HISTOLOGY

1. (a) Describe the structure and distribution of the following tissues.

(i) Parenchyma.

Structure:

Parenchyma consists of roughly spherical cells; which may be elongated at times;

Each parenchyma cell has a large central nucleus; a thin cell wall; and a thin layer of cytoplasm at the periphery;

Many air spaces exist between the cells;

Distribution:

Parenchyma is distributed in the central pith of stems; outer cortex of stems and roots; xylem; phloem; and medullary rays of wood;

(ii) Collenchyma.

Structure:

Collenchyma consists of polygonal; and elongated cells; with end walls that are often pointed;

Cells have deposition of extra cellulose at their corners; and thinner side walls;

Between the cells are extremely small or non-existent air spaces;

Distribution:

Collenchyma is located in the outer region of cortex of the stem; midrib of leaves; and petioles of leaves;

(iii) **Sclerenchyma.**

Structure:

Sclerenchyma consists of fibres; and sclereids;

Fibres are polygonal; and elongated; with tapering interlocking ends walls; while sclereids are roughly spherical;

Both fibres and sclereids have heavily lignified cell walls; with simple pits in their walls where there is no lignin deposition; and an empty lumen;

Distribution:

Fibres are distributed in the pericycle of stems; xylem; and phloem; While sclereids are located in the cortex; pith; phloem; fruits; and seeds;

(b) Explain how each of the following tissues is suited for its functions.

(i) Parenchyma.

- Has many intercellular air spaces; for easy gaseous exchange;
- Parenchyma cells have a large central vacuole; for storage of large amounts of water and nutrients;
- Parenchyma cells have thin cell walls; for easy passage of materials into and out of the cells;

- Parenchyma cells have permeable cell walls; permitting entry of water into them to cause turgidity to provide support;
- Mesophyll (chlorenchyma) cells contain numerous chloroplasts; for carrying out photosynthesis;
- Transparent cell walls of the mesophyll cells; allow penetration of light for photosynthesis to take place;
- The aerenchyma in many aquatic plants contains many large intercellular air spaces; for easy diffusion of gases to provide buoyancy;

(ii) Collenchyma.

- Cells are polygonal, elongated parallel to the longitudinal axis of the organ and closely packed; to increase their combined strength to provide support;
- Cells have deposition of extra cellulose at their corners; to increase their strength to provide mechanical support;
- Cells have non-lignified cell walls and thus living; enabling the tissue to grow and stretch without imposing limitations on the growth of other cells around it;

(iii) Sclerenchyma.

- Consists of elongated fibres and roughly spherical sclereids whose cells walls are heavily thickened with lignin; of great tensile strength; and compressional strength; increasing their strength to provide support;
- The end walls of fibres interlock with one another; increasing their combined strength to provide support;
- Fibres are arranged into sheets of tissue extending for a considerable distance longitudinally; increasing their combined strength to provide support;
- Fibres and sclereids are closely packed; to increase their combined strength to provide support;

2. Explain the distribution of the following mechanical tissues in plants.

(a) Xylem.

- Centrally located in the roots; to withstand the strains of the aerial parts of the plant as they bend or lean over;
- Separate rods of xylem run through the stem of either dicots where vascular bundles are arranged peripherally in a ring or of monocots where vascular bundles are scattered; to provide support;

(b) Collenchyma.

- Located towards the periphery of stems and petioles; and just below the epidermis in the outer region of the cortex; to increase support;

- Appears as solid masses running the length of the midrib of dicot leaves; providing support for the vascular bundles;

(c) Sclerenchyma.

- Fibres occur in bundles around the vascular bundles of dicots; and may form a layer below the epidermis; where they provide rigidity;
- Sclereids occur singly or in groups in stems, leaves, fruits and seeds; where they confer rigidity or firmness to the organ;

3. (a) Describe the function(s) of the following tissues.

(i) Parenchyma tissue.

