La-Net

BIO 101

GENERAL BIOLOGY I

Course video is available on our app

lanetonline.com

Course code: BIO 101

Course title: General Biology I

Course credit load: 2 Units

Series 1: Cell Structure and Organization

- **Part 1.1: The Cell as the Unit of Life**
    - Sub Part 1.1.1: Cell theory and discovery
    - Sub Part 1.1.2: Levels of biological organisation
    - Sub Part 1.1.3: Cell size and shape
- **Part 1.2: Prokaryotic and Eukaryotic Cells**
    - Sub Part 1.2.1: Prokaryotic cell structure
    - Sub Part 1.2.2: Eukaryotic cell structure
    - Sub Part 1.2.3: Comparing prokaryotic and eukaryotic cells
- **Part 1.3: Plant and Animal Cell Differences**
    - Sub Part 1.3.1: Distinctive plant cell features
    - Sub Part 1.3.2: Distinctive animal cell features
    - Sub Part 1.3.3: Shared cellular features
- **Part 1.4: The Cell Membrane and Transport**
    - Sub Part 1.4.1: Membrane structure
    - Sub Part 1.4.2: Passive transport mechanisms
    - Sub Part 1.4.3: Active transport mechanisms

Introduction

All living things are built from cells, the smallest units capable of carrying out the basic processes of life. Understanding cell structure provides the foundation for nearly every other topic in biology, from how organisms grow and reproduce to how they obtain energy and respond to their environment.

This opening Series introduces the cell as the basic unit of life and the levels of biological organisation; the structural differences between prokaryotic and eukaryotic cells; the distinguishing features of plant and animal cells; and the structure of the cell membrane together with the mechanisms by which substances cross it. This foundation supports the organelle function, classification, and reproduction topics covered later in this course.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** explain cell theory and the levels of biological organisation (Linked to Part 1.1),
- **SLO 1.2** distinguish prokaryotic and eukaryotic cell structure (Linked to Part 1.2),
- **SLO 1.3** distinguish plant and animal cell features (Linked to Part 1.3), and
- **SLO 1.4** describe the cell membrane structure and transport mechanisms (Linked to Part 1.4).

1.1 The Cell as the Unit of Life

1.1.1 Cell theory and discovery

The cell theory states that all living organisms are composed of one or more cells, the cell is the basic structural and functional unit of life, and new cells arise from the division of existing cells; this theory, developed gradually through the work of several scientists using improving microscope technology, remains a foundational, unifying principle across all of biology.

Robert Hooke first observed and named cells in cork tissue in 1665, while later microscopists, including Anton van Leeuwenhoek, observed living cells directly; the formal cell theory was articulated more fully in the nineteenth century, establishing that the cell, rather than any larger or smaller unit, is the fundamental building block shared by every living organism, from single-celled bacteria to large multicellular plants and animals.

Fill in the blank: The cell theory states that all living organisms are composed of cells, the cell is the basic structural and functional unit of life, and new cells arise from the division of ________ cells.

1.1.2 Levels of biological organisation

Living systems are organised hierarchically: atoms combine into molecules, molecules combine into organelles (specialised structures within a cell), organelles combine into cells, and, in multicellular organisms, cells combine into tissues (groups of similar cells performing a shared function), tissues into organs, organs into organ systems, and organ systems into a complete organism.

Beyond the individual organism, biological organisation extends further: populations (groups of the same species in a given area), communities (multiple species populations interacting in an area), ecosystems, and ultimately the biosphere represent successively broader levels, with each level displaying properties (emergent properties) not present at the level below it, a concept relevant throughout this course.

Fill in the blank: Each level of biological organisation displays ________ properties not present at the level below it, such as a tissue function not predictable from any single cell alone.

1.1.3 Cell size and shape

Most cells are microscopic, generally ranging from about 1 to 100 micrometres in diameter, far too small to see with the unaided eye; this small size is not incidental but functionally important, since it keeps the ratio of cell surface area to cell volume relatively high, supporting efficient exchange of nutrients, gases, and waste products across the cell membrane.

Cell shape varies considerably and often relates closely to cell function: red blood cells are flattened discs supporting efficient gas exchange, nerve cells have long, thin extensions supporting signal transmission over distance, and many plant cells are roughly rectangular, reflecting the supportive role of the surrounding rigid cell wall; this form-function relationship recurs throughout the study of cell biology.

Fill in the blank: Small cell size keeps the ratio of cell surface area to cell ________ relatively high, supporting efficient exchange of nutrients, gases, and waste.

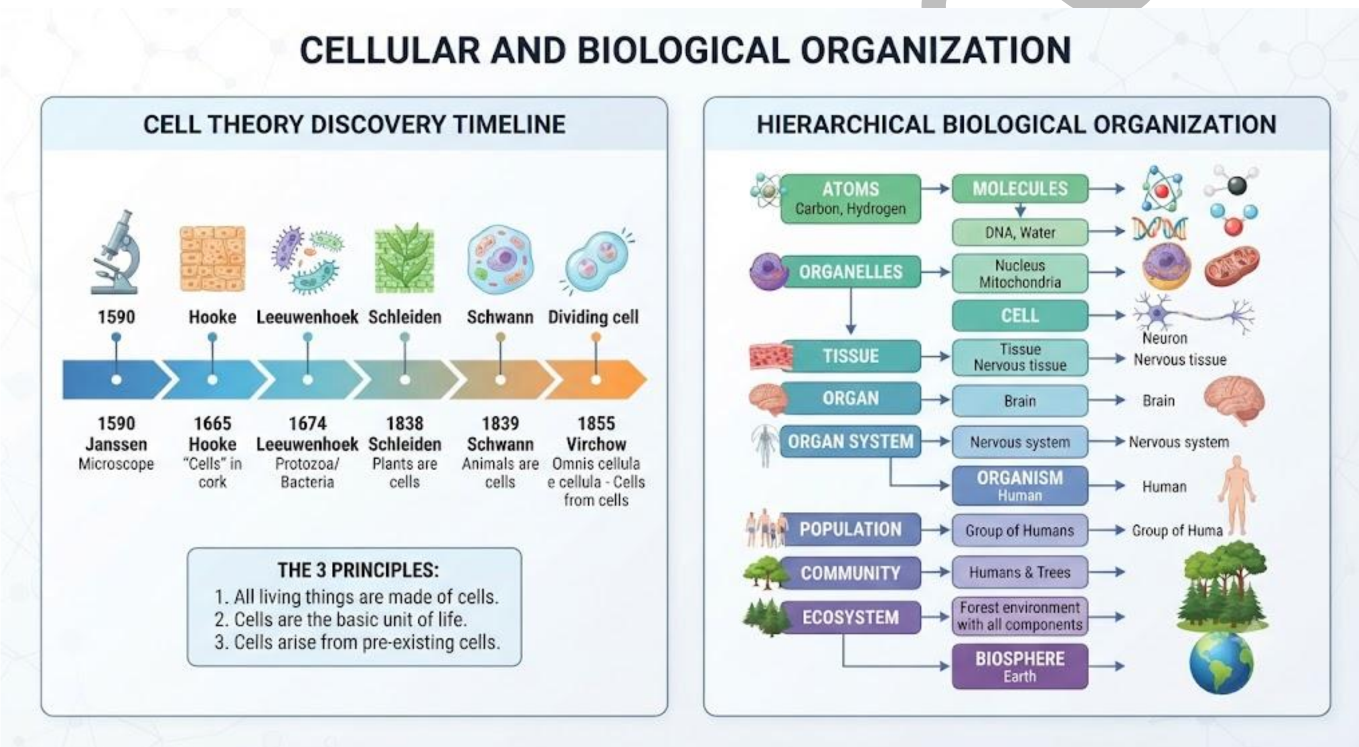

Figure 1.1: Cell theory and biological organisation

Pilot questions 1.1

1. State the three components of cell theory.
2. Name the scientist who first observed and named cells.
3. List the levels of biological organisation from atom to organism.
4. Define emergent property.
5. Explain why small cell size supports efficient exchange of materials.

1.2 Prokaryotic and Eukaryotic Cells

1.2.1 Prokaryotic cell structure

Prokaryotic cells (found in bacteria and archaea) lack a membrane-bound nucleus and most membrane-bound organelles, instead containing their genetic material as a single, circular DNA molecule located in a region called the nucleoid, along with ribosomes (the cellular structures responsible for protein synthesis) suspended directly in the cytoplasm.

Prokaryotic cells are generally smaller and structurally simpler than eukaryotic cells, typically enclosed by both a cell membrane and, in most bacteria, a rigid cell wall providing structural support and protection; despite this structural simplicity, prokaryotic cells carry out the essential life processes of metabolism, growth, and reproduction successfully across an enormous diversity of environments.

Fill in the blank: Prokaryotic cells lack a membrane-bound nucleus, instead containing their genetic material in a region called the ________ .

1.2.2 Eukaryotic cell structure

Eukaryotic cells (found in plants, animals, fungi, and protists) contain a membrane-bound nucleus enclosing the genetic material, along with numerous other membrane-bound organelles (mitochondria, endoplasmic reticulum, Golgi apparatus, and others, examined individually in detail in this course) that compartmentalise different cellular functions within distinct internal spaces.

This internal compartmentalisation allows eukaryotic cells to carry out multiple specialised chemical processes simultaneously within separate organelles without these processes interfering with one another, supporting the greater structural and functional complexity generally associated with eukaryotic cells compared to prokaryotic cells, and underlying the capacity of eukaryotic cells to form the complex multicellular organisms (plants, animals, fungi) that make up much of visible life.

Fill in the blank: Eukaryotic cells contain a membrane-bound ________ enclosing the genetic material, distinguishing them from prokaryotic cells.

1.2.3 Comparing prokaryotic and eukaryotic cells

Prokaryotic cells are generally smaller (typically 1 to 10 micrometres) than eukaryotic cells (typically 10 to 100 micrometres), reflect simpler internal organisation lacking membrane-bound organelles, and possess a single circular DNA molecule, while eukaryotic cells are larger, internally compartmentalised by membrane-bound organelles, and possess DNA organised into multiple linear chromosomes contained within the nucleus.

Despite these substantial structural differences, both cell types share certain fundamental features: a surrounding cell membrane regulating what enters and exits the cell, cytoplasm (the gel-like internal cell contents), ribosomes for protein synthesis, and DNA carrying hereditary information, underscoring that the cell theory basic principles apply across both major cell types despite their considerable structural divergence.

Fill in the blank: Both prokaryotic and eukaryotic cells share certain fundamental features, including a cell membrane, cytoplasm, ribosomes, and ________ carrying hereditary information.

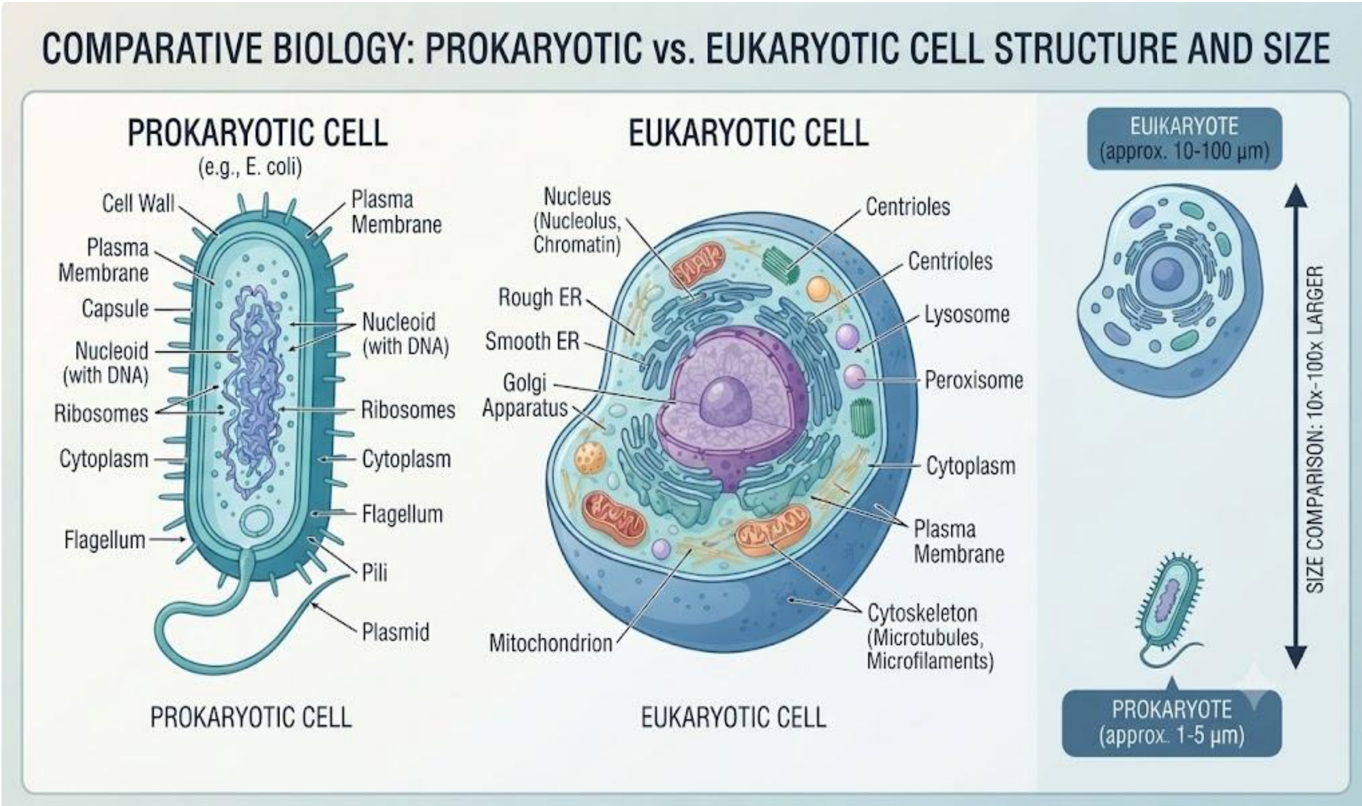

Figure 1.2: Prokaryotic and eukaryotic cell structure

Pilot questions 1.2

1. Define prokaryotic cell and name two organism groups that have this cell type.
2. Define eukaryotic cell and name two organism groups that have this cell type.
3. Explain the function of membrane-bound organelles in eukaryotic cells.
4. Compare the typical size range of prokaryotic and eukaryotic cells.
5. Name three features shared by both prokaryotic and eukaryotic cells.

1.3 Plant and Animal Cell Differences

1.3.1 Distinctive plant cell features

Plant cells possess a rigid cell wall (composed primarily of cellulose) surrounding the cell membrane, providing structural support and shape, alongside chloroplasts (organelles containing chlorophyll, capturing light energy to drive photosynthesis) and a large central vacuole (a fluid-filled sac occupying much of the mature plant cell interior, important for storage and maintaining internal pressure against the cell wall).

These features collectively support the plant characteristic stationary, photosynthetic lifestyle: the cell wall provides support without requiring a skeletal system, chloroplasts enable plants to manufacture their own food from sunlight, and the large vacuole helps maintain cell rigidity (turgor pressure) that keeps non-woody plant structures upright.

Fill in the blank: Plant cells possess a rigid cell wall composed primarily of ________ , providing structural support and shape.

1.3.2 Distinctive animal cell features

Animal cells lack a cell wall, chloroplasts, and a large central vacuole, instead being bounded only by a flexible cell membrane that allows greater shape variability and, in many cell types, the capacity for movement (such as white blood cells moving through tissue, or the contraction of muscle cells), reflecting the animal characteristic mobile, food-consuming (rather than self-manufacturing) lifestyle.

Animal cells often contain centrioles (structures involved in organising cell division, discussed further when reproduction is examined later in this course) more prominently than typical plant cells, and may contain small vacuoles when present, quite different from the single large central vacuole characteristic of mature plant cells; these differences in vacuole size and number again reflect the differing storage and structural needs of plant versus animal life.

Fill in the blank: Animal cells lack a cell wall, instead being bounded only by a flexible cell membrane that allows greater shape variability and, in many cell types, the capacity for ________ .

1.3.3 Shared cellular features

Despite their differences, plant and animal cells share the fundamental eukaryotic features already introduced: a membrane-bound nucleus, mitochondria (organelles generating usable cellular energy), endoplasmic reticulum, Golgi apparatus, ribosomes, and a cell membrane, reflecting their shared eukaryotic ancestry and shared basic cellular requirements regardless of the very different overall lifestyles plants and animals have evolved.

Recognising both the differences (cell wall, chloroplasts, and large central vacuole in plant cells; centrioles and shape flexibility in animal cells) and the shared features (nucleus, mitochondria, and other common organelles) between plant and animal cells supports accurate cell identification under the microscope, a practical skill directly relevant to laboratory study of biology.

Fill in the blank: Plant and animal cells share fundamental eukaryotic features including a membrane-bound nucleus, ________ , endoplasmic reticulum, Golgi apparatus, and ribosomes.

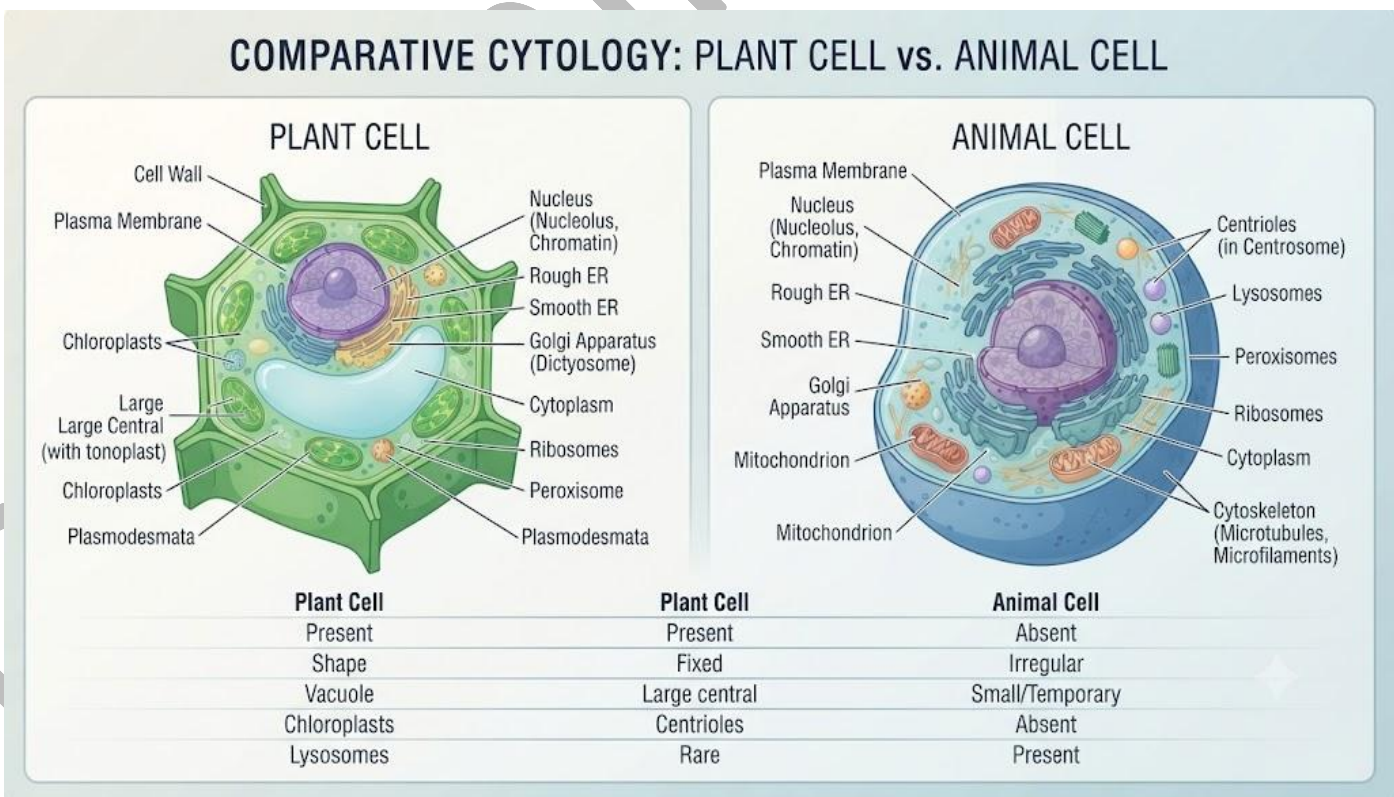

Figure 1.3: Plant and animal cell comparison

Pilot questions 1.3

1. Name three structures found in plant cells but not typical animal cells.
2. Explain the function of the plant cell wall.
3. Explain the function of chloroplasts.
4. Name a structure more prominent in animal cells than typical plant cells.
5. Name three organelles shared by both plant and animal cells.

