Reducing sugars include all monosaccharides (such as glucose and fructose) and some disaccharides (like maltose and lactose, but not sucrose). They are called "reducing" because they can donate electrons during chemical reactions, usually through their free aldehyde groups (in aqueous medium, reducing sugars generate one or more compounds containing an aldehyde group). This property allows them to reduce blue copper(II) ions (Cu^{2+}) in Benedict's solution to form insoluble copper(I) oxide (Cu_2O), which appears as a coloured precipitate.

Principle: In the presence of reducing sugars, Benedict's reagent changes colour depending on the concentration of sugar: from blue → green → yellow → orange → brick-red. If no reducing sugar is present, the solution remains blue.

Procedure:

1. Add about 2 cm^3 of the test solution to a clean test tube.
2. Add a few drops of Benedict's solution (Contains alkaline solution of copper (II) sulphate solution. which is blue in colour).
3. Shake gently and heat the tube in a boiling water bath for a few minutes.

Result: A colour change from blue to brick-red indicates the presence of reducing sugar. The exact colour (green, yellow, orange, or red) gives a rough estimate of the amount of sugar present. In the absence of reducing sugar, the blue color of Benedict's solution remains.

Test for Reducing Sugars	Observation
Benedict solution	The initial blue coloration of the mixture turns green, then yellowish, and may finally form a brick-red precipitate.
Add $2cm^3$ of solution of reducing sugar to a test tube.	
Add few drops of Benedict's solution.	
Shake and heat in a boiling water bath.	

Understanding Semi-Quantitative Nature of the Benedict's Test

The Benedict's test is **semi-quantitative**, meaning it not only shows whether reducing sugar is present but also gives a rough estimate of its amount based on colour changes.

- A **small amount** of reducing sugar produces a **green precipitate** (a mix of yellow and blue from copper sulfate).
- A **moderate amount** gives a **yellow to orange precipitate**.
- A **large amount** results in a **brick-red or red-brown precipitate** of copper(I) oxide.

Thus, the more intense the colour, the greater the concentration of reducing sugar in the sample.

3. Biochemical Test for Non-Reducing Sugars

Some carbohydrates, like sucrose, are **non-reducing sugars**. In alkaline conditions, they do not form aldehyde groups and therefore cannot donate electrons to reduce copper(II) ions in Benedict's solution. Because of this, non-reducing sugars give a **negative result** with Benedict's test unless they are first **hydrolyzed by dilute acid** (in this case, HCl) into their constituent monosaccharides (glucose and fructose).

Principle: Non-reducing sugars such as sucrose are broken down (hydrolyzed) into monosaccharides like glucose and fructose by boiling with dilute hydrochloric acid. These monosaccharides are reducing sugars and will test positive with Benedict's reagent once the solution is neutralized with alkali.

Procedure:

1. Place about 2 cm^3 of sucrose solution in a test tube.
2. Add a few drops of dilute hydrochloric acid.
3. Boil the mixture for about one minute, then allow it to cool.
4. Add about 2 cm^3 of sodium hydroxide to neutralize the acid.

5. Add 2 cm^3 of Benedict's solution, shake, and reheat in a boiling water bath for one minute.

Result: A colour change from blue → green → yellow → orange → brick-red confirms that the non-reducing sugar has been hydrolyzed into reducing sugars.

Test non-reducing	observation
Add 2$cm^3$of sucrose solution to a test tube.	The initial blue coloration of the mixture turns green, then yellowish, and finally forms a brick-red precipitate.
Add few drops of dilute hydrochloric acid.	
Boil for one minute and let it cool.	
Add 2cm^3 of sodium hydroxide to neutralize the acid.	
Add 2cm^3 of Benedict's solution.	
Shake and boil again for one minute.	

Biochemical Test for Proteins

Proteins are large, complex organic molecules made of long chains of amino acids linked by peptide bonds. Each amino acid has a carboxyl group (–COOH), an amino group (–NH_2), and a variable side chain, all attached to a central carbon atom. The type, number, and arrangement of amino acids determine the structure and function of each protein.

Several methods can be used to test for proteins, but the most common is the **Biuret test**, which detects the presence of peptide bonds.

Principle: In an alkaline solution, peptide bonds in proteins react with copper(II) ions (Cu^{2+}) from copper sulphate to form a purple or violet complex. The more peptide bonds present, the deeper the colour change.

Procedure:

1. Place 2 cm^3 of the test solution in a clean test tube.
2. Add 2 cm^3 of sodium hydroxide (or potassium hydroxide) and shake gently.
3. Add two drops of dilute copper(II) sulphate solution and shake well.

Result: A violet or purple colour indicates the presence of proteins. A blue colour (unchanged colour of copper(II) sulphate solution) means proteins are absent.

Test for Proteins	Observation
Biuret test	The colour of the mixture changes to violet or purple.
Add 2cm^3 of protein solution to a test tube.	
Add 2cm^3 of sodium hydroxide or potassium hydroxide and shake.	
Add two drops of copper(II) sulphate and shake well.	

It is worth noting that:

The test is called the *Biuret test* because the compound **biuret** (formed by heating urea), which contains the −CONH− group (peptide-like bonds) found in proteins, also gives a violet colour.

Biochemical Test for Lipids

Lipids are **non-polar molecules** that do not dissolve in polar solvents such as water. Instead, they dissolve in non-polar solvents like alcohol, ether, benzene, or chloroform. This property makes it possible to test for lipids using dyes, translucency tests, or emulsification methods. The three common laboratory tests are the **Sudan III test**, the **grease spot test**, and the **emulsification test**.

1. **Sudan III Test (Red Dye)**

Principle: Lipid globules absorb the Sudan III dye, which stains them red. Because lipids are less dense than water and insoluble in it, a red-stained oil layer floats on the surface.

Procedure: Put 2 cm^3 of a lipid solution in a clean, dry test tube. Add three drops of Sudan III solution, shake well, and allow the mixture to settle for one minute.

Result: A distinct red-stained oil layer separates on top of the solution, confirming the presence of lipids.

2. **Grease Spot Test**

Principle: Lipids leave translucent spots on paper because they do not evaporate like water.

Procedure: Rub a drop of the sample onto a piece of paper and allow it to dry (warming gently can speed up evaporation).

Result: A permanent translucent (grease) spot indicates the presence of lipids.

3. **Emulsification Test**

Principle: Lipids are immiscible with water. When dissolved in alcohol and then mixed with cold water, they form a suspension of tiny droplets (emulsion), which scatters light and looks cloudy white.

Procedure: Put 2 cm^3 of ethanol in a test tube, add 2 cm^3 of the lipid sample, and shake vigorously to dissolve. Then add 2 cm^3 of cold water.

Result: A milky-white emulsion confirms the presence of lipids.

Test for Lipids	**Observation**
Sudan III Test (Red Dye)	A red-stained oil layer separates on top of the solution.
Put 2cm^3 of a solution containing lipid in a clean and dry test tube.	
Add three (3) drops of Sudan III solution and shake well.	
Allow the mixture to settle for one minute.	
Grease spot test	A permanent transparent (translucent) spot on the paper.
Rub a drop of the sample onto a piece of paper.	
Allow time for any water to evaporate.	
Warm gently in order to speed up the process or reaction.	
Emulsification test	A cloudy white suspension (emulsification).
Put 2$cm^3$of absolute ethanol in a clean and dry test tube, then add 2cm^3 of lipids.	
Shake vigorously to dissolve the lipids, then add 2cm^3 of cold water.	

Summary of Food Tests

Nutrient	Reagent / Test	Procedure	Observation / Result
Starch	Iodine solution	Add a few drops of iodine solution to the sample	Blue-black colour indicates presence of starch; orange-brown if absent
Reducing sugars	Benedict's solution	Add Benedict's solution and heat in boiling water bath	Colour changes from blue → green → yellow → orange → brick-red depending on sugar concentration
Non-reducing sugars	Dilute HCl + NaOH + Benedict's solution	Hydrolyze with dilute HCl (boil), cool, neutralize with NaOH, then add Benedict's solution and heat	Blue → brick-red precipitate indicates presence of non-reducing sugar after hydrolysis
Proteins	Biuret reagent (NaOH + $CuSO_4$)	Add NaOH, then a few drops of $CuSO_4$ to the solution and mix	Violet / purple colour indicates presence of proteins
Lipids	Sudan III / Grease spot / Emulsion test	1. Sudan III: Add dye and shake 2. Grease spot: Rub sample on paper 3. Emulsion: Dissolve in ethanol, add water	1. Red-stained oil layer forms 2. Permanent translucent spot 3. Cloudy white emulsion forms

EXPERIMENTS

Experiment 8

It was a bright morning in the school biology laboratory. Kipute, with her curious eyes, walked in holding a small beaker labeled **solution Q**. Mr. Akilikubwa had placed it on the lab bench, but today he chose to watch silently from across the room, sipping his tea.

Kipute remembered how her grandmother always sweetened porridge with sugar, and she wondered: *"Could this solution Q be hiding sugar too?"* She was determined to uncover the mystery through **food tests**. With three test tubes lined up neatly—A, B, and C—she prepared to carry out Benedict's test under different conditions.

This experiment reminded her of real-life food analysis, like how food industries test for sugar content in juices and soft drinks before bottling. With her white coat buttoned and notebook ready, Kipute took a deep breath and began the test.

Procedure followed by Kipute

1. She took three test tubes and label them as test tube A, B, and C.
2. She put $2cm^3$ of solution Q to each of the test tubes A, B, and C.
3. She added 2mL of dilute hydrochloric acid to test tube A and warmed the mixture. Then added 4mL of Benedict's solution and observed the changes.
4. She added 2mL of dilute hydrochloric acid to test tube B and warmed the mixture. Then she added 3mL of sodium hydroxide solution followed by 4ml of Benedict's solution and observed the changes.
5. She warmed the solution contained in test tube C, then added 2mL of Benedict's solution and observed the changes.

Questions

Table 1

Experiment	observation
(3)	
(4)	
(5)	

Questions:

(a) Name the type of food substance contained in solution Q.

(b) Why do the experiments (3)–(5) provide different results on Benedict's test? Give two reasons for each.

(c) Briefly explain how the following factors affect enzyme activity in experiment (4):

(i) Temperature

(ii) pH

(d) Explain why it was necessary to neutralize the acid with sodium hydroxide in test tube B before adding Benedict's solution.
(e) Suggest one real-life example where hydrolysis of non-reducing sugars is important before testing for sugar content. Explain.

Response to Questions

a) **Table 1**

Experiment	observation
(3)	Solution remains blue or slightly changes due to the presence of unhydrolyzed substance.
(4)	Brick Red precipitate forms, indicating the presence of reducing sugars after hydrolysis and neutralization.
(5)	No significant color change; solution remains blue due to the absence of reducing sugars.

(a) Non-reducing sugar (e.g., sucrose).
(b) In experiment (iii), the solution was acidic but not neutralized, so Benedict's test was not effective due to acidic pH.

- In experiment (iv), the solution was first hydrolyzed by acid, then neutralized with alkali, allowing reducing sugars were to form and detected.
- In experiment (v), the non-reducing sugar was not hydrolyzed, so no reducing sugar was present to react with Benedict's reagent.

(c) i. Temperature

Increased temperature raises enzyme activity up to an optimum level. Beyond this level, enzymes denature and lose function.

ii. pH

Each enzyme has an optimum pH. Deviation from this pH affects the shape of the active site, reducing efficiency or denaturing the enzyme.

(d) Benedict's solution works properly under **slightly alkaline conditions**. If the mixture remained acidic, the copper ions in Benedict's reagent would not react properly with reducing sugars. By adding sodium hydroxide, **the acid was neutralized**, creating an environment where any reducing sugars formed by hydrolysis could react and produce the **brick-red precipitate**.
(e) In the **food industry**, sucrose (a non-reducing sugar) is often hydrolyzed into glucose and fructose before testing sugar content in **fruit juices, soft drinks, or honey**. This ensures that all sugar content can be accurately measured.

Experiment 9

It was another busy afternoon in the biology laboratory. This time, Mr. Akilikubwa himself called Kipute to the bench and handed her two small test tubes, carefully labeled **S2** and **S3**.

"These," he said with a grin, *"could be hiding important food substances. Your task is to find out what they are."*

Kipute smiled. She loved these food tests because they reminded her of real life—like when scientists test whether maize porridge has enough starch for energy, or whether fruit juice contains glucose that provides quick energy to the body. With her lab coat adjusted, she sharpened her focus. The challenge was clear: identify the food substances present in the two solutions.

Questions

(a) Identify the food substances present in solutions *S*2 and *S*3 by using the chemicals and reagents provided. Tabulate your work as shown in Table 1.

Food test	**procedure**	**observation**	**inference**
S2			
S3			

(b) Explain the basis of each test which produced positive results in 2(a).

(c) An excess of one food substance identified in 2(a) is stored in the body.

(i) Identify the food.

(ii) Name the hormone which influences the conversion of this food substance to a form that can be stored, and the organ which produces the hormone.

(iii) State the form relevant for storage.

(d) Why did iodine solution change colour in S2 but not in S3?

(e) Suggest a real-life application where Benedict's test is useful.

Response to Questions

(a)

Food test	**procedure**	**observation**	**inference**
S2 (Starch)	Add iodine solution	Blue-black color appears	Starch present
S3 (Glucose)	Add Benedict's solution, then heat	Brick-red precipitate forms	Reducing sugar present

(b)

- Iodine reacts with starch to form a blue-black complex, confirming the presence of starch.
- Benedict's solution reacts with reducing sugars under heat, producing a brick-red precipitate, indicating that reducing sugar is present.

(c)

(i) Glucose

(ii) Hormone: **Insulin**; Organ: **Pancreas**

(iii) Stored form: **Glycogen**

(d) Iodine reacts with the coiled structure of starch to form a starch-iodine complex, which is blue-black. S3 contained glucose, which has no such structure, so no colour change occurred.

(e) Benedict's test is used in medical laboratories to test for the presence of glucose in urine, an important diagnostic tool for diabetes.

Experiment 10

The lab was unusually quiet that afternoon, except for the sound of glassware clinking. Mr. Akilikubwa, with his usual mischievous smile, handed Kipute two fresh test tubes labeled **S2** and **S3**.

"Last time you solved the puzzle well," he said, *"but can you still prove yourself a true food detective*?"

Kipute grinned. She enjoyed these experiments because they reminded her of hospitals where doctors test for glucose in patients' urine or starch in food samples for nutrition checks. With her sleeves rolled up, she prepared to unravel the mystery again.

Questions

(a) Identify the food substances present in each of the solutions S2 and S3 by using the chemicals and reagents provided only. Tabulate your work as shown in the following table.

Food test	**procedure**	**observation**	**inference**
S2			
S3			

(b) Which excess food substance identified in 2(a) is stored in the body?

(c) Briefly explain the process responsible for the conversion of the food substance you named in 2(b) to a form that can be eliminated from the body.

(d) Suggest one real-life condition where the food substance you named in 2(b) appears in urine and explain why.
(e) Why Benedict's test is classified as a test for reducing sugars?

Response to Questions

(a)

Food test	procedure	observation	inference
S2	Add iodine solution	Blue-black color appears	Starch present
S3	Add Benedict's solution and heat	Brick-red precipitate forms	Reducing sugar present

(b) Excess reducing sugar (**glucose**) is the food substance stored in the body.

(c) Excess glucose is first converted into **glycogen** for storage in the liver and muscles. If storage capacity is exceeded, glucose is converted into **fats**. In diabetic conditions, when glucose cannot be properly utilized, it is excreted in the **urine.**

(d) In **diabetes mellitus**, glucose appears in urine because insulin is insufficient or ineffective. This prevents glucose uptake into cells, causing blood glucose to rise above the kidney threshold and spill into urine.

(e) Because only reducing sugars (like glucose, maltose, lactose) have free carbonyl groups that can **donate electrons** to reduce the copper(II) ions in Benedict's solution, forming the coloured precipitate.

Experiment 11

At a food-processing factory, the Quality Control Unit received two samples labeled **Solution A** and **Solution B**. The factory manager suspected that one of them was a starch-based additive while the other might be a sugar used for sweetening beverages. The QC officer, Mr. Akilikubwa tasked to run biochemical tests to confirm their identities before they could be approved for use in production.

Your role is to help Mr. Akilikubwa by carefully performing the required food tests, recording observations, and making deductions just like in a real industrial laboratory.

Questions

a) Using the chemicals and reagents provided, carry out the biochemical experiments to identify the food substances contained in each solution. Tabulate your results as shown in the following table.

Food test	procedure	observation	inference
Solution A			
Solution B			

b)

(i) What is main the role of the food substance(s) identified in solution A and B?

(ii) Briefly explain how the alimentary canal is adapted for the absorption of the food substances identified in solutions A and B.

c) With respect to energy availability, which solution (A or B), would an athlete prefer to consume just before a race? Explain your choice.

d) Which solution (A or B) represents a more efficient form of energy storage for the body in the long term? Explain.

Response to Questions

(a)

Food test	**procedure**	**observation**	**inference**
Solution A	Add iodine solution	Blue-black color appears	Starch present
Solution B	Add Benedict's solution and heat	Brick-red precipitate forms	Reducing sugar present

(b) (i)

- Starch: Provides long-term energy storage.
- Reducing Sugar (Glucose): Provides quick energy for metabolism.

(ii)

- The small intestine has numerous villi and microvilli to increase surface area for absorption.
- It has a rich blood supply to transport absorbed sugars.
- Presence of enzymes breaks starch into glucose for efficient absorption.
- The lining of the small intestine is made up of one-cell thickness to reduce diffusion distances during absorption.

c) The athlete would prefer **Solution B (glucose)** just before the race.

Explanation

Glucose is a simple sugar that can be **absorbed directly into the bloodstream**, providing **immediate energy** for the muscles. In contrast, Solution A (starch) is a complex carbohydrate that must first be **digested into glucose**, which takes time and delays energy availability. Therefore, glucose ensures a **rapid energy boost**, which is crucial for peak performance during the race as it is already in its absorbable form.

d) **Solution A (starch)** represents a more efficient form of long-term energy storage for the body.