- Acts as packing tissue between the more specialized tissues;
- Parenchyma cells are sites of food storage in storage organs like tubers;
- Cell walls of parenchyma cells provide a pathway for movement of water and mineral salts through the plant;
- Parenchyma cells are sites for most of the vital activities of the plant body since they are metabolically active;
- Parenchyma cells provide support most especially to herbaceous plants by taking in water by osmosis and becoming turgid;
- Parenchyma tissue allows gaseous exchange due to possession of many intercellular air spaces;

(ii) Collenchyma.

- Provides mechanical support to the plant;

(iii) Sclerenchyma.

- Provides mechanical support to the plant;

(b) How is the parenchyma tissue different from the sclerenchyma tissue?

Parenchyma	Sclerenchyma
• Mature cells are living;	• Mature cells are dead;
• Cell walls are non-lignified;	• Cells have lignified cell walls;
• No pits in the cell walls;	• Simple pits occur in the cell walls;
• Many intercellular air spaces present;	• Intercellular air spaces absent;
• Consists of one type of parenchyma cell;	• Consists of fibres and sclereids;
• Cells contain a large central vacuole, cytoplasm and a nucleus(contain living contents);	• Cells have an empty lumen;
• Cells have thin cell walls;	• Cells have thick cell walls;
• Functionally unspecialized;	• Specialised to provide mechanical support;

(c) Describe the different modifications of the parenchyma tissue in different parts of the plant to suit its functions.

- Epidermis;
  - ✓ consists of a single layer of elongated and flattened cells; covering the entire primary plant body; protecting the plant from dessication and infection by producing cutin;
  - ✓ Epidermis of leaves has stomata at intervals; which allow gaseous exchange for photosynthesis and respiration;
  - ✓ Epidermis in roots grows unicellular hairs called root hairs; to increase surface area for absorption of water and mineral salts;
  - ✓ In climbing plants such as goosegrass, hooked hairs grow from the epidermis; which prevent the stems from slipping from their supports;
  - ✓ The epidermis of some plants like the stinging nettle grows hard hairs; which offer mechanical protection;
  - ✓ Epidermis in flowers may grow hairs; preventing access to crawling insects and helping to promote cross pollination by larger flying insects;
  - ✓ Hair-like glandular cells in the epidermis of carnivorous plants secrete a sticky substance; that traps and kills insects either for protection; or for digestion and subsequent absorption if the secretion contains enzymes;
- Mesophyll/chlorenchyma;
  - ✓ Found between the two epidermal layers of the leaves;
  - ✓ Cells contain numerous chloroplasts for photosynthesis;
  - ✓ Many large intercellular air spaces are present for efficient gaseous exchange;
- Endodermis;
  - ✓ A layer of cells surrounding the vascular tissue;
  - ✓ Endodermal cells in the roots develop a band of suberin called casparian strip in their cell walls; which serves as a selective barrier to the movement of water and mineral salts between the cortex and the xylem;
  - ✓ Starch sheath in the endodermis in stems; plays a role in geotropic response;
- Pericycle;
  - ✓ A layer of cells between the endodermis and the central vascular tissue;
  - ✓ Retains the capacity for cell division producing lateral roots; and contributing to secondary growth if it occurs;
- Companion cells;
  - ✓ Located adjacent to sieve tubes in the phloem;
  - ✓ Contain numerous mitochondria to produce energy;

4. (a) Describe the structure of the xylem.

- Xylem consists of tracheids; vessel elements; parenchyma; and fibres;
- Tracheids have an empty lumen; lignified cell walls; bordered pits in their side walls; and tapering interlocking end walls; perforated with pits;
- Vessel elements are open-ended; joined end to end to form a vessel; have lignified cell walls; bordered pits in their side walls; and an empty lumen;
- Vessel elements are shorter and wider than tracheids;

(b) How is the structure of the xylem related to its

(i) Physiological function?

- Vessel elements are joined end to end to form a continuous vessel; for continuous flow of water up the xylem;
- Vessel elements are open-ended; allowing continuous flow of water from one element to another up the xylem;
- Tracheids and vessel elements have an empty lumen; allowing large volumes of water to be transported without obstruction by the living contents;
- End walls of tracheids are perforated with pits; permitting flow of water from one tracheid to another up the xylem;
- Bordered pits in the side walls of tracheids and vessel elements; allow lateral/horizontal flow of water from one cell to another;
- Bordered pits have a torus; which controls the lateral flow of water from one cell to another;
- Tracheids and vessel elements have lignified cell walls; making them more rigid such that they don't collapse under the high tension created by the transpiration pull;
- Tracheids and vessel elements have lignified cell walls; preventing leakage of water out of them;
- Tracheids and vessel elements have lignified cell walls; increasing the adhesion of water molecules onto the walls thereby increasing the rise of water by capillarity;
- Tracheids and vessel elements have a narrow lumen; increasing the rise of water by capillarity;

(ii) Structural function?

- Cell walls of tracheids, vessel elements and fibres are heavily thickened with lignin; of great tensile and compressional strength; increasing their strength to provide mechanical support;

- Tracheids and fibres have tapering end walls which interlock with one another; increasing their combined strength to provide support;
- Xylem parenchyma cells can take in water by osmosis and become turgid to provide support;
- The xylem is centrally located in roots; to withstand strains of the aerial parts of the plant as they bend or lean over;

(d) (i) State the water conducting cells of the xylem.

- Tracheids;
- Vessel elements;

(iii) Compare the structures of the water conducting cells stated in d(i) above.

Similarities:

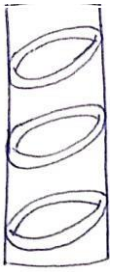
- Both have an empty lumen;
- Both have lignified cells walls;
- Both have bordered pits in their side walls;

Differences:

Tracheids	Vessel elements
• Are narrower;	Are wider;
• Are longer;	Are shorter;
• Have a narrower lumen;	Have a wider lumen;
• Have perforated end walls;	Are open-ended;
• Have tapering end walls;	Have circular end walls;
• End walls overlap/interlock with one another;	Are joined end to end to form a vessel;

5. (a) Using diagrammatic illustrations, describe the different patterns of thickening/lignification of the xylem vessels

Annular thickening;



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Spiral thickening;

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Reticulate thickening;

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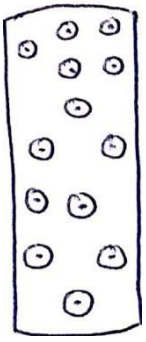
Pitted thickening;



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(b) Describe the role of the xylem in photosynthesis.

- Xylem transports water from the roots up the stem to the leaves; where it is used as a raw material in photosynthesis; by providing the hydrogen used in the reduction of carbon dioxide to a carbohydrate;

6. (a) Describe the structure of the phloem.

- Phloem consists of sieve tube elements/sieve elements; companion cells; parenchyma; fibres; and sclereids;
- Sieve elements lack a nucleus, ribosomes and golgi apparatus; and have a thin layer of cytoplasm confined at the periphery;
- Sieve elements are joined end to end to form sieve tubes; which are spanned at intervals by sieve plates that mark successive sieve elements;
- Sieve plates are perforated by sieve pores; through which fine cytoplasmic filaments run from one element to another;
- Companion cells possess a nucleus, dense cytoplasm, dense endoplasmic reticulum and numerous mitochondria;
- Plasmodesmata connect each sieve element to its adjacent companion cells;

(b) Explain how the structure of the phloem is related to its function.

- Sieve elements are joined end to end to from a continuous tube; for continuous flow of solution down the sieve tube;
- Sieve plates have pores; permitting the flow of solution from one sieve element to another;
- Sieve elements lack a nucleus and have a thin layer of cytoplasm confined at the periphery; reducing resistance to the flow of solution;
- Companion cells contain numerous mitochondria to produce energy in form of ATP; for active loading of sugar into the sieve tubes;
- Plasmodesmata connect sieve elements to companion cells; allowing exchange of materials between the companion cells and sieve elements;
- Fine cytoplasmic filaments run from one sieve element to another via sieve pores; for transport of the organic solutes by cytoplasmic streaming;
- Cell walls of the sieve elements are thin; for easy entry of water at the source by osmosis to build up pressure;

(c) Compare the xylem and the phloem.

Similarities:

- Both contain a mixture of living and dead cells;
- Both contain fibres; and parenchyma;
- Both transport materials from one part of the plant to another;
- Transport of materials occurs by mass flow in both;

Differences:

Xylem	Phloem
• Transport occurs in tracheids and vessel elements;	• Transport occurs only in the sieve elements;
• Transport in the xylem is unidirectional (only occurs upwards);	• Transport in the phloem is bidirectional(occurs upwards and downwards);
• Transport in the xylem is passive;	• Translocation in the phloem is an active process;
• Provides support;	• Provides no support;
• Vessels and tracheids have an empty lumen;	• Sieve tubes contain some living contents;
• Cell walls of vessels and tracheids are lignified;	• Cell walls of Sieve tubes are non-lignified;
• Lacks sclereids;	• Has Sclereids;
• Transports water and mineral salts;	• Transports organic solutes like sucrose, amino acids;

7. Describe the structural adaptations of the different epithelial tissues in animals.

- Squamous epithelium;
  - ✓ It is thin; to reduce distance for diffusion of materials through it;
  - ✓ Has smooth free surface; allowing a relatively friction-free passage of blood through blood vessels and the heart;
- Cuboidal epithelium;
  - ✓ Bears many microvilli on the free surface in the Proximal convulated tubule and distal convulated tubule; to increase surface area for reabsorption of substances;
  - ✓ Bears many microvilli in glands like salivary glands; to increase surface area for secretion;
- Columnar epithelium;
  - ✓ Bears many microvilli on the free surface in the intestine; to increase surface area for absorption;

- ✓ Goblet cells in the epithelium secrete mucus; which protects the stomach and intestine from self-digestion; lubricates the intestine for smooth passage of food; and protects stomach walls against acidic contents;

- Cilliated epithelium;
  - ✓ Possesses many cilia on the free surface; which beat rhythmically to move materials from one location to another;
  - ✓ Goblet cells in the epithelium secrete mucus; which traps bacteria and other foreign materials in the respiratory passages;
- Stratified epithelium;
  - ✓ Consists of several layers of cells; to provide protection against abrasion and mechanical damage for the underlying tissues;
- Transitional epithelium;
  - ✓ Consists of several layers of cells; to prevent leakage of urine into surrounding tissues;
  - ✓ Cells are able to change shape; to allow the urinary bladder to stretch to accommodate large volumes of urine;

8. Explain the distribution of the different epithelial tissues in animals.

- Squamous epithelium;
  - ✓ Lines the renal capsules of kidneys; alveoli of lungs; and blood capillaries; where its thinness permits diffusion of materials across it;
  - ✓ Lines the inside of blood vessels and heart chambers; where its smoothness allows a relatively friction-free passage of blood through them;
- Cuboidal epithelium;
  - ✓ Lines proximal convulated tubule; and distal convulated tubule; where the microvilli on its free surface increase surface for reabsorption of substances;
  - ✓ Lines salivary; sweat; and thyroid glands; where the microvilli on its free surface increase surface area for secretion;
- Columnar epithelium;
  - ✓ Lines stomach; and small intestine; where a brush border of microvilli on its free surface increase surface area for absorption;
- Ciliated epithelium;
  - ✓ Lines the oviducts; ventricles of the brain; and respiratory passages (trachea, bronchi and bronchioles); where the cilia on its free surface beat rhythmically to move materials from one location to another;
- Stratified epithelium;
  - ✓ Lines external skin surface; oesophagus; buccal cavity; and vagina; where its thickness protects the underlying tissues against abrasion/wear and mechanical damage;

- Transitional epithelium;
  - ✓ Lines urinary bladder; and ureters; where its ability to stretch allows large quantities of urine to be accommodated; and its thickness prevents escape of urine into surrounding tissues;

9. (a) State the functions of the different types of cells present in the areolar tissue.

- Fibroblast; produces collagen and elastic fibres;
- Mast cell; secretes an anticoagulant;
- Fat cell; stores fat;
- Macrophage; engulfs bacteria and other foreign materials;

(b) Of what importance is the areolar tissue in the body of a living organism?

- Acts as packing tissue filling spaces between adjacent tissues;
- Binds tissues and organs together;
- Forms sheaths around organs separating them so that they don't interfere with each other's activities;
- Provides protection against bacterial invasion;

(c) How is the structure of the areolar tissue suited for its functions?

- Contains inelastic collagen fibres to increase its strength;
- Contains elastic fibres giving the tissue elasticity;
- Contains macrophages which engulf bacteria;

10. (a) State the distribution of the different types of cartilage.

Type of cartilage	Distribution
• Hyaline cartilage;	• Trachea, bronchi; • Nose(Nasal septum); • Ends(Epiphyses) of long bones; • Between ribs and sternum; • Skeleton of cartilaginous fish e.g sharks; • Embryonic skeleton of bony vertebrates;
• Yellow elastic cartilage/elastic cartilage;	• Pinna of the ear; • Epiglottis;
• White fibrous cartilage/fibrocartilage;	• Intervertebral discs; • Symphysis pubis; • Ligamentous capsules surrounding joints;

(b) Explain how cartilage is adapted to its functions.

- Elastic cartilage contains numerous elastic fibres in its matrix; giving it greater elasticity and flexibility such that the tissue recovers its shape quickly after distortion;
- Fibrocartilage and hyaline cartilage have smooth and lubricated surfaces; allowing frictionless movement of bones at joints;
- Fibrocartilage contains a large number of densely packed collagen fibres; giving it great tensile strength;
- Cartilage has an elastic and compressible matrix; to absorb mechanical shock such as that frequently produced at joints;
- Cartilage is hard but flexible; providing a rigid framework in structures where it is found;
- Hyaline cartilage and elastic cartilage are enclosed by a dense fibrous tissue called perichondrium; which provides protection against mechanical damage and infection;

11. (a) Describe the structure of hyaline cartilage.

- Hyaline cartilage consists of a semi-transparent matrix of chondrin; containing cells called chondroblasts/chondrocytes; and fine collagen fibrils;
- Chondroblasts/chondrocytes are enclosed in spaces called lacunae; with each lacuna enclosing one, two, four or eight chondrocytes;
- Hyaline cartilage except the articular cartilage is enclosed by a dense layer of cells and fibres called perichondrium;

(b) How does the structure of hyaline cartilage differ from fibrocartilage?

Hyaline cartilage	Fibrocartilage
• Contains a larger number of chondrocytes;	• Has an opaque matrix;
• Contains a smaller number of collagen fibres in the matrix;	• Contains a larger number of collagen fibres in the matrix;
• Enclosed by perichondrium except articular hyaline cartilage;	• Not enclosed by perichondrium;

(c) How does the structure of hyaline cartilage differ from that of elastic cartilage?

Hyaline cartilage	Elastic cartilage
• Collagen fibres are predominant in the matrix;	Elastic fibres are predominant in the matrix;
• Less flexible;	More flexible;
• Contains a smaller number of chondrocytes;	Contains a larger number of chondrocytes;

(d) Explain why cartilage heals slowly as compared to bone when injured.

- Cartilage is not supplied by blood vessels unlike bone; and therefore cartilage receives oxygen and nutrients required in repair only through diffusion; which is a slow process;

12. (a) Describe the structure of a compact bone.

- Compact bone consists of a glycoprotein matrix; containing collagen fibres; and impregnated with mineral salts; mainly a form of calcium phosphate called hydroxyapatite; Bone cells called chondroblasts/chondrocytesare also embedded in the matrix;
- Matrix is arranged in concentric layers called lamellae; surrounding a central Haversian canal; with each set of lamellae surrounding each Haversian canal constituting a Haversian system/osteon;
- Between the lamellae are concentric rings of spaces called lacunae; containing chondrocytes;
- Fine cytoplasm containing channels called canaliculi radiate from each lacuna; which may link up with the central Haversian canal or with other lacunae or pass from one lamella to another;
- Each Haversian canal contains an artery, vein, lymph vessel and nerve fibres;
- Haversian canals are connected with each other by transverse canals called Volkmann canals; which contain larger blood vessels;
- Blood capillaries pass from the Haversian canal through the canaliculi to the lacunae;
- Covering the bone is a dense layer connective tissue called periosteum;

(b) How does a compact bone differ from a spongy bone?

Compact bone	Spongy bone
• Matrix is harder as it contains more mineral salts;	Matrix is softer as it contains less mineral salts;
• Consists of Haversian canal systems/osteons;	Consists of thin interconnected bony plates called trabeculae;
• Osteons are closely packed without spaces between them;	Trabecuae have spaces between them;
• Yellow marrow fills the marrow cavity in its centre;	Red marrow fills the spaces between the trabeculae;
• Forms the shaft (diaphysis) of long bones;	Forms the ends (epiphyses) of long bones;

(c) Compare bone and cartilage.

Similarities

- Both contain a ground substance called the matrix;
- Both contain spaces called lacunae in the matrix which enclose cells;
- Both are hard;
- Both are enclosed by a dense connective tissue;

Differences

Bone	Cartilage
• Harder, rigid and inelastic;	Softer, flexible and elastic;
• Matrix contains mineral salts;	Matrix doesn't contain mineral salts;
• Matrix contains blood vessels;	Is avascular (no blood vessels in matrix);
• Innervated;	Not innervated;
• Lacunae have canaliculi radiating from them in compact bone;	Lacunae lack canaliculi radiating from them;
• Lacuna encloses only one bone cell;	Lacuna may enclose more than one chodroblast;
• Matrix is synthesized by osteoblasts;	Matrix is synthesized by chondroblasts;
• Compact bone has haversian canal systems;	Lacks Haversian canal systems;
• Cells embedded in the matrix are osteoblasts and osteocytes;	Cells embedded in the matrix are chondroblasts and chondrocytes;
• Enclosed by periosteum;	Enclosed by perichondrium;

(e) State the different functions of bone to an organism.

- Protection of delicate body organs for example skull protects the brain;
- Provides shape and support to the body;
- For locomotion by providing surfaces for attachment of muscles;
- Production of blood cells by the bone marrow;
- Storage and release of calcium and phosphate into blood when needed;

(c) How is the structure of bone related to its functions?

- Matrix of bone is impregnated with mineral salts; giving it extreme hardness to withstand compressional strains and tension;
- Blood vessels run through the Haversian canals; allowing passage of nutrients, respiratory gases and metabolic wastes towards and away from the bone cells;
- Bone is innervated; allowing coordination of bone resorption and reconstruction;

- Matrix contains numerous collagen fibres; which give the bone additional mechanical strength;
- Trabeculae of spongy bone have spaces between them; reducing the weight of the bone for easy locomotion;
- Trabeculae are oriented in the direction in which the bone is stressed; to withstand tension and compression forces;
- Tough fibrous layer called periosteum encloses bone; protecting the underlying tissue from damage;
- Bundles of collagen fibres from the periosteum pierce the bone; increasing its mechanical strength and giving a firm base for tendon insertions;
- Bone contains bone marrow; which produces blood cells;
- In compact bone, fine cytoplasmic channels called canaliculi project from lacunae and connect with other lacunae or central haversian canals; allowing exchange of materials between lacunae and with Haversian canals;
- Compact bone contains Volkmann canals; which allow communication between Haversian canals;