1.4 The Cell Membrane and Transport

1.4.1 Membrane structure

The cell membrane is composed primarily of a phospholipid bilayer (two layers of phospholipid molecules arranged with their water-attracting heads facing outward and their water-repelling tails facing inward), embedded with various proteins that serve transport, signalling, and structural functions, an arrangement often described as the fluid mosaic model given the membrane flexible, mosaic-like arrangement of components.

The cell membrane is selectively permeable, meaning it allows some substances to cross relatively freely while restricting or actively regulating the passage of others, a property essential for maintaining a cell stable internal environment distinct from its external surroundings, and the basis for the various transport mechanisms examined in the remainder of this Part.

Fill in the blank: The cell membrane is composed primarily of a phospholipid ________ embedded with various proteins, an arrangement described by the fluid mosaic model.

1.4.2 Passive transport mechanisms

Diffusion (the net movement of particles from a region of higher concentration to a region of lower concentration, driven by random particle motion, requiring no cellular energy expenditure) and osmosis (the diffusion of water specifically, across a selectively permeable membrane, from a region of higher water concentration to lower water concentration) are passive transport mechanisms occurring spontaneously down a concentration gradient.

Facilitated diffusion (movement of specific substances, such as glucose, across the membrane with the assistance of specific transport proteins, still moving down a concentration gradient and still requiring no direct cellular energy) extends simple diffusion to substances that cannot easily cross the phospholipid bilayer unaided, illustrating that passive transport, while not requiring energy input, can still depend on specific membrane protein assistance for certain substances.

Fill in the blank: ________ is the diffusion of water specifically across a selectively permeable membrane, from higher to lower water concentration.

1.4.3 Active transport mechanisms

Active transport (movement of substances across the membrane against their concentration gradient, from lower to higher concentration, requiring cellular energy, typically supplied by ATP) allows cells to accumulate substances at concentrations different from their surroundings when needed for cellular function, a capability not available through passive transport mechanisms alone.

Endocytosis (the cell membrane engulfing material from outside the cell, forming an internal vesicle, used for taking in larger particles or fluid) and exocytosis (the reverse process, a vesicle fusing with the cell membrane to release its contents outside the cell) represent additional active, energy-requiring transport processes handling larger material than individual molecules can typically cross through transport proteins alone.

Fill in the blank: Active transport moves substances against their concentration gradient and requires cellular energy, typically supplied by ________ .

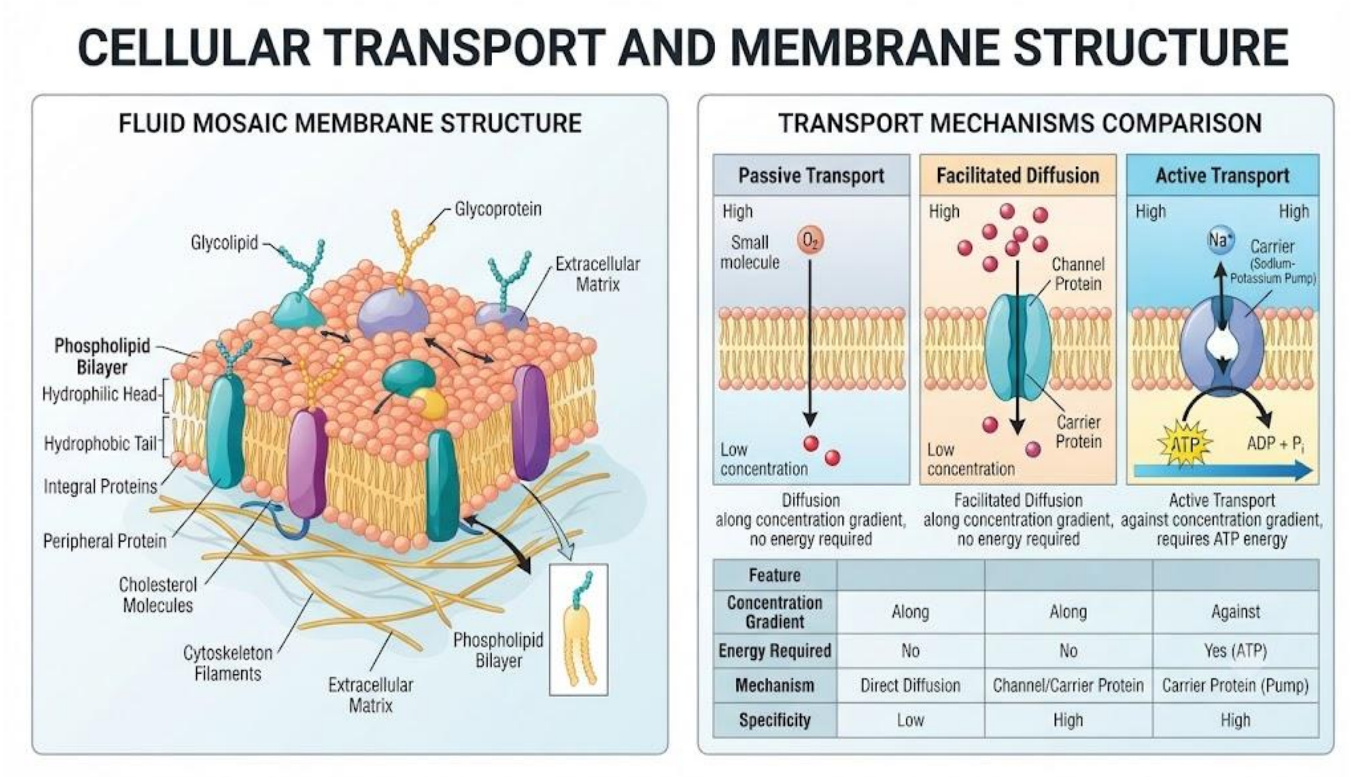

Figure 1.4: Cell membrane structure and transport

Pilot questions 1.4

1. Describe the fluid mosaic model of the cell membrane.
2. Define diffusion.
3. Define osmosis.
4. Distinguish between passive and active transport in terms of energy requirement and direction of movement.
5. Define endocytosis and exocytosis.

Series Summary

This Series introduced **the cell as the basic structural and functional unit of life**, based on **cell theory**, which states that all living organisms are composed of cells, the cell is the basic unit of life, and all cells arise from pre-existing cells. It also covered the **levels of biological organisation**, from atoms to the biosphere, and explained how **cell size and shape** are adapted to function through the **surface area-to-volume ratio**. The Series distinguished **prokaryotic cells**, which lack a true nucleus and membrane-bound organelles, from **eukaryotic cells**, which possess both. Despite these differences, both cell types contain a **cell membrane, cytoplasm, ribosomes, and DNA**.

The Series also examined **plant and animal cells** and **cell membrane transport**. Plant cells possess a **cell wall, chloroplasts, and a large central vacuole**, whereas animal cells have a **flexible plasma membrane and prominent centrioles**. Both share essential organelles such as the **nucleus, mitochondria, endoplasmic reticulum, Golgi apparatus, and ribosomes**. The **cell membrane** was explained using the **fluid mosaic model**, with transport occurring through **passive mechanisms** (diffusion, osmosis, and facilitated diffusion) and **active mechanisms**, including energy-dependent transport against concentration gradients as well as **endocytosis and exocytosis**. By completing this Series, students should achieve SLOs **1.1–1.4**.

Glossary of Terms

- **Active transport:** movement of substances across a membrane against their concentration gradient, requiring cellular energy.
- **Cell theory:** the principle that all organisms are composed of cells, the cell is the basic unit of life, and new cells arise from existing cells.
- **Diffusion:** the net movement of particles from higher to lower concentration, requiring no cellular energy.
- **Eukaryotic cell:** a cell containing a membrane-bound nucleus and membrane-bound organelles.
- **Osmosis:** the diffusion of water across a selectively permeable membrane.

- **Prokaryotic cell:** a cell lacking a membrane-bound nucleus, with genetic material in a region called the nucleoid.
- **Selectively permeable:** allowing some substances to cross a membrane freely while restricting others.

Concept Check Questions [Series 1]

Objective Questions

1. New cells arise from the division of ________ cells, according to cell theory. (Linked to SLO 1.1)
2. Prokaryotic cells contain their genetic material in a region called the ________ . (Linked to SLO 1.2)
3. Plant cells possess a rigid cell wall composed primarily of ________ . (Linked to SLO 1.3)
4. ________ is the diffusion of water across a selectively permeable membrane. (Linked to SLO 1.4)
5. Active transport requires cellular energy, typically supplied by ________ . (Linked to SLO 1.4)

Short-Answer Questions

6. State the three components of cell theory. (Linked to SLO 1.1)
7. Distinguish between prokaryotic and eukaryotic cells. (Linked to SLO 1.2)
8. Name three structures unique to plant cells. (Linked to SLO 1.3)
9. Define diffusion and osmosis. (Linked to SLO 1.4)
10. Name three organelles shared by plant and animal cells. (Linked to SLO 1.3)

Long-Answer Questions

11. Explain cell theory and the levels of biological organisation. (Linked to SLO 1.1)
12. Distinguish prokaryotic and eukaryotic cells, and plant and animal cells. (Linked to SLOs 1.2, 1.3)
13. Describe the cell membrane structure and passive and active transport mechanisms. (Linked to SLO 1.4)

Answers to Concept Check Questions [Series 1]

Objective Questions

1. Existing.
2. Nucleoid.
3. Cellulose.

4. Osmosis.
5. ATP.

Short-Answer Questions

6. Organisms are composed of cells; the cell is the basic unit of life; new cells arise from existing cells.
7. Prokaryotic cells lack a nucleus and membrane-bound organelles; eukaryotic cells possess both.
8. Cell wall, chloroplasts, and large central vacuole.
9. Diffusion is net movement from higher to lower concentration; osmosis is diffusion of water specifically.
10. Nucleus, mitochondria, and endoplasmic reticulum (or Golgi apparatus, ribosomes).

Long-Answer Questions

11. Cell theory holds that organisms are made of cells, the cell is the basic unit, and cells arise from existing cells. Organisation proceeds from atoms through molecules, organelles, cells, tissues, organs, and systems to the organism and beyond.
12. Prokaryotic cells lack a nucleus and membrane-bound organelles, unlike eukaryotic cells. Plant cells additionally have a cell wall, chloroplasts, and a large vacuole, while animal cells have a flexible membrane and prominent centrioles; both share nucleus and mitochondria.
13. The cell membrane is a fluid mosaic of phospholipids and proteins. Passive transport (diffusion, osmosis, facilitated diffusion) requires no energy and moves down a gradient; active transport requires energy and can move substances against a gradient, including via endocytosis and exocytosis.

Answers to Pilot Questions [Series 1]

Part 1.1

1. Organisms are composed of cells; the cell is the basic unit of life; new cells arise from existing cells.
2. Robert Hooke.
3. Atom, molecule, organelle, cell, tissue, organ, organ system, organism.
4. An emergent property is a property present at a given level of organisation but not at the level below it.

5. Small size keeps surface area to volume ratio high, supporting efficient exchange of materials.

Part 1.2

1. A prokaryotic cell lacks a membrane-bound nucleus; found in bacteria and archaea.
2. A eukaryotic cell has a membrane-bound nucleus; found in plants and animals.
3. Membrane-bound organelles compartmentalise different cellular processes within separate internal spaces.
4. Prokaryotic cells are typically 1 to 10 micrometres; eukaryotic cells are typically 10 to 100 micrometres.
5. Cell membrane, cytoplasm, and ribosomes (or DNA).

Part 1.3

1. Cell wall, chloroplasts, and large central vacuole.
2. The cell wall provides structural support and shape.
3. Chloroplasts capture light energy to drive photosynthesis.
4. Centrioles.
5. Nucleus, mitochondria, and endoplasmic reticulum (or Golgi apparatus, ribosomes).

Part 1.4

1. The fluid mosaic model describes the membrane as a flexible phospholipid bilayer embedded with proteins.
2. Diffusion is net movement of particles from higher to lower concentration.
3. Osmosis is the diffusion of water across a selectively permeable membrane.
4. Passive transport needs no energy and moves down a gradient; active transport needs energy and can move against a gradient.
5. Endocytosis is engulfing material into the cell; exocytosis is releasing material out of the cell via vesicle fusion.

References and Attributions

Textual References (Books and External Sources)

- Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2014). Molecular biology of the cell (6th ed.). Garland Science.
- Campbell, N. A., & Reece, J. B. (2018). Biology (11th ed.). Pearson.
- Raven, P. H., Johnson, G. B., Mason, K. A., Losos, J. B., & Singer, S. R. (2017). Biology (11th ed.). McGraw-Hill Education.
- National Open University of Nigeria (NOUN). (2023). General biology course material. NOUN Press.

Figures, Plates, Tables, and Boxes

- Figure 1.1: Cell theory and biological organisation Attribution: AI generated. Suggested OER search string: "cell theory discovery biological organisation hierarchy levels OER".
- Figure 1.2: Prokaryotic and eukaryotic cell structure Attribution: AI generated. Suggested OER search string: "prokaryotic eukaryotic cell structure comparison diagram biology OER".
- Figure 1.3: Plant and animal cell comparison Attribution: AI generated. Suggested OER search string: "plant cell animal cell comparison diagram structure biology OER".
- Figure 1.4: Cell membrane structure and transport Attribution: AI generated. Suggested OER search string: "cell membrane fluid mosaic diffusion osmosis active transport biology OER".

Course code: BIO 101

Course title: General Biology I

Course credit load: 2 Units

Series 2: Functions of Cellular Organelles

- **Part 2.1: The Nucleus and Genetic Material**
  - Sub Part 2.1.1: Nucleus structure and function
  - Sub Part 2.1.2: Chromosomes
  - Sub Part 2.1.3: Genes and their importance
- **Part 2.2: Energy-Related Organelles**
  - Sub Part 2.2.1: Mitochondria
  - Sub Part 2.2.2: Chloroplasts
  - Sub Part 2.2.3: Comparing mitochondria and chloroplasts
- **Part 2.3: Protein Synthesis and Processing Organelles**
  - Sub Part 2.3.1: Ribosomes
  - Sub Part 2.3.2: Endoplasmic reticulum
  - Sub Part 2.3.3: Golgi apparatus
- **Part 2.4: Storage, Digestion, and Support Organelles**
  - Sub Part 2.4.1: Lysosomes
  - Sub Part 2.4.2: Vacuoles
  - Sub Part 2.4.3: Cytoskeleton

Introduction

Each cellular organelle performs a specific function that contributes to the overall life of the cell, much as each organ in a multicellular organism performs a specific function contributing to the life of the whole body. This Series examines the structure and function of the major cellular organelles, beginning with the nucleus and its genetic content, then energy-producing organelles, protein synthesis and processing structures, and finally storage, digestion, and support structures.

This Series covers the nucleus, chromosomes, and genes; mitochondria and chloroplasts as energy-related organelles; ribosomes, endoplasmic reticulum, and Golgi apparatus as protein synthesis and processing organelles; and lysosomes, vacuoles, and the cytoskeleton as storage, digestion, and support structures. This organelle-level knowledge supports the classification and reproduction topics covered later in this course.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** describe the structure and function of the nucleus, chromosomes, and genes (Linked to Part 2.1),
- **SLO 2.2** explain the structure and function of mitochondria and chloroplasts (Linked to Part 2.2),
- **SLO 2.3** describe the structure and function of ribosomes, endoplasmic reticulum, and Golgi apparatus (Linked to Part 2.3), and
- **SLO 2.4** explain the structure and function of lysosomes, vacuoles, and the cytoskeleton (Linked to Part 2.4).

2.1 The Nucleus and Genetic Material

2.1.1 Nucleus structure and function

The nucleus is a large, membrane-bound organelle that houses the cell genetic material (DNA) and serves as the control centre coordinating cellular activities; it is surrounded by a double membrane called the nuclear envelope, perforated by nuclear pores that regulate the passage of molecules, such as RNA and proteins, between the nucleus and the surrounding cytoplasm.

Within the nucleus, a dense region called the nucleolus is responsible for assembling ribosomal components, which are then exported to the cytoplasm for final ribosome assembly; the nucleus also contains chromatin, a combination of DNA and associated proteins that condenses into visible chromosomes during cell division, discussed further in this Part.

Fill in the blank: The nucleus is surrounded by a double membrane called the nuclear ________ , perforated by pores regulating molecule passage to and from the cytoplasm.

2.1.2 Chromosomes

Chromosomes are tightly coiled, organised structures of DNA and protein, becoming visible under a microscope specifically when a cell is preparing to divide; each chromosome carries a linear sequence of genes, and the total number of chromosomes is characteristic of a given species, with most body cells of a given organism containing the same chromosome number.

Chromosomes typically occur in pairs in many organisms (a condition called diploid), with one member of each pair inherited from each parent, while reproductive cells (sperm and egg cells) contain only a single set of chromosomes (a condition called haploid), an arrangement essential for maintaining a constant chromosome number across generations during sexual reproduction.

Fill in the blank: Reproductive cells contain only a single set of chromosomes, a condition called ________ , essential for maintaining a constant chromosome number across generations.

2.1.3 Genes and their importance

A gene is a specific segment of DNA that carries the instructions for producing a particular protein or functional RNA molecule, representing the basic unit of hereditary information; the complete set of genes in an organism, together with non-coding DNA, makes up its genome, while the specific version of a gene an individual carries is called an allele.

Genes are important because they determine an organism inherited characteristics (traits), from observable physical features to less visible biochemical and physiological characteristics, by directing the production of specific proteins that carry out or regulate nearly every cellular process; understanding genes is therefore essential to understanding both individual development and the patterns of inheritance examined later in this course.

Fill in the blank: The specific version of a gene that an individual organism carries is called an ________ .

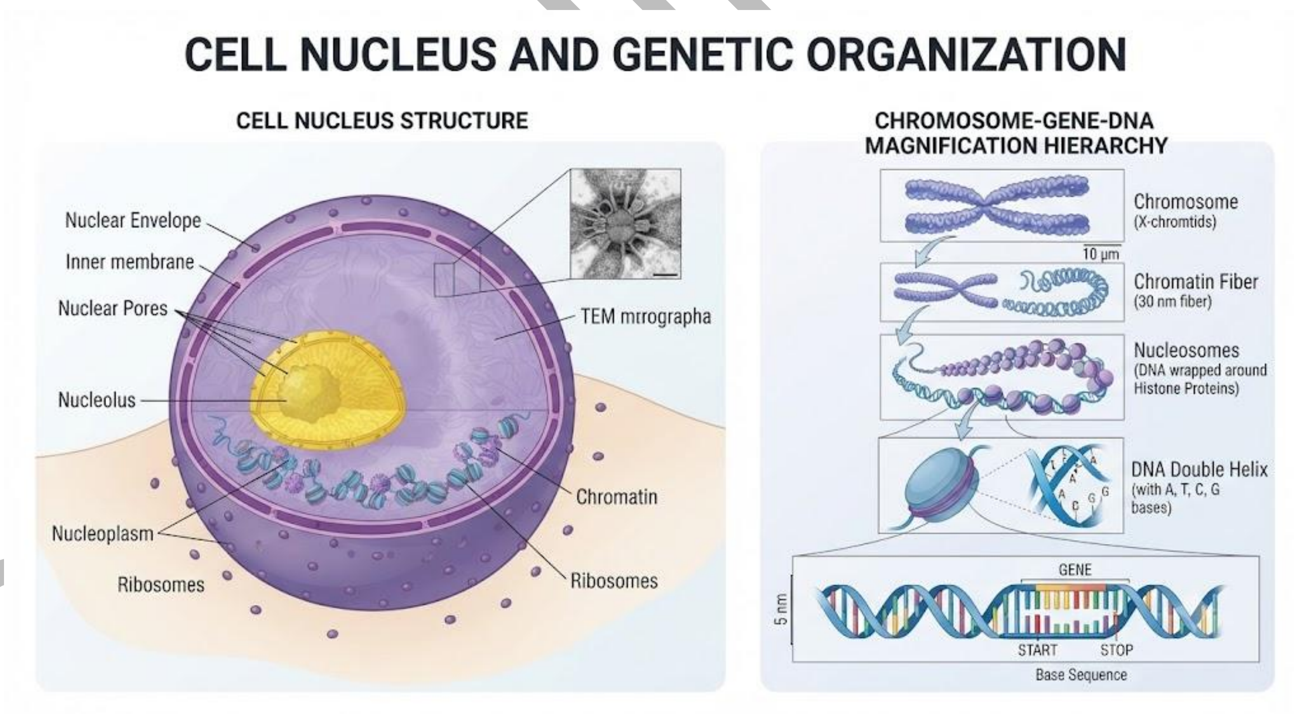

Figure 2.1: The nucleus, chromosomes, and genes

Pilot questions 2.1

1. Describe the structure of the nuclear envelope.
2. Define nucleolus and state its function.
3. Define chromosome.
4. Distinguish between diploid and haploid.
5. Define gene and explain why genes are important.