Explanation

Starch is insoluble and compact, allowing large amounts of energy to be stored without causing osmotic imbalances in cells. In contrast, Solution B (glucose) is soluble and cannot be stored in large quantities, as it would draw water into cells and disrupt cellular function.

Experiment 12

It was a rainy afternoon, and the school laboratory smelled faintly of fresh chemicals. Mr. Akilikubwa, the ever-attentive laboratory technician, was in charge of preparing food analysis tests for the biology students. On his bench lay two colourless solutions, **S2** and **S3**, neatly labeled but with their contents kept secret.

He knew the task at hand was not just about mixing chemicals—it was about revealing which type of sugar, if any, was lurking inside. He carefully arranged the reagents: Benedict's solution, dilute hydrochloric acid, and sodium hydroxide. Each of them had a very specific role, like detectives in an investigation.

He smiled to himself, recalling how in real life such biochemical tests are vital. Today's experiment was a miniature version of what food scientists do every day.

Questions

(a) Using the reagents provided, carry out a biochemical test to identify the food substances present in each solution. Tabulate your work as shown in the following table.

Food test	**procedure**	**observation**	**inference**
S2			
S3			

(b) Why do we use sodium hydroxide and dilute hydrochloric acid in the biochemical experiment?

(c) Considering energy needs, which solution, **S2** or **S3** would be more suitable for an athlete just before a sprint race? Explain.

(d) Suggest one real-life application of testing for reducing and non-reducing sugars. Explain briefly.

Response to Questions

(a)

Food test	procedure	observation	inference
S2	Add Benedict's solution and heat	Brick-red precipitate forms	Reducing sugar present
S3	Add dilute HCl, boil, neutralize with NaOH, then add Benedict's solution	No brick-red precipitate forms	Non-reducing sugar present

(b)

- Dilute Hydrochloric acid (HCl): Hydrolyzes non-reducing sugars (e.g., sucrose) into reducing sugars.
- Sodium hydroxide (NaOH): Is used to neutralize the solution after hydrolysis to allow Benedict's test to work properly. (Benedict's solution requires a slightly alkaline condition).

(c) Solution **S2** would be more suitable because it contains reducing sugars (like glucose) that can be directly absorbed into the bloodstream and provide an immediate energy boost. Solution **S3**, being a non-reducing sugar, would require hydrolysis and digestion first, delaying energy release.

(d) In the **food industry**: These tests are used to check for added sugars in fruit juices, energy drinks, or baby foods, ensuring product quality and consumer safety.

Experiment 13

The biology laboratory buzzed with excitement as students prepared for a food test investigation. Among them, Kipute was especially eager. On her bench, she had two mystery samples: **Solution A** and **Solution B**. They looked plain, but she knew that inside them hid some of the essential building blocks of life.

Armed with iodine solution, Biuret reagent, Benedict's solution, and ethanol, Kipute began her detective work. She imagined herself as a food scientist working in a quality-control lab for a cereal company, checking if their products truly contained starch for energy, protein for growth, or fats for storage.

Questions

(a) Identify the food substances present in solutions A and B by using the chemicals and reagents provided. Tabulate your work as shown in the following table.

Food test	procedure	observation	inference
Solution A			
Solution B			

(b) Explain the basis of each test which produced positive results in (a).

(c) An excess of one food substance identified in (a) is stored in the body.

(i) Identify which of the food substances needs to be converted before storage.

(ii) Name the organ and the hormone influencing the conversion of the food substance to a form that can be stored.

(d) If a malnourished child lacks the food substance found in Solution B, what major symptoms would you expect? Why?

(e) Which solution; A or B would be most immediately useful for a child recovering from an injury? Rationalize your answer.

Response to Questions

(a)

Food test	**procedure**	**Observation**	**inference**
Solution A	Add iodine solution	Blue-black color forms	Starch present
Solution B	Add Biuret solution	Purple/violet color forms	Protein present

(b)

- Iodine forms a blue-black complex with starch, indicating the presence of starch.
- Biuret solution reacts with peptide bonds in proteins to form a purple colour, indicating the presence of protein.

(c)
(i) Starch is broken down into glucose.
(ii) Organ: Liver
Hormone: Insulin
(iii) Glycogen

(d) The child would suffer from poor growth, weak muscles, and possibly kwashiorkor, because proteins are essential for body-building and tissue repair.

(e) **Solution B**: This is because it contains proteins which provide the amino acids required for tissue repair and building new cells, which is vital during recovery.

Experiment 14

The sun was already high when Mr. Akilikubwa began preparing for the afternoon practical. Today, the students were not dealing with single, simple food solutions. Instead, he had placed before them a mysterious mixture labeled **B2**. It was a cocktail of different food substances, just like the meals children eat every day—balanced but complex.

As he arranged Benedict's solution, Biuret reagent, iodine, and ethanol on the bench, he thought of a real-world parallel. Nutritionists in children's hospitals often test foods to confirm whether they contain the right mix of nutrients. **B2** was like a miniature version of a full diet that needed to be analyzed and understood.

Questions

a) Design and carry out experiments to identify these foods using the reagents provided. Record your working as shown in the table below.

Food test	**procedure**	**observation**	**inference**
Reducing sugar			
Proteins			
Starch			
Lipids			

(b) What role is played by each food substance you have identified in **B2** in children?

(c) Excess of one of the food substances identified in **B2** is usually stored in the body.

(i) Name the hormone which influences the conversion of the food substance into a form that can be stored in the body.

(ii) Write a word equation for the process mentioned above.

(iii) In which body organ does the process mentioned above occur?

(d) In a children's hospital, why would nutritionists prefer testing foods like B2 instead of testing individual pure substances?

(e) Imagine B2 represented a school lunch. Why would it be important to include all four food types identified rather than just carbohydrates?

Response to Questions

(a)

Food test	procedure	observation	inference
Reducing sugar	Add Benedict's solution and heat	Brick-red precipitate forms	Reducing sugar present
Proteins	Add Biuret reagent	Violet or purple color forms	Protein present
Starch	Add iodine solution	Blue-black color appears	Starch present
Lipids	Add ethanol, shake, then add water	Milky white emulsion forms	Lipids present

(b)

- Reducing sugar: Provides instant energy for physical and mental activity.
- Proteins: Essential for growth and tissue repair.
- Starch: Serves as stored energy that can be broken down over time.
- Lipids: Provide insulation and long-term energy storage.

(c)
(i) Hormone: Insulin
(ii) Word Equation: Glucose + Glucose + Glucose → Glycogen
(iii) Organ: Liver

(d) Because children's meals are usually mixtures, not pure foods. Testing mixtures gives a more realistic picture of whether a diet contains the right balance of nutrients required for growth and recovery.

(e) Carbohydrates alone provide energy but cannot support tissue repair (proteins), insulation (lipids), or long-term energy reserves (starch). A balanced diet ensures children remain healthy, active, and able to grow properly.

Chapter three
CLASSIFICATION

INTRODUCTION

In biology practicals, classification activities often involve obtaining and studying specimens from different kingdoms and phyla. Careful observation of these specimens provides valuable information about their **characteristics, adaptations, habitats, and structural differences**, which form the basis for scientific classification.

Most of the specimens commonly used in school laboratories are drawn from three major kingdoms: **Plantae, Fungi, and Animalia**. These kingdoms represent a wide range of diversity, from simple fungi such as moulds, to complex flowering plants and highly adapted animals. Through hands-on examination, students are able to appreciate how external features such as body symmetry, type of body covering, method of reproduction, or mode of nutrition, are used as key criteria in grouping organisms.

Classification practicals not only prepare students for examination questions but also build deeper scientific understanding. By comparing specimens across kingdoms, learners discover both the unity of life (shared features like cells, reproduction, or response to the environment) and the diversity of life (different body forms, organs, and ecological roles). This approach reflects the true purpose of classification: to organize the living world in a way that highlights both similarities and evolutionary differences.

Kingdom Plantae

The plant kingdom (Plantae) consists of multicellular, eukaryotic organisms that make their own food through photosynthesis. They play a central role in sustaining life on Earth by producing oxygen, storing energy in the form of starch, and providing habitats and resources for other organisms. Plants range from simple non-vascular types such as mosses to advanced seed-bearing plants, and they exhibit unique life cycles involving alternation of generations.

General Features of Kingdom Plantae

1. Multicellular and eukaryotic, with photoautotrophic nutrition.
2. Cells have cellulose cell walls and large permanent vacuoles.
3. Carbohydrates stored as starch.
4. Reproduce sexually by spores or seeds, ranging from bryophytes to seed plants.
5. Exhibit alternation of generations (gametophyte ↔ sporophyte).
6. Limited locomotion but show curvature movements in response to stimuli.
7. Vegetative body divided into root system and shoot system.

Division Bryophyta

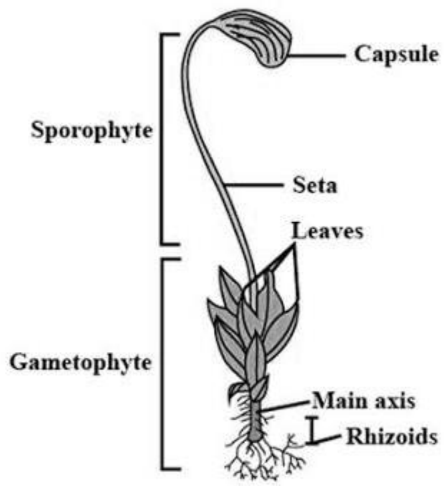
Bryophytes are small, non-vascular plants that include mosses such as *Funaria sp*. They are unique because their gametophyte generation is dominant, while the sporophyte generation remains attached to it and depends on it for food and support. Since they lack vascular tissues like xylem and phloem, as well as true roots, stems, and leaves, they rely on simple structures and moist environments for survival. Bryophytes reproduce using spores and require water to allow the male gametes (sperms) to swim to the female gametes for fertilization.

General Characteristics of Bryophyta

1. Exhibit alternation of generations, with the haploid gametophyte dominant over the diploid sporophyte.
2. Sporophyte is attached to and nutritionally dependent on the gametophyte.
3. Lack vascular tissues (no xylem or phloem).
4. Do not have true stems, leaves, or roots; instead, they possess rhizoids.
5. Contain chlorophyll for photosynthesis.
6. Reproduce by homospores, produced by the sporophyte.
7. Found mainly in damp, shady environments, since sexual reproduction requires water for sperm movement.

Distinctive Features of Bryophyta

1. Lack specialized conducting tissues.
2. Possess rhizoids instead of true roots.
3. Have a dominant gametophyte generation with the dependent sporophyte attached.
4. Homosporous, with haploid spores germinating into a branched structure called protonema, which later develops into the gametophyte.



Structure of moss plant (Funaria sp)

Adaptations of Funaria (Moss Plant) to Its Mode of Life

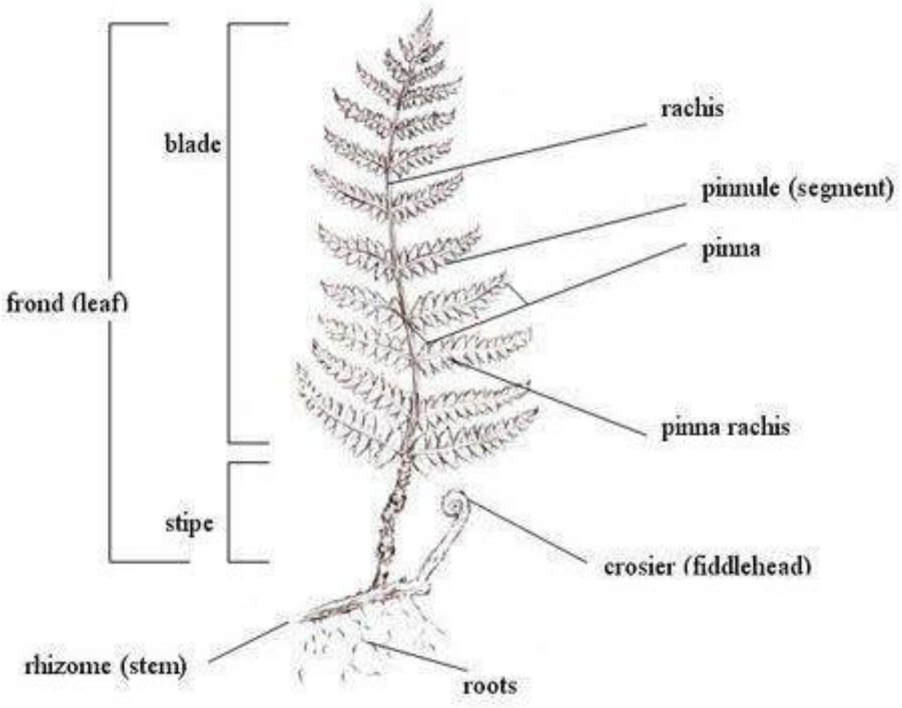
1. Possess chlorophyll in their leaf-like structures, enabling them to carry out photosynthesis.
2. Have limited height, which helps them survive without vascular tissues by reducing the need for long-distance transport of water and nutrients.
3. Possess rhizoids that anchor them to the substrate and absorb water and mineral salts directly from their surroundings.
4. Produce male gametes with flagella, allowing them to swim through water to reach the archegonia for fertilization.
5. Produce small, light spores that are easily dispersed by wind, ensuring colonization of new areas.
6. Have an elongated seta, which raises the capsule into the air to enhance spore dispersal.
7. Archegonia secrete chemicals that attract antherozoids (male gametes), guiding them toward the egg for successful fertilization.

Division Filicinophyta (Pteridophyta)

The members of this division are known as pteridophytes, which include ferns such as *Dryopteris sp.* Pteridophytes are more advanced than bryophytes because they possess vascular tissues, but they still reproduce by spores instead of seeds. Their life cycle shows alternation of generations, with the sporophyte generation dominant and independent, while the gametophyte generation is much reduced.

Distinctive Features of Pteridophytes

1. Exhibit alternation of generations with a dominant sporophyte generation.
2. Contain vascular tissues (xylem and phloem), though these are less advanced compared to seed plants.
3. Most produce homospores, but some ferns are heterosporous, producing two different types of spores (microspores and megaspores).



Structure of fern plant (Dryopteris sp)

Adaptations of Dryopteris (Fern) to Its Mode of Life

1. Possess chloroplasts with chlorophyll for capturing light energy during photosynthesis.
2. Have true roots that anchor the plant firmly into the ground and absorb water and mineral salts.
3. Their leaves contain stomata, which facilitate efficient gaseous exchange.
4. Contain xylem vessels for transporting water and dissolved mineral salts upward through the plant.
5. Contain phloem tissues that transport food and organic materials downward to other parts of the plant.
6. Leaves are covered by a waxy cuticle to reduce excessive water loss.
7. Archegonia release chemical attractants that guide motile male gametes (antherozoids) toward the egg for fertilization.

Division Coniferophyta

The Coniferophyta are a group of seed-bearing, non-flowering plants. Unlike angiosperms, their seeds are not enclosed in fruits but are borne on cones. Members include pines, cypresses, and firs. These plants are well adapted to survive in cold or dry environments and are among the most dominant trees in many forests around the world.

General Characteristics of Coniferophyta

1. Produce seeds that are not enclosed in ovaries or fruits (naked seeds).
2. Sexual reproduction involves microspores (pollen grains) formed in male cones and megaspores (ovules) formed in female cones.
3. Fertilization does not require water, as pollen is carried by wind.
4. Xylem is made up of tracheids only (no vessel elements).
5. Phloem lacks companion cells but is associated with albuminous cells.
6. Leaves are needle-like, an adaptation to minimize water loss through transpiration.

Distinctive Features of Coniferophyta

1. Produce cones as reproductive structures: male cones bear pollen (microspores) and female cones bear ovules (megaspores).
2. Are wind-pollinated; pollen grains are small and have wing-like extensions for buoyancy.
3. Lack true fruits, since there are no ovaries; instead, seeds are borne on scales of cones.
4. Xylem contains only tracheids as conducting elements.
5. Phloem tissue has no companion cells, but functions with albuminous cells.
6. Most are evergreen plants with narrow, needle-shaped leaves.

Adaptations of Pines to Their Mode of Life

1. Possess well-developed root and shoot systems for anchorage and access to soil and atmosphere.
2. Roots absorb water and nutrients efficiently from the soil.
3. Have strong mechanical tissues for support and vascular tissues for transport of water and food.
4. Show adaptations to reduce water loss, such as thick, waxy cuticles and needle-like leaves.
5. Produce light pollen grains with two wing-like structures, enabling them to float in the air for wind pollination.
6. Can reproduce sexually without water, ensuring reproduction even in dry environments.
7. Seeds are exposed (naked) and can be easily dispersed by wind, aiding colonization of new areas.

Division Angiospermophyta

The Angiospermophyta, or flowering plants, are the most advanced and diverse group of plants, highly adapted to life on land. Their defining feature is the production of seeds enclosed within an ovary, which later develops into a fruit. This group includes staple food crops, fruits, and trees that are essential for human life and global ecosystems.

Classes of Angiospermophyta

1. **Class Monocotyledoneae (Monocots)**
   Examples: grasses such as maize, millet, and sugarcane.

Distinctive Features

(i) Leaves show parallel venation.

(ii) Vascular bundles are scattered within the ground tissue of the stem.

(iii) Possess a fibrous root system, arising from the base of the stem and replacing the primary root.

(iv) Seeds have one cotyledon (seed leaf).

(v) Pollen grains with a single aperture.

(vi) Floral parts are arranged in multiples of three.

2. **Class Dicotyledoneae (Dicots)**
   Examples: bean, mango, and orange plants.

Distinctive Features

(i) Leaves show reticulate venation (net-like).

(ii) Stems have vascular tissues arranged in a ring form.

(iii) Possess a tap root system, derived from the primary root.

(iv) Seeds contain two cotyledons.

(v) Floral parts are arranged in fours, fives, or multiples of these numbers.

(vi) Pollen grains with three apertures.

Economic Importance of Plants

Plants are essential for the survival of all other living organisms. They provide food, oxygen, shelter, and countless materials that support human life and ecosystems. Without plants, animal and human life would not be possible, since nearly every food chain begins with plants as the primary producers. However, while plants are mostly beneficial, some can also cause problems when they grow as weeds, parasites, or produce toxins.

Advantages of Kingdom Plantae

1. Plants are the primary source of food for heterotrophs (e.g., grazers) and humans, providing vegetables, cereals, fruits, and sugars.
2. They help to purify the atmosphere by absorbing carbon dioxide (CO_2) during photosynthesis, reducing its concentration.
3. Leguminous plants have root nodules with nitrogen-fixing bacteria, enriching soil fertility.
4. Plant communities such as grasslands, woodlands, and forests provide habitats for wildlife; birds also use plant materials to build nests.
5. They are sources of traditional fuels like firewood and charcoal, widely used for domestic energy.
6. Leaves of plants like banana, coconut, and palm are used for thatching houses and wrapping materials.
7. Some plants are used in traditional medicine, e.g., neem tree (*Azadirachta indica*).
8. Plants release oxygen, which is vital for aerobic respiration in animals and humans.

Disadvantages of Kingdom Plantae

1. Some plants produce toxic metabolites or poisonous substances, which can harm consumers.
2. Weeds compete with food crops for nutrients, water, and light, leading to reduced yields.
3. Certain plants are parasitic, depending on other plants for nutrients and weakening their hosts.
4. Aquatic weeds (e.g., water hyacinth) colonize water bodies, disrupt ecosystems, and interfere with fishing and boating activities.

Kingdom Animalia

Animals are multicellular, eukaryotic, heterotrophic organisms that obtain energy by feeding on other organisms. They typically lack cell walls, show specialized tissues and organs, and most exhibit active locomotion at some stage of life. *In classification practicals, students use observable features such as body symmetry, segmentation, type of body cavity, skeletal/support structures, appendages, and habitat to place specimens into the correct phyla.*

General Features (quick cues for practicals)

1. Heterotrophic nutrition, no cell walls.
2. Nervous and muscular tissues enable responsiveness and movement.
3. Reproduction usually sexual; development may include larval stages.
4. Body plans vary by symmetry (none/radial/bilateral), segmentation, and coelom (acoelomate, pseudocoelomate, coelomate).

1. Phylum Annelida

Members of this phylum are commonly called **segmented or ringed worms**. They include familiar examples such as earthworms, lungworms, and leeches. Annelids are among the first invertebrates to develop a true body cavity (coelom) and show clear segmentation, which allows for more efficient movement and organ specialization. They are mostly found in moist soils, freshwater, or marine environments.

Characteristics of Phylum Annelida

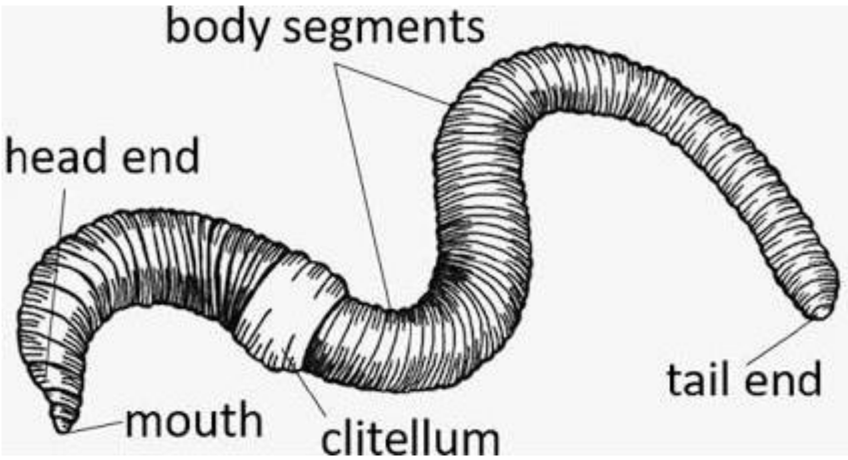
1. They are triploblastic (body derived from three germ layers) and coelomate organisms.
2. Show bilateral symmetry.
3. Their bodies are metamerically segmented (divided into repeated segments).
4. Possess an outer protective layer called a cuticle.
5. Have chaetae (bristle-like structures made of chitin) that aid in movement.

Classes of Annelida

The phylum **Annelida** is divided into three main classes: **Polychaeta** (marine worms), **Hirudinea** (leeches), and **Oligochaeta** (earthworms). *For practical studies, **Class Oligochaeta** is most often chosen because earthworms are common, easily available, harmless, and simple to handle in the laboratory.* In addition, *their structure and adaptations clearly demonstrate the key features of annelids, such as segmentation, chaetae, and a closed circulatory system.*

Structure of the Earthworm

Earthworms have elongated, cylindrical, segmented bodies covered with a moist cuticle. Each segment contains bristle-like structures called **chaetae**, which aid in burrowing and locomotion. The digestive system is well developed, including a muscular **gizzard** for grinding food. The **clitellum** is a thickened band used during reproduction. Their circulatory system is closed, with blood containing hemoglobin for oxygen transport.



Structure of earthworm

Adaptations of Earthworm to Its Mode of Life

1. Streamlined body with chaetae that assist in burrowing.
2. Possess a gizzard for breaking down plant tissues.
3. Clitellum holds worms together during copulation.
4. Secrete mucus, which smooths passage through soil and binds burrow walls.
5. Omnivorous diet, feeding on both plant and animal matter.
6. Hemoglobin with high oxygen affinity, useful in low-oxygen soils.
7. Chaetae also provide grip and aid locomotion.

Advantages of Annelids

1. Improve soil aeration, drainage, and fertility by mixing organic matter.
2. Used as bait in fishing and in certain industries.
3. Serve as a food source for fish, birds, and other animals.
4. Act as decomposers, recycling nutrients in ecosystems.
5. Some species help in removing soil pollutants (bioremediation).
6. Widely used as biological specimens for scientific studies.

Disadvantages of Annelids

1. Excessive soil burrowing can disrupt paddy fields, making them less suitable for rice cultivation.
2. Some may damage tender roots of young plants.
3. Leeches (another annelid group) are harmful to humans, reptiles, and fishes by sucking blood.

Phylum Arthropoda

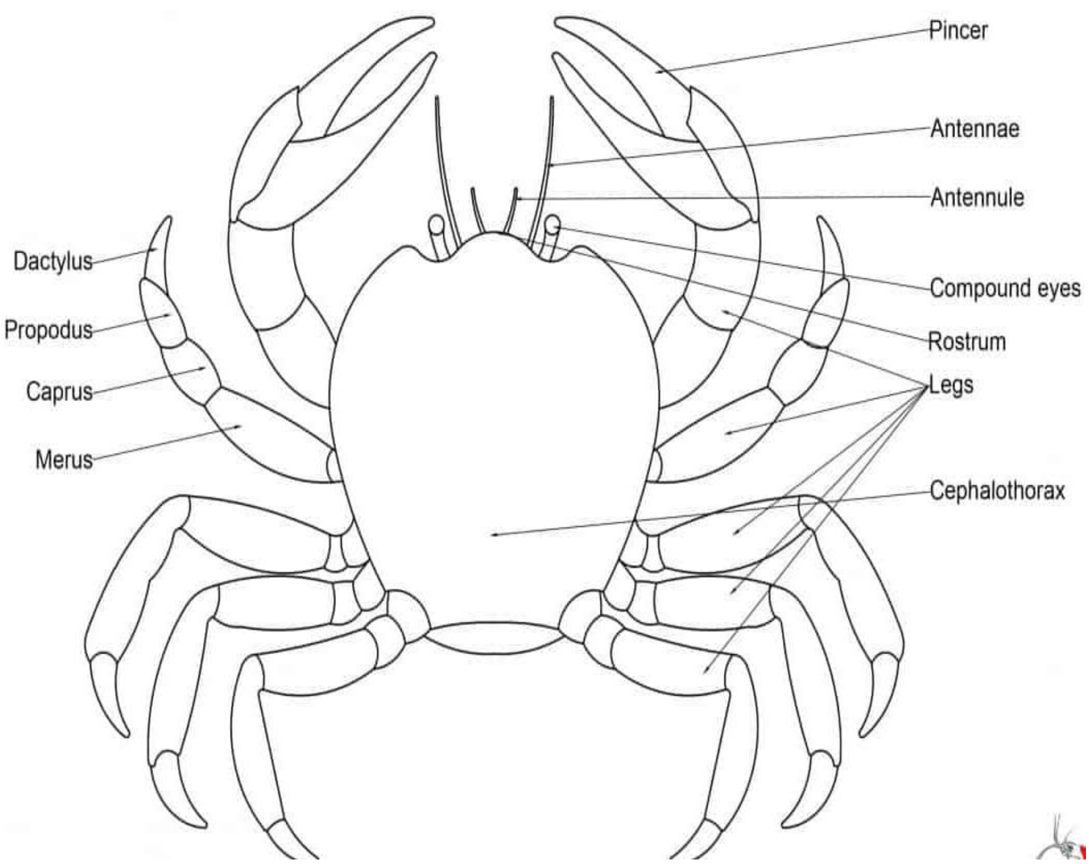
Arthropods are the largest and most diverse group of animals on Earth. They are found in nearly every habitat; from oceans and rivers to forests, deserts, and even inside other organisms. Their success is largely due to their **chitinous exoskeleton**, **jointed appendages**, and **segmented body plan**, which allow flexibility, protection, and specialization of functions.

General Characteristics of Arthropods

1. Possess an exoskeleton made of chitin, providing protection and support.
2. Have jointed, paired appendages such as legs, antennae, and mouthparts.
3. Body is segmented, typically divided into regions: head, thorax, and abdomen.
4. Show bilateral symmetry.
5. Nervous system is ventral, and circulation is open (hemolymph flows freely in body cavity).

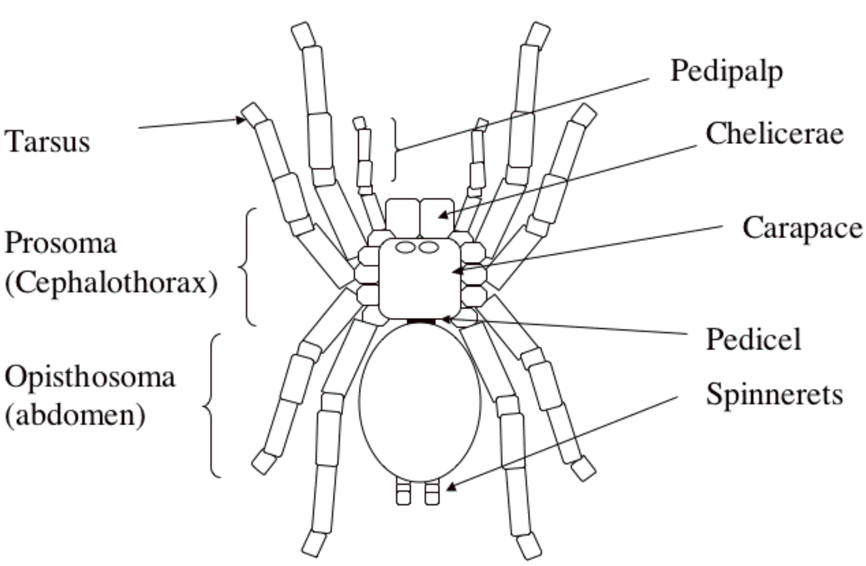
Classes of Arthropods.

1) Class Crustacea – e.g. crabs, lobsters, shrimps.



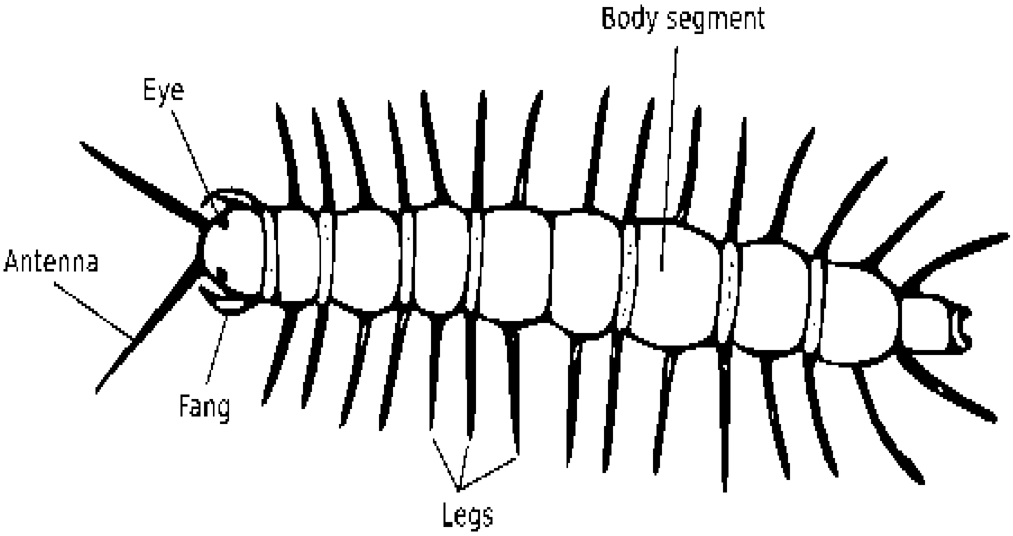
Crab

2) Class Arachnida – e.g. spiders, scorpions, ticks.



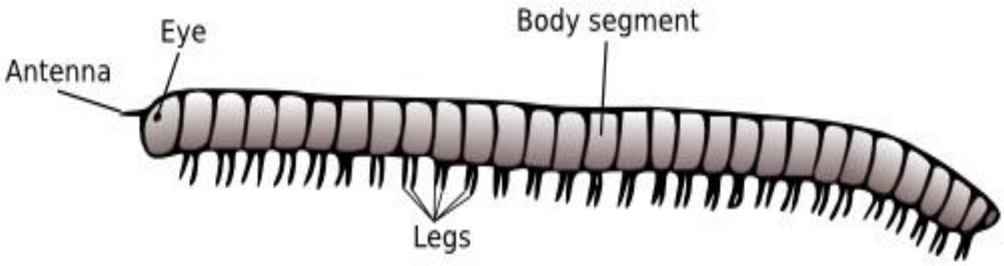
Spider

3) Class Chilopoda (centipedes)



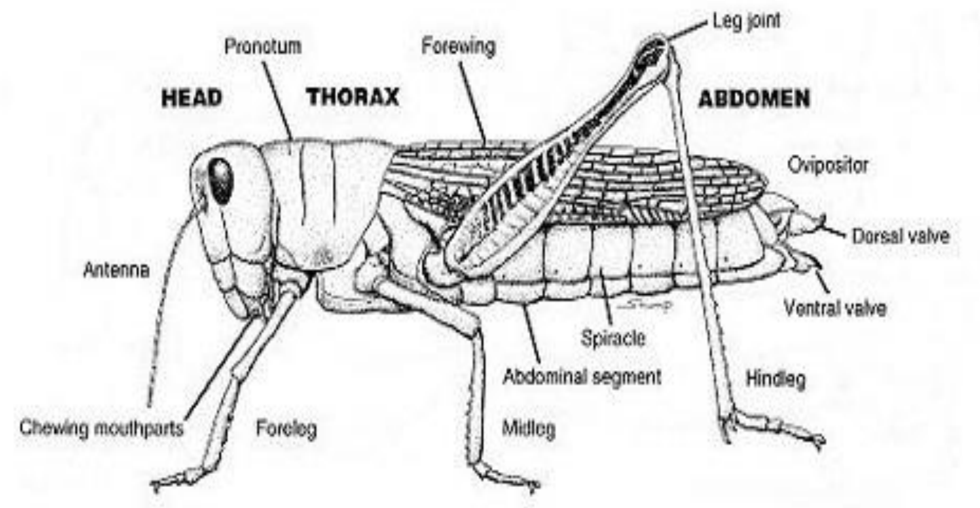
Centipede

4) Class Diplopoda (millipedes)



Millipede

5) Class Insecta – e.g. housefly, grasshopper, cockroach.



Grasshopper

Class Insecta

Insects are the most diverse class of arthropods, occupying almost every ecosystem on Earth. Their structural features and high adaptability make them the most successful animals in terms of numbers and diversity.

Distinctive Features of Insects

1. The body is divided into three main regions (tagmata): head, thorax, and abdomen.
2. They have three pairs of walking legs, all attached to the thorax.
3. Most possess one or two pairs of wings on the thorax, although some species are wingless.
4. Gas exchange occurs through a tracheal system with openings called spiracles.
5. Growth involves moulting (ecdysis) and metamorphosis (complete or incomplete).
6. Possess a pair of compound eyes and additional simple eyes (ocelli) for vision.
7. Have at least three pairs of mouthparts (mandibles, maxillae, and labrum), specialized for different feeding habits.

Class Diplopoda (Millipedes)

Millipedes are slow-moving arthropods commonly found in moist soils and decaying vegetation. They play an important role in breaking down organic matter, making nutrients available to plants.

Distinctive Features of Millipedes

1. Body is elongated, cylindrical (round) with a clearly defined head, followed by many similar segments.
2. Each segment bears two pairs of legs (except the first few segments behind the head).
3. Possess numerous short legs, giving them the name *Diplopoda*.
4. Most species are herbivorous or detritivorous, feeding mainly on decaying plant material.

Adaptations of Millipedes to Their Mode of Life

1. Numerous short, strong legs enable them to burrow into soil and move through leaf litter.
2. Produce moistening secretions that help soften and digest decaying organic matter.
3. Curl up into a tight coil when threatened, protecting the softer ventral side.
4. Release an offensive-smelling fluid as a chemical defense against predators.

Class Chilopoda (Centipedes)

Centipedes are fast-moving arthropods commonly found in soil, leaf litter, and under logs or stones. Unlike millipedes, which are slow herbivores, centipedes are active carnivorous predators that use speed and poison to capture their prey.

Distinctive Features of Centipedes

1. Body is elongated and dorsoventrally flattened, with a distinct head and trunk segments.
2. Each segment bears one pair of legs (unlike millipedes, which have two).
3. Possess a pair of poisonous fangs (forcipules), modified from the appendages of the first trunk segment, used to inject venom.
4. Carnivorous diet: feed mainly on insects, worms, and other small invertebrates.
5. Equipped with a pair of long antennae for detecting prey and sensing the environment.

Adaptations of Centipedes to Their Mode of Life

1. Fast-moving locomotion enables them to chase and capture prey.
2. Venomous fangs (forcipules) kill or paralyze prey quickly, and also act as defense weapons.
3. Sensitive antennae detect vibrations and chemical signals in the environment.
4. Numerous legs provide speed, agility, and grip on different surfaces.
5. The last pair of legs often bears hooks or spines used for defense against predators.

Class Arachnida – Example: Spiders

Arachnids are terrestrial arthropods that include spiders, scorpions, ticks, and mites. They are easily distinguished from insects by their two-part body plan and four pairs of walking legs. Spiders, in particular, are specialized predators with unique adaptations for hunting and survival.

Distinctive Features of Spiders (Class Arachnida)

1. The body is divided into two main regions: the prosoma (cephalothorax) and the opisthosoma (abdomen), joined by a narrow waist-like constriction.
2. They lack antennae but have pedipalps, sensory appendages that detect external stimuli and assist in handling prey.
3. Eyes are simple (ocelli), not compound; most spiders have multiple simple eyes arranged on the prosoma.
4. Possess four pairs of walking legs, all attached to the cephalothorax.
5. Respiration occurs through book lungs or tracheae, depending on species.

Adaptations of Spiders to Their Mode of Life

1. Chelicerae (fangs) inject venom to paralyze or kill prey.
2. Specialized abdominal glands secrete silk, used for building webs, egg sacs, and capturing prey.
3. Pedipalps serve sensory functions and also assist in manipulating food.
4. Four pairs of legs allow quick movement and effective predation.
5. Some species have hair-covered bodies that improve sensory detection of vibrations and help in self-defense.

Class Crustacea – Example: Crabs

Crustaceans are mostly aquatic arthropods, commonly found in both freshwater and marine environments. They include crabs, lobsters, prawns, and shrimps. Their hard exoskeleton and specialized appendages make them highly adapted to life in water.

Distinctive Features of Crustaceans

1. Body is divided into two main regions: the cephalothorax (head and thorax fused together) and the abdomen.
2. Possess a tough exoskeleton hardened with calcium salts, which serves as a protective shell.
3. Have biramous (branched) appendages, including two pairs of antennae for sensing the environment.
4. Possess a pair of compound eyes located on movable stalks for wide vision.
5. Have at least three pairs of mouthparts, adapted for feeding and handling food.
6. Typically have five pairs of legs (10 legs in total), though some can be modified for swimming, walking, or defense.

Adaptations of Crabs to Their Mode of Life

1. Hard exoskeleton (carapace) protects the body from predators and prevents water loss.
2. Gills located under the carapace enable efficient gas exchange in aquatic environments.
3. Strong pincers (chelae) are used for defense, catching prey, and handling food.
4. Sideways walking provides agility and quick escape from predators.
5. Compound eyes on stalks allow wide-range vision to detect food and threats.
6. Antennae act as sensory organs, detecting chemical signals, vibrations, and touch in water.

Kingdom Fungi

Fungi are a unique group of organisms that were once placed in Kingdom Plantae under the old two-kingdom system. Later studies showed that they differ greatly from plants in structure, nutrition, and physiology, leading to their recognition as a separate kingdom. Members of this kingdom include familiar organisms such as **mushrooms, yeasts, moulds (e.g., Rhizopus), Penicillium**, and toadstools.

Fungi are eukaryotic, and may be unicellular (like yeasts) or multicellular (like mushrooms). Their bodies are made up of thread-like filaments called hyphae, which together form a network called mycelium. In some species, hyphae are divided into cells by cross walls called septa, while in others the cytoplasm is continuous. Unlike plants, fungi are thallophytes (they lack chlorophyll and cannot make their own food). Instead, they obtain nutrients either saprophytically (from dead organic matter) or parasitically (from living hosts).

Fungi digest food externally by secreting enzymes, then absorb the soluble products through special structures such as haustoria. Their cell walls are made of chitin (not cellulose as in plants), and they store carbohydrates in the form of glycogen, a feature they share with animals. Reproduction occurs both asexually, through spores, and sexually, when compatible hyphae fuse to form a zygote.

Similarities between Fungi and Animals

1. Both have chitin as a structural carbohydrate (in fungi cell walls; in animals, in exoskeletons of arthropods).
2. Both store carbohydrates as glycogen rather than starch.
3. Both are heterotrophs, depending on external sources of food.

Similarities between Fungi and Plants

1. Both have cell walls.
2. Some fungi show root-like and shoot-like structures.
3. Growth is restricted to apical cells, as in many plants.
4. They are non-motile.
5. They reproduce sexually by forming spores (e.g., ascospores in yeast, basidiospores in mushrooms).
6. They lack centrioles, as in plant cells.

Phyla of Kingdom Fungi

Fungi are divided into several major groups, or phyla, based mainly on their modes of reproduction and structural features. The three main phyla are:

1. **Phylum Zygomycota** – e.g., Rhizopus (bread mould)
2. **Phylum Ascomycota** – e.g., yeasts and Penicillium
3. **Phylum Basidiomycota** – e.g., mushrooms and toadstools

1. Phylum Zygomycota

Members of this phylum are best known for forming a thick-walled resting spore called a zygospore, produced when two opposite mating hyphae fuse and their haploid nuclei unite. Zygospores are resistant to harsh conditions and allow the fungus to survive long periods of dormancy. A common example is the **bread mould (*Rhizopus stolonifer*)**, often seen as black mould growing on stale bread.

Although they are mainly saprophytes, feeding on dead organic matter by secreting extracellular enzymes, some species are parasitic on plants, insects, or animals.

General Characteristics

1. They are eukaryotic organisms with aseptate (coenocytic) hyphae that are multinucleate and lack cross walls.
2. They reproduce both asexually (by sporangia producing haploid spores) and sexually (by conjugation, where gametangia fuse to form zygospores).
3. They are mostly saprophytes, although a few are parasitic.
4. Their hyphae are differentiated into three main types: stolons, rhizoids, and sporangiophores.
5. They play a major role in decomposing dead organic matter and recycling nutrients.

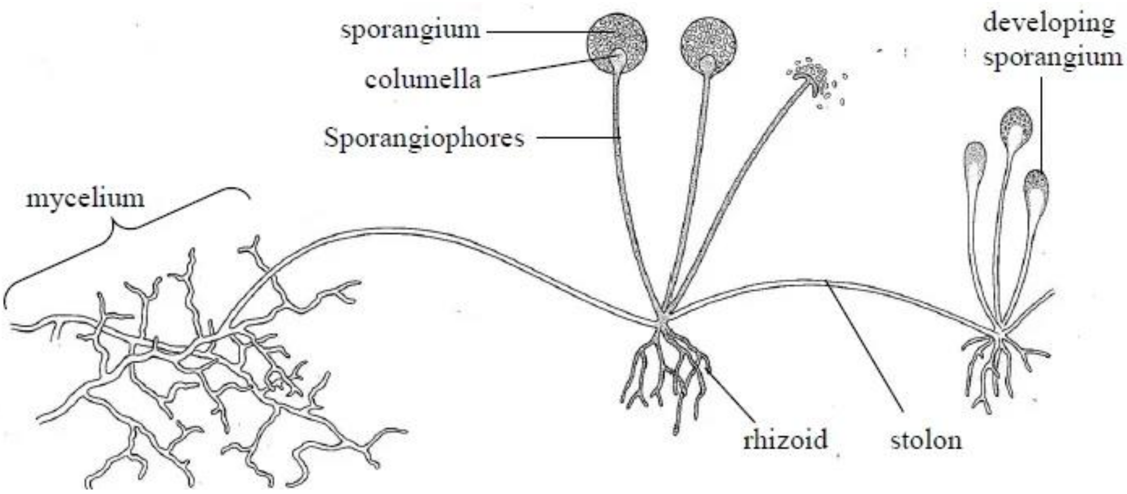
Distinctive Features

1. Aseptate, coenocytic hyphae with continuous cytoplasm and many nuclei.
2. Characteristic sexual reproduction involving gametangial fusion and formation of a zygospores.
3. Rapid growth on moist substrates, especially bread, fruits, and decaying matter.

Structure of *Rhizopus* (Bread Mould)

The body of *Rhizopus* consists of a branching mycelium made of three types of hyphae:

- **Stolons** – horizontal hyphae that spread over the surface of the substrate.
- **Rhizoids** – root-like hyphae that penetrate the substrate, anchoring the fungus and absorbing nutrients.
- **Sporangiophores** – upright hyphae that bear spherical sporangia, which contain asexual spores. Each sporangium is supported internally by a swollen structure called the columella.



Structure of a Rhizopus (Bread mould)

Adaptations of *Rhizopus* to Its Mode of Life

1. **Efficient spore release** – Pressure in the columella builds up until the sporangium bursts, releasing haploid spores. Each spore can germinate into a new hypha when it lands in a favourable environment.
2. **Anchorage and absorption** – The rhizoids firmly attach the fungus to the substrate and absorb nutrients.
3. **Chemotropism** – Hyphae grow directionally towards digested food substances, ensuring maximum nutrient uptake.
4. **Dormant zygospores** – Thick-walled, resistant zygospores allow survival during unfavourable or harsh conditions.
5. **Brittle sporangium walls** – The thin, fragile walls of the sporangium break easily, helping spores disperse efficiently.
6. **High spore production** – Asexual reproduction produces large numbers of spores, increasing the chances of survival and colonisation.
7. **Wind dispersal** – The spores are small, light, and elevated on sporangiophores, enabling easy dispersal by air currents.

2. Phylum Ascomycota

Ascomycota, also called *sac fungi*, are a group of fungi that produce their sexual spores inside a sac-like structure called an ascus. Each ascus usually contains haploid spores known as ascospores. They also reproduce asexually by producing conidia, which form at the tips of specialized hyphae called conidiophores. Common examples include **yeast (*Saccharomyces*)**, **Aspergillus**, and **Penicillium**.

General Characteristics

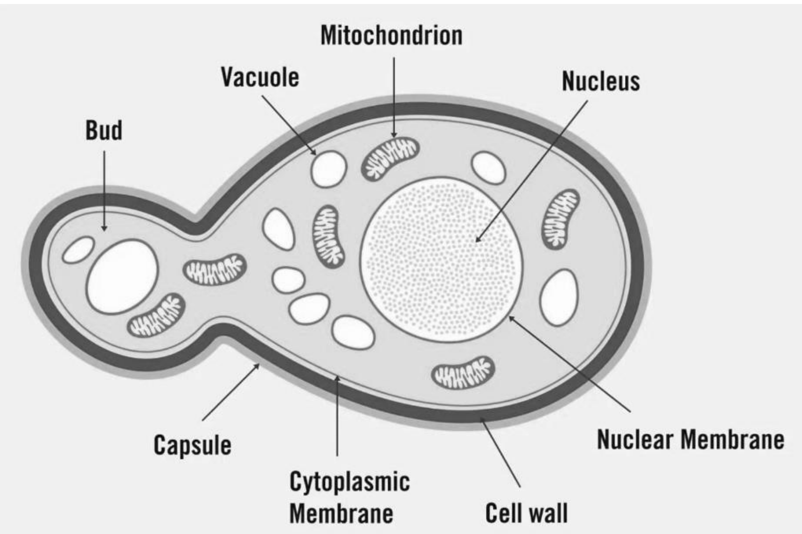
1. Their mycelium is made up of septate hyphae, except in yeasts, which are unicellular.
2. They are heterotrophic, mostly saprophytes, though some are parasites. For example:
    - *Candida albicans* (an infectious ascomycete that causes oral thrush in humans).
    - Powdery mildew fungi (infect cereal grains and other crops).
3. They have a fruiting body containing sac-like asci, each producing haploid ascospores that can germinate into new hyphae.
4. They form conidia at the tips of conidiophores for asexual reproduction. These conidia are numerous, resistant, and ensure survival in harsh conditions.
5. Sexual reproduction involves the mating of compatible hyphae, resulting in dikaryotic hyphae before fusion occurs.
6. Some members (e.g., yeasts) are unicellular and reproduce asexually by budding, where a new cell grows directly on the parent cell.

Distinctive Features

1. Presence of specialized spore-producing structures called ascocarps.
2. Asexual reproduction mainly through conidia, though budding also occurs in unicellular members like yeasts.
3. Some are unicellular heterotrophs lacking typical hyphae (e.g., *Saccharomyces*).

Structure of *Saccharomyces* (Yeast)

- *Saccharomyces* (yeast) are unicellular fungi, usually smooth, flat, and moist in appearance.
- They lack hyphae and instead exist as single cells.
- Their cells contain eukaryotic organelles such as mitochondria, ribosomes, Golgi apparatus, and vacuoles suspended in the cytoplasm.
- They have an elastic cell wall that maintains the shape of the cell and provides osmotic as well as physical protection.



Structure of Saccharomyces (Yeast)

Adaptations of *Saccharomyces* to Its Mode of Life

1. They store carbohydrates in the form of glycogen, which serves as an energy reserve during food scarcity.
2. Their permeable cell wall allows easy absorption of simple sugars, amino acids, and vitamins from their surroundings.
3. They secrete extracellular enzymes such as sucrase (to break down sucrose), cellulase (to digest cellulose), and proteases (to digest proteins).
4. They reproduce rapidly through budding, ensuring quick multiplication and colonization.
5. Their spores can remain dormant under unfavorable conditions, enabling survival until conditions improve.
6. Some species are facultative anaerobes, meaning they can respire aerobically when oxygen is available or switch to anaerobic respiration (fermentation) when oxygen is absent.

3. Phylum Basidiomycota

The name *Basidiomycota* comes from the presence of a characteristic club-shaped structure called a basidium (plural: basidia). Basidia are the sites where basidiospores (sexual spores) are produced, making them the hallmark of this group. Members of this phylum include mushrooms, bracket fungi, puffballs, rusts, smuts, and toadstools.

General Characteristics

1. Possess a fruiting body called a basidiocarp, which bears the club-shaped basidia.
2. Sexual reproduction typically results in the formation of dikaryotic hyphae (two nuclei per cell).
3. Hyphae are septate (divided by cross walls).
4. Nutrition is variable: some are saprophytic (decomposers), while others are parasitic on plants or animals.

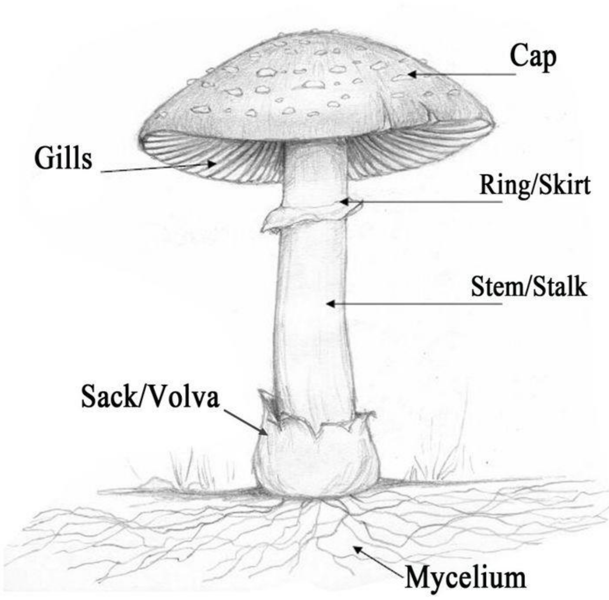
Distinctive Features

1. Produce sexual spores known as basidiospores, which develop externally on the basidia.
2. Hyphae are septate with distinctive pores in the septa that allow cytoplasmic streaming between cells.

Structure of *Agaricus* (Mushroom)

- The fruiting body consists of a stalk (stipe) topped by a broad cap (pileus).
- The underside of the pileus has numerous gills, which contain basidia that produce basidiospores.
- The main vegetative body of the mushroom is a network of underground mycelium, which absorbs nutrients from the substrate.

- Minute thread-like structures called rhizoids extend from the hyphae into the soil, helping in anchorage and nutrient absorption.
- A protective cup (volva) is found at the base of the stem.
- A thin ring (annulus) encircles the stem, a remnant of the protective veil that covered the gills in young mushrooms.



Structure of Agaricus (Mushroom)

Adaptations of Agaricus to its saprophytic mode of life

1. They have the ability to secrete a variety of hydrolytic enzymes for extracellular digestion of various organic matters.
2. They possess rhizomorphs which are responsible for absorption of nutrients from the substratum.
3. They have stipe for upward transport of nutrients to reach cap cells.
4. They store carbohydrates in the form of glycogen for use during shortage of food supply.
5. They are able to grow and survive on different substrates to increase chances of survival.
6. They produce a large number of basidiospores which are easily dispersed and resistant to harsh conditions.
7. They have a pileus or cap made up of piled hyphae to confer protection to the gills

Advantages of the kingdom Fungi

1. Some members of the kingdom fungi, such as Agaricus species, are sources of food for human beings.
2. Yeasts are used in fermentation to produce alcohol in brewing industries.
3. They are important in the production of organic solvents such as acetic acid, lactic acid, and glycerol.
4. They are important in the soil as they decompose dead organic matter and recycle nutrients back into dead plants and animals.

5. Fungi are used in the production of medicine (antibiotics) such as penicillin from Penicillium.
6. They are sources of important hormones such as gibberellins obtained from Gibberela fujikuroi; this hormone regulates vegetative and fruit growth in plants.
7. They are important in the cheese industry and in the production of some enzymes such as amylase.
8. They are used in research such as biochemical genetics.

Disadvantages of the kingdom Fungi

1. Some fungi produce toxins that can affect plants and animals; for example, some fungi are so poisonous that when consumed by mammals they can cause death. Example of poisonous mushrooms.
2. Some fungi cause diseases, for example, ringworms.
3. They lead to the destruction of crops such as grains, tubers, and fruits. Such as Mucor and Rhizopus.
4. Some fungi affect the nervous system when accidentally consumed in food; this may cause hallucinations. Example: an invasive fungus called Cryptococcus may cause serious inflammation of brain and spinal cord.
5. Some fungi, such as Penicillium which are used in pharmaceutical and cheese industries, cause various types of allergic conditions to some people.

EXPERIMENTS

Experiment 15

Kipute froze for a moment when she saw the tray laid out in front of her. Three very different creatures, labelled **D_1, D_2, and D_3**, stared back at her in silence. One had moist, soft skin; another showed dry scales and sharp toes; and the third had a long, limbless body coiled neatly on the tray.

Mr. Akilikubwa smiled knowingly. *"You see, students, classification is like detective work. The body of each specimen carries clues—skin texture, limbs, body shape—all are evidence. Your task is to read those signs carefully and uncover their true identity."*

The class leaned closer. It felt less like a biology practical and more like solving a mystery. The only difference was that instead of fingerprints, they were studying skin, limbs, and adaptations to life on land or in water.

Now, as a student following in Kipute's and Mr. Akilikubwa's steps, answer questions below:

Questions

(a) Identify specimens D_1, D_2 and D_3 by their common names.
(b) State two adaptations shown by each of the specimens D_2 and D_3 to its habitat.
(c) Classify each of the specimens D_1, D_2 and D_3 to class level.
(d) Study specimens D_2 and D_3 carefully, then explain why they belong to the same kingdom but different classes. Give two features for each.
(e) Specimen D_1 is often found in moist environments, while specimens D_2 and D_3 thrive in dry habitats. Based on your dissection and observations, explain how their body coverings support survival in these environments.
(f) Specimen D_3 is known to produce venom in some species. How is this adaptation important for survival, and what medical benefits have humans gained from it?

Response to Questions

(a) $D_1 = \text{Toad}$

$D_2 = \text{Lizard}$

$D_3 = \text{Snake}$

(b)

D_2 (Lizard):
• Scales prevent water loss in dry environments.
• Clawed toes for climbing and gripping surfaces.

D_3 (Snake):
• Limbless, elongated body adapted for slithering through narrow spaces.
• Scales reduce friction and conserve moisture.

(c)

Specimen	Kingdom	Phylum	Class
D_1	Animalia	Chordata	Amphibia
D_2	Animalia	Chordata	Reptilia
D_3	Animalia	Chordata	Reptilia

(d)

Similarities (same kingdom – Animalia):

1) Both are multicellular and heterotrophic.
2) Both have a backbone (Chordata).

Differences (different classes):

1) Specimen D_2 has limbs while Specimen D_3 is limbless.
2) Specimen D_2 has dry, scaly body covering, while Specimen D_3 has elongated body with modified skull and flexible jaw (for swallowing large prey).

(e) Specimen D_1 has moist skin that allows gaseous exchange but requires damp conditions to prevent drying out. Specimens D_2 and D_3 are covered with scales that prevent water loss, enabling them to live successfully in dry environments.

(f) Venom enables specimen D_3 to paralyze its prey rapidly, ensuring survival through efficient food capture and enhanced defense against threats.
In humans, components of snake venom have been developed into important medicines, including blood pressure drugs and anticoagulants.

Experiment 16

Kipute stared at six labeled trays: **L, T, W, X, Y, Z**—like a detective at a crime scene. Mr. Akilikubwa leaned in with a grin: *"Kingdoms, classes, keys… today you'll prove who belongs where. No guessing—only evidence."*

The room felt like a tiny taxonomy courtroom. Vials, hand lenses, scales, wings, body partitions—*exhibits A to Z.* Time to classify.

Now, as a student following in Kipute's and Mr. Akilikubwa's steps, answer the questions below:

Questions

(a) Give **three** distinctive features used to place **each** of specimens **L** and **Y** in their respective kingdoms.
(b) State **one** advantage and **one** disadvantage of specimens **L** and **Y**.
(c) Construct a **bracketed (dichotomous) key** to identify specimens **T, W, X, Y, Z** using the following features:
i) Nature of the skeleton
ii) Wings

iii) Scales
iv) Body partition

(d) While using your key, two students disagree whether specimen T has a "clearly three-part" body. What practical step ensures a reliable identification?

(e) What functional advantage do **scales** give to specimen **X** compared to **Z**, and how does this relate to habitat?

Responses to Questions

(d) Kingdom features

L (Kingdom Plantae)

1) Presence of a **cell wall (cellulose)**.
2) **Chlorophyll** present; capable of **photosynthesis** (autotrophic).
3) **Stationary** (non-motile as an organism); growth localized at meristems.

Y (Kingdom Animalia)

1) **Heterotrophic** nutrition by ingestion (no photosynthesis).
2) **No cell wall**; cells bounded by plasma membrane only.
3) **Multicellular and motile**, with nervous/coordinating systems for rapid response.

(b) One advantage and one disadvantage

L (Plantae)

Advantage: Produces its own food via **photosynthesis** (independent energy production).

Disadvantage: It is **immobile**, therefore cannot escape unfavorable conditions.

Y (Animalia)

Advantage: Motility—can search for food, mates, and favorable habitats.

Disadvantage: Depends on other organisms for energy; risk of **starvation** if food is scarce.

(c) Bracketed (dichotomous) key for T, W, X, Y, Z

1a. **Exoskeleton** present .... → Go to 2
1b. **Endoskeleton** present .... → Go to 3

2a. **Wings present** .... → **Y**
2b. **No wings** .... → Go to 4

4a. **Body divided into three distinct regions** (head, thorax, abdomen) .... → **T**
4b. **Body not clearly divided into three regions** .... → **W**

3a. **Body covered with scales** .... → **X**
3b. **Body not covered with scales** .... → **Z**

(d) Use a **hand lens** and examine **visible constrictions** and **tagmata** boundaries; confirm presence of **distinct head–thorax–abdomen** and note **jointed appendages**. Record features **before** choosing a branch.

(e) **Scales** reduce **water loss** and **abrasion**, aiding survival in **dry or aquatic** environments; **Z** (no scales) relies on other coverings/physiology (e.g., hair/skin/mucus) suited to its habitat.

Experiment 17

Kipute squinted at the jars labeled **A_1, A_2, A_3**. Each specimen looked so different, yet she knew they all held secrets about classification.

"Today," Mr. Akilikubwa announced, *"you will prove that features don't lie. Look closely—count the legs, check the body divisions, search for antennae. These details tell you who belongs where."*

The class leaned forward. Specimen A_1 looked segmented, with delicate legs and wings. Specimen A_2, bulkier, had no antennae but more legs than any insect. And Specimen A_3? Well, it didn't look like an animal part at all—it seemed to be the framework from inside something larger.

"Classification is like solving a riddle," said Mr. Akilikubwa, smiling. *"Every feature is a clue. Follow them carefully, and the organisms will reveal their true identity."*

Now, as a student following in Kipute's and Mr. Akilikubwa's steps, answer the questions below:

Questions

(a) Suggest four organisms from which specimen A_1 might have been taken.

(b) Carefully observe specimens A_1 and A_2;

(i) What are their kingdom and phylum?
(ii) What observable features in specimens A_1 and A_2 represent their respective class levels?

(c) What are the functions of specimen A_3 to the organism from which it was taken? (Give three functions).

(d) Specimen A_1 and specimen A_2 both occupy important ecological roles. Compare their significance in ecosystems.

(e) Specimen A_3 represents an internal supporting structure. Why is such a structure essential in larger animals compared to smaller organisms like insects?

Responses to Questions

(a) Possible organisms for specimen A_1:

1) Frog,
2) Lizard,
3) Rat,
4) Fish.

(b) (i)

Specimen A_1:

Kingdom: Animalia

Phylum: Arthropoda

Specimen A_2:

Kingdom: Animalia

Phylum: Arthropoda

(ii)

Specimen A_1 (Class Insecta):

- Body divided into three distinct parts: head, thorax, abdomen.
- One pair of antennae
- Compound eyes
- Three pairs of legs

Specimen A_2 (Class Arachnida):

- Body divided into two parts: cephalothorax and abdomen
- Four pairs of legs
- Absence of antennae
- Simple eyes

(c) Functions of specimen A_3:

1) Provides support and shape to the body.
2) Protects and anchors internal organs.
3) Enables locomotion by providing attachment for muscles.

(d) Insects (A_1) act as pollinators, decomposers, and prey for many species, supporting food webs. Arachnids (A_2), such as spiders, are mainly predators that control insect populations, maintaining ecological balance.

(e) Larger animals require a rigid internal skeleton to support greater body mass, protect organs, and allow for complex movement. Smaller organisms, such as insects, can rely on lighter exoskeletons since their small size reduces structural demands.

Experiment 18

Kipute almost laughed when she saw the tray: five different creatures labelled **P_1, P_2, P_3, P_4, P_5**, all staring up at her like contestants in a reality show.

Mr. Akilikubwa folded his arms. *"Don't be fooled. These aren't random creatures—they're all cousins. Once upon a time, taxonomists placed them in the same phylum. Your job is to prove why."*

He leaned in with his forceps, tapping gently on one specimen's shell. *"Notice the armor? That's an exoskeleton. And these legs? Always jointed. That's the family secret: they're Arthropods."*

The students chuckled as Kipute muttered, *"Some have wings, some have claws, some look like walking centipede noodles. How do we even sort this out?"*

"Easy," said Mr. Akilikubwa, smiling. *"Follow the classification key. One question at a time. The truth is always in the features."*

Now, as a student following in Kipute's and Mr. Akilikubwa's steps, answer the questions below:

Questions

(a) Why were specimens P_1, P_2, P_3, P_4, and P_5 formerly placed in the same phylum? Give two reasons.

(b) Use the following classification key to identify the specimens P_1, P_2, P_3, P_4, and P_5.

1a. Wings present → go to 2
1b. Wings absent → go to 3

2a. Outer wings are soft
2b. Outer wings are hard

3a. Numerous similar limbs
3b. Numerous similar limbs absent → go to 4

4a. First appendages bear pincers (chelicerae)
4b. First appendages are antennae (used as jaws)

(c) Identify the structures concerned with gaseous exchange in each of the specimens.

(d) Outline two common adaptive features for the specimens you named in (c).

(e) P_2 and P_3 both have wings but of different types (soft vs hard outer wings). What does this show about insect adaptation?

(f) Why are P_2, P_3, and P_4 more successful in terrestrial habitats than P_1?

Responses to Questions

(a) Reasons they were all placed in the same phylum (Arthropoda):
1) They all have jointed appendages.
2) They all possess an exoskeleton made of chitin.

(b)

1a. Wings present → go to 2
1b. Wings absent → go to 3

2a. Outer wings are soft → **P_2** (True fly)
2b. Outer wings are hard → **P_3** (Beetle-type insect)

3a. Numerous similar limbs → **P_4** (Centipede/Millipede)
3b. Numerous similar limbs absent → go to 4

4a. First appendages bear pincers (chelicerae) → **P_5** (Arachnid)
4b. First appendages are antennae (used as jaws) → **P_1** (Crustacean)

c) Structures for gaseous exchange:

- P_1: Gills
- P_2: Spiracles and tracheae
- P_3: Spiracles and tracheae
- P_4: Spiracles and tracheae
- P_5: Book lungs (sometimes tracheae)

d) Common adaptive features for gaseous exchange structures:

1) Large surface area for maximum diffusion.
2) Thin, moist membranes to allow gases to diffuse easily.

e) It shows diversification within insects; some adapted lightweight wings for agile flight, while others evolved protective hardened wings (elytra) for survival in tougher environments.

f) Insects (P_2, P_3, P_4) evolved tracheal systems and waterproof exoskeletons suited for land, while crustaceans (P_1) remain dependent on moist or aquatic environments for gill function.

Experiment 19

The lab lights flickered as Kipute stepped into what felt more like a crime scene than a biology classroom. Three "suspects" were waiting on the bench, tagged neatly as **R, S,** and **T**.

Mr. Akilikubwa, acting as chief inspector, announced: *"Team, we have three mysterious characters: one slippery soil dweller, one nimble jumper, and one buzzing intruder. Our mission is to unmask their identities and place them in the correct classes."*

The students leaned in with their notebooks like detectives ready to file a case report. Kipute carefully examined each specimen on the tray—counting segments, noting the arrangement of legs, and observing eyes and wings. Every feature was a potential clue to crack the classification mystery.

"Remember," Akilikubwa said with a grin, *"no fingerprints here, only body parts. But the principle is the same: follow the evidence."*

Now, as a student-detective following in Kipute's steps, answer the questions below:

Questions

(a)

(i) What are the common names of specimens R, S, and T?
(ii) Specimens S and T belong to which class?
(iii) Why do specimens R, S, and T belong to their respective classes?

(b)

(i) Where is the habitat for specimens R and S?
(ii) In what ways do specimens S and T adapt to their habitats?
(iii) In what ways are specimens S and T useful to human beings?

(c) Why is specimen R sometimes called a "farmer's friend"?
(d) Although S can be eaten as food, is often regarded as pest. Why?
(e) Why is specimen T considered dangerous to human health?
(f) Why are S and T generally more widespread and diverse than specimen R?

Responses to Questions

(a)
(i) Common names:

R: Earthworm

S: Grasshopper

T: Housefly

(ii) Classes:

S: Insecta

T: Insecta

(iii) Reasons for class placement:

R (Earthworm): Belongs to class **Oligochaeta** because it has a segmented body, lacks appendages, and possesses setae.

S and T (Grasshopper and Housefly): Belong to class **Insecta** because they have three distinct body parts (head, thorax, abdomen), compound eyes, antennae, and three pairs of jointed legs.

(b)
(i) Habitats:

R (Earthworm): Moist soil and underground burrows.

S (Grasshopper): Grassy fields, farms, and shrubs.

(ii) Adaptations:

S (Grasshopper):

- Strong hind legs for jumping.
- Camouflaged body colour for protection.
- Exoskeleton to reduce water loss.
- Wings for short-distance flight.

T (Housefly):

- Compound eyes for wide vision.
- Wings for agile flight.
- Mouthparts adapted for sucking and feeding on liquids.
- High reproductive rate ensuring survival.

(iii) Importance to humans:

S (Grasshopper): Edible in some cultures; useful in biological research.

T (Housefly): Aids decomposition by feeding on waste; used in forensic investigations to estimate time of death.

(c) Earthworms (specimen R) aerate the soil through burrowing and enrich it with organic matter via their castings, improving fertility and crop growth.
(d) Large populations of specimen S (grasshoppers) consumes large quantities of crops and vegetation rapidly, especially when present in swarms, leading to significant agricultural damage and economic loss despite their potential nutritional value.
(e) Houseflies (T) carry and transmit disease-causing microorganisms on their bodies and mouthparts. By contaminating food and surfaces, they spread illnesses such as dysentery, cholera, and typhoid fever.
(f) Insects (S and T) have versatile adaptations (flight, exoskeleton, varied feeding structures, rapid reproduction) that allow them to exploit many habitats, while annelids (R) are limited mostly to soil and moist environments.

Experiment 20

The lab was unusually noisy. As soon as the tray with **specimens G_1, G_2, G_3, and G_5** was revealed, half the class leaned in eagerly while the other half leaned back in disgust.

"Why does it always have to be creepy-crawlies?" one student whispered.

Mr. Akilikubwa raised his chalk like a judge with a gavel. *"Settle down, class! Whether they crawl, buzz, or bite, they all belong to nature's grand design. And today, your task is to prove where each specimen fits."*

Kipute, trying not to laugh, pointed at one specimen and muttered, *"This one looks like it skipped leg day… while the other brought too many legs to the party."* The whole class chuckled, but they knew the work ahead was serious: count, compare, and classify.

Now, as a student following in Kipute's steps, answer the questions below:

Questions

(a)
(i) Give two reasons why you agree or disagree that specimens G_1, G_2, G_3, and G_5 are members of the same kingdom.
(ii) What are the observable differences between specimens G_2 and G_5?
(b) State three adaptations of specimen G_4 to its life.
(c)
  (i) In what ways are specimens G_2 and G_5 important in the ecosystem?
  (ii) Where can we find specimen G_2?
  (iii) Classify specimen G_4 to class level.
  (iv) Where can we find specimen G_5?
(d) Specimen G_2 has wings, while specimen G_5 does not. Explain how each body plan is still well adapted to survival in its habitat.

(e) Why might farmers consider specimen G_2 both a friend and a foe?

Responses to Questions

(a) (i) Agree

Reasons:

1) All are multicellular organisms.
2) They exhibit locomotion and have specialized tissues and organs.

(ii) Observable differences between G_2 and G_5:

- **G_2 (Insect):** Has wings and three body parts (head, thorax, abdomen).
- **G_5 (Arachnid):** Has eight legs, no wings, and body divided into cephalothorax and abdomen.

(b) Adaptations of specimen G_4 to its life:

- Camouflage colouring for protection.
- Clawed limbs for grasping or climbing.
- Well-developed claws/teeth for hunting or defense.

(c)

(i) Importance in the ecosystem:

- **G_2 (Insect):** Pollination, decomposition of waste, and serving as food for other animals.
- **G_5 (Arachnid):** Controls insect populations by predation.

(ii) Habitat of G_2:

Found in open fields, farms, or near flowering plants.

(iii) Classification of G_4:

- Kingdom: Animalia
- Phylum: Arthropoda
- Class: Insecta

(iv) Habitat of G_5:

Found in dark places such as leaf litter, under stones, or beneath wood.

(d) G_2 uses wings for pollination, dispersal, and escaping predators. G_5 relies on stealth, webs, and strong legs to capture prey, making wings unnecessary.

(e) It benefits humans by pollinating crops, but in large numbers it can damage leaves and grains, thereby acting as a pest.

Experiment 21

The laboratory had been transformed into a mock surgical theatre. Three "patients" lay on the table, tagged **M_1, M_2, and M_3**.

Mr. Akilikubwa put on a mock surgeon's mask. *"Ladies and gentlemen,"* he said dramatically, *"today's operation is not about saving lives, but about uncovering life's secrets. Each specimen before us carries the marks of evolution—your job is to diagnose their adaptations."*

The class chuckled when Kipute whispered, *"So… a soil wriggler, a jumper, and a kitchen intruder?"* Akilikubwa raised his hand like a surgeon about to make the first incision. *"Focus, team. Examine carefully. No patient leaves unidentified."*

Now, as a student in this interesting theatre, answer the questions below:

Questions

(a)
(i) Identify the specimens M_1, M_2, and M_3 by their common names.
(ii) Point out three observable features of each specimen (M_1, M_2, and M_3) which enable them to adapt to their environments.

(b)
(i) Classify the specimens M_1, M_2, and M_3 to phylum level.
(ii) Draw a large, well-labeled diagram of specimen M_1.

(c) Examine the role performed by specimen M_1.

(d) Why do M_2 and M_3 belong to the same phylum but different ecological niches?

(e) Specimen M_3 is adapted to survive in kitchens and houses. Why is it a concern to human health despite its survival success?

Responses to Questions

(a) (i) Identification:

M_1: Earthworm

M_2: Grasshopper

M_3: Cockroach

(ii) Observable features and adaptations:

M_1 (Earthworm):

- Segmented, elongated body for burrowing through soil.
- Moist skin for gaseous exchange.
- Presence of setae for movement through soil.

M_2 (Grasshopper):

- Long hind legs for powerful jumping.
- Compound eyes for wide vision.

- Green or brown body coloration for camouflage.

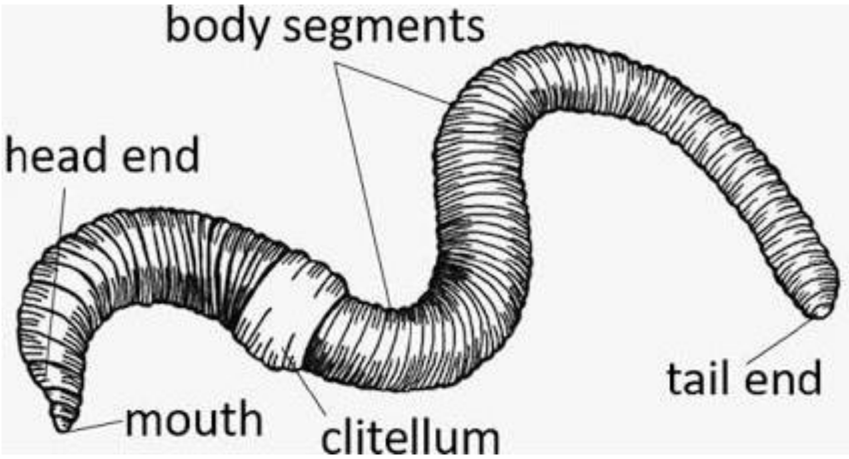
M_3 (Cockroach):

- Flattened body to squeeze into narrow spaces.
- Long antennae for detecting food and predators.
- Wings for short-distance flight and rapid escape.

(b)(i).

Specimen	Kingdom	Phylum
M1	Animalia	Annelida
M2	Animalia	Arthropoda
M3	Animalia	Arthropoda

(ii) Diagram of Specimen M1 (Earthworm):



(c) Roles Performed by Specimen M1 :

- Aerates and loosens soil for plant roots.
- Increases soil fertility through castings.
- Breaks down organic matter into humus.
- Serves as food for birds and other animals.

(d) **Reason for the same phylum:** Both grasshoppers (M_2) and cockroaches (M_3) are arthropods with exoskeletons, jointed legs, and segmented bodies.
Reason for different ecological niches: Grasshoppers (M_2) are adapted for herbivory and open fields (jumping, camouflage), while cockroaches (M_3) thrive as scavengers in dark human dwellings (flattened body, rapid escape).

(e) Cockroaches (M_3) contaminate food with disease-causing microorganisms and allergens, leading to illnesses such as food poisoning and asthma.

Experiment 22

This time, the "laboratory" wasn't indoors. Kipute and Mr. Akilikubwa stood in the school garden with insect nets, bottles, and notebooks. Around them, small creatures hopped through the grass, others fluttered among flowers, while a few buzzed annoyingly close to their ears.

"This," Akilikubwa declared, *"is a practical exam delivered by nature herself. The air is alive with specimens G_3, G_4, G_5, and G_6. Your task is to identify them, compare them, and prove their importance."*

Kipute swatted at her arm and groaned. *"I think one of these specimens has already classified me as its dinner."*

The class laughed, but everyone knew the work was serious: today's answers would come not from trays in the lab, but from living field observations.

Now, as a student following in Kipute's and Mr. Akilikubwa's steps, answer the questions below:

Questions

(a) (i) Identify the specimens G3, G4, G5, and G6 by their common names.

(ii) Classify G3, G5, and G6 to class level.

(b) What are the observable differences between the specimens G4 and G6 at the class level?

(c) In what ways are the specimens G4 and G6 important in the ecosystem?

(d) Where can we find specimen G6.

(e) Why might farmers view specimen G4 more positively than specimen G6, despite both being insects?

Responses to Questions

(a) (i)

G3: Grasshopper

G4: Butterfly

G5: Housefly

G6: Mosquito

(ii)

Specimen	Kingdom	Phylum	Class
G4	Animalia	Arthropoda	Insecta
G5	Animalia	Arthropoda	Insecta
G6	Animalia	Arthropoda	Insecta

(b) Observable differences between G_4 (Butterfly) and G_6 (Mosquito):

SN	G_4 (Butterfly)	G_6 (Mosquito)
1	Has broad wings covered with scales	Has narrow, slender wings.
2	Has long proboscis for sucking nectar	Has piercing-sucking mouthparts for feeding on blood/plant juices.
3	Is active during the day (diurnal)	Is active mainly at night (nocturnal).

(c) Importance of Specimens G4 and G6 in the Ecosystem:

Butterfly (G_4): Key pollinators of flowering plants, supporting reproduction and biodiversity.

Mosquito (G_6): Serve as food for fish, birds, and bats; part of aquatic and terrestrial food chains.

(d) Found near stagnant water, swamps, and damp areas where they breed.
(e) Specimen G4 (butterflies) contribute directly to crop pollination, enhancing yields, whereas specimen G6 (mosquitoes) harm humans and livestock by spreading diseases such as malaria, dengue, and yellow fever without offering agricultural benefits.

Experiment 23

The classroom was warm, and the specimens on the bench looked more like tiny green mats and leaves than "serious biology." A few students giggled.

Kipute poked one specimen with her pencil and whispered, *"This doesn't even look like a plant. Are we sure this isn't algae pretending?"*

Mr. Akilikubwa, overhearing, raised an eyebrow. *"Oh, it's a plant, alright. But not like the ones you eat for lunch. Today's suspects—**E_1, E_2,** and **E_3**—are masters of surviving without flowers. Pay attention, because the real trick is how they reproduce."*

The class leaned in. Laughter faded. They knew that what looked ordinary was about to turn into a classification puzzle.

Now, as a student following in Kipute's and Mr. Akilikubwa's steps, answer questions below:

Questions

(a) Identify specimens E_1, E_2, and E_3 by their common names.
(b) State two adaptations shown by each specimen to its habitat.
(c) Classify specimens E_1 and E_2 to class level.
(d) On the underside of a frond of specimen E_3, identify the structure responsible for reproduction.
(e) Study specimens E_1 and E_2 carefully. These specimens are said to belong to the same kingdom but not the same division/phylum. Explain.
(f) How are specimens E_1 and E_3 useful to humans?

Responses to Questions

(a) Identification:

E_1: Moss

E_2: Liverwort

E_3: Fern

(b) Adaptations to habitat:

E_1 (Moss):

1) Rhizoids for anchorage on surfaces.
2) Ability to retain water in moist environments.

E_2 (Liverwort):

1) Flat rhizoids for absorbing water directly.
2) Gemma cups for asexual reproduction.

E_3 (Fern):

1) Vascular tissue (xylem, phloem) for water and nutrient transport.
2) Large fronds with sori to produce spores.

(c)

Specimen	Kingdom	Phylum/division	Class
E_1	Plantae	Bryophyta	Bryopsida
E_2	Plantae	Marchantiophyta	Hepatopsida

(d) **Sori** (clusters of sporangia on the underside of fronds, produce spores).

(e) Both E_1 (Moss) and E_2 (Liverwort) belong to Kingdom Plantae but fall into different divisions. Mosses are non-vascular plants classified under Division Bryophyta, while liverworts are non-vascular plants in Division Marchantiophyta. Their separation into different divisions is based on differences in tissue organization, reproductive methods (e.g., gemma cups in liverworts versus leafy gametophytes in mosses), and the structure of their spore-producing organs.

(f) Human use of **E_3** **(**Ferns) and **E_1** (Mosses):

Ferns (**E_3**) are ornamental, some edible, and used in traditional medicine.

Mosses (**E_1**) are used in gardening (as mulch or decoration), and in some cases for wound dressing due to water absorption.

Experiment 24

The atmosphere in the lab was different this time. No jokes, no detective games—this was the final classification trial. The bench displayed specimens **G_3, G_4, G_5, G_6,** and **G_7**. Each one represented not just an insect, but the end of a journey through classification.

Mr. Akilikubwa adjusted his glasses and addressed the class.

"Today you will not only identify specimens, but also prove your ability to use a dichotomous key correctly. Treat this as your final field report—your answers should be precise, systematic, and evidence-based."

The students nodded seriously. Notebooks opened, pencils sharpened. This was their last test.

Now, as a student preparing your final classification report, answer the questions below:

Questions

(a) Identify specimens G_3, G_4, G_5, and G_6 by their common names.
(b) State the observable differences between specimens G_4 and G_6 at the class level.
(c) State two economic importance of specimen G_4 and specimen G_6.
(d) Classify specimen G_6 to class level and state its habitat.
(e) By listing the number of statements from the dichotomous key below, identify the order for each specimen G_5, G_6, and G_7.

1a. Body dorsoventrally flattened → **Dictyoptera**
1b. Body not dorsoventrally flattened → go to 2

2a. Body covered with hair → **Hymenoptera**
2b. Body not covered with hair → go to 3

3a. Number of obvious wings = 2 → **Diptera**
3b. Number of obvious wings = 4 → go to 4

4a. Forewings hardened (elytra), hindwings membranous → **Coleoptera**
4b. Both forewings and hindwings soft, membranous → go to 5

5a. Hind limbs larger than the rest → **Orthoptera**
5b. Limbs all similar size → **Lepidoptera**

(f) Why is G_7 considered more dangerous to humans than G_5 or G_6?

Responses to Questions

(a) Identification

G_3: Housefly

G_4: Grasshopper

G_5: Butterfly

G_6: Beetle

(b) Observable differences between specimens G_4 and G_6 at the class level:

Feature	**Specimen G_4: Grasshopper**	**Specimen G_6: Beetle**
Hind limbs	Long and adapted for jumping	All legs similar size
Wings	Forewings leathery, hindwings membranous	Forewings hardened into elytra
Body form	Elongated, segmented clearly	Compact and rigid
Mouthparts	Chewing type for vegetation	Chewing type for varied diet

(c) Economic importance

Specimen G_4 (Grasshopper):

1) Acts as a serious crop pest.
2) Serves as food for birds, reptiles, and humans in some cultures.

Specimen G_6 (Beetle):

1) Many species decompose organic matter, aiding nutrient recycling.
2) Some species are pests of crops and stored products.

(d) Classification of specimen G_6 (Beetle) to class level:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Habitat: Found in soil, under logs, in leaf litter, or within crops depending on species.

(e) Using the dichotomous key:

Specimen G_5 (Butterfly):
1(b) → 2(b) → 3(b) → 4(b) → 5(b) → **Order: Lepidoptera**

Specimen G_6 (Beetle):
1(b) → 2(b) → 3(b) → 4(a) → **Order: Coleoptera**

Specimen G_7 (Housefly):
1(b) → 2(a) → 3(a) → **Order: Diptera**

(g) G_7 (houseflies) transmit pathogens by contaminating food and surfaces, spreading diseases such as cholera, typhoid, and dysentery, while G_5 (butterflies) and most beetles (G_6) rarely transmit human pathogens.

Chapter 4
ADDITIONAL PRACTICALS

In this chapter, we focus on practicals that may not appear as often in the final NECTA examinations, but are still essential for building a complete understanding of biology. These experiments help students connect theory with real-life applications and strengthen problem-solving skills in laboratory work.

The practicals covered here include:

1) **Enzymology** – exploring how enzymes act as biological catalysts, how temperature and pH affect their activity, and why this knowledge is vital in food processing, medicine, and biotechnology.
2) **Reproduction** – studying structures and processes related to reproduction, helping learners understand concepts such as fertilization, germination, and reproductive adaptations.
3) **Osmosis and Diffusion** – investigating the movement of molecules across membranes, which is fundamental to understanding nutrition, excretion, water balance, and even medical practices such as intravenous fluid therapy.
4) **Growth and development**- examining how organisms increase in size and change through different stages such as germination and metamorphosis. It helps learners understand the factors influencing growth and the importance of development in survival and reproduction.

Although these practicals may be asked less frequently in examinations, mastering them builds confidence, scientific thinking, and practical skills that are valuable both in academic settings and real-world applications.

ENZYMOLOGY

Enzymes are **biological catalysts** made up of globular proteins. Their unique three-dimensional structure allows them to bind specific substrates and speed up biochemical reactions with remarkable precision.

A **catalyst** is defined as a substance that alters the rate of a chemical reaction without itself undergoing a permanent change. Enzymes work in exactly this way, accelerating metabolic reactions but remaining unchanged at the end.

Because they are not consumed during the reactions they catalyze, enzymes can be used repeatedly, even in very small amounts. This efficiency makes them essential to life processes such as digestion, respiration, photosynthesis, and DNA replication.

Enzymology experiments are designed to demonstrate the role of enzymes as biological catalysts and to observe how their activity can be influenced by different factors. Such experiments not only highlight the delicate balance required for optimal enzyme function but also show the biological significance of enzymes in processes like digestion, respiration, and metabolism.

Factors Affecting the Rate of Enzyme Activity

The rate at which enzymes catalyze reactions is influenced by several key factors.

1. Substrate concentration

At a fixed enzyme concentration, increasing the substrate concentration increases the reaction rate. This is because more substrate molecules collide with enzyme molecules, forming more enzyme–substrate complexes and producing more products over time.

2. Enzyme concentration

When conditions such as temperature and pH are optimal, and substrates are in excess, the reaction rate is directly proportional to the enzyme concentration. More enzyme molecules provide more active sites, enabling more reactions to occur simultaneously.

3. Temperature

In general, raising the temperature increases the kinetic energy of molecules, leading to more frequent and energetic collisions between enzyme and substrate molecules. This results in a higher reaction rate. However, beyond a certain point, high temperatures disrupt hydrogen and ionic bonds that stabilize the enzyme's structure. This denaturation reduces enzyme activity, and eventually the reaction slows or stops.

4. pH

Each enzyme functions best at a specific pH level (its optimum pH). At this point, the enzyme's active site maintains the correct shape for maximum activity. Deviations above or below the optimum pH alter the enzyme's structure, reducing its ability to bind to substrates and thereby decreasing the reaction rate.

EXPERIMENTS

Experiment 25

One Saturday morning, Kipute entered the biology laboratory where she found a small piece of fresh liver wrapped neatly on a tray. On the counter stood a mortar and pestle, a beaker of water, and a bottle labeled **"Solution X."** She knew from experience that Solution X was going to reveal something about the nature of enzymes found in the liver.

With curiosity bubbling inside her, she carefully prepared the liver solution as instructed and then tested the second portion with Solution X. This was more than just a chemical test; it was a peek into how the body works every second of the day.

Procedures followed by Kipute:

1. She cut the $5cm^3$ of liver into small pieces, then crushed it to paste by using a mortar and pestle provided. Added a little amount of water into the paste, mixed well, and labeled it as **liver solution**.
2. She put the remaining $5cm^3$ of liver into a test tube, added 3 drops of **Solution X** in the test tube. Observed the results.

Questions

(a) Using the chemical reagents provided, carry out biochemical tests to identify the food substances present in the liver solution. Tabulate your results as shown in the following table:

Food test	procedure	observation	inference

(b) What is the identity of Solution X, and what observation is expected when it is added to the liver?

(c) Imagine a child accidentally ingests a substance that releases hydrogen peroxide in the stomach. Using the reaction observed in procedure (2), explain — with the aid of the chemical formula, why the presence of catalase in the liver and blood cells would be life-saving.

(d) How can one set up a control experiment for the reaction presented in (c)?

(e) Give one medical and one industrial application where the liver's ability to break down peroxides is relevant.

(f) The liver solution tested positive for proteins, reducing sugars and lipids. How do these components reflect the liver's roles in metabolism?

Response to Questions

Food test	procedure	observation	inference
Proteins	Add Biuret solution to liver solution	Color changes to purple	Protein present
Reducing sugars	Add Benedict's solution to liver solution and heat	Brick-red precipitate forms	Reducing sugar present
Fat (Lipids)	Add ethanol, shake, then add water	Emulsion forms	Fat present

(b) Solution X is hydrogen peroxide (H_2O_2). On adding it to liver tissue, brisk effervescence (bubbles of oxygen gas) is observed because the enzyme catalase in the liver breaks down hydrogen peroxide into water and oxygen.

(c) When hydrogen peroxide (H_2O_2) is produced in the body, it is highly toxic and can damage cells by oxidizing proteins, lipids, and DNA. The enzyme catalase, present in liver and blood cells, rapidly decomposes hydrogen peroxide into harmless products according to the reaction:

$$2H_2O_2 \xrightarrow{\text{Catalase}} 2H_2O + O_2$$

This breakdown releases water and oxygen, both non-toxic, thereby preventing harmful accumulation of hydrogen peroxide in the stomach and bloodstream. The presence of catalase is therefore life-saving, as it protects cells from oxidative damage and maintains metabolic balance.

(d) Use a test tube with boiled liver (to denature the enzymes) and add hydrogen peroxide. No bubbling or effervescence should be observed. This confirms that the enzyme catalase is responsible for the reaction.

(e) **Medical application:** In clinical toxicology and pharmacology where understanding hepatic enzyme activity is crucial for drug safety and for treating poisonings that produce oxidative metabolites.

Industrial application: In food industries where knowledge of peroxide-breaking enzymes helps in controlling spoilage when peroxides are used as preservatives.

(f) Proteins (enzymes and structural proteins) indicate the liver's synthetic role; reducing sugars reflect glycogenolysis or carbohydrate processing; lipids reflect lipid metabolism and storage/transport functions.

Experiment 26

Kipute was curious about how food starts to be broken down the moment it enters the mouth. Today, her task was to explore the **role of saliva in the first stage of digestion**. She prepared her materials carefully: two test tubes, starch suspension, and a beaker of warm water. Her challenge was simple yet important — to investigate how something produced naturally in the mouth could initiate the breakdown of food, setting the stage for energy release in the body.

With the setup ready, Kipute focused on conducting the experiment systematically, knowing that the results would reveal an essential function of the human digestive system.

Procedures followed by Kipute:

1. Took 2 test tubes and labeled them as Test Tube 1 and Test Tube 2 respectively.
2. Rinsed her mouth with pure drinking water and then collected her saliva by spitting 2ml into Test Tube 1.
3. Added 2ml of water into Test Tube 2.
4. Added 2ml of starch suspension to each test tube. Shook the test tubes.
5. Put the tubes in a beaker of water at 40∘C. Left them for ten (10) minutes.
6. Dipped 2 drops from each test tube into separate dimples of the white tile, then she added a drop of iodine solution. She noted the results.
7. Added 2ml of Benedict's solution to each test tube, and then she boiled the test tubes for 5 minutes. She noted the results.

Questions

(a) Based on the observations in Procedures (v) and (vi), write what happened to the iodine test and Benedict's test, respectively. Record your experimental results as shown in Table 1.

Test Tube	**Result of iodine**	**Results of Benedicts Test**
1		
2		

(b) Why was water in Test Tube 2 needed in place of saliva?

(c) In which test tube contained starch at the end of the experiment? Give a reason to support your answer.

(d) What is the effect of saliva on starch?

(e) Why is warmth in procedure (4) and (5) of the experiment important to our bodies?

(f) What is the importance of the food substance contained in Test Tube 1 at the end of the experiment?

(g) In what ways is the knowledge used in this experiment useful in your daily life?

Response to Questions

(a) Table 1

Test Tube	**Result of iodine**	**Results of Benedicts Test**
1	No blue-black colour; starch absent.	Brick-red precipitate; reducing sugar present.
2	Blue-black colour; starch present.	No colour change; no reducing sugar.

(b) Water served as a control to show the effect of saliva (which contains amylase). It does not break down starch.

(c) Test tube 2 contained starch because water cannot break down starch, so iodine turned blue-black, indicating starch presence.

(d) Saliva contains amylase, which breaks down starch into maltose, a reducing sugar.

(e) Warmth (around 40°C) provides an optimal temperature for amylase enzyme activity. Without warmth, enzyme action would be slow or inactive.

(f) The reducing sugar (maltose) produced is an energy source for body metabolism.

(g) This helps us understand how digestion works in the mouth, the importance of enzymes, and why temperature affects digestion.

Experiment 27

On a quiet weekday afternoon, Mr. Akilikubwa prepared five test tubes for his students, each carefully labeled 1 to 5. The lesson of the day was not just about chemical reagents, but about something much closer to everyday life: how food begins its journey of digestion the very moment it enters the mouth.

As the students chewed rubber bands to stimulate saliva, Mr. Akilikubwa reminded them, *"This experiment is more than just colors in test tubes—it explains why chewing food well is important for energy release. Without proper breakdown of starch, the body cannot access the sugars needed for activity."*

The test was set up: starch solution, saliva, iodine, and Benedict's solution. The challenge was to trace the invisible transformation of starch into simple sugars, a chemical change that fuels every heartbeat and step we take.

As one of Mr. Akilikubwa's students, follow the instructions below:

(a) Label five test tubes 1–5 and collect saliva as follows:

1. Rinse your mouth with water to remove food residue.
2. Chew a rubber band to stimulate the flow of saliva.
3. Collect about 30cm^3 of saliva.

(b) Using a graduated pipette, place 5cm^3 of solution Y in test tubes 1–4.

(c) Rinse the pipette and draw up 4cm^3 of saliva. Place 2cm^3 in each of test tubes 2 and 3, and shake the test tubes for 5 minutes. Copy the table below into your answer booklet.

(d) After 5 minutes, add 3 drops of iodine solution to test tubes 1 and 2.

(e) Use the graduated pipette to add 3cm^3 of Benedict's solution to test tubes 3 and 4, and place both test tubes in a water bath for 5 minutes.

(f) Compare the final colors in the test tubes and complete the table of results.

Test tubes	**contents**	**Test with**	**results**	**interpretation**
1	Solution Y	Iodine solution		
2	2%Solution Y+ Saliva	Iodine solution		
3	2%SolutionY+ Saliva	Benedict's solution		
4	2%SolutionY	Benedict's solution		

Questions

(a) Test-tube 3 contained a food substance present in solution Y at the beginning of the experiment. How do you explain the reaction with iodine solution at the end of the experiment?

(b)

(i) What food substance is Benedict's solution a test for?
(ii) Was this food substance present in test tube 3 or 4 at the beginning of the experiment?
(iii) What evidence support your answer?

(c)
(i) What chemical change could have taken place in test tubes 2 and 3 after adding saliva?
(ii) What part could saliva have played in this chemical change?
(iii) Why does chewing food longer aid digestion, based on this experiment?

(d) Why was test tube 1 important in this experiment?
(e) How does this experiment explain the quick energy boost we feel after eating sweet fruits compared to starchy foods like ugali or rice?
(f) Name at least four natural food sources for the food substance contained in solution Y.
(g) Gianna has been diagnosed with hypertension due to excess fat around her heart and blood vessels. Which among the above-mentioned food sources should she reduce to lower her blood pressure, and why?

Response to Questions

Test tube	content	Test with	results	interpretation
1	2%solution*Y*	Iodine solution	Blue-black colour	Starch present
2	2%solution*Y*+ saliva	Iodine solution	No colour change	Starch absent
3	2%solution*Y*+ saliva	Benedict's solution	Brick-red precipitate	Reducing sugar present
4	2%solution*Y*	Benedict's solution	No change	Reducing sugar absent

(a) The starch in solution Y was broken down by saliva (amylase) into simple sugars, so iodine did not detect starch at the end.

(b)
(i) Reducing sugars (e.g., glucose and maltose).
(ii) It was present in test tube 3.
(iii) The appearance of a brick-red precipitate after Benedict's test confirmed reducing sugars were formed due to enzyme activity.

(c)
(i) Starch was hydrolyzed into reducing sugars (maltose/glucose).

$$\text{Starch} \xrightarrow{\text{amylase}} \text{Maltose/Glucose}$$

(ii) Saliva supplied the enzyme amylase, which catalyzed the hydrolysis of starch.

(iii)Chewing increases the surface area for amylase to act on starch, speeding up its breakdown into sugars for faster absorption in the body.

(d) It served as a baseline control to prove that starch was present at the beginning and only disappeared in the presence of saliva.

(e) Sweet fruits already contain reducing sugars (glucose, fructose), so energy is released quickly. Starch foods must first be broken down by amylase into sugars before the body can use them.

(f) Maize, rice, potatoes, wheat, cassava, bananas, and other starch-rich foods.

(g) She should reduce starch-rich foods like rice, maize, potatoes, and wheat products because excess starch is broken down into glucose, which can be stored as fat when consumed in large amounts. This fat contributes to weight gain and high blood pressure.

Experiment 28

One afternoon, Kipute entered the biology laboratory carrying a fresh piece of liver. She was curious about a mysterious **substance X** inside the liver that could break down potentially harmful chemicals. Today's task was to observe how hydrogen peroxide reacts with substance X in the liver, revealing an essential chemical process that protects living organisms from damage.

With test tubes, a knife, a mortar, and a 2% hydrogen peroxide solution ready, Kipute carefully prepared her samples, eager to see the invisible reaction that makes the liver a natural detoxifier.

Procedures followed by Kipute:

1. She labelled three test tubes: 1, 2, and 3.
2. She cut the liver tissue into three cubes of about 1cm^3 each.
3. She placed one of the cubes in test tube 1, added 2mL of hydrogen peroxide solution, and observed the changes.
4. She took the second cube of liver tissue, ground it, placed the ground liver in test tube 2, Added 2mL of hydrogen peroxide in the test tube, and observed the changes.
5. She took the third cube of the liver tissue and ground it. She placed the ground liver in test tube 3, boiled it, allowed it to cool, added 2mL of hydrogen peroxide solution and then observed the changes.

Questions

(a) Present the observations of test tubes 1, 2, and 3 in tabular form and give reasons for the observed changes.

(b)

(i) Identify a cellular organelle where substance X can be found.
(ii) Name the biochemical reaction catalyzed by substance X in the liver.
(c) State the purpose of grinding and boiling the liver.
(d)
(i) Write the balanced chemical equation for the reaction between substance X and hydrogen peroxide.
(ii) State the biological significance of the reaction in living organisms.
(e) Suggest two other organs or tissues in the body, apart from the liver, where the activity of substance X would be important. Explain your answer briefly.
(f) In industrial or everyday life, how can the *substance X* reaction be applied or demonstrated?

Response to Questions

(a)

Test tube	**Observation**	**Reason for observation**
1	Bubbling/fizzing	Substance X in liver catalyzes the breakdown of H_2O_2 into O_2 and H_2O.
2	Vigorous bubbling	Grinding exposes more surface area, increasing the reaction rate.
3	No bubbling	Boiling denatures substance X, inactivating its catalytic ability.

(b)

(i) Peroxisomes.

(ii) Decomposition of hydrogen peroxide.

(c)

Grinding: Increases surface area, exposing more enzyme (substance X) for faster reaction.

Boiling: Denatures the enzyme to show that the reaction depends on active substance X.

(d)

(ii) $2H_2O_2 \xrightarrow{\text{Enzyme catalase}} 2H_2O + O_2$

(iii) Protects cells from toxic accumulation of hydrogen peroxide by breaking it down into harmless water and oxygen.

(e)

1) **Kidneys**: In detoxification of waste products. Enzyme catalase (substance X) helps to detoxify harmful by-products of metabolism, preventing oxidative damage to kidney cells.
2) **Red blood cells**: Catalase (X) protects hemoglobin and other cellular components from oxidative damage caused by hydrogen peroxide produced during normal metabolic processes.

(f) The substance X (catalase) reaction can be demonstrated or applied in:

1) **Laboratory:** Demonstrating enzyme activity or studying reaction rates.
2) **Food industry:** Removing hydrogen peroxide used in food sterilization.
3) **First aid:** Understanding why hydrogen peroxide foams when applied to a wound.

REPRODUCTION IN FLOWERING PLANTS

A flower is essentially a **modified leaf**, highly specialized for reproduction. It may be **bisexual**, containing both male and female reproductive organs, or **unisexual**, having only one type of reproductive structure. In studying reproduction in flowering plants, practical work begins with observing the **major floral parts** and their roles in pollination and fertilization.

Through examination of flowers, students learn to identify these parts, understand their functions in reproduction, and appreciate the adaptations that make pollination and fertilization successful. These practicals not only demonstrate the structure of flowers but also connect to real-life applications in **agriculture, horticulture,** and **plant breeding.**

Structure of a Flower

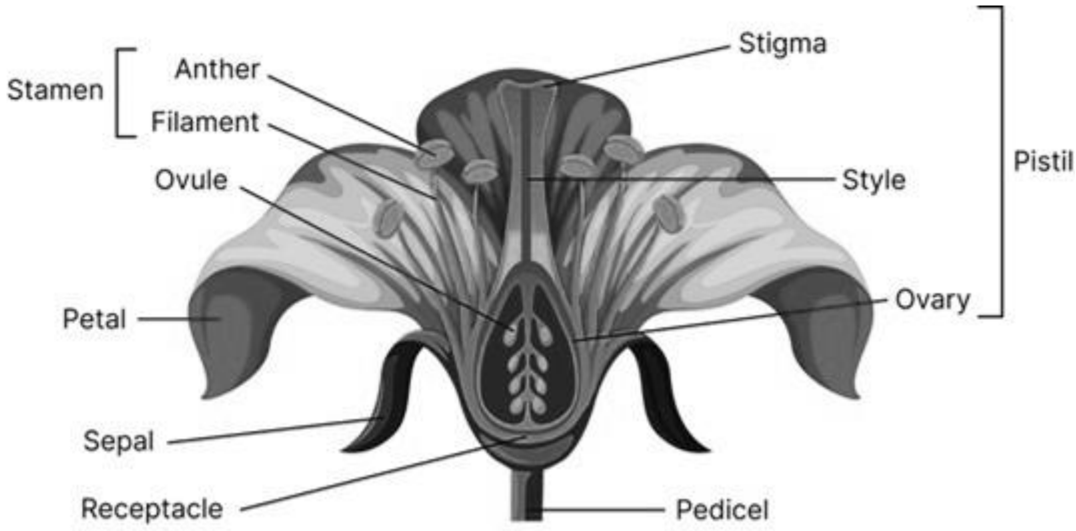
A flower is the reproductive organ of angiosperms, arranged in concentric whorls on a swollen tip of the stalk called the receptacle. Each part of the flower is specialized for a particular role, ensuring protection, attraction of pollinators, and successful reproduction.

Major Parts of a Flower

1. **Receptacle**
   - The swollen tip of the pedicel on which all floral parts are attached.
   - Its growth is limited and ceases once the last floral part is formed.
2. **Sepals (Calyx)**
   - The outermost whorl, usually green and leaf-like.
   - Protect the developing flower while it is still in the bud stage.
3. **Petals (Corolla)**
   - Brightly coloured and often scented structures that form the most conspicuous part of the flower.

- Their primary function is to attract pollinators such as insects and birds, facilitating pollination.

4. **Androecium (Male Reproductive Whorl)**
   - The collective term for all stamens in a flower.
   - Each stamen consists of a **filament** (slender stalk) and an **anther** (often yellow or orange), which produces pollen grains containing male gametes.
5. **Gynoecium (Female Reproductive Whorl)**
   - The collective term for the female reproductive parts, also called the **pistil** or **carpel**.
   - It consists of:
     - ✓ **Stigma** – sticky surface for receiving pollen grains.
     - ✓ **Style** – slender stalk that connects the stigma to the ovary.
     - ✓ **Ovary** – basal part containing ovules, which develop into seeds after fertilization.



Flower structure

Experiment 29

Kipute stared at the bright flower labeled **Specimen H** resting on her tray. Its colourful petals looked as if they belonged more in a wedding bouquet than in a laboratory. She grinned and whispered to herself, *"Poor flower, today you're not here to look pretty—you're here to spill your secrets."*

Her job was clear: strip away the beauty of the petals and expose the hidden machinery that makes plant reproduction possible. She knew that behind the perfume, nectar, and flashy colors, flowers are serious workers—busy ensuring the survival of their species.

With scalpel in hand, she leaned closer, ready to take apart nature's delicate design and reveal how it all worked.

As Kipute's friend and lab partner, cooperate with her to carry out the following:

(a) Observe the specimen carefully, then answer:

(i) What function do the structures constituting the female and male parts play in the specimen?
(ii) How does the specimen attract insects for pollination?
(iii)How does fertilization take place in the specimen?

(b) Using a scalpel, help Kipute remove all petals and sepals from the specimen. Then answer the following questions:
(i) Draw a neat, well-labeled diagram of the remaining part of the specimen.
(ii) Which part of the specimen receives the male gametes during pollination?
(iii)How are the parts responsible for transferring male gametes adapted to their function?

(c) Why do most crop plants depend on insect pollination, and what would happen to food supply if pollinators declined drastically?

(d) Why is the ovary located at the base of the flower?

(e) How does this experiment explain the importance of biodiversity conservation?

Response to Questions

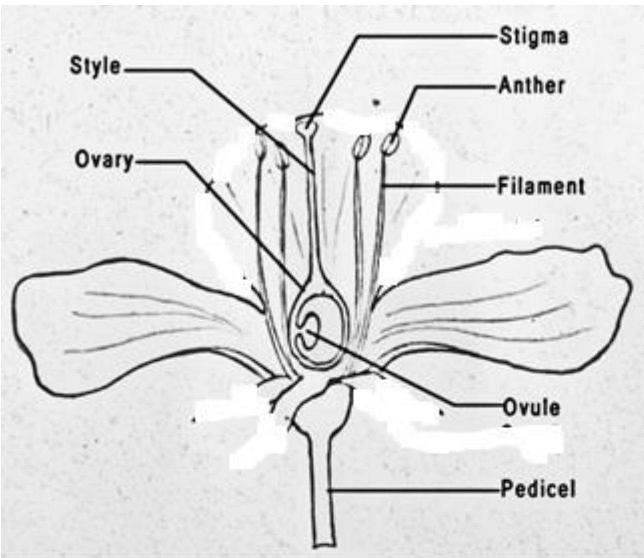
(a)

(i) **Female parts (carpel/pistil):** Stigma, style, and ovary — receive pollen and house ovules for fertilization.
Male parts (stamen): Anther and filament — produce and release pollen grains.

(ii) The specimen attracts insects through **brightly colored petals, nectar production, and scent emission.**

(iii) Fertilization occurs when pollen grains land on the stigma, germinate, and grow a pollen tube down the style into the ovary, where sperm cells fertilize the ovules to form a zygote.

(b) (i)



(ii) The stigma receives the male gametes during pollination.

(iii)**Adaptations:**

1) The style is long and hollow, allowing the pollen tube to grow through it.

2) The stigma is sticky or feathery to capture pollen effectively.

(c)

- Insect-pollinated flowers produce fruits and seeds that are essential for food.
- A decline in pollinators would reduce yields, threatening food security.

(d) So that it protects ovules deep inside the flower, reducing damage from external factors and ensuring successful fertilization.

(e) The flower depends on insects for pollination. Protecting ecosystems ensures pollinators survive, safeguarding plant reproduction and food chains.

DIFFUSION

Diffusion is the natural movement of molecules from a region of high concentration to one of low concentration until they are evenly spread out. It is a passive process, requiring no energy, and is vital for many biological functions. The rate of diffusion is influenced by factors such as temperature, concentration gradient, and surface area. For example, higher temperatures or steeper gradients speed up diffusion, while larger surface areas provide more space for molecules to spread.

In living organisms, diffusion is essential for processes such as gaseous exchange in lungs, gills, and leaves; absorption of nutrients in the small intestine; and removal of metabolic wastes like carbon dioxide. Practical experiments using substances such as potassium permanganate in water demonstrate how diffusion occurs and allow learners to analyze the impact of conditions such as temperature. By studying diffusion, learners gain insight into how simple physical processes sustain life and why diffusion alone is insufficient in larger animals, which require specialized transport systems.

Experiment 30

Kipute found Mr. Akilikubwa staring at a jar of potassium permanganate crystals. The dark purple crystals looked harmless, but she knew he was up to something.

"Today," he said dramatically, *"we are going to prove that even without legs, molecules can travel."*

Kipute laughed, *"So… invisible marathon runners?"*

"Exactly!" Mr. Akilikubwa replied, placing a beaker of clean water on the bench. *"Now let's work together to see how these tiny particles spread themselves out until everything is balanced. That, my friends, is diffusion in action."*

Task

As Kipute's lab partner, cooperate with her to carry out the following:

1. Fill a beaker with about 200 mL of clean water.
2. Gently drop a few crystals of potassium permanganate (or copper sulfate) into the water without stirring.
3. Observe the beaker carefully at intervals of 1, 5, and 15 minutes.
4. Record the changes in color distribution of the solution.

Questions

(a) State the changes observed in the beaker over time.
(b) Explain why the colour spread without stirring.
(c) Suggest how the rate of diffusion would change if the water was warm instead of cold.
(d) Why is it important not to stir the water during this experiment?
(e) Kipute jokingly referred to molecules as *"invisible marathon runners"* during the diffusion experiment. Explain how the movement of molecules in diffusion justifies Kipute's statement.
(f) State three ways in which diffusion is important in living organisms.
(g) Why is diffusion not sufficient as the main transport method in large animals?

Response to Questions

(a) Observations:

- At the beginning: colour concentrated at the bottom around the crystals.
- After 5 minutes: colour spreads slowly upward.
- After 15 minutes: the entire beaker becomes uniformly coloured.

(b) The molecules of potassium permanganate move from the region of high concentration (crystals) to regions of low concentration (water) until evenly distributed.
(c) Increase in temperature through warming increases kinetic energy of molecules, so diffusion occurs faster.
(d) This is to ensure the spreading is due to **natural diffusion only**, not mechanical mixing.
(e) Molecules move continuously and randomly, spreading from areas of high concentration to low concentration, much like marathon runners moving until they are evenly dispersed.
(f) Importance of diffusion in living organisms:

1. Gaseous exchange (oxygen and carbon dioxide in lungs, gills, and leaves).
2. Absorption of nutrients in the small intestine.
3. Removal of metabolic waste products (like CO_2 from tissues).

(g) Because it is too slow over long distances, so organisms need circulatory systems to transport substances efficiently.

OSMOSIS

Osmosis is a special type of diffusion involving the movement of water molecules across a semipermeable membrane, from a region of higher water potential (dilute solution) to a region of lower water potential (concentrated solution). Like diffusion, it is a passive process, but it specifically requires a membrane that controls what passes through. The rate and direction of osmosis are influenced by solute concentration (solute potential), membrane integrity, and temperature.

Osmosis is crucial in biological systems: it enables root hairs to absorb water from the soil, maintains turgor pressure in plants, regulates water balance in animal cells, and supports vital processes such as kidney reabsorption. Experiments with Irish potatoes or dialysis tubing demonstrate osmosis clearly and help learners analyze the role of controls, the effect of boiling (membrane destruction), and the importance of solute potential. By linking osmosis to diffusion, students appreciate that while diffusion moves many types of molecules, osmosis focuses specifically on water — making it one of the most important life-supporting processes in both plants and animals.

Experiment 31

It was one of those days when Mr. Akilikubwa wanted to "spice up" biology class. He placed a pile of Irish potatoes on the lab bench and winked at Kipute.

"Today," he announced, *"we shall make the potatoes work harder than they ever have in their lives!"*

Kipute burst into laughter, whispering to her deskmate, *"Poor potatoes… they thought they were for lunch, not science!"*

With the water trough ready, a scalpel shining under the fluorescent light, and sample M in hand, Kipute and her friend leaned in. Mr. Akilikubwa raised his eyebrows dramatically and said:

"Now, let's see if you can prove that life's tiniest workers—water molecules—know how to move without being told."

And with that, the task began…

Task

As Kipute's lab partner, cooperate with her to carry out the following procedures:

1. Cut each Irish potato into two equal halves using a knife or scalpel.
2. Label the two halves of the **unboiled potato** as **A** and **B**, and one half of the **boiled potato** as **C**.
3. Use a scooper to make holes ~2.5 cm deep in A, B, and C, ensuring walls are thin (5–8 mm) to act as semipermeable membranes.
4. Put 3 g of sample M in holes of B and C; leave hole A empty.
5. Place all three potato halves in a trough.
6. Add water until the potatoes are half immersed. Record the initial water levels.
7. Leave for 30 minutes, then observe carefully and record changes.

Questions

(a) State the changes observed after 30 minutes of the experiment.
(b) Explain how the solute potential in holes A, B, and C acted to bring about the observed results.
(c) Explain the necessity of potato A for this experiment.
(d) Explain six ways in which the investigated process is important in nature.
(e) What would happen if potato B was left for several hours instead of 30 minutes?
(f) How does this experiment explain why farmers apply fertilizer sparingly?

(g) In hospitals, why are patients sometimes given saline instead of pure water through IV drips?

Response to Questions

(a) **Observations:**

- In **A (empty cavity):** No significant change; water level remains constant.
- In **B (unboiled + solute M):** Water rises in the cavity.
- In **C (boiled + solute M):** No change in water level.

(b) **Explanation (solute potential):**

- **A:** No solute present; solute potential is zero, so no osmosis occurs.
- **B:** Solute M reduces solute potential in the cavity. Water enters from surrounding tissue by osmosis through the semipermeable wall, raising water level.
- **C:** Though solute is present, **boiling destroyed membrane** permeability. Osmosis cannot occur, so water level remains unchanged.

(c) **Necessity of Potato A:**

Acts as a **control experiment** to confirm that water movement is due to osmosis caused by solute presence, not other factors.

(d) **Importance of osmosis in nature (six points):**

1. Absorption of water by root hairs in plants.
2. Transport of water between plant cells (turgidity maintenance).
3. Opening and closing of stomata for gas exchange.
4. Movement of water in xylem vessels.
5. Regulation of water balance in animal cells (e.g., red blood cells).
6. Reabsorption of water in kidneys to maintain body fluid balance.

(e) Water would continue to rise until equilibrium is reached, after which no further net movement occurs.
(f) Excess fertilizer lowers soil water potential, causing water to move out of plant roots by osmosis, leading to wilting.
(g) Pure water would cause red blood cells to swell and burst (hemolysis) by osmosis. Saline is isotonic, maintaining balance.

GROWTH AND DEVELOPMENT

Growth and development are key processes that explain how organisms increase in size and undergo changes in form and function throughout their life cycles. Growth refers to an irreversible increase in size, usually measured by mass, volume, or length, while development involves the progressive changes that lead to maturity, reproduction, and specialization of structures.

Factors influencing growth and development include genetic makeup, nutrition, hormones, and environmental conditions such as light and temperature. For example, cell division (mitosis) underlies growth in both plants and animals, while hormones coordinate events like metamorphosis in insects or puberty in humans.

The significance of these processes is observed in practical work such as studying seed germination, insect metamorphosis, or dissection of animals to examine organ systems. Such experiments help learners analyze how internal and external factors regulate growth, and why understanding these processes is essential in fields like agriculture (crop improvement, animal husbandry), medicine (tissue repair, child health), and conservation biology.

Experiment 32

Mr. Akilikubwa entered the lab carrying two jars, each with a different insect specimen, **N** and **W**. One was restless, hopping around impatiently, while the other looked delicate, flapping its patterned wings as though posing for attention.

Kipute, seated at her bench, nudged her deskmate and whispered, *"They couldn't be more different, could they? I bet one is the troublemaker and the other is the show-off."*

Mr. Akilikubwa chuckled, replying, *"Exactly! Today, your challenge is to uncover how these two specimens grow and transform. Watch closely—nature has given them very different life stories, and both are fascinating."*

He placed the jars carefully on the desk and concluded:

"Work together, observe carefully, and then answer the questions. You'll soon discover why these insects remind us that there is more than one way to grow up."

As Kipute's lab partner, cooperate with her to answer the following questions:

Questions

(a) State the type of metamorphosis undergone by each of the specimens N and W.
(b) Describe the developmental stages in the life cycles of the specimens N and W with the aid of diagrams.
(c) State the advantage and disadvantage of specimen N in the ecosystem.
(d) Why is it important for farmers to understand the life cycles of insect specimens like N and W?
(e) In ecosystems, how does the transformation of Specimen W help maintain balance in food chains?
(f) Why might Specimen N be more likely to damage crops over a longer time compared to Specimen W?
(g) If pollinators such as Specimen W decline drastically, what would be the consequence on food supply?

Response to Questions

(a) Type of metamorphosis

Specimen N (Grasshopper): Incomplete metamorphosis (hemimetabolous).

Specimen W (Butterfly): Complete metamorphosis (holometabolous).

(b) Developmental stages

Specimen N (Grasshopper – Incomplete Metamorphosis)

Stage 1: Egg

Laid in soil or on vegetation.

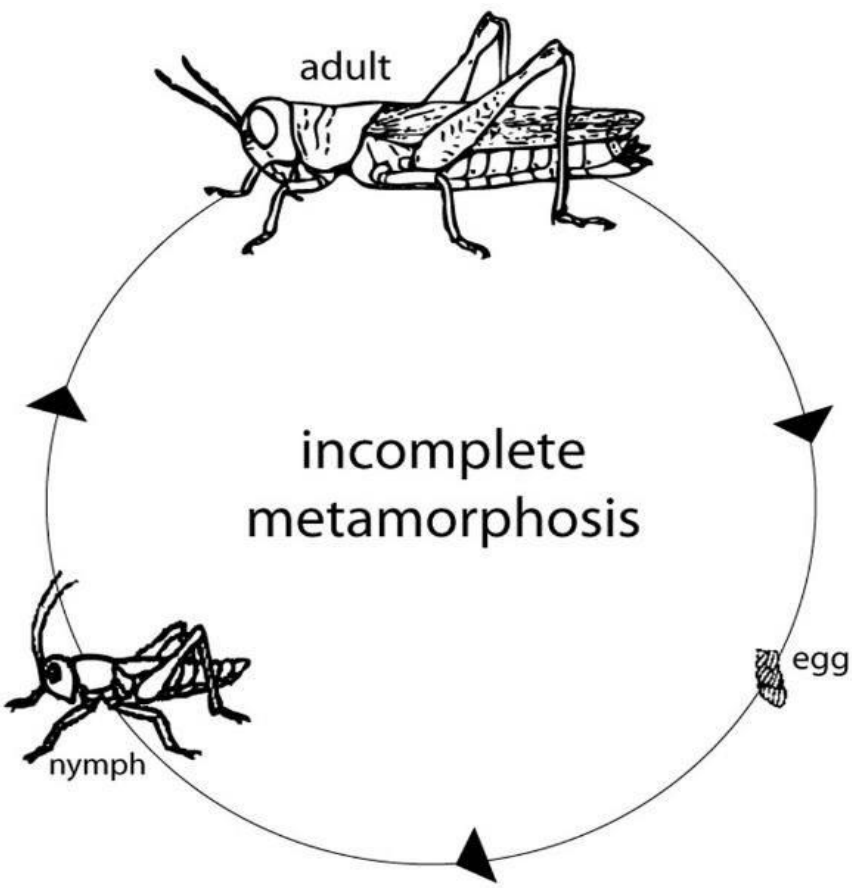
Stage 2: Nymph

- Resembles a small adult but lacks wings and reproductive organs.
- Feeds on the same food as adults.
- Undergoes several moults (shedding the exoskeleton).

Stage 3: Adult

- Fully developed with wings and reproductive organs.
- Capable of reproduction.

Growth is gradual; no pupal stage exists.



Life cycle of grasshopper

Specimen W (Butterfly – Complete Metamorphosis)

Stage 1: Egg

Laid on leaves or plant surfaces.

Stage 2: Larva (Caterpillar)

- Active feeding stage; eats leaves voraciously.
- Increases rapidly in size through several moults.

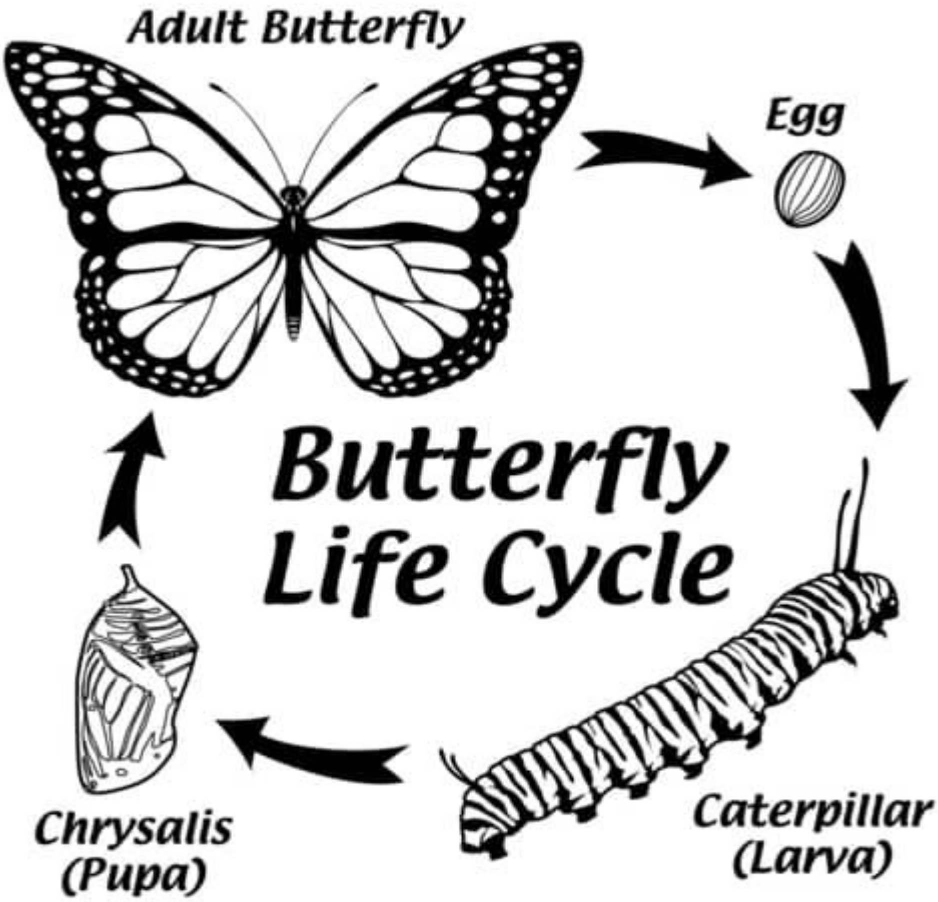
Stage 3: Pupa (Chrysalis)

- Resting stage; body tissues reorganized completely.
- Major transformation occurs here.

Stage 4: Adult

- Emerges with wings and reproductive capacity.
- Feeds mainly on nectar, unlike the larva.

Growth involves a dramatic transformation; both body form and feeding habits change.



Life cycle of butterfly

(c) **Advantage and disadvantage of Specimen N in the ecosystem**

Advantage: Primary consumer in the food chain; provides food for birds, reptiles, and other predators.

Disadvantage: In large populations, becomes a destructive agricultural pest, reducing crop yields.

(d) Knowing the stages helps farmers target control measures effectively; for example, applying pesticides when the insects are most vulnerable (nymph/larval stages) rather than when they are fully mature.
(e) Since the immature stage (larva) consumes plant material and the adult consumes nectar, they support multiple trophic levels without exhausting a single food source.
(f) Because both its immature and adult stages feed on the same crops, causing continuous damage.
(g) Reduced pollination would mean fewer fruits and seeds, leading to decreased crop yields and hence poor food supply.