La-Net

ZOO316

HISTOLOGY

ZOO 316: Histology (2 Units C: LH 15; PH 45)

Course Code: ZOO 316

Course Title: Histology

Course Unit: 2 Units C

Series 1: Cellular Basis Of Tissue Formation And Organisation

Series 2: Structure And Function Of Vertebrate Tissues

Series 3: Histological Study Of Mammalian Organs

Series 4: Histochemistry And Staining Techniques

Series 5: Histopathology And Tissue Stability

Series 1 Cellular Basis Of Tissue Formation And Organisation

Part 1.1 Differentiation of cells
1.1.1 Cellular specialisation and gene regulation
1.1.2 Stability of the differentiated state
Part 1.2 Organisation of tissues
1.2.1 Principles of tissue formation
1.2.2 Cell communication and coordination
Part 1.3 Integration into organ systems

1.3.1 Distribution and structural arrangement of vertebrate tissues
1.3.2 Functional organisation within organ systems

Introduction

Cells are the fundamental units of life, yet their ability to differentiate and organise into tissues and organs is what makes complex organisms possible. Understanding how cells specialise, communicate, and maintain their identity provides the foundation for histology, which is the study of tissues and their organisation.

The aim of this Series is to explain the processes of cellular differentiation, analyse how tissues are formed and maintained, and evaluate how these tissues integrate into organ systems.

We shall commence this Series by examining the differentiation of cells, focusing on specialisation, gene regulation, and the stability of the differentiated state. Next, we will explore the organisation of tissues, considering principles of tissue formation and the role of cell communication. Finally, we will conclude with integration into organ systems, looking at how vertebrate tissues are distributed and structurally arranged to support function.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 1.1 explain how cells differentiate and specialise,
SLO 1.2 analyse the stability of the differentiated state,
SLO 1.3 describe the principles of tissue formation,
SLO 1.4 evaluate the role of cell communication in tissue organisation,
SLO 1.5 explain the distribution and structural arrangement of vertebrate tissues, and
SLO 1.6 assess how tissues integrate into organ systems to support function.

1.1 Differentiation Of Cells

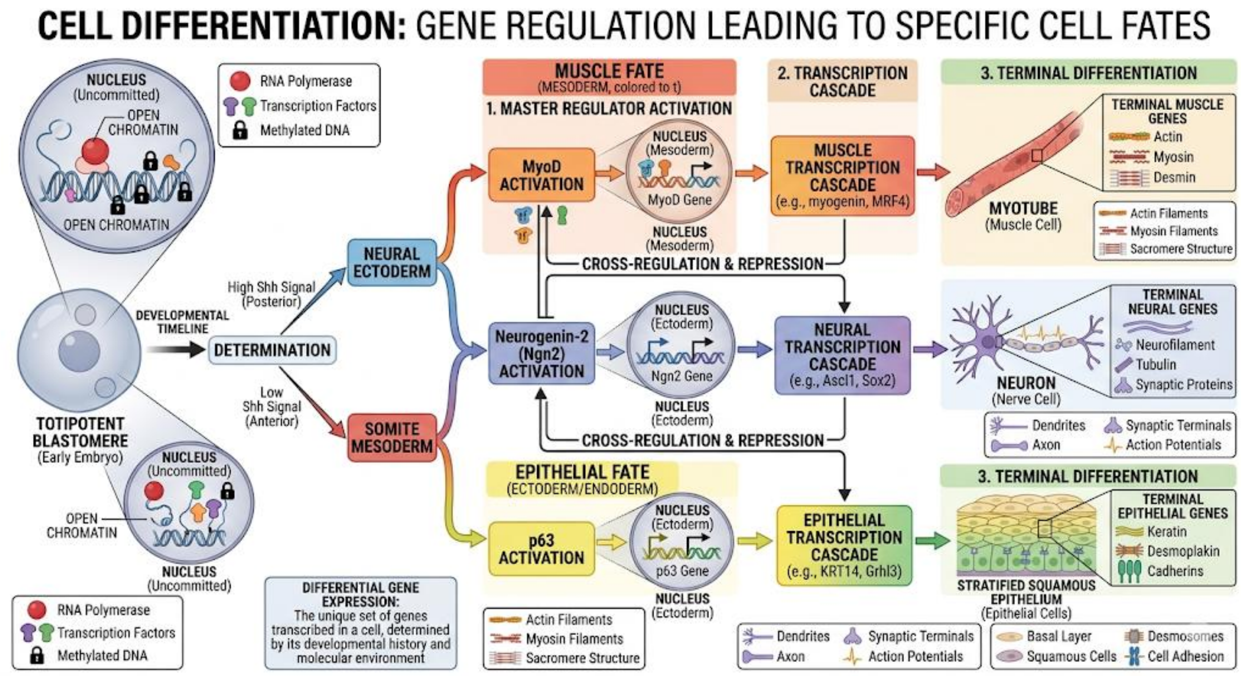
1.1.1 Cellular specialisation and gene regulation

Cell differentiation is the process by which unspecialised cells acquire distinct structures and functions. This specialisation allows cells to perform specific roles within tissues and organs. For example, muscle cells develop contractile proteins, while nerve cells produce neurotransmitters.

The regulation of differentiation is controlled by **gene expression**, which refers to the activation or silencing of particular genes. Although all cells share the same DNA, only certain genes are expressed in each cell type. This selective expression ensures diversity of cell functions.

Short description: Diagram showing how gene expression leads to different specialised cell types.

Caption: **Figure 1.1 Gene regulation in cellular differentiation**



Fill in the blank: Although all cells contain the same DNA, only certain ______ are expressed in each cell type.

1.1.2 Stability of the differentiated state

Once cells have differentiated, they must maintain their specialised identity. This is referred to as the **stability of the differentiated state**. Stability ensures that cells continue to perform their designated roles throughout the life of the organism.

Mechanisms such as epigenetic modifications, including DNA methylation and histone changes, help preserve this state. These modifications lock in patterns of gene expression, preventing cells from reverting to an unspecialised form. Stability is crucial for tissue integrity and proper organ function.

Box 1.2 Stability of the differentiated state

Category	Process / Focus	Key Stages or Components	Practical Application
Developmental Biology	**Gametogenesis**	**Male:** Spermatogonia $\rightarrow$ Spermatocytes $\rightarrow$ Spermatids $\rightarrow$ **Spermatozoa**. **Female:** Oogonia $\rightarrow$ Oocytes $\rightarrow$ Polar Bodies $\rightarrow$ **Mature Ovum**.	Foundations of reproductive biology and fertility studies.
Developmental Biology	**Embryogenesis**	Zygote $\rightarrow$ Cleavage $\rightarrow$ **Blastula** $\rightarrow$ **Gastrulation**.	Key milestones in early life development.
Cellular Biology	**Differentiation**	Multipotent cells $\rightarrow$ Specialized **Muscle**, **Nerve**, and **Skin** cells.	Histology, anatomy, and tissue engineering.
Field Entomology	**Collection Methods**	**Handpicking**, **Sweeping Nets**, and **Beating Trays**.	Biodiversity sampling and vector monitoring.
Field Entomology	**Safety & PPE**	Respiratory protection, gloves, and protection from thorns/ticks/snakes.	Fieldwork risk management and safe sampling.
Specimen Curation	**Preservation**	**Pinning** (Thorax/Elytra), **Wing Spreading** (Lepidoptera), and **Labelling**.	Museum archiving and long-term research data.

Category	Process / Focus	Key Stages or Components	Practical Application
Taxonomy & ID	**Morphology**	**Mouthparts** (Siphoning, Lapping), **Wings** (Elytra, Scaled), and **Antennae**.	Traditional species classification and morphological keys.
Modern Tech	**Advanced ID**	**Digital Imaging** (High-mag) and **DNA Barcoding** (PCR sequencing).	High-accuracy molecular and digital archiving.

Fill in the blank: DNA methylation and histone modification are examples of ______ mechanisms that stabilise cell identity.

Pilot questions 1.1

What is cell differentiation?
How does gene expression regulate differentiation?
Why is stability of the differentiated state important?
Name one epigenetic mechanism that maintains cell identity.
Give an example of a specialised cell type and its function.

1.2 Organisation Of Tissues