2.2 Energy-Related Organelles

2.2.1 Mitochondria

Mitochondria are membrane-bound organelles often called the powerhouse of the cell, responsible for cellular respiration, the process converting chemical energy from food molecules into adenosine triphosphate (ATP), the cell main usable energy currency; mitochondria possess a folded inner membrane (forming structures called cristae) that increases the surface area available for the chemical reactions of respiration.

Cells with particularly high energy demands, such as muscle cells, typically contain larger numbers of mitochondria than less energy-demanding cells, illustrating the close relationship between mitochondrial abundance and a cell specific energy requirements; mitochondria are present in nearly all eukaryotic cells, reflecting the universal cellular need for a continuous, efficient energy supply.

Fill in the blank: Mitochondria possess a folded inner membrane forming structures called ________ , increasing the surface area available for cellular respiration reactions.

2.2.2 Chloroplasts

Chloroplasts are membrane-bound organelles found in plant cells and some protists, responsible for photosynthesis, the process capturing light energy and converting it, along with carbon dioxide and water, into glucose and oxygen; chloroplasts contain chlorophyll, a green pigment that absorbs light energy, housed within internal membrane stacks called thylakoids.

The glucose produced through photosynthesis provides both an immediate energy source and the raw material for building other organic molecules the plant requires for growth, while the oxygen released as a by-product supports the cellular respiration (Part 2.2.1) of the plant itself and of the many other organisms that depend, directly or indirectly, on atmospheric oxygen.

Fill in the blank: Chloroplasts contain chlorophyll, a green pigment that absorbs light energy, housed within internal membrane stacks called ________ .

2.2.3 Comparing mitochondria and chloroplasts

Mitochondria and chloroplasts share several notable similarities: both possess a double membrane, both contain their own small amount of DNA separate from the nuclear DNA, and both are believed to have originated, according to a widely supported scientific theory, from free-living prokaryotic ancestors that were engulfed by an early eukaryotic cell and gradually became permanent, mutually beneficial residents within it.

Despite these similarities, the two organelles serve essentially opposite energy roles: mitochondria break down energy-rich molecules to release usable energy (respiration), while chloroplasts capture light energy to build energy-rich molecules (photosynthesis); most plant cells contain both organelles, since plants require respiration just as animals do, while only photosynthetic organisms additionally possess chloroplasts.

Fill in the blank: Mitochondria and chloroplasts are both believed to have originated from free-living ________ ancestors that became permanent residents within an early eukaryotic cell.

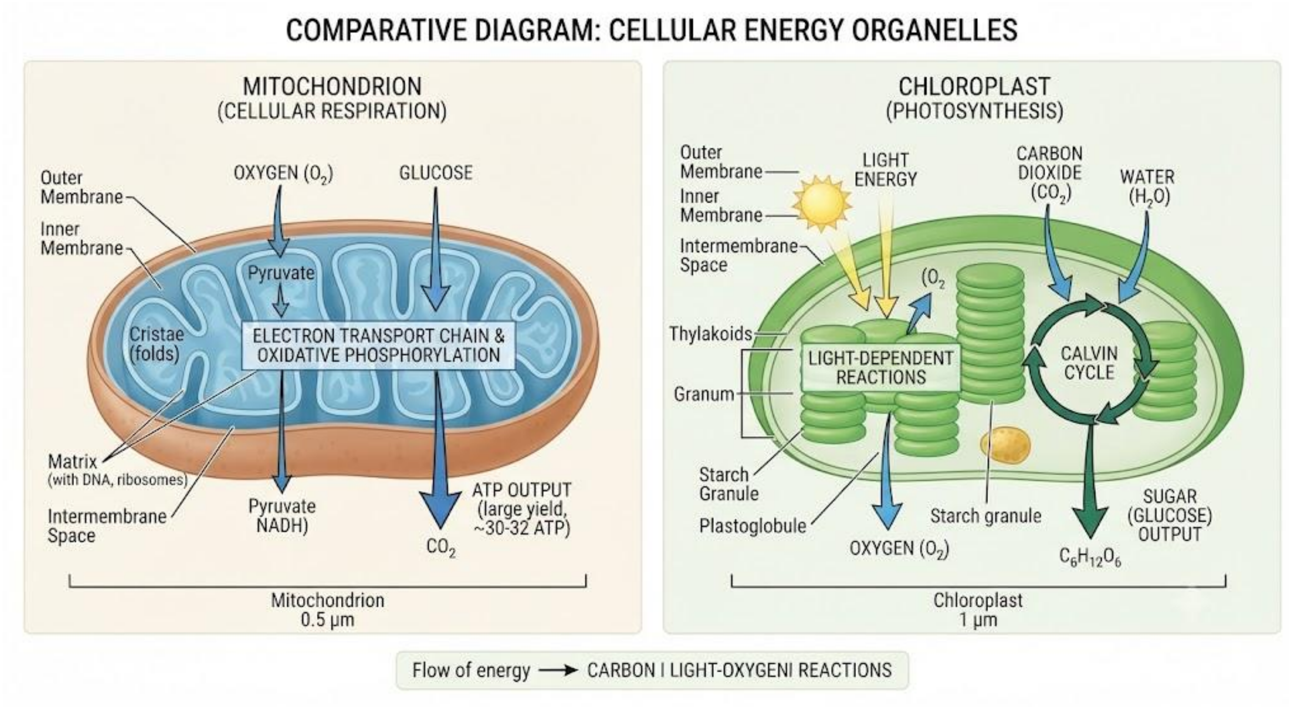

Figure 2.2: Mitochondria and chloroplast structure and function

Pilot questions 2.2

1. Define cellular respiration and state where it primarily occurs.
2. Describe the function of cristae in mitochondria.
3. Define photosynthesis.
4. Describe the function of thylakoids in chloroplasts.
5. Name two similarities between mitochondria and chloroplasts.

2.3 Protein Synthesis and Processing Organelles

2.3.1 Ribosomes

Ribosomes are small, dense structures, composed of ribosomal RNA and protein, responsible for protein synthesis (translation), the process of assembling amino acids into a specific protein according to instructions carried by messenger RNA; ribosomes occur either freely suspended in the cytoplasm (producing proteins used within the cytoplasm itself) or attached to the endoplasmic reticulum (producing proteins destined for secretion or for use within other organelles or the cell membrane).

Unlike most other organelles discussed in this Series, ribosomes are not surrounded by a membrane, and they are present in both prokaryotic and eukaryotic cells, underscoring protein synthesis as one of the most fundamental and universally shared processes across all forms of cellular life.

Fill in the blank: Ribosomes are responsible for protein synthesis, also called ________ , assembling amino acids into a specific protein according to messenger RNA instructions.

2.3.2 Endoplasmic reticulum

The endoplasmic reticulum (ER) is an extensive network of interconnected membranes within the cytoplasm, existing in two forms: rough ER, studded with ribosomes on its outer surface and responsible for processing and folding proteins destined for secretion or membrane insertion, and smooth ER, lacking ribosomes and responsible for lipid synthesis and, in some cell types, detoxification of harmful substances.

Proteins processed within the rough ER are packaged into small membrane-bound sacs called vesicles, which then transport these proteins to the Golgi apparatus for further processing, illustrating the endoplasmic reticulum role as an early, essential stage within the broader cellular protein processing and transport pathway examined throughout this Part.

Fill in the blank: Rough endoplasmic reticulum is studded with ________ on its outer surface, distinguishing it from smooth endoplasmic reticulum.

2.3.3 Golgi apparatus

The Golgi apparatus is a stack of flattened, membrane-bound sacs that receives proteins and lipids from the endoplasmic reticulum, modifies them further (such as by adding sugar molecules in a process called glycosylation), sorts them according to their final destination, and packages them into vesicles for transport to their destination within or outside the cell.

The Golgi apparatus is often compared to a postal sorting and packaging facility, receiving incoming material, processing and labelling it appropriately, and dispatching it to the correct destination, whether that destination is the cell membrane (for secretion or membrane incorporation), a lysosome (Part 2.4.1), or another organelle, completing the protein processing pathway that began at the ribosome and continued through the endoplasmic reticulum.

Fill in the blank: The Golgi apparatus modifies proteins received from the endoplasmic reticulum, sorts them, and packages them into ________ for transport to their final destination.

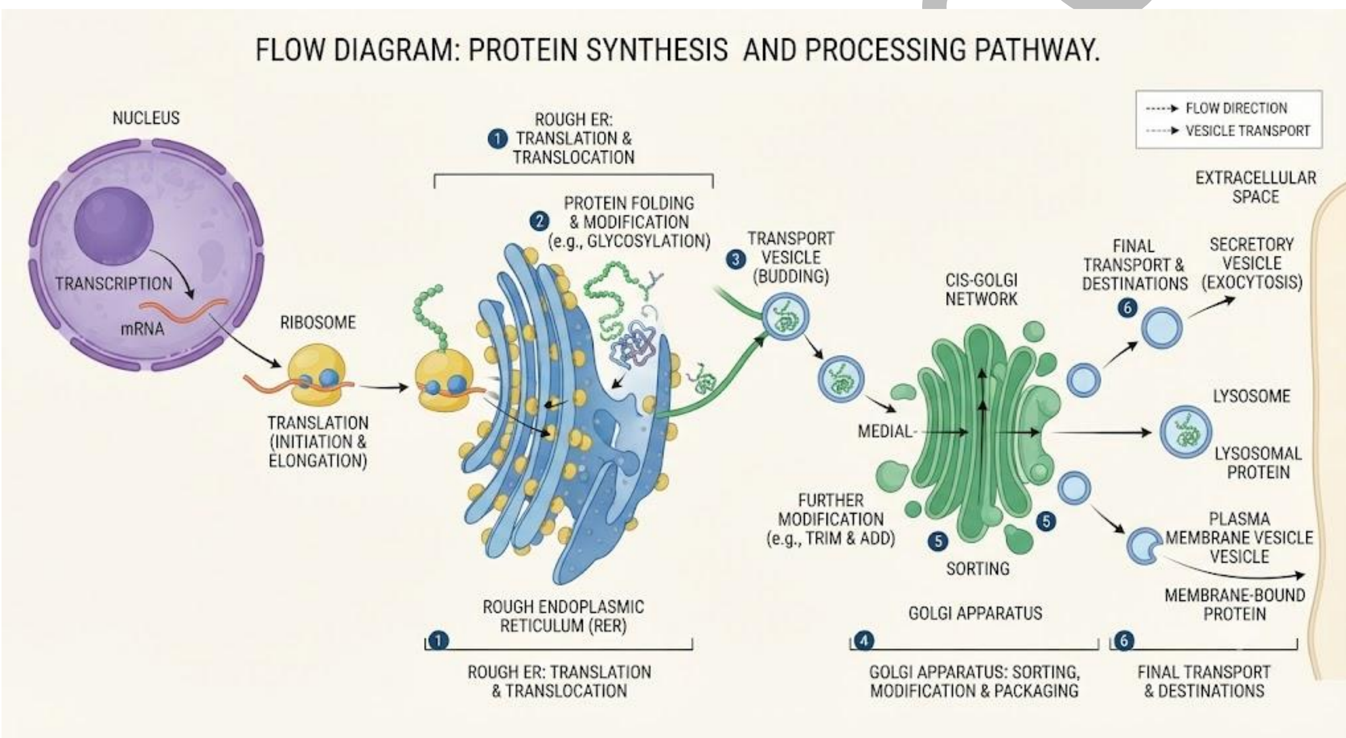

Figure 2.3: Protein synthesis and processing pathway

Pilot questions 2.3

1. Define translation and state which organelle carries it out.
2. Distinguish between rough and smooth endoplasmic reticulum.
3. Describe the function of the Golgi apparatus.
4. Define glycosylation.
5. Trace the pathway of a secreted protein from ribosome to final destination.

2.4 Storage, Digestion, and Support Organelles

2.4.1 Lysosomes

Lysosomes are membrane-bound organelles containing digestive enzymes capable of breaking down proteins, lipids, carbohydrates, and nucleic acids; they function as the cell waste disposal and recycling system, digesting worn-out organelles, foreign material taken in by the cell, and, in some specialised cells, material engulfed from outside the cell.

The enzymes within lysosomes are kept safely contained within the surrounding membrane, since their release into the general cytoplasm could damage healthy cellular components; this containment illustrates a broader principle relevant throughout cell biology, that compartmentalisation by membranes allows potentially harmful or incompatible processes to occur safely within a single cell.

Fill in the blank: Lysosomes contain digestive ________ capable of breaking down proteins, lipids, carbohydrates, and nucleic acids.

2.4.2 Vacuoles

Vacuoles are membrane-bound, fluid-filled sacs serving storage and other functions that vary by cell type and organism; plant cells typically contain one large central vacuole occupying much of the cell interior, important for storing water, nutrients, and waste products, and for maintaining turgor pressure that helps keep plant structures rigid.

Animal cells, and many protists, may contain smaller, more numerous vacuoles serving more specialised functions, such as temporarily storing material taken in by the cell before its digestion by lysosomes, or, in certain freshwater protists, regulating internal water balance through a specialised contractile vacuole that periodically expels excess water.

Fill in the blank: The large central vacuole in plant cells helps maintain ________ pressure, which keeps non-woody plant structures rigid and upright.

2.4.3 Cytoskeleton

The cytoskeleton is an internal network of protein filaments (including microtubules, the largest filament type, and microfilaments, the smallest) extending throughout the cytoplasm, providing structural support, maintaining cell shape, and enabling various forms of movement, including the movement of organelles within the cell and, in some cell types, the movement of the entire cell itself.

The cytoskeleton also plays an essential role during cell division, with specific cytoskeletal structures responsible for separating chromosomes and pulling the dividing cell apart into two daughter cells; this dynamic, constantly remodelled internal scaffold therefore supports both the structural stability and the active, changing processes that characterise living cells.

Fill in the blank: The cytoskeleton includes microtubules and microfilaments, providing structural support, maintaining cell shape, and enabling ________ within and of the cell.

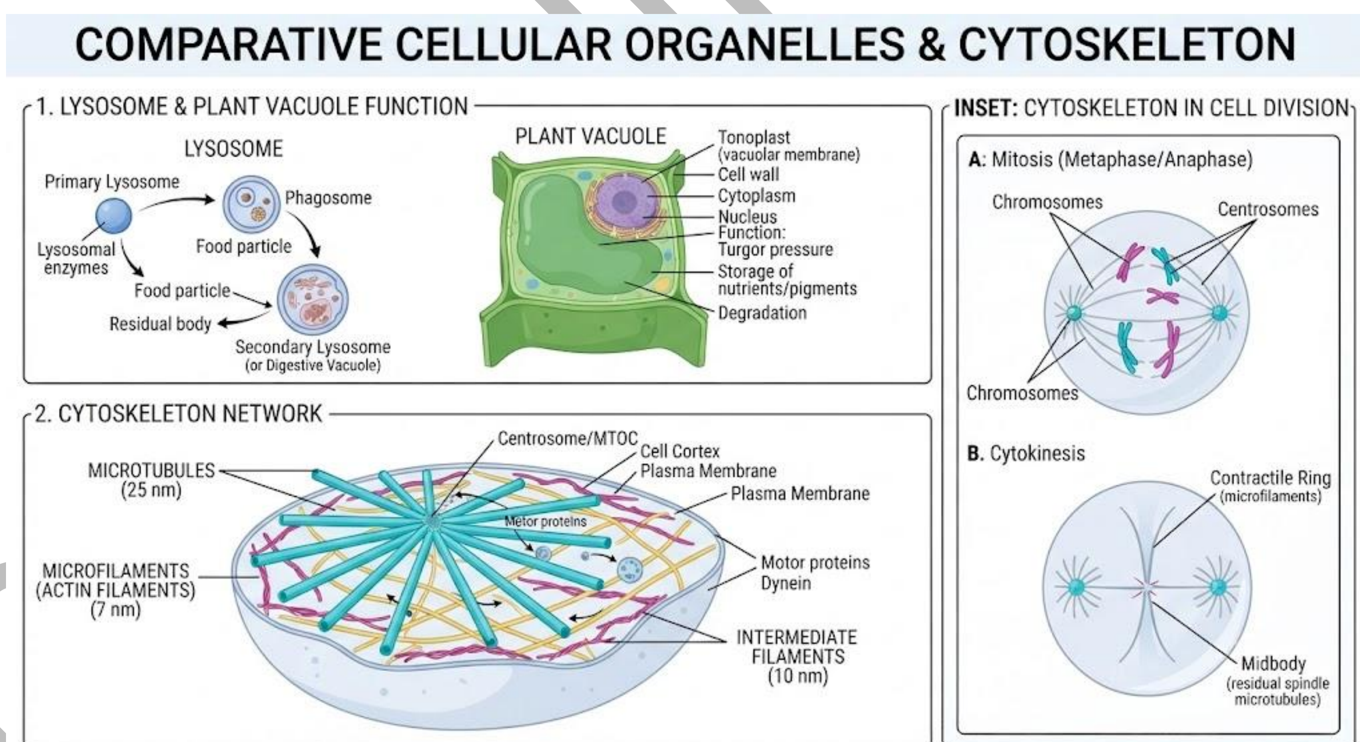

Figure 2.4: Lysosomes, vacuoles, and cytoskeleton

Pilot questions 2.4

1. Define lysosome and describe its main function.
2. Explain why lysosome enzymes are kept contained within a membrane.
3. Describe the function of the large central vacuole in plant cells.
4. Name two filament types making up the cytoskeleton.
5. Describe the role of the cytoskeleton during cell division.

Series Summary

This Series examined **the structure and functions of major cell organelles involved in genetic control, energy production, and cellular activities**. The **nucleus** serves as the control centre of the cell and contains the **nuclear envelope, nuclear pores, and nucleolus**, where genetic information is stored and gene expression is regulated. The Series also covered **chromosomes**, distinguishing **diploid and haploid cells**, and explained that **genes are the fundamental units of heredity**. Energy-producing organelles include the **mitochondria**, where cellular respiration generates ATP, and **chloroplasts**, where photosynthesis occurs within chlorophyll-containing thylakoids. Both organelles possess **double membranes and their own DNA**, supporting the proposed **endosymbiotic (prokaryotic origin) theory**.

The Series also covered **protein synthesis, intracellular transport, storage, and structural support**. **Ribosomes** are the sites of protein synthesis through translation, while the **rough endoplasmic reticulum** synthesises and transports proteins and the **smooth endoplasmic reticulum** functions in lipid synthesis and detoxification. The **Golgi apparatus** modifies, sorts, and packages proteins and other molecules for transport or secretion. Other important organelles include **lysosomes**, which contain digestive enzymes for intracellular digestion and waste removal; **vacuoles**, which store water and other substances and maintain turgor pressure in plant cells; and the **cytoskeleton**, composed of microtubules and microfilaments that provide structural support, enable movement, and assist in cell division. By completing this Series, students should achieve SLOs **2.1–2.4**.

Glossary of Terms

- **Allele:** a specific version of a gene that an individual organism carries.
- **Chloroplast:** an organelle in plant cells that carries out photosynthesis.
- **Cytoskeleton:** an internal network of protein filaments providing structural support and enabling movement within a cell.

- **Gene:** a segment of DNA carrying instructions for producing a particular protein or functional RNA.
- **Lysosome:** a membrane-bound organelle containing digestive enzymes that break down cellular waste and foreign material.
- **Mitochondrion:** an organelle responsible for cellular respiration, producing ATP for the cell.
- **Ribosome:** a structure composed of RNA and protein responsible for protein synthesis.

Concept Check Questions [Series 2]

Objective Questions

1. The nucleus is surrounded by a double membrane called the nuclear ________ . (Linked to SLO 2.1)
2. Mitochondria possess a folded inner membrane forming structures called ________ . (Linked to SLO 2.2)
3. Rough endoplasmic reticulum is studded with ________ on its outer surface. (Linked to SLO 2.3)
4. Lysosomes contain digestive ________ that break down cellular waste. (Linked to SLO 2.4)
5. Chloroplasts contain chlorophyll housed within internal membrane stacks called ________ . (Linked to SLO 2.2)

Short-Answer Questions

1. Define gene. (Linked to SLO 2.1)
2. Distinguish between mitochondria and chloroplasts in function. (Linked to SLO 2.2)
3. Describe the function of the Golgi apparatus. (Linked to SLO 2.3)
4. Describe the function of the large central vacuole in plant cells. (Linked to SLO 2.4)
5. Name two filament types in the cytoskeleton. (Linked to SLO 2.4)

Long-Answer Questions

1. Describe the structure and function of the nucleus, chromosomes, and genes. (Linked to SLO 2.1)
2. Explain the structure and function of mitochondria and chloroplasts. (Linked to SLO 2.2)
3. Describe the protein synthesis pathway and the role of storage/support organelles. (Linked to SLOs 2.3, 2.4)

Answers to Concept Check Questions [Series 2]

Objective Questions

1. Envelope.
2. Cristae.
3. Ribosomes.
4. Enzymes.
5. Thylakoids.

Short-Answer Questions

1. A gene is a DNA segment carrying instructions for producing a protein or functional RNA.
2. Mitochondria carry out respiration, releasing energy; chloroplasts carry out photosynthesis, capturing energy.
3. The Golgi apparatus modifies, sorts, and packages proteins and lipids for transport to their destination.
4. It stores water, nutrients, and waste, and maintains turgor pressure keeping plant structures rigid.
5. Microtubules and microfilaments.

Long-Answer Questions

1. The nucleus, bounded by the nuclear envelope and containing the nucleolus, houses chromosomes made of DNA and protein. Genes are DNA segments within chromosomes carrying hereditary instructions.
2. Mitochondria use cristae to carry out respiration, producing ATP. Chloroplasts use thylakoids and chlorophyll to carry out photosynthesis, producing glucose and oxygen. Both share a double membrane and their own DNA.
3. Proteins are synthesised by ribosomes, processed in the endoplasmic reticulum, and modified/sorted by the Golgi apparatus. Lysosomes digest waste, vacuoles store material and maintain pressure, and the cytoskeleton supports shape and movement.

Answers to Pilot Questions [Series 2]

Part 2.1

1. The nuclear envelope is a double membrane perforated by pores regulating molecule passage.
2. The nucleolus is a dense nuclear region responsible for assembling ribosomal components.
3. A chromosome is a tightly coiled, organised structure of DNA and protein.
4. Diploid cells have paired chromosomes; haploid cells have a single set.
5. A gene is a DNA segment carrying protein-making instructions; genes are important because they determine inherited traits.

Part 2.2

1. Cellular respiration converts food energy into ATP, occurring primarily in mitochondria.
2. Cristae increase the surface area available for respiration reactions.
3. Photosynthesis is the process capturing light energy to produce glucose and oxygen from carbon dioxide and water.
4. Thylakoids house chlorophyll, which absorbs light energy for photosynthesis.
5. Both have a double membrane and their own DNA.

Part 2.3

1. Translation is protein synthesis, carried out by ribosomes.
2. Rough ER has ribosomes and processes secreted/membrane proteins; smooth ER lacks ribosomes and makes lipids.
3. The Golgi apparatus modifies, sorts, and packages proteins and lipids for transport.
4. Glycosylation is the addition of sugar molecules to a protein.
5. Ribosome synthesises the protein, rough ER processes it, a vesicle carries it to the Golgi apparatus, which sorts and packages it for secretion.

Part 2.4

1. A lysosome is a membrane-bound organelle with digestive enzymes; its main function is breaking down waste and foreign material.
2. Containment prevents the enzymes from damaging healthy cellular components if released into the cytoplasm.

3. It stores water, nutrients, and waste, and maintains turgor pressure.
4. Microtubules and microfilaments.
5. Cytoskeletal structures separate chromosomes and pull the dividing cell apart into two daughter cells.

References and Attribution

Textual References (Books and External Sources)

- Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2014). Molecular biology of the cell (6th ed.). Garland Science.
- Campbell, N. A., & Reece, J. B. (2018). Biology (11th ed.). Pearson.
- Raven, P. H., Johnson, G. B., Mason, K. A., Losos, J. B., & Singer, S. R. (2017). Biology (11th ed.). McGraw-Hill Education.
- National Open University of Nigeria (NOUN). (2023). General biology course material. NOUN Press.

Figures, Plates, Tables, and Boxes

- Figure 2.1: The nucleus, chromosomes, and genes Attribution: AI generated. Suggested OER search string: "nucleus chromosome gene DNA structure diagram biology OER".
- Figure 2.2: Mitochondria and chloroplast structure and function Attribution: AI generated. Suggested OER search string: "mitochondria chloroplast structure function diagram cellular respiration photosynthesis OER".
- Figure 2.3: Protein synthesis and processing pathway Attribution: AI generated. Suggested OER search string: "ribosome endoplasmic reticulum Golgi apparatus protein synthesis pathway diagram biology OER".
- Figure 2.4: Lysosomes, vacuoles, and cytoskeleton Attribution: AI generated. Suggested OER search string: "lysosome vacuole cytoskeleton structure function diagram biology OER".

Course code: BIO 101

Course title: General Biology I

Course credit load: 2 Units

Series 3: Classification and Reproduction of Living Things

- **Part 3.1: Characteristics of Living Things**
  - Sub Part 3.1.1: Defining life
  - Sub Part 3.1.2: Distinguishing living from non-living things
  - Sub Part 3.1.3: Common characteristics across living organisms
- **Part 3.2: Principles of Biological Classification**
  - Sub Part 3.2.1: Purpose and basis of classification
  - Sub Part 3.2.2: Taxonomic hierarchy
  - Sub Part 3.2.3: The five (or more) kingdom system
- **Part 3.3: Major Groups of Living Things**
  - Sub Part 3.3.1: Microorganisms: bacteria and protists
  - Sub Part 3.3.2: Fungi
  - Sub Part 3.3.3: Plants and animals
- **Part 3.4: General Reproduction in Living Things**
  - Sub Part 3.4.1: Asexual reproduction
  - Sub Part 3.4.2: Sexual reproduction
  - Sub Part 3.4.3: Comparing asexual and sexual reproduction

Introduction

Living things display a remarkable variety of forms, yet share certain fundamental characteristics that distinguish them from non-living matter. This Series examines what defines life, the principles biologists use to classify the enormous diversity of living organisms into manageable, informative groups, the major groups of living things recognised by modern classification, and the general patterns of reproduction by which living things produce new individuals.

This Series covers the defining characteristics of living things and how they differ from non-living matter; the purpose, basis, and hierarchy of biological classification, including the kingdom system; the major recognised groups of living organisms, from microorganisms through fungi, plants, and animals; and the general principles of asexual and sexual reproduction. This prepares students for the organism interrelationship topics covered in the next Series.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** describe the characteristics that define and distinguish living things (Linked to Part 3.1),
- **SLO 3.2** explain the principles and hierarchy of biological classification (Linked to Part 3.2),
- **SLO 3.3** describe the major recognised groups of living organisms (Linked to Part 3.3), and
- **SLO 3.4** distinguish asexual and sexual reproduction (Linked to Part 3.4).

3.1 Characteristics of Living Things

3.1.1 Defining life

Life is generally defined not by any single feature but by a combination of characteristics displayed together: living things are organised (composed of one or more cells), carry out metabolism (the sum of chemical reactions sustaining life), grow and develop, respond to stimuli from their environment, reproduce, maintain homeostasis (a stable internal environment), and, over generations, undergo evolutionary adaptation to their surroundings.

No single one of these characteristics alone reliably distinguishes living from non-living matter, since some non-living things display individual life-like features in isolation (a growing crystal increases in size, for example, without being alive); it is the combination of characteristics occurring together within a single organised, self-sustaining system that biologists use to identify something as living.

Fill in the blank: Life is defined by a combination of characteristics occurring together, including organisation, metabolism, growth, response to stimuli, reproduction, and ________ .

3.1.2 Distinguishing living from non-living things

Non-living matter, even matter that was once part of a living organism (such as a fallen leaf or a piece of wood), lacks the capacity for self-sustained metabolism, growth from internal processes, and reproduction; while a non-living object may change over time (rusting, eroding, or decaying), such change is driven entirely by external physical and chemical forces rather than by internally regulated, self-directed life processes.

Viruses present a particularly informative borderline case frequently discussed in introductory biology, since they possess genetic material and can reproduce, but only by hijacking the cellular machinery of a host cell, lacking independent metabolism or cellular structure of their own; this borderline status illustrates that the boundary between living and non-living is not always perfectly sharp, even though the great majority of organisms are clearly classifiable as one or the other.

Fill in the blank: Viruses present a borderline case since they can reproduce only by hijacking the cellular machinery of a ________ cell, lacking independent metabolism of their own.

3.1.3 Common characteristics across living organisms

Despite their vast diversity, all living organisms share certain underlying common features: all are built from one or more cells, all use DNA (or, in some viruses, RNA) as their hereditary material, all require energy obtained from their environment to sustain metabolism, and all respond in some way to changes in their surroundings, whether through rapid behavioural response in animals or slower, more gradual responses such as plant growth toward a light source.

These shared underlying features, despite the enormous outward diversity of living forms from microscopic bacteria to large trees and animals, reflect the common evolutionary origin of all life and provide the unifying biological principles that make it possible to study living things scientifically as a single, coherent subject rather than as an unconnected collection of unrelated phenomena.

Fill in the blank: All living organisms use DNA, or in some viruses RNA, as their ________ material, despite their enormous outward diversity of form.

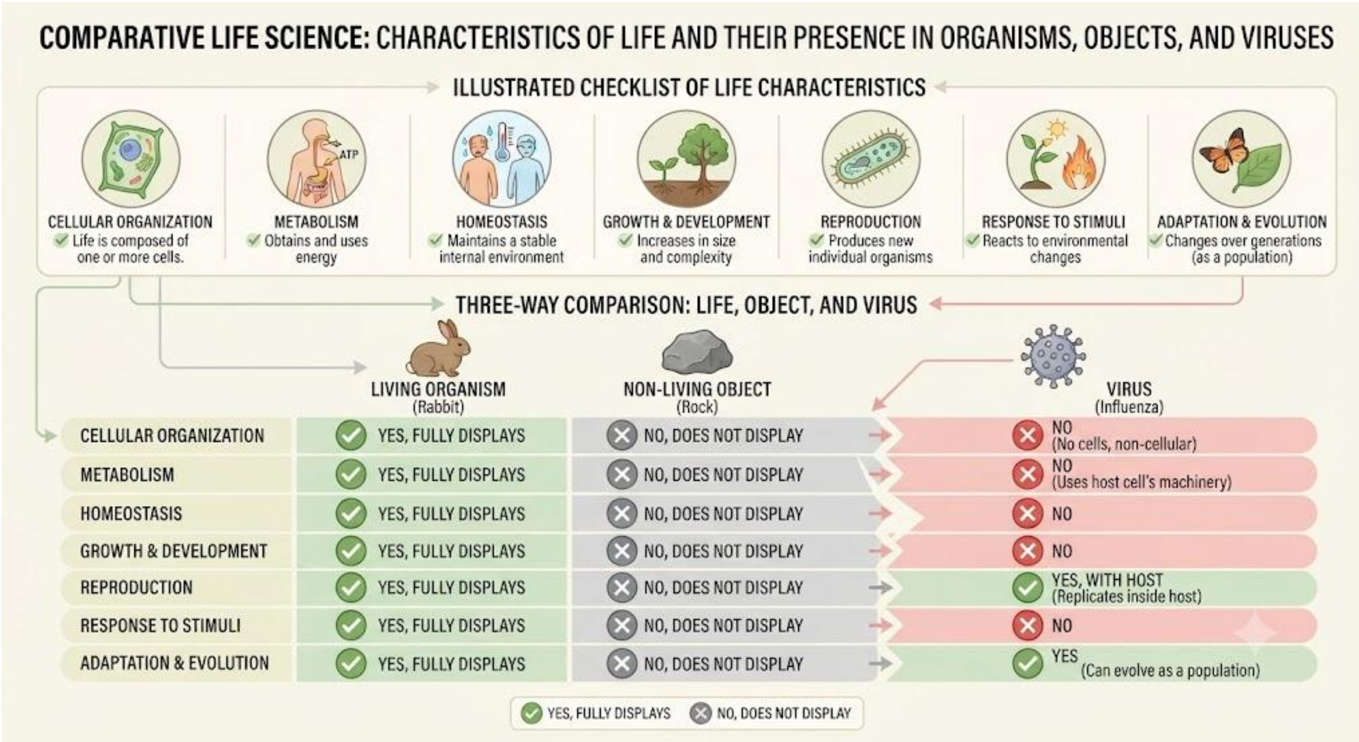

Figure 3.1: Characteristics of living things

Pilot questions 3.1

1. List the characteristics generally used to define life.
2. Explain why no single characteristic alone reliably distinguishes living from non-living matter.
3. Explain why viruses are considered a borderline case between living and non-living.
4. Name two features shared by all living organisms.
5. Define homeostasis.

3.2 Principles of Biological Classification

3.2.1 Purpose and basis of classification

Biological classification (taxonomy) organises the immense diversity of living organisms into a structured system of named, nested groups, supporting clear communication among scientists (through standardised naming), efficient organisation of biological knowledge, and insight into evolutionary relationships between organisms, since modern classification is based primarily on shared evolutionary ancestry rather than superficial appearance alone.

Classification criteria have evolved over time from primarily structural/anatomical similarity (used historically, before the relevant underlying biology was understood) to increasingly incorporate genetic, biochemical, and developmental evidence, allowing more accurate grouping based on true evolutionary relationship rather than superficial resemblance that can sometimes mislead purely appearance-based classification.

Fill in the blank: Modern biological classification is based primarily on shared evolutionary ________ rather than superficial appearance alone.

3.2.2 Taxonomic hierarchy

The standard taxonomic hierarchy, from broadest to most specific, proceeds through domain, kingdom, phylum, class, order, family, genus, and species, with each level nested within the one above it, so that a species belongs to a genus, a genus to a family, and so on up to the broadest domain level; this hierarchical structure allows organisms to be classified with increasing precision as one moves down the hierarchy.

Each organism is given a standardised two-part scientific name (binomial nomenclature) consisting of its genus and species, written in italics with the genus capitalised, providing a single, universally recognised name for each species regardless of the many different common names that may exist for the same organism across different languages and regions.

Fill in the blank: Each organism is given a standardised two-part scientific name, called binomial ________ , consisting of its genus and species.

3.2.3 The five (or more) kingdom system

A widely taught classification scheme recognises five major kingdoms: Monera (bacteria, prokaryotic organisms lacking a nucleus), Protista (mostly single-celled eukaryotic organisms, including many algae and protozoa), Fungi (eukaryotic organisms, mostly multicellular, that absorb nutrients from their surroundings), Plantae (multicellular, photosynthetic organisms), and Animalia (multicellular organisms that obtain nutrients by consuming other organisms).

More recent classification systems, informed by genetic evidence, often divide certain groups further, such as separating bacteria into two distinct domains (true bacteria and a separate group called archaea) above the kingdom level, reflecting the continually refining, evidence-based nature of biological classification rather than a single, permanently fixed system.

Fill in the blank: The five-kingdom system recognises Monera, Protista, Fungi, Plantae, and ________ as the major kingdoms of living organisms.

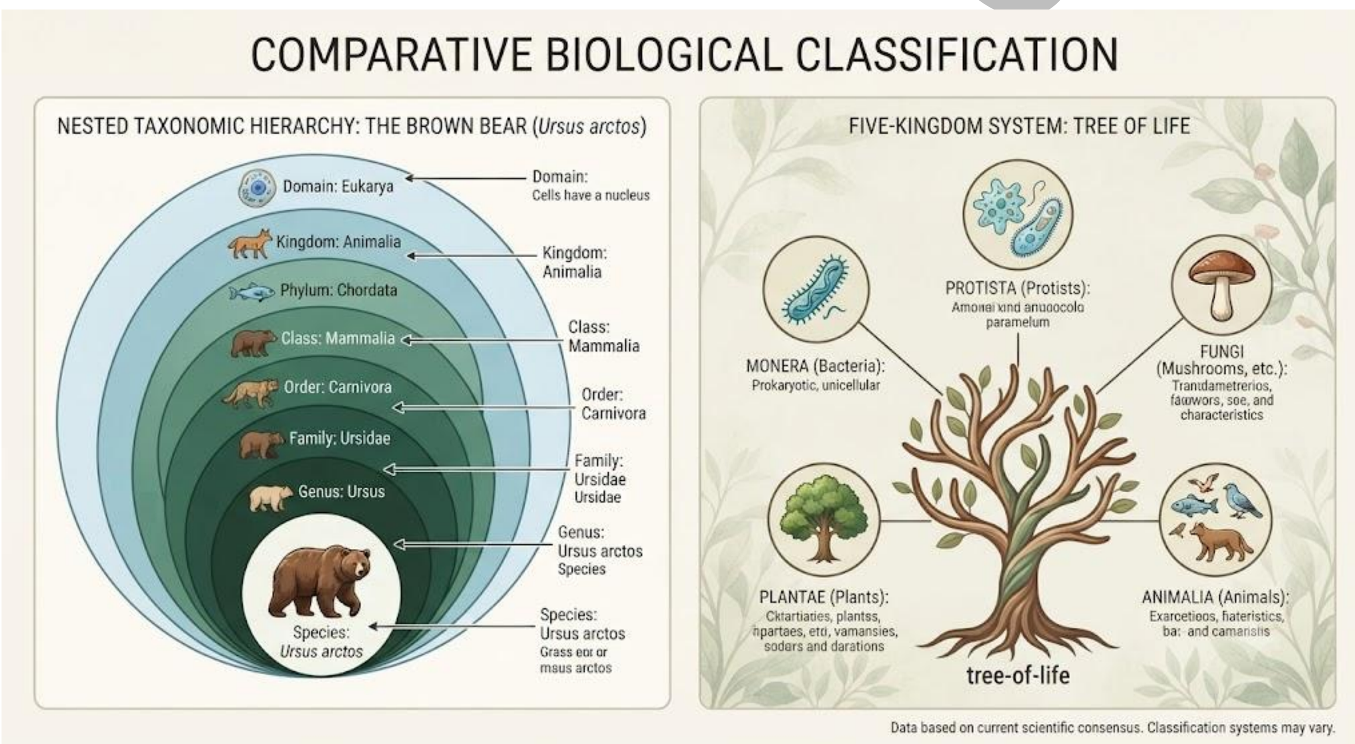

Figure 3.2: Biological classification hierarchy and kingdoms

Pilot questions 3.2

1. Define taxonomy and state its purpose.
2. List the taxonomic hierarchy from domain to species.
3. Define binomial nomenclature.
4. Name the five kingdoms in the five-kingdom system.

6. Explain why modern classification incorporates genetic evidence rather than appearance alone.

3.3 Major Groups of Living Things

3.3.1 Microorganisms: bacteria and protists

Bacteria are single-celled prokaryotic organisms found in nearly every environment on Earth, including extreme environments uninhabitable by most other life; while some bacteria cause disease, the great majority play essential, often beneficial roles, including decomposing dead organic matter, fixing atmospheric nitrogen into forms plants can use, and assisting digestion within the gut of many animals.

Protists are a highly diverse group of mostly single-celled eukaryotic organisms, including photosynthetic algae (some of which form the basis of aquatic food chains) and various protozoa (heterotrophic, animal-like protists); the protist group is often described as a catch-all category for eukaryotic organisms that do not clearly belong to the fungi, plant, or animal kingdoms, reflecting their considerable underlying diversity.

Fill in the blank: Protists are often described as a ________ category for eukaryotic organisms that do not clearly belong to the fungi, plant, or animal kingdoms.

3.3.2 Fungi

Fungi are eukaryotic organisms, mostly multicellular (with yeasts being a notable single-celled exception), that obtain nutrients by absorbing dissolved organic material from their surroundings rather than through photosynthesis or by ingesting food internally; most fungi are composed of thread-like structures called hyphae, which together form a larger network called mycelium.

Fungi play an essential ecological role as decomposers, breaking down dead organic matter and recycling nutrients back into the ecosystem, and form important relationships with other organisms, including symbiotic partnerships with plant roots (mycorrhizae) that improve plant nutrient uptake; fungi also include economically and medically significant species, from those used in food production to those producing important antibiotics.

Fill in the blank: Most fungi are composed of thread-like structures called ________ , which together form a larger network called mycelium.

3.3.3 Plants and animals

Plants are multicellular, photosynthetic eukaryotic organisms possessing cell walls and chloroplasts, generally fixed in place (non-motile) and obtaining energy directly from sunlight; plants range from simple, non-vascular mosses to complex, vascular flowering plants and trees, with vascular tissue (specialised transport tissue) supporting the larger size and greater structural complexity found in most familiar plant species.

Animals are multicellular eukaryotic organisms lacking cell walls and chloroplasts, generally capable of movement at some life stage, and obtaining nutrients by consuming other organisms; animals range from simple, soft-bodied invertebrates to complex vertebrates possessing a backbone, with the animal kingdom representing the most behaviourally and structurally diverse kingdom in terms of locomotion, sensory capability, and nervous system complexity.

Fill in the blank: ________ tissue, specialised transport tissue, supports the larger size and greater structural complexity found in most familiar plant species.

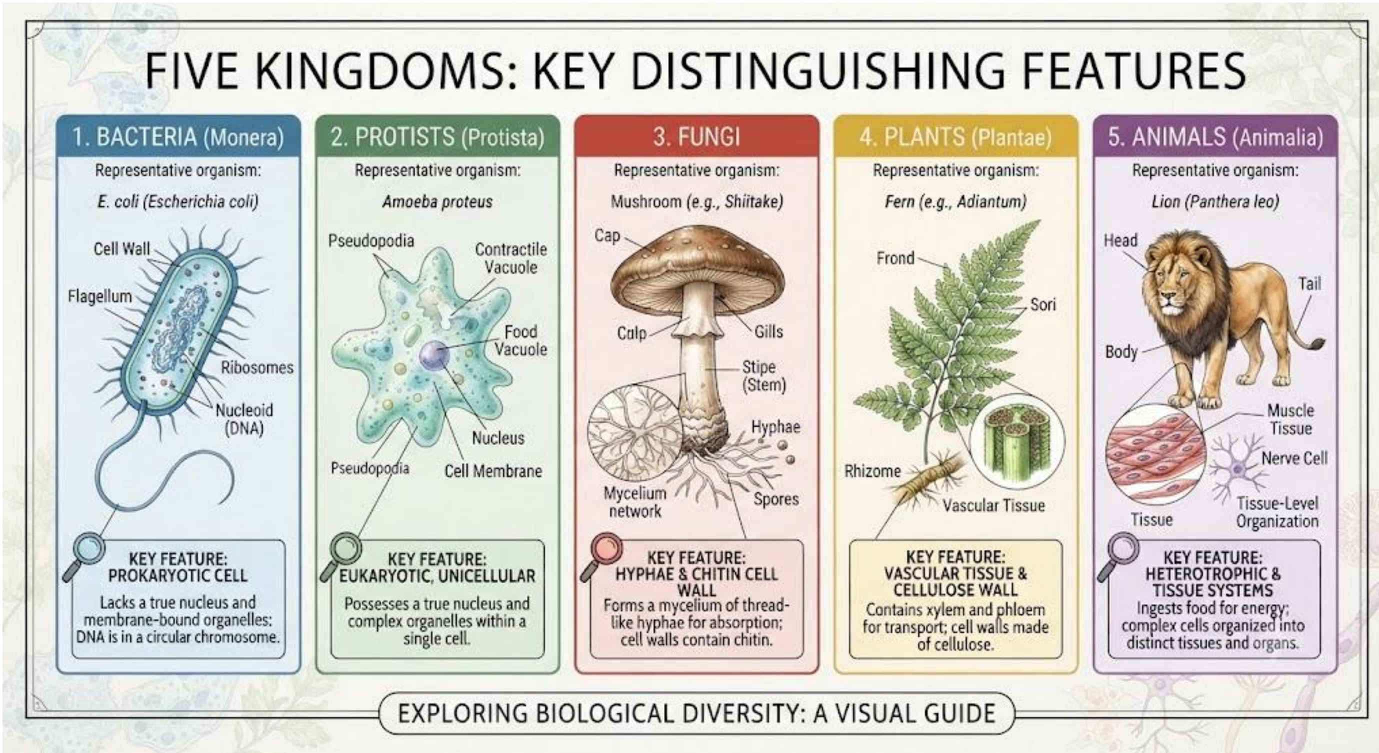

Figure 3.3: Major groups of living things

Pilot questions 3.3

1. Name two beneficial roles bacteria play in nature.
2. Define protist.
3. Define hyphae and mycelium.
4. Distinguish between plants and animals in terms of nutrient acquisition.
5. Define vascular tissue and explain its significance for plants.

3.4 General Reproduction in Living Things

3.4.1 Asexual reproduction

Asexual reproduction produces new individuals from a single parent organism, without the fusion of specialised reproductive cells, resulting in offspring that are genetically identical (or very nearly identical) to the parent; common forms include binary fission (a single cell dividing into two, characteristic of bacteria), budding (a new individual growing as an outgrowth from the parent before separating), and vegetative propagation in plants (new plants growing from a parent plant root, stem, or leaf fragment).

Asexual reproduction allows rapid population increase, since it does not require finding a mate or the time investment associated with sexual reproduction, making it particularly advantageous in stable, favourable environments where the parent organism well-adapted characteristics are likely to remain advantageous for the offspring as well, though it provides relatively limited genetic variation among offspring.

Fill in the blank: Asexual reproduction produces offspring that are genetically ________ , or very nearly so, to the single parent organism.

3.4.2 Sexual reproduction

Sexual reproduction involves the fusion of two specialised reproductive cells (gametes), typically one from each of two parent organisms, producing offspring with a combination of genetic material from both parents and, correspondingly, greater genetic variation than asexual reproduction; this process typically involves meiosis (a specialised cell division producing gametes with half the normal chromosome number) followed by fertilisation (the fusion of two gametes restoring the full chromosome number).

The genetic variation produced through sexual reproduction provides a significant evolutionary advantage in changing or unpredictable environments, since a genetically varied population is more likely to include at least some individuals with characteristics suited to new or altered conditions, supporting the longer-term adaptive capacity of a sexually reproducing population compared to a genetically uniform asexually reproducing one.

Fill in the blank: Sexual reproduction typically involves meiosis, producing gametes with half the normal chromosome number, followed by ________ , which restores the full chromosome number.

3.4.3 Comparing asexual and sexual reproduction

Asexual reproduction is generally faster and simpler, requiring only a single parent and no mate-finding process, and produces offspring well suited to stable environments where the parent characteristics remain advantageous; sexual reproduction is generally slower and more resource-intensive, requiring two parents and specialised reproductive structures, but produces genetically varied offspring better equipped, as a population, to cope with environmental change.

Many organisms are capable of both reproductive strategies at different times or under different conditions, switching to asexual reproduction when conditions are favourable and stable (maximising reproductive rate) and to sexual reproduction when conditions are less predictable or stressful (maximising genetic variation among offspring), illustrating that the two strategies are not mutually exclusive alternatives but complementary approaches suited to different circumstances.

Fill in the blank: Some organisms switch between asexual reproduction under stable conditions and sexual reproduction under less predictable conditions, illustrating that the two strategies are ________ rather than mutually exclusive.

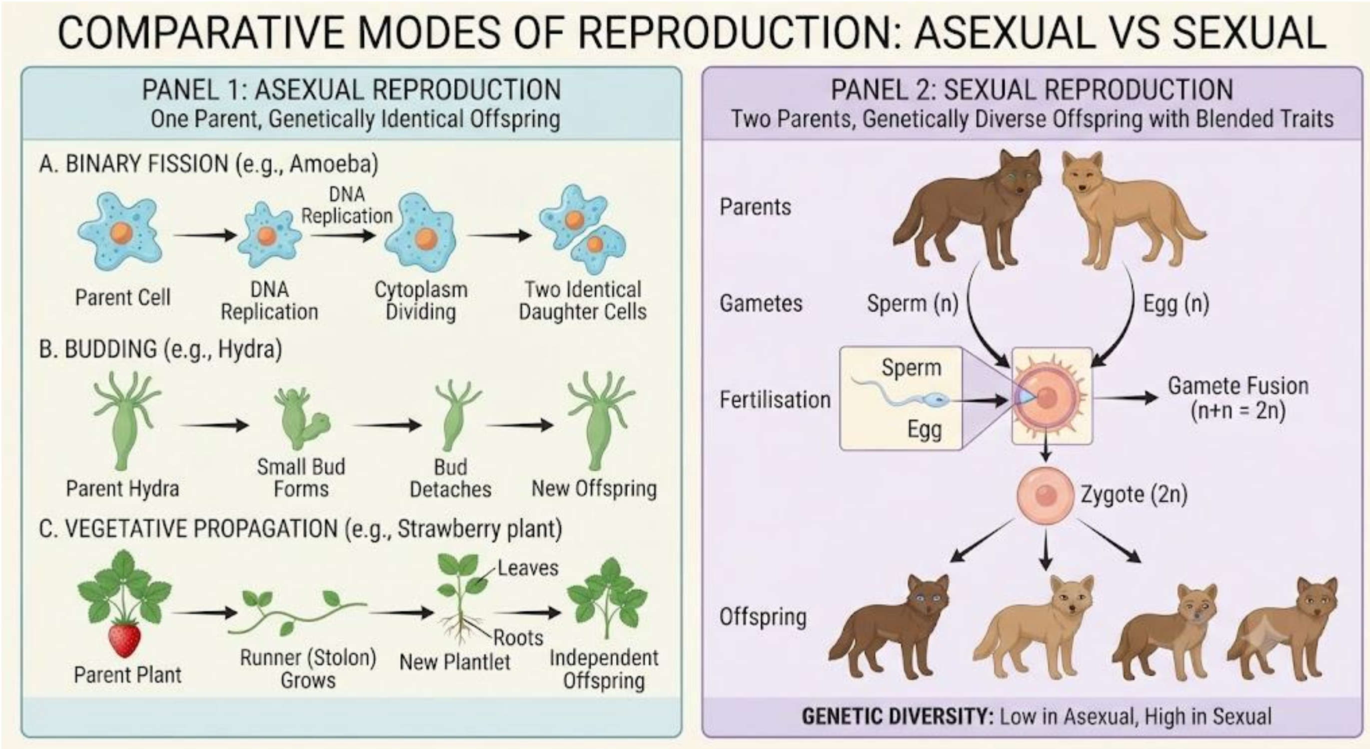

Figure 3.4: Asexual and sexual reproduction

Pilot questions 3.4

1. Define asexual reproduction and name two of its forms.
2. Define sexual reproduction.
3. Distinguish between meiosis and fertilisation.
4. Explain the main advantage of sexual reproduction over asexual reproduction.
5. Explain why some organisms use both reproductive strategies under different conditions.

Series Summary

This Series examined **the characteristics, classification, and reproduction of living organisms**. Living things are distinguished by **cellular organisation, metabolism, growth, response to stimuli, reproduction, homeostasis, and evolutionary adaptation**, while **viruses** are considered a borderline case because they possess genetic material but can reproduce only inside living cells. All living organisms share fundamental features, including the presence of **cells, DNA, and the ability to obtain and use energy**. The Series also introduced **biological classification (taxonomy)** based on evolutionary relationships, the taxonomic hierarchy from **domain to species**, **binomial nomenclature**, and the **five-kingdom classification system**: Monera, Protista, Fungi, Plantae, and Animalia.

The Series also covered the **major groups of organisms and their reproductive strategies**. **Bacteria** and **protists** represent simple microorganisms, **fungi** are characterised by hyphae and mycelia and play important roles as decomposers, **plants** possess vascular tissues and carry out photosynthesis, while **animals** are multicellular organisms that obtain food by consumption and are generally capable of movement. Reproduction occurs through **asexual methods**, such as binary fission, budding, and vegetative propagation, which produce genetically identical offspring, or **sexual reproduction**, involving meiosis and fertilisation, which generates genetic variation. Both reproductive strategies play complementary roles in the survival and adaptation of living organisms. By completing this Series, students should achieve SLOs **3.1–3.4**.

Glossary of Terms

- **Asexual reproduction:** reproduction producing genetically identical offspring from a single parent without gamete fusion.
- **Binomial nomenclature:** the standardised two-part scientific naming system consisting of genus and species.
- **Fertilisation:** the fusion of two gametes, restoring the full chromosome number.
- **Homeostasis:** the maintenance of a stable internal environment within a living organism.

- **Meiosis:** a specialised cell division producing gametes with half the normal chromosome number.
- **Mycelium:** a network formed by the thread-like hyphae of a fungus.
- **Taxonomy:** the science of classifying living organisms into a structured, hierarchical system.

Concept Check Questions [Series 3]

Objective Questions

1. Life is defined by characteristics including organisation, metabolism, growth, response, reproduction, and ________ . (Linked to SLO 3.1)
2. Each organism is given a standardised two-part scientific name called binomial ________ . (Linked to SLO 3.2)
3. Most fungi are composed of thread-like structures called ________ . (Linked to SLO 3.3)
4. Asexual reproduction produces offspring genetically ________ to the single parent. (Linked to SLO 3.4)
5. The five-kingdom system includes Monera, Protista, Fungi, Plantae, and ________ . (Linked to SLO 3.2)

Short-Answer Questions

1. List four characteristics used to define life. (Linked to SLO 3.1)
2. List the taxonomic hierarchy from domain to species. (Linked to SLO 3.2)
3. Name three major groups of living things. (Linked to SLO 3.3)
4. Distinguish between asexual and sexual reproduction. (Linked to SLO 3.4)
5. Explain why viruses are considered a borderline case between living and non-living. (Linked to SLO 3.1)

Long-Answer Questions

1. Describe the characteristics that define and distinguish living things. (Linked to SLO 3.1)
2. Explain the principles of classification and the major groups of living organisms. (Linked to SLOs 3.2, 3.3)
3. Distinguish asexual and sexual reproduction. (Linked to SLO 3.4)

Answers to Concept Check Questions [Series 3]

Objective Questions

1. Homeostasis.
2. Nomenclature.
3. Hyphae.
4. Identical.
5. Animalia.

Short-Answer Questions

1. Organisation, metabolism, growth, and reproduction (or response, homeostasis).
2. Domain, kingdom, phylum, class, order, family, genus, species.
3. Bacteria, fungi, and plants (or protists, animals).
4. Asexual reproduction uses one parent and produces identical offspring; sexual reproduction uses two parents and produces varied offspring.
5. Viruses reproduce only by hijacking a host cell, lacking independent metabolism of their own.

Long-Answer Questions

1. Life is defined by organisation, metabolism, growth, response, reproduction, homeostasis, and evolutionary adaptation occurring together, distinguishing it from non-living matter and borderline cases like viruses.
2. Classification organises organisms by evolutionary relationship into a nested hierarchy with binomial names. Major groups include bacteria, protists, fungi, plants, and animals, each with distinguishing features.
3. Asexual reproduction uses one parent and produces genetically identical offspring rapidly; sexual reproduction uses meiosis and fertilisation between two parents, producing varied offspring better suited to changing conditions.

Answers to Pilot Questions [Series 3]

Part 3.1

1. Organisation, metabolism, growth, response to stimuli, reproduction, homeostasis, and evolutionary adaptation.
2. Some non-living things display individual life-like features alone without being alive.
3. Viruses can reproduce but only by hijacking a host cell, lacking independent metabolism.
4. Use of DNA as hereditary material and requirement for energy from the environment.
5. Homeostasis is the maintenance of a stable internal environment.

Part 3.2

1. Taxonomy classifies organisms into a structured system; its purpose is clear communication and insight into evolutionary relationships.
2. Domain, kingdom, phylum, class, order, family, genus, species.
3. Binomial nomenclature is the two-part scientific name consisting of genus and species.
4. Monera, Protista, Fungi, Plantae, and Animalia.
5. Genetic evidence reveals true evolutionary relationships that appearance alone can sometimes mislead.

Part 3.3

1. Decomposing organic matter and fixing atmospheric nitrogen.
2. A protist is a mostly single-celled eukaryotic organism not clearly belonging to fungi, plants, or animals.
3. Hyphae are thread-like fungal structures; mycelium is the network they form together.
4. Plants photosynthesise to produce their own food; animals consume other organisms for nutrients.
5. Vascular tissue is specialised transport tissue supporting larger size and structural complexity in plants.

Part 3.4

1. Asexual reproduction produces identical offspring from one parent; forms include binary fission and budding.

2. Sexual reproduction is the fusion of two gametes from typically two parents, producing varied offspring.
3. Meiosis produces gametes with half the chromosome number; fertilisation fuses gametes to restore the full number.
4. Sexual reproduction produces genetic variation, helping a population adapt to changing conditions.
5. Asexual reproduction suits stable conditions for rapid increase; sexual reproduction suits unpredictable conditions needing variation.

References and Attribution

Textual References (Books and External Sources)

- Campbell, N. A., & Reece, J. B. (2018). Biology (11th ed.). Pearson.
- Raven, P. H., Johnson, G. B., Mason, K. A., Losos, J. B., & Singer, S. R. (2017). Biology (11th ed.). McGraw-Hill Education.
- Mayr, E. (2001). What evolution is. Basic Books.
- National Open University of Nigeria (NOUN). (2023). General biology course material. NOUN Press.

Figures, Plates, Tables, and Boxes

- Figure 3.1: Characteristics of living things Attribution: AI generated. Suggested OER search string: "characteristics of life living nonliving virus comparison diagram biology OER".
- Figure 3.2: Biological classification hierarchy and kingdoms Attribution: AI generated. Suggested OER search string: "taxonomic hierarchy five kingdom classification tree of life diagram biology OER".
- Figure 3.3: Major groups of living things Attribution: AI generated. Suggested OER search string: "bacteria protist fungi plant animal kingdom comparison illustration biology OER".
- Figure 3.4: Asexual and sexual reproduction Attribution: AI generated. Suggested OER search string: "asexual sexual reproduction binary fission budding fertilisation diagram biology OER".

Course code: BIO 101

Course title: General Biology I

Course credit load: 2 Units

Series 4: Interrelationships Among Organisms

- **Part 4.1: Competition and Predation**
  - Sub Part 4.1.1: Competition
  - Sub Part 4.1.2: Predation
  - Sub Part 4.1.3: Effects on population dynamics
- **Part 4.2: Parasitism and Disease**
  - Sub Part 4.2.1: Defining parasitism
  - Sub Part 4.2.2: Types of parasites
  - Sub Part 4.2.3: Host-parasite relationships
- **Part 4.3: Symbiotic Relationships**
  - Sub Part 4.3.1: Mutualism
  - Sub Part 4.3.2: Commensalism
  - Sub Part 4.3.3: Distinguishing symbiotic relationships
- **Part 4.4: Saprophytism and Decomposition**
  - Sub Part 4.4.1: Defining saprophytism
  - Sub Part 4.4.2: Organisms involved in decomposition
  - Sub Part 4.4.3: Ecological significance of decomposition

Introduction

No organism lives in isolation; every living thing interacts, directly or indirectly, with other organisms sharing its environment. This Series examines the major categories of interaction between organisms, ranging from competitive and predatory relationships that can harm one or both participants, through parasitic relationships, to cooperative symbiotic relationships, and finally to the decomposer relationships that recycle nutrients within ecosystems.

This Series covers competition and predation and their effects on population numbers; parasitism, including types of parasites and host-parasite relationships; symbiotic relationships, including mutualism and commensalism; and saprophytism and the broader ecological significance of decomposition. This prepares students for the heredity, evolution, and ecology topics covered in the final Series of this course.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** describe competition and predation and their effects on population dynamics (Linked to Part 4.1),
- **SLO 4.2** explain parasitism, types of parasites, and host-parasite relationships (Linked to Part 4.2),
- **SLO 4.3** distinguish mutualism and commensalism as symbiotic relationships (Linked to Part 4.3), and
- **SLO 4.4** explain saprophytism and the ecological significance of decomposition (Linked to Part 4.4).

4.1 Competition and Predation

4.1.1 Competition

Competition occurs when two or more organisms require the same limited resource, such as food, water, light, breeding space, or territory, with the demand for that resource exceeding the available supply; competition may occur between individuals of the same species (intraspecific competition) or between individuals of different species (interspecific competition), with both forms generally reducing the fitness, growth, or survival of the competing individuals to some degree.

Competition outcomes can range from one competitor largely excluding another from a shared resource or habitat, to both competitors persisting through some form of resource partitioning, in which competing species come to use slightly different parts of a shared resource (different food types, feeding times, or microhabitats), reducing the intensity of direct competition between them over time.

Fill in the blank: Competition between individuals of different species is called ________ competition, distinguishing it from competition between individuals of the same species.

4.1.2 Predation

Predation is an interaction in which one organism, the predator, kills and consumes another organism, the prey, for nutrition; predation is a widespread and fundamentally important interaction shaping the behaviour, physical characteristics, and population dynamics of both predator and prey species through the ongoing evolutionary pressure each exerts on the other.

Predator adaptations (such as speed, stealth, sharp teeth or claws, or venom) and corresponding prey adaptations (such as camouflage, speed, defensive structures, or group living for collective vigilance) frequently evolve together over time in a process sometimes described as an evolutionary arms race, with improvements in predator hunting ability favouring corresponding improvements in prey defence, and vice versa.

Fill in the blank: Predator and prey adaptations frequently evolve together over time in a process sometimes described as an evolutionary arms ________ .

4.1.3 Effects on population dynamics

Competition tends to limit population growth by restricting access to needed resources, often contributing to a population levelling off at a relatively stable size (its carrying capacity) once resource availability becomes limiting, rather than growing indefinitely; intense competition can also influence which species persist within a given community over time, particularly when two species compete very closely for an identical resource.

Predator and prey populations frequently display linked, sometimes cyclical fluctuations over time, since an increase in prey numbers can support increased predator numbers (more food available), while the resulting larger predator population then reduces prey numbers, which in turn later reduces predator numbers, illustrating the dynamic, interconnected nature of population sizes within an ecological community rather than each population varying independently.

Fill in the blank: Predator and prey populations frequently display linked, sometimes ________ fluctuations over time, since changes in one population affect the other in turn.

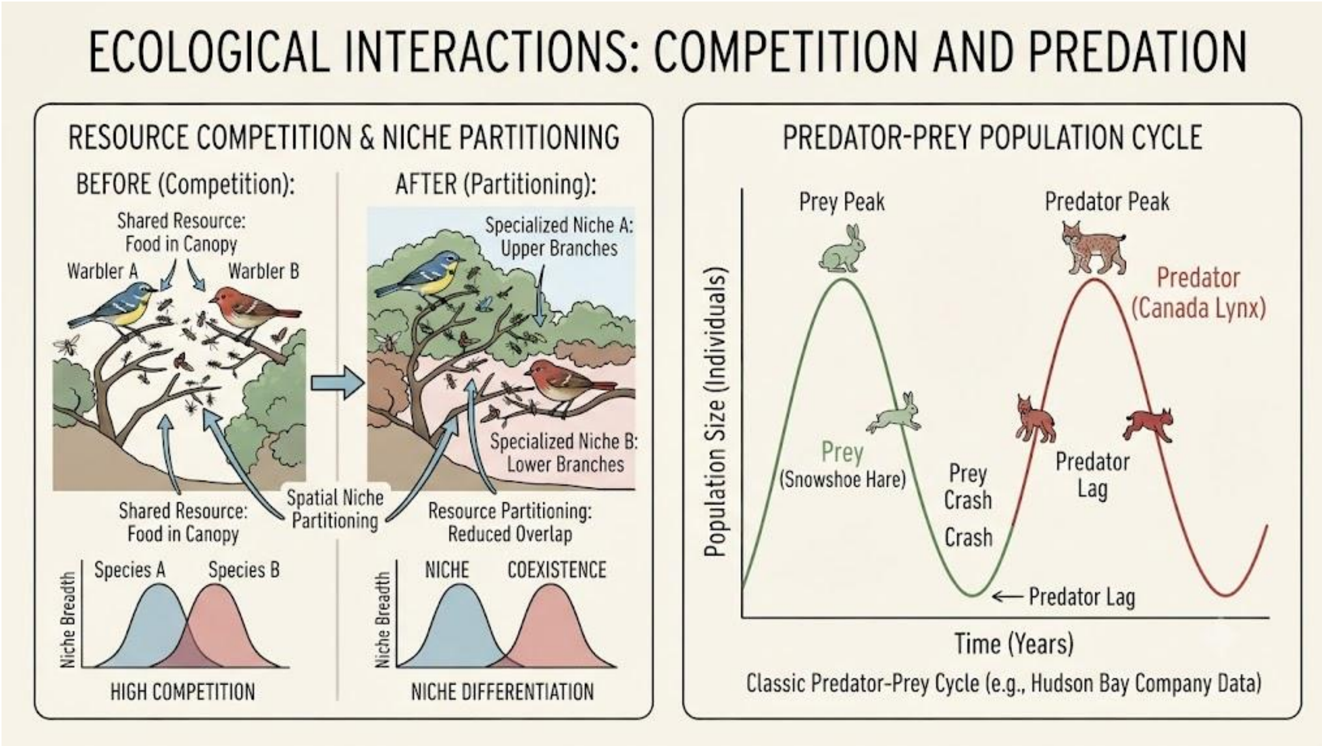

Figure 4.1: Competition and predation

Pilot questions 4.1

1. Define competition and distinguish intraspecific from interspecific competition.
2. Define resource partitioning.
3. Define predation.
4. Explain the concept of an evolutionary arms race between predator and prey.
5. Explain why predator and prey population sizes are often linked.

4.2 Parasitism and Disease

4.2.1 Defining parasitism

Parasitism is a relationship in which one organism, the parasite, lives on or within another organism, the host, obtaining nutrients from the host, typically to the host detriment; unlike predation, parasitism usually does not immediately kill the host, since a parasite generally benefits from a living host that continues to provide nutrients over an extended period, though severe or prolonged parasitic infection can still seriously harm or eventually kill the host.

Parasitism differs from the mutually beneficial symbiotic relationships examined later in this Series in that only the parasite benefits, while the host experiences a cost, ranging from relatively mild nutrient loss or irritation to more serious disease, reduced reproduction, or increased vulnerability to other threats such as predation.

Fill in the blank: Unlike predation, parasitism usually does not immediately kill the ________ , since a parasite generally benefits from a living host providing nutrients over an extended period.

4.2.2 Types of parasites

Ectoparasites live on the external surface of their host, such as ticks, fleas, and lice, generally feeding on host blood or skin and capable of moving relatively easily between hosts; endoparasites live within the host body, such as tapeworms and many disease-causing microorganisms, often having a more complex life cycle and a more intimate, less easily interrupted relationship with their host.

Parasites are also distinguished by host specificity, the degree to which a given parasite is restricted to one or a few host species rather than capable of infecting many different species; highly host-specific parasites have typically evolved a close, long-standing relationship with their particular host species, while less specific parasites can exploit a wider range of hosts, sometimes including humans alongside other animal species.

Fill in the blank: ________ live on the external surface of their host, such as ticks, fleas, and lice, distinguishing them from parasites living within the host body.

4.2.3 Host-parasite relationships

Host organisms have evolved various defences against parasites, including immune system responses (in animals), physical barriers, and behavioural strategies (such as grooming to remove ectoparasites), while parasites have correspondingly evolved mechanisms to evade or counter these host defences, again illustrating the evolutionary arms race dynamic also discussed for predator-prey relationships in this Series.

Over long periods of co-evolution, some host-parasite relationships can become less severely harmful to the host than they once were, since a parasite that kills its host too quickly or too often loses its own resource base, creating an evolutionary pressure, though not a guarantee, toward reduced parasite virulence over time in some, though certainly not all, host-parasite relationships.

Fill in the blank: A parasite that kills its host too quickly or too often loses its own ________ base, creating evolutionary pressure toward reduced harm in some host-parasite relationships over time.

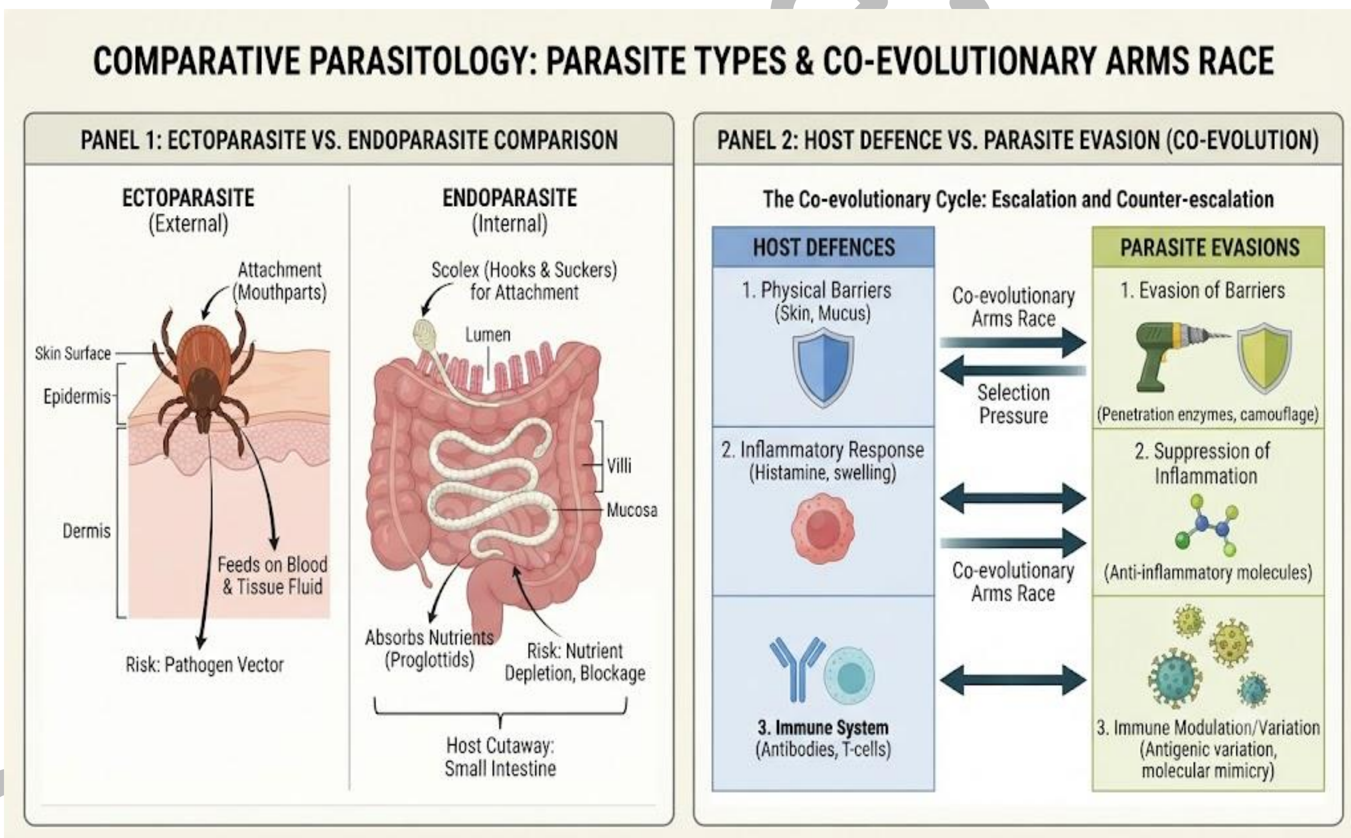

Figure 4.2: Parasitism and host-parasite relationships

Pilot questions 4.2

1. Define parasitism.

2. Distinguish between ectoparasites and endoparasites.
3. Define host specificity.
4. Name two host defences against parasites.
5. Explain why some host-parasite relationships may become less harmful over long periods of co-evolution.

4.3 Symbiotic Relationships

4.3.1 Mutualism

Mutualism is a symbiotic relationship in which both participating species benefit from the association; well-known examples include the relationship between certain flowering plants and their pollinators (the plant receives pollination service while the pollinator receives food in the form of nectar) and the relationship between certain bacteria and the digestive systems of many animals (the bacteria receive a stable habitat and food supply while the host receives assistance digesting otherwise difficult-to-process food material).

Mutualistic relationships often involve a degree of co-evolution between the participating species, sometimes resulting in close physical or biochemical adaptation specific to the partner species, such as flower shapes adapted to a specific pollinator species or root structures specifically adapted to host particular beneficial soil microorganisms.

Fill in the blank: Mutualism is a symbiotic relationship in which ________ participating species benefit from the association.

4.3.2 Commensalism

Commensalism is a symbiotic relationship in which one species benefits while the other experiences neither significant benefit nor significant harm; a frequently cited example involves certain birds that feed on insects disturbed by the movement of large grazing animals, with the bird benefiting from easier access to food while the grazing animal experiences little or no effect from the bird presence.

Distinguishing true commensalism from mild mutualism or mild parasitism can sometimes be difficult in practice, since the precise costs and benefits experienced by the apparently unaffected partner are not always easy to measure with certainty, meaning some relationships classified as commensal may, on closer or more sensitive measurement, eventually be found to involve a very slight cost or benefit not initially detected.

Fill in the blank: Commensalism is a symbiotic relationship in which one species benefits while the other experiences neither significant ________ nor significant harm.

4.3.3 Distinguishing symbiotic relationships

Symbiotic relationships can be distinguished by the costs and benefits experienced by each participating species: mutualism involves benefit to both species, commensalism involves benefit to one species and no significant effect on the other, and parasitism (already examined earlier in this Series) involves benefit to one species at a cost to the other; some biologists also separately discuss amensalism, in which one species is harmed while the other is unaffected.

In practice, the classification of a given relationship as mutualistic, commensal, or parasitic can sometimes shift depending on specific environmental conditions or the relative abundance of the species involved, since the same pair of interacting species might experience a more clearly mutualistic relationship under one set of conditions and a more neutral or even parasitic relationship under different conditions, illustrating that these categories, while useful, describe a continuum of possible interactions rather than entirely fixed, permanent relationship types.

Fill in the blank: The classification of a given relationship as mutualistic, commensal, or parasitic can sometimes shift depending on specific environmental conditions or the relative ________ of the species involved.

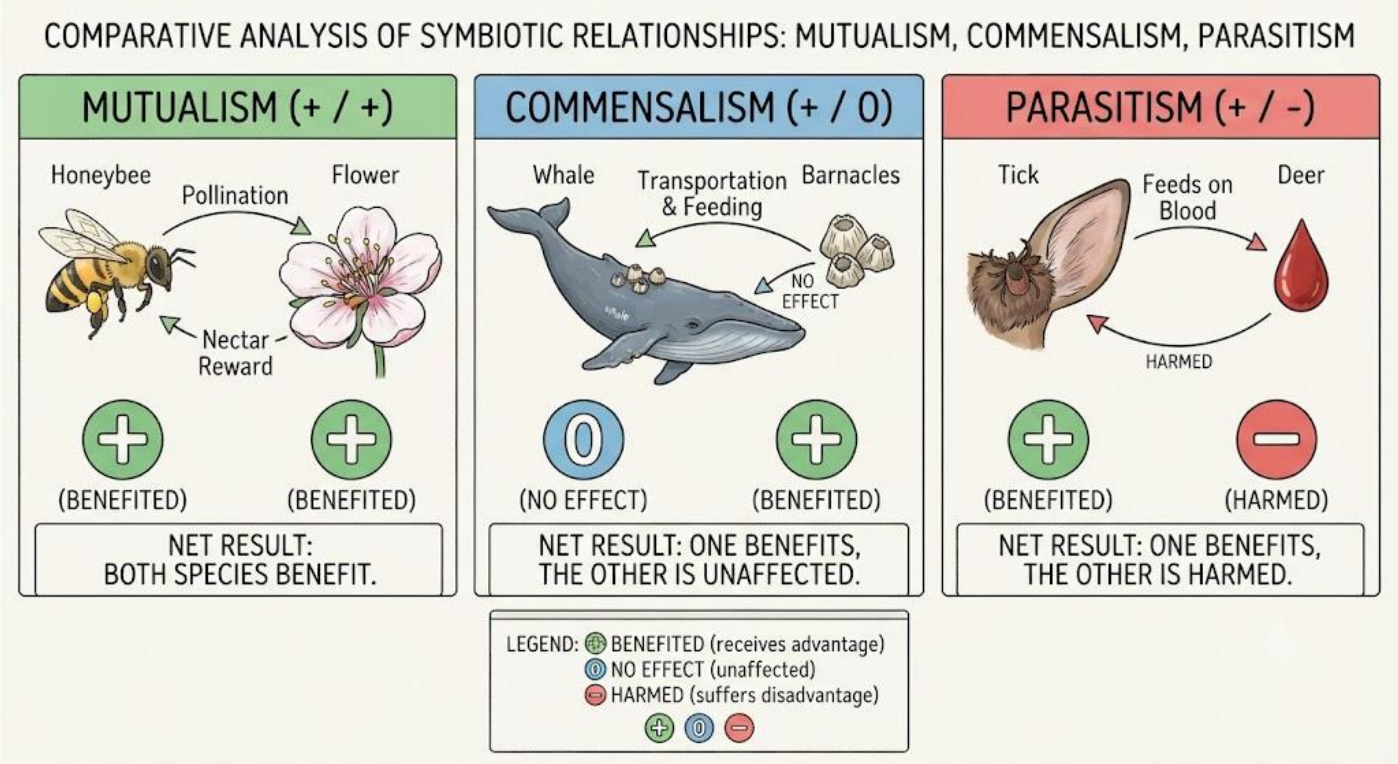

Figure 4.3: Symbiotic relationships compared

Pilot questions 4.3

1. Define mutualism and give one example.
2. Define commensalism and give one example.
3. Explain why distinguishing commensalism from mild mutualism or parasitism can be difficult.
4. Define amensalism.
5. Explain why symbiotic relationships are sometimes described as existing on a continuum rather than as entirely fixed categories.

4.4 Saprophytism and Decomposition

4.4.1 Defining saprophytism

Saprophytism (also called saprotrophy) is a mode of nutrition in which an organism obtains nutrients by breaking down and absorbing dissolved material from dead organic matter, rather than from a living host (as in parasitism) or by capturing living prey (as in predation); organisms relying on this nutritional mode are called saprophytes or saprotrophs.

Saprophytic organisms typically secrete digestive enzymes onto the dead organic material they are breaking down, then absorb the resulting simpler, dissolved nutrient molecules, a nutritional strategy well suited to organisms, such as fungi, that lack the capacity to ingest solid food internally in the manner of most animals.

Fill in the blank: Saprophytic organisms typically secrete digestive ________ onto dead organic material, then absorb the resulting simpler, dissolved nutrient molecules.

4.4.2 Organisms involved in decomposition

Fungi are among the most important decomposer organisms, capable of breaking down tough plant material, including wood and other materials resistant to decay by most other organisms, given their specialised enzymes; many bacteria are also significant decomposers, particularly effective at breaking down softer organic material and completing the decomposition process alongside fungi.

Various invertebrate animals, including earthworms and many insects, also contribute to decomposition, though generally through a combination of mechanical breakdown (physically fragmenting dead material into smaller pieces, increasing the surface area available for fungal and bacterial action) and their own digestion, rather than through the purely absorptive saprophytic nutrition characteristic of fungi and many decomposer bacteria specifically.

Fill in the blank: Invertebrate decomposers such as earthworms contribute to decomposition partly through mechanical ________ of dead material, increasing the surface area available for fungal and bacterial action.

4.4.3 Ecological significance of decomposition

Decomposition releases nutrients locked within dead organic matter back into the surrounding soil or water, making these nutrients available again for uptake by living plants and, through them, the wider food chain; without decomposition, nutrients would remain permanently locked within accumulating dead organic material, eventually depleting the nutrient supply available to support new plant growth.

Decomposers therefore perform an essential ecological recycling function, completing the cycle of matter through an ecosystem and preventing the accumulation of dead organic material that would otherwise occur indefinitely; this decomposer function complements the roles played by producers (organisms that capture energy, typically through photosynthesis) and consumers (organisms that obtain energy by eating other organisms) within a functioning ecosystem.

Fill in the blank: Decomposers perform an essential ecological ________ function, releasing nutrients locked in dead organic matter back into the soil or water for renewed use by living organisms.

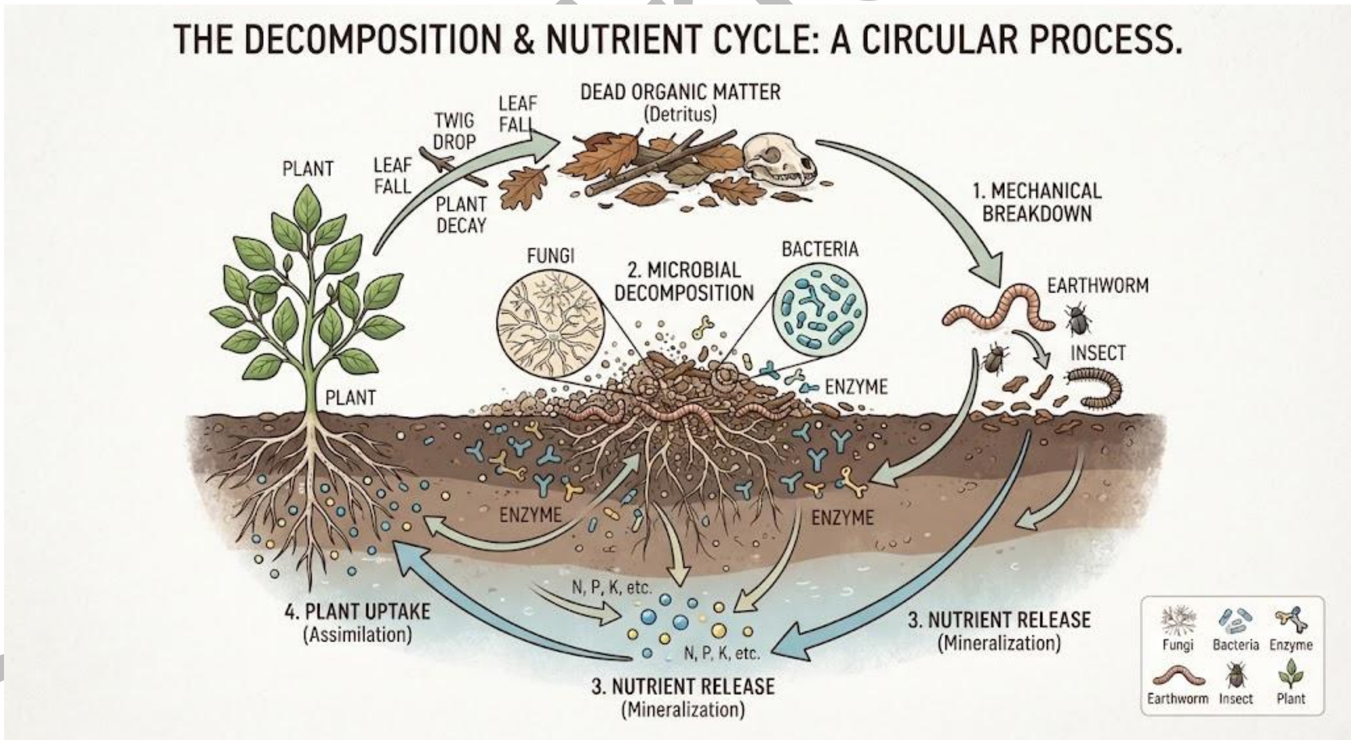

Figure 4.4: Saprophytism and the decomposition cycle

Pilot questions 4.4

1. Define saprophytism.

2. Explain how saprophytic organisms obtain nutrients from dead organic matter.
3. Name two types of organisms that act as decomposers.
4. Explain the contribution of earthworms and insects to decomposition.
5. Explain the ecological significance of decomposition for nutrient availability.

Series Summary

This Series examined **ecological interactions among organisms and their effects on populations and ecosystems**. **Competition** occurs within a species (**intraspecific**) or between different species (**interspecific**) for limited resources, with **resource partitioning** helping to reduce competition. **Predation** involves one organism feeding on another and is accompanied by predator and prey adaptations that influence population size and may produce cyclical population fluctuations. The Series also covered **parasitism**, where parasites benefit at the expense of their hosts, distinguishing between **ectoparasites** and **endoparasites**, and explaining host specificity, host defence mechanisms, parasite evasion strategies, and the potential for reduced virulence through co-evolution.

The Series also covered **symbiotic relationships and decomposition**. **Mutualism** benefits both organisms, while **commensalism** benefits one organism without affecting the other, and both exist on a continuum with parasitism and amensalism. **Saprophytism** is the mode of nutrition in which organisms absorb dissolved nutrients from dead organic matter, with **fungi and bacteria** serving as the primary decomposers and organisms such as **earthworms and insects** contributing to the physical breakdown of organic materials. These processes are essential for **nutrient recycling** and maintaining ecosystem productivity. By completing this Series, students should achieve SLOs **4.1–4.4**.

Glossary of Terms

- **Commensalism:** a symbiotic relationship in which one species benefits while the other is largely unaffected.
- **Ectoparasite:** a parasite that lives on the external surface of its host.
- **Endoparasite:** a parasite that lives within the body of its host.
- **Mutualism:** a symbiotic relationship in which both participating species benefit.
- **Parasitism:** a relationship in which one organism obtains nutrients from a host, typically to the host detriment.

- **Resource partitioning:** the use of slightly different parts of a shared resource by competing species, reducing competition intensity.
- **Saprophyte:** an organism that obtains nutrients by breaking down and absorbing material from dead organic matter.

Concept Check Questions [Series 4]

Objective Questions

1. Competition between individuals of different species is called ________ competition. (Linked to SLO 4.1)
2. Unlike predation, parasitism usually does not immediately kill the ________ . (Linked to SLO 4.2)
3. Mutualism is a symbiotic relationship in which ________ participating species benefit. (Linked to SLO 4.3)
4. Saprophytic organisms secrete digestive ________ onto dead organic matter before absorbing nutrients. (Linked to SLO 4.4)
5. ________ live on the external surface of their host, distinguishing them from endoparasites. (Linked to SLO 4.2)

Short-Answer Questions

1. Distinguish intraspecific from interspecific competition. (Linked to SLO 4.1)
2. Define parasitism and distinguish ectoparasites from endoparasites. (Linked to SLO 4.2)
3. Distinguish mutualism from commensalism. (Linked to SLO 4.3)
4. Define saprophytism and name two decomposer organism groups. (Linked to SLO 4.4)
5. Explain why predator and prey populations often show linked fluctuations. (Linked to SLO 4.1)

Long-Answer Questions

1. Describe competition and predation and their effects on population dynamics. (Linked to SLO 4.1)
2. Explain parasitism, types of parasites, and host-parasite relationships. (Linked to SLO 4.2)
3. Distinguish symbiotic relationships and explain saprophytism and decomposition. (Linked to SLOs 4.3, 4.4)

Answers to Concept Check Questions [Series 4]

Objective Questions

1. Interspecific.
2. Host.
3. Both.
4. Enzymes.
5. Ectoparasites.

Short-Answer Questions

1. Intraspecific competition is within a species; interspecific competition is between different species.
2. Parasitism is obtaining nutrients from a host at its cost; ectoparasites live on the host surface, endoparasites live within the host.
3. Mutualism benefits both species; commensalism benefits one species while the other is largely unaffected.
4. Saprophytism is nutrition by absorbing material from dead organic matter; fungi and bacteria are key decomposers.
5. Changes in prey numbers affect food availability for predators, and resulting predator number changes then affect prey numbers in turn.

Long-Answer Questions

1. Competition (intraspecific and interspecific) limits resource access and population growth, sometimes resolved through resource partitioning. Predation shapes predator and prey adaptations and produces linked, sometimes cyclical population fluctuations.
2. Parasitism benefits the parasite at the host cost, with ectoparasites living externally and endoparasites internally. Host defences and parasite evasion mechanisms co-evolve, sometimes reducing harm over time.
3. Mutualism, commensalism, and parasitism differ in costs and benefits to each species, existing on a continuum. Saprophytism, carried out mainly by fungi and bacteria, decomposes dead matter and recycles nutrients essential to ecosystem function.

Answers to Pilot Questions [Series 4]

Part 4.1

1. Competition is when organisms require the same limited resource; intraspecific is within a species, interspecific is between species.
2. Resource partitioning is competing species coming to use slightly different parts of a shared resource.
3. Predation is one organism killing and consuming another for nutrition.
4. Predator and prey adaptations evolve together over time, each improvement prompting a corresponding counter-adaptation.
5. Changes in one population affect food or pressure on the other, creating linked, sometimes cyclical fluctuations.

Part 4.2

1. Parasitism is a relationship where a parasite obtains nutrients from a host, typically to the host detriment.
2. Ectoparasites live on the host external surface; endoparasites live within the host body.
3. Host specificity is the degree to which a parasite is restricted to one or a few host species.
4. Immune response and grooming behaviour.
5. A parasite that kills its host too often loses its resource base, favouring reduced harm over time.

Part 4.3

1. Mutualism benefits both species; example: flowering plants and their pollinators.
2. Commensalism benefits one species while the other is largely unaffected; example: birds feeding near grazing animals.
3. The precise costs and benefits to the apparently unaffected partner are not always easy to measure with certainty.
4. Amensalism is a relationship where one species is harmed while the other is unaffected.
5. The same relationship can shift between categories depending on conditions or relative abundance of the species involved.

Part 4.4

1. Saprophytism is nutrition by breaking down and absorbing material from dead organic matter.
2. They secrete digestive enzymes onto the material, then absorb the resulting dissolved nutrients.
3. Fungi and bacteria.
4. They mechanically fragment dead material, increasing surface area for fungal and bacterial action.
5. Decomposition releases locked nutrients back into the soil or water for renewed use by living organisms.

References and Attribution

Textual References (Books and External Sources)

- Campbell, N. A., & Reece, J. B. (2018). Biology (11th ed.). Pearson.
- Odum, E. P., & Barrett, G. W. (2005). Fundamentals of ecology (5th ed.). Brooks/Cole.
- Raven, P. H., Johnson, G. B., Mason, K. A., Losos, J. B., & Singer, S. R. (2017). Biology (11th ed.). McGraw-Hill Education.
- National Open University of Nigeria (NOUN). (2023). General biology course material. NOUN Press.

Figures, Plates, Tables, and Boxes

- Figure 4.1: Competition and predation Attribution: AI generated. Suggested OER search string: "competition predation population dynamics predator prey cycle diagram biology OER".
- Figure 4.2: Parasitism and host-parasite relationships Attribution: AI generated. Suggested OER search string: "parasitism ectoparasite endoparasite host parasite relationship diagram biology OER".
- Figure 4.3: Symbiotic relationships compared Attribution: AI generated. Suggested OER search string: "mutualism commensalism parasitism symbiosis comparison diagram biology OER".
- Figure 4.4: Saprophytism and the decomposition cycle Attribution: AI generated. Suggested OER search string: "saprophytism decomposition nutrient cycle fungi bacteria diagram biology OER".

Course code: BIO 101

Course title: General Biology I

Course credit load: 2 Units

Series 5: Heredity, Evolution, and Ecology

- **Part 5.1: Foundations of Heredity**
  - Sub Part 5.1.1: Key genetic terms
  - Sub Part 5.1.2: Mendelian inheritance
  - Sub Part 5.1.3: Patterns beyond simple dominance
- **Part 5.2: Theories of Evolution**
  - Sub Part 5.2.1: Lamarckian theory
  - Sub Part 5.2.2: Darwinian theory
  - Sub Part 5.2.3: Evidence supporting evolution
- **Part 5.3: Elements of Ecology**
  - Sub Part 5.3.1: Ecological terms and concepts
  - Sub Part 5.3.2: Food chains and food webs
  - Sub Part 5.3.3: Energy flow and nutrient cycling
- **Part 5.4: Habitat Types and Their Characteristics**
  - Sub Part 5.4.1: Terrestrial habitats
  - Sub Part 5.4.2: Aquatic habitats
  - Sub Part 5.4.3: Habitat characteristics and adaptation

Introduction

This final Series of the course addresses three closely connected topics: heredity, the mechanism by which characteristics pass from parent to offspring; evolution, the process by which populations of organisms change over generations; and ecology, the study of how organisms interact with one another and their physical environment, including the variety of habitats organisms occupy.

This Series covers key genetic terms and Mendelian inheritance patterns; the Lamarckian and Darwinian theories of evolution and supporting evidence; fundamental ecological concepts, food relationships, and energy/nutrient flow; and the major terrestrial and aquatic habitat types together with the concept of adaptation to habitat conditions.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** explain key genetic terms and Mendelian inheritance patterns,
- **SLO 5.2** distinguish Lamarckian and Darwinian theories of evolution and describe supporting evidence,
- **SLO 5.3** explain fundamental ecological concepts, food relationships, and energy/nutrient flow, and
- **SLO 5.4** describe major habitat types and the concept of adaptation.

5.1 Foundations of Heredity

5.1.1 Key genetic terms

A genotype is the specific genetic makeup of an organism for a given trait, while a phenotype is the observable physical or biochemical expression of that genetic makeup, often influenced by both genotype and environmental factors; an allele is a particular version of a gene, with an organism described as homozygous when it carries two identical alleles for a given gene and heterozygous when it carries two different alleles.

A dominant allele is one whose effect is expressed in the phenotype whenever present, even alongside a different allele, while a recessive allele is one whose effect is only expressed in the phenotype when present in two copies (homozygous), since a single dominant allele alongside it would mask the recessive allele effect; these foundational terms underlie the inheritance patterns examined in the remainder of this Part.

Fill in the blank: A genotype is the specific genetic makeup of an organism for a given trait, while a ________ is the observable physical or biochemical expression of that genetic makeup.

5.1.2 Mendelian inheritance

Gregor Mendel, through careful breeding experiments with pea plants, established the foundational laws of inheritance: the law of segregation (each parent contributes one of two alleles for a given gene to each offspring, with the two alleles separating during gamete formation) and the law of independent assortment (alleles for different genes are typically inherited independently of one another, assuming the genes are located on different chromosomes or are far apart on the same chromosome).

A simple cross between two heterozygous parents for a single gene typically produces offspring in a predictable ratio (commonly three individuals showing the dominant phenotype to one individual showing the recessive phenotype), a pattern that can be predicted and visualised using a Punnett square, a simple grid tool showing all possible allele combinations resulting from a given cross.

Fill in the blank: The law of ________ states that each parent contributes one of two alleles for a given gene to each offspring, with the two alleles separating during gamete formation.

5.1.3 Patterns beyond simple dominance

Not all inheritance follows the simple complete dominance pattern described by Mendel original experiments; incomplete dominance occurs when a heterozygous individual displays a phenotype intermediate between the two homozygous phenotypes (such as a flower colour blending the colours of its two parent varieties), while codominance occurs when both alleles are fully and separately expressed in the phenotype (such as certain blood type patterns in which both alleles are detectable).

Many traits are also influenced by multiple genes acting together (polygenic inheritance), producing a more continuous range of phenotypes (such as human height) rather than the few discrete categories typical of simple single-gene traits, illustrating that real-world inheritance patterns are often considerably more complex than the foundational single-gene patterns first described by Mendel, even though those foundational patterns remain essential for understanding the underlying principles.

Fill in the blank: ________ inheritance occurs when multiple genes acting together influence a single trait, producing a more continuous range of phenotypes rather than a few discrete categories.

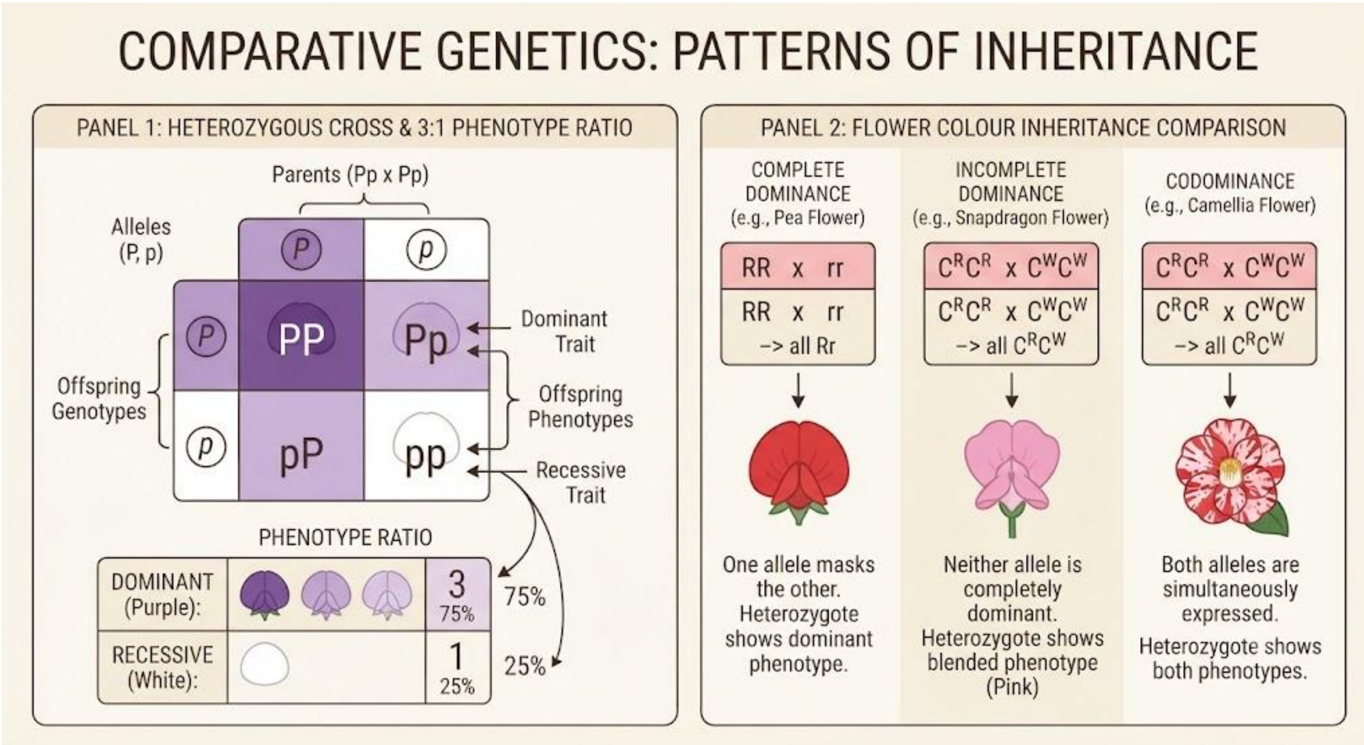

Figure 5.1: Heredity and inheritance patterns

Pilot questions 5.1

1. Distinguish between genotype and phenotype.
2. Distinguish between homozygous and heterozygous.
3. State the law of segregation.
4. Distinguish between incomplete dominance and codominance.
5. Define polygenic inheritance.

5.2 Theories of Evolution

5.2.1 Lamarckian theory

Jean-Baptiste Lamarck proposed an early theory of evolution centred on the inheritance of acquired characteristics, suggesting that traits an organism develops or modifies during its own lifetime in response to its environment (such as a muscle strengthened through repeated use) could be passed directly to its offspring, gradually transforming a population over successive generations.

While Lamarck theory was an important early step toward recognising that species change over time, the specific mechanism he proposed, direct inheritance of acquired characteristics, has not been supported by subsequent genetic evidence, since modifications acquired during an individual lifetime generally do not alter that individual underlying hereditary genetic material in a way that could be passed to offspring through reproduction.

Fill in the blank: Lamarck theory centred on the inheritance of ________ characteristics, traits developed during an organism own lifetime being passed directly to its offspring.

5.2.2 Darwinian theory

Charles Darwin proposed natural selection as the primary mechanism driving evolutionary change, based on several observations: individuals within a population display variation in their characteristics, some of this variation is heritable, individuals with characteristics better suited to their environment tend to survive and reproduce more successfully than less well-suited individuals, and, over many generations, this differential survival and reproduction gradually shifts the characteristics typical of the population.

Unlike Lamarck mechanism, natural selection does not require an individual organism to actively modify its own characteristics; instead, existing heritable variation within a population, already present before any environmental challenge arises, is acted upon by the environment, with favourable variants becoming more common over generations purely through their relatively greater reproductive success rather than through any direct, intentional modification.

Fill in the blank: Darwin proposed ________ selection as the primary mechanism driving evolutionary change, acting on existing heritable variation within a population.

5.2.3 Evidence supporting evolution

Multiple independent lines of evidence support evolutionary theory: the fossil record documents change in organism form over geological time and reveals transitional forms connecting major groups; comparative anatomy reveals homologous structures (structures with a similar underlying form but different function across related species, such as the forelimbs of different vertebrate groups) suggesting common ancestry; and molecular biology reveals genetic similarities between species that closely match the relationships predicted by anatomical and fossil evidence.

Direct observation of evolutionary change occurring over relatively short, observable timescales, such as antibiotic resistance developing in bacterial populations or pesticide resistance developing in insect populations under selective pressure, provides additional, directly observable confirmation of natural selection acting in real time, complementing the historical evidence drawn from the fossil record and comparative biology.

Fill in the blank: ________ structures are structures with a similar underlying form but different function across related species, providing comparative anatomical evidence for common ancestry.

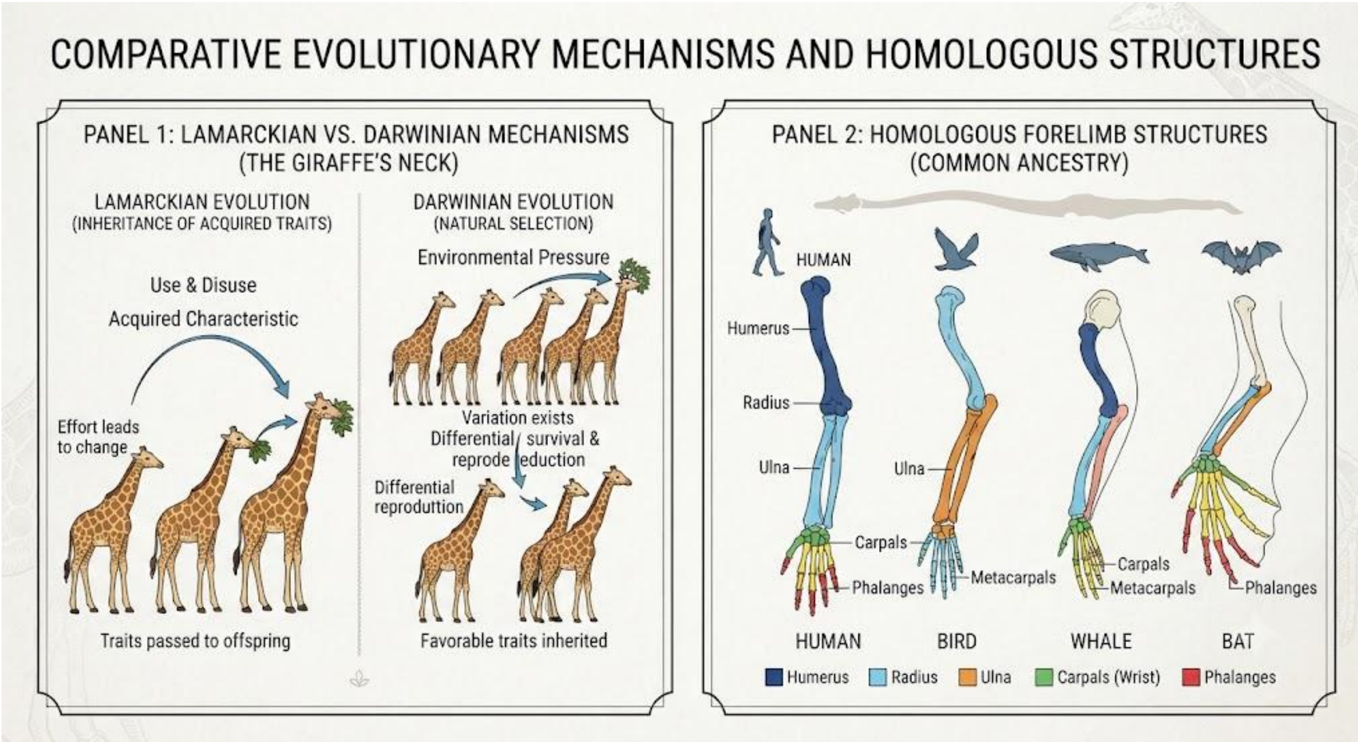

Figure 5.2: Theories and evidence of evolution

Pilot questions 5.2

1. State the core idea of Lamarck theory of evolution.
2. Explain why Lamarck mechanism has not been supported by genetic evidence.
3. State the core mechanism Darwin proposed for evolutionary change.
4. Define homologous structure and give one example.
5. Name one example of evolutionary change observed over a short, directly observable timescale.

5.3 Elements of Ecology

5.3.1 Ecological terms and concepts

A population is a group of individuals of the same species living in a given area at a given time; a community is the collection of all populations of different species living and interacting within that area; and an ecosystem encompasses a community together with the non-living physical environment (soil, water, climate) with which it interacts, the basic unit ecologists generally study.

A habitat is the specific physical environment in which a species normally lives, providing the food, water, shelter, and space it requires, while a niche is a species particular functional role within its ecosystem, including its specific habitat use, feeding behaviour, and interactions with other species, distinguishing where a species lives from what it actually does there.

Fill in the blank: A ________ is a species particular functional role within its ecosystem, including its habitat use, feeding behaviour, and interactions with other species.

5.3.2 Food chains and food webs

A food chain is a simple, linear sequence showing the transfer of energy from one organism to another, typically beginning with a producer (an organism, usually a plant, that captures energy directly, generally through photosynthesis), proceeding through one or more consumers (organisms obtaining energy by eating other organisms, classified as primary, secondary, and further consumers based on their position in the chain), and often ending with decomposers, which break down dead organic matter.

A food web is a more realistic, interconnected representation of feeding relationships within an ecosystem, showing the numerous overlapping food chains that actually exist, since most consumers eat more than one type of food and are, in turn, eaten by more than one type of predator, making the food web a considerably more accurate depiction of real ecosystem feeding relationships than any single, isolated food chain alone.

Fill in the blank: A food ________ is a more realistic, interconnected representation of feeding relationships within an ecosystem than a single food chain, showing numerous overlapping pathways.

5.3.3 Energy flow and nutrient cycling

Energy enters most ecosystems as sunlight, captured by producers and converted into chemical energy through photosynthesis; this energy then flows through the food chain or web in one direction only, with a substantial proportion (commonly estimated at around 90 percent) lost as heat at each transfer between feeding levels, explaining why ecosystems generally support progressively fewer organisms at each successively higher feeding level.

Unlike energy, chemical nutrients (such as carbon, nitrogen, and phosphorus) cycle repeatedly through an ecosystem rather than flowing in a single direction, moving between living organisms and the non-living environment through processes including photosynthesis, consumption, and decomposition, with decomposers playing an essential role in releasing nutrients from dead organic matter back into a form usable by producers once again.

Fill in the blank: Energy flows through an ecosystem in one direction only, with a substantial proportion, commonly estimated at around ________ percent, lost as heat at each transfer between feeding levels.

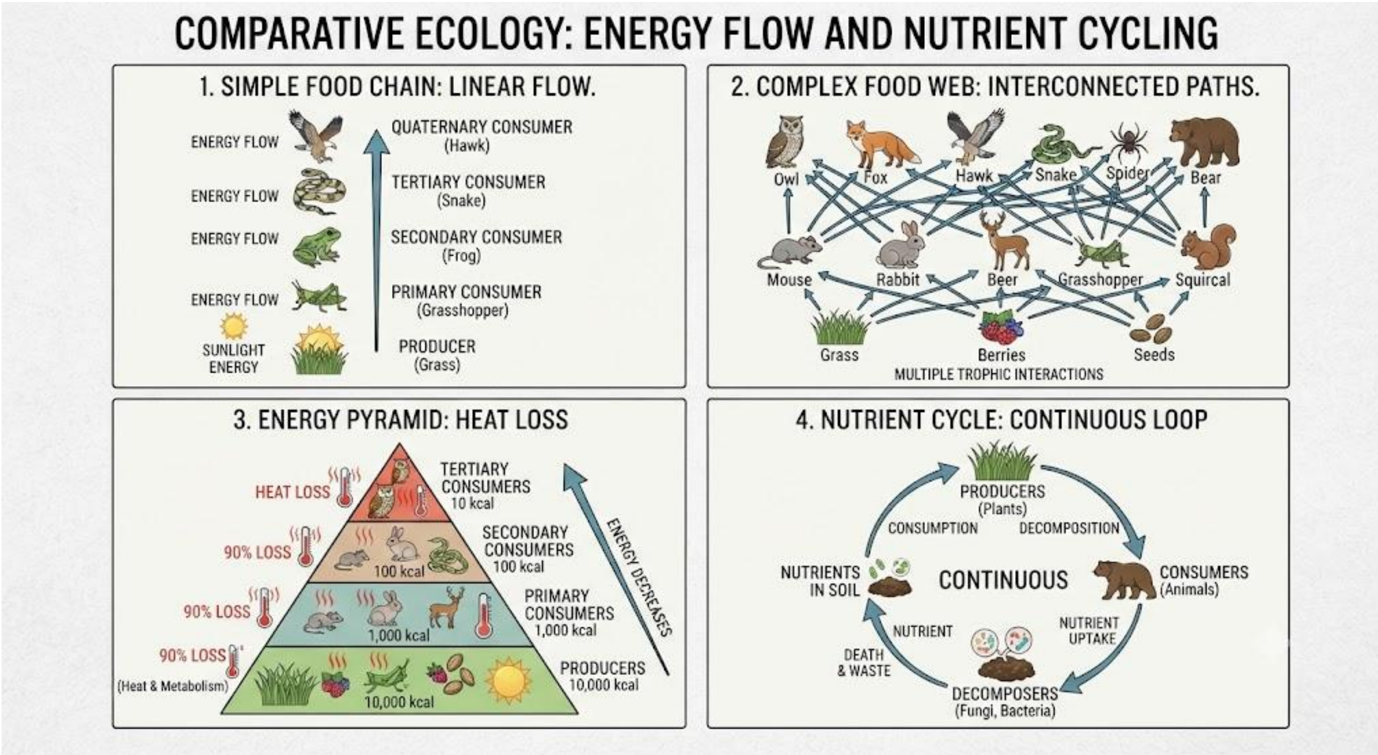

Figure 5.3: Ecological concepts, food relationships, and energy flow

Pilot questions 5.3

1. Distinguish between population, community, and ecosystem.
2. Distinguish between habitat and niche.
3. Distinguish between a food chain and a food web.
4. Explain why ecosystems support progressively fewer organisms at higher feeding levels.
5. Explain why nutrients cycle while energy flows in one direction through an ecosystem.

5.4 Habitat Types and Their Characteristics

5.4.1 Terrestrial habitats

Terrestrial habitats occur on land and vary considerably in their characteristic vegetation, climate, and resident species: forest habitats (characterised by dense tree cover and generally higher, more reliable rainfall) support a different community of organisms than grassland/savanna habitats (characterised by grass-dominated vegetation with scattered trees and a more pronounced seasonal rainfall pattern), while desert habitats (characterised by very low rainfall and often extreme temperature variation) support organisms specifically adapted to scarce water availability.

Each terrestrial habitat type presents a distinctive combination of environmental conditions (temperature range, rainfall amount and seasonality, soil type, and available shelter) that determines which species can successfully survive and reproduce there, with closely related habitat types sometimes grading gradually into one another across a landscape rather than always displaying a sharp, easily defined boundary.

Fill in the blank: Desert habitats are characterised by very low rainfall and often extreme temperature variation, supporting organisms specifically adapted to scarce ________ availability.

5.4.2 Aquatic habitats

Aquatic habitats occur in water and are broadly divided into freshwater habitats (rivers, lakes, and ponds, generally with low dissolved salt content) and marine habitats (oceans and seas, with substantially higher dissolved salt content), each presenting distinct physical and chemical conditions, including water movement, light penetration with depth, and salt concentration, that shape which organisms can live there.

Estuarine habitats, occurring where freshwater rivers meet the sea, present an intermediate, often fluctuating salt concentration that supports a distinctive community of organisms specifically adapted to tolerate this variable condition, illustrating that aquatic habitats, like terrestrial ones, do not always fall neatly into entirely separate, sharply bounded categories.

Fill in the blank: ________ habitats occur where freshwater rivers meet the sea, presenting an intermediate, often fluctuating salt concentration supporting specifically adapted organisms.

5.4.3 Habitat characteristics and adaptation

Organisms occupying a given habitat typically display adaptations, inherited characteristics that improve their ability to survive and reproduce under the specific conditions of that habitat, such as water-conserving features in desert organisms, streamlined body shapes in actively swimming aquatic organisms, or broad, light-capturing leaves in forest understory plants adapted to limited light availability beneath a dense canopy.

These habitat-specific adaptations arise through the same process of natural selection examined earlier in this Series, with organisms whose inherited characteristics better suit their particular habitat conditions tending to survive and reproduce more successfully than less well-suited individuals, gradually shaping each species toward a closer fit with the specific demands of the habitat it occupies over many generations.

Fill in the blank: Habitat-specific adaptations arise through the process of ________ selection, with better-suited individuals tending to survive and reproduce more successfully over many generations.

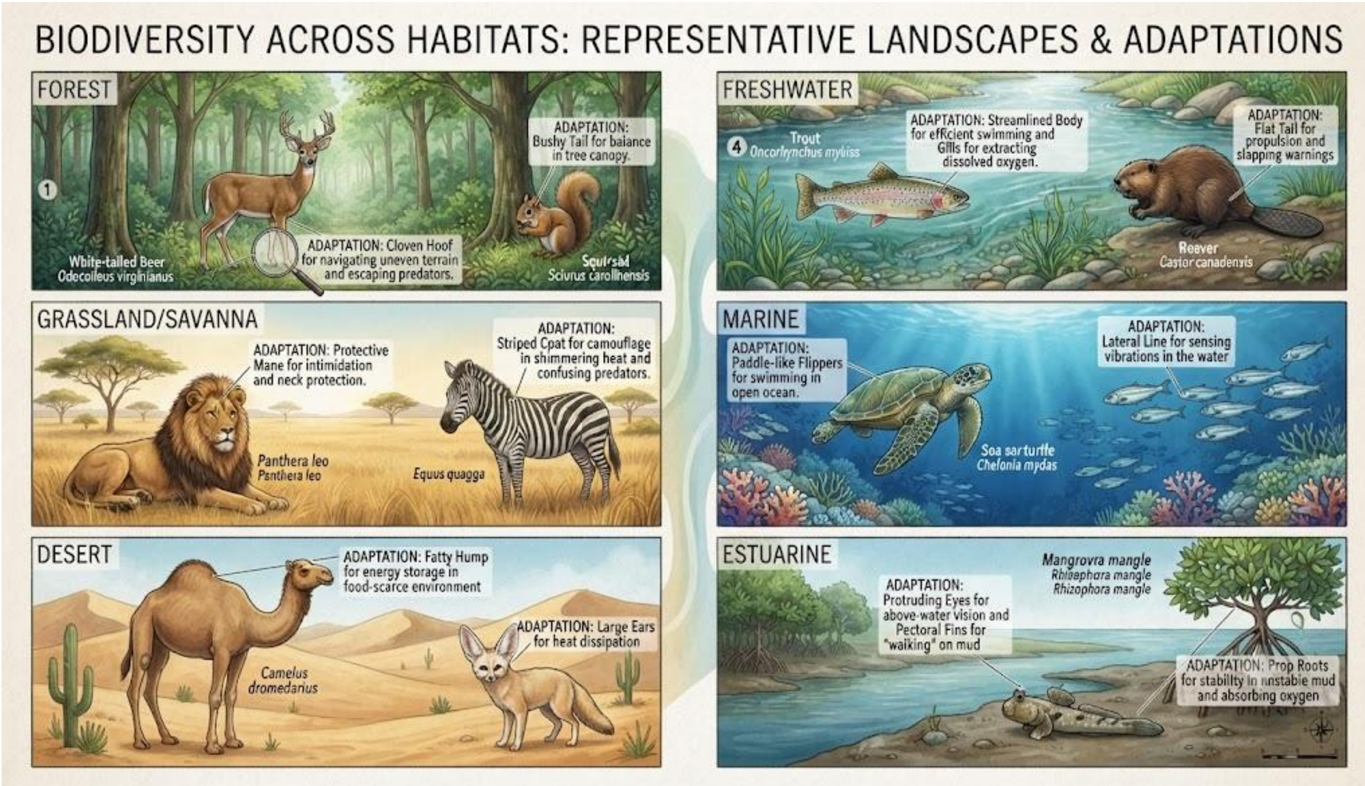

Figure 5.4: Habitat types and adaptation

Pilot questions 5.4

1. Name three terrestrial habitat types.
2. Distinguish between freshwater and marine habitats.
3. Define estuarine habitat.
4. Define adaptation in an ecological context.
5. Explain how natural selection produces habitat-specific adaptations over time.

Series Summary

This Series examined **heredity, evolution, and ecological principles**. In heredity, it covered the concepts of **genotype, phenotype, alleles, dominance, and recessiveness**, together with **Mendel's laws of segregation and independent assortment**, and the use of **Punnett squares** to predict inheritance patterns. It also introduced **incomplete dominance, codominance, and polygenic inheritance** as extensions of simple Mendelian genetics. The Series compared **Lamarck's theory** of inheritance of acquired characteristics, which is not supported by modern genetic evidence, with **Darwin's theory of natural selection**, which explains evolution through the selection of existing heritable variation. Evidence supporting evolution includes **fossil records, comparative anatomy, molecular biology, and direct observations** of evolutionary change.

The Series also explored **ecological organisation and habitat relationships**. Key ecological concepts included **population, community, ecosystem, habitat, and niche**, together with **food chains and food webs** that illustrate the transfer of energy through ecosystems. It emphasised that **energy flows in one direction**, with losses at each trophic level, whereas **nutrients are continuously recycled** through ecosystems. Major habitat types include **terrestrial habitats** (forests, grasslands, and deserts) and **aquatic habitats** (freshwater, marine, and estuarine environments), with organisms developing **habitat-specific adaptations through natural selection**. By completing this Series, students should achieve all SLOs and the overall course outcomes.

Glossary of Terms

- **Adaptation:** an inherited characteristic that improves an organism ability to survive and reproduce in its habitat.
- **Allele:** a particular version of a gene.
- **Genotype:** the specific genetic makeup of an organism for a given trait.

- **Natural selection:** the process by which individuals with favourable heritable characteristics survive and reproduce more successfully, gradually changing a population.
- **Niche:** a species particular functional role within its ecosystem.
- **Phenotype:** the observable physical or biochemical expression of an organism genotype.
- **Population:** a group of individuals of the same species living in a given area at a given time.

Concept Check Questions [Series 5]

Objective Questions

1. A ________ is the observable physical or biochemical expression of a genotype. (Linked to SLO 5.1)
2. Lamarck theory centred on the inheritance of ________ characteristics. (Linked to SLO 5.2)
3. Darwin proposed ________ selection as the primary mechanism of evolutionary change. (Linked to SLO 5.2)
4. A food ________ shows the more realistic, interconnected feeding relationships within an ecosystem. (Linked to SLO 5.3)
5. ________ habitats occur where freshwater rivers meet the sea. (Linked to SLO 5.4)

Short-Answer Questions

1. Distinguish between genotype and phenotype. (Linked to SLO 5.1)
2. State the core mechanism Darwin proposed for evolution. (Linked to SLO 5.2)
3. Distinguish between a food chain and a food web. (Linked to SLO 5.3)
4. Name three terrestrial habitat types. (Linked to SLO 5.4)
5. Define homologous structure. (Linked to SLO 5.2)

Long-Answer Questions

1. Explain key genetic terms and Mendelian inheritance patterns. (Linked to SLO 5.1)
2. Distinguish Lamarckian and Darwinian evolution and describe supporting evidence. (Linked to SLO 5.2)
3. Explain ecological concepts, food relationships, energy flow, and habitat types. (Linked to SLOs 5.3, 5.4)

Answers to Concept Check Questions [Series 5]

Objective Questions

1. Phenotype.
2. Acquired.
3. Natural.
4. Web.
5. Estuarine.

Short-Answer Questions

1. Genotype is genetic makeup; phenotype is its observable expression.
2. Natural selection: heritable variation acted on by the environment, with better-suited individuals reproducing more successfully.
3. A food chain is a simple linear sequence; a food web shows the more realistic, interconnected feeding relationships.
4. Forest, grassland/savanna, and desert.
5. A homologous structure is a structure with similar underlying form but different function across related species.

Long-Answer Questions

1. Genotype, phenotype, and alleles underlie inheritance. Mendel laws of segregation and independent assortment, visualised with Punnett squares, explain predictable ratios, while incomplete dominance, codominance, and polygenic inheritance extend beyond simple dominance.
2. Lamarck proposed inheritance of acquired characteristics, unsupported by genetic evidence. Darwin proposed natural selection acting on existing heritable variation, supported by fossils, comparative anatomy, molecular evidence, and direct observation of change.
3. Ecology examines populations, communities, ecosystems, habitats, and niches, linked through food chains/webs with one-directional energy flow and cycling nutrients. Terrestrial and aquatic habitats present distinct conditions producing habitat-specific adaptations through natural selection.

Answers to Pilot Questions [Series 5]

Part 5.1

1. Genotype is genetic makeup; phenotype is its observable expression.
2. Homozygous means two identical alleles; heterozygous means two different alleles.
3. Each parent contributes one of two alleles to each offspring, with the alleles separating during gamete formation.
4. Incomplete dominance produces a blended intermediate phenotype; codominance expresses both alleles separately.
5. Polygenic inheritance is when multiple genes together influence a single trait, producing a continuous range of phenotypes.

Part 5.2

1. Traits developed during an organism lifetime could be passed directly to its offspring.
2. Acquired modifications generally do not alter the underlying hereditary genetic material passed to offspring.
3. Natural selection acting on existing heritable variation, with better-suited individuals reproducing more successfully.
4. A homologous structure has similar underlying form but different function across related species; example: vertebrate forelimbs.
5. Antibiotic resistance in bacteria (or pesticide resistance in insects).

Part 5.3

1. A population is one species in an area; a community is multiple species populations; an ecosystem adds the physical environment.
2. Habitat is where a species lives; niche is its functional role within the ecosystem.
3. A food chain is a single linear sequence; a food web shows multiple interconnected, overlapping pathways.
4. A substantial proportion of energy is lost as heat at each transfer between feeding levels.
5. Energy is used up and lost as heat, while nutrients are not destroyed and can be reused repeatedly.

Part 5.4

1. Forest, grassland/savanna, and desert.
2. Freshwater habitats have low dissolved salt content; marine habitats have substantially higher salt content.
3. An estuarine habitat is where freshwater rivers meet the sea, with intermediate, fluctuating salt concentration.
4. Adaptation is an inherited characteristic improving survival and reproduction in a given habitat.
5. Better-suited individuals survive and reproduce more successfully, gradually shifting the population toward a closer habitat fit over generations.

References and Attribution

Textual References (Books and External Sources)

- Campbell, N. A., & Reece, J. B. (2018). Biology (11th ed.). Pearson.
- Mayr, E. (2001). What evolution is. Basic Books.
- Odum, E. P., & Barrett, G. W. (2005). Fundamentals of ecology (5th ed.). Brooks/Cole.
- National Open University of Nigeria (NOUN). (2023). General biology course material. NOUN Press.

Figures, Plates, Tables, and Boxes

- Figure 5.1: Heredity and inheritance patterns Attribution: AI generated. Suggested OER search string: "Punnett square Mendelian inheritance dominance codominance diagram biology OER".
- Figure 5.2: Theories and evidence of evolution Attribution: AI generated. Suggested OER search string: "Lamarck Darwin natural selection evolution homologous structures diagram biology OER".
- Figure 5.3: Ecological concepts, food relationships, and energy flow Attribution: AI generated. Suggested OER search string: "food chain food web energy flow pyramid nutrient cycle diagram ecology OER".
- Figure 5.4: Habitat types and adaptation Attribution: AI generated. Suggested OER search string: "terrestrial aquatic habitat types adaptation forest desert marine diagram ecology OER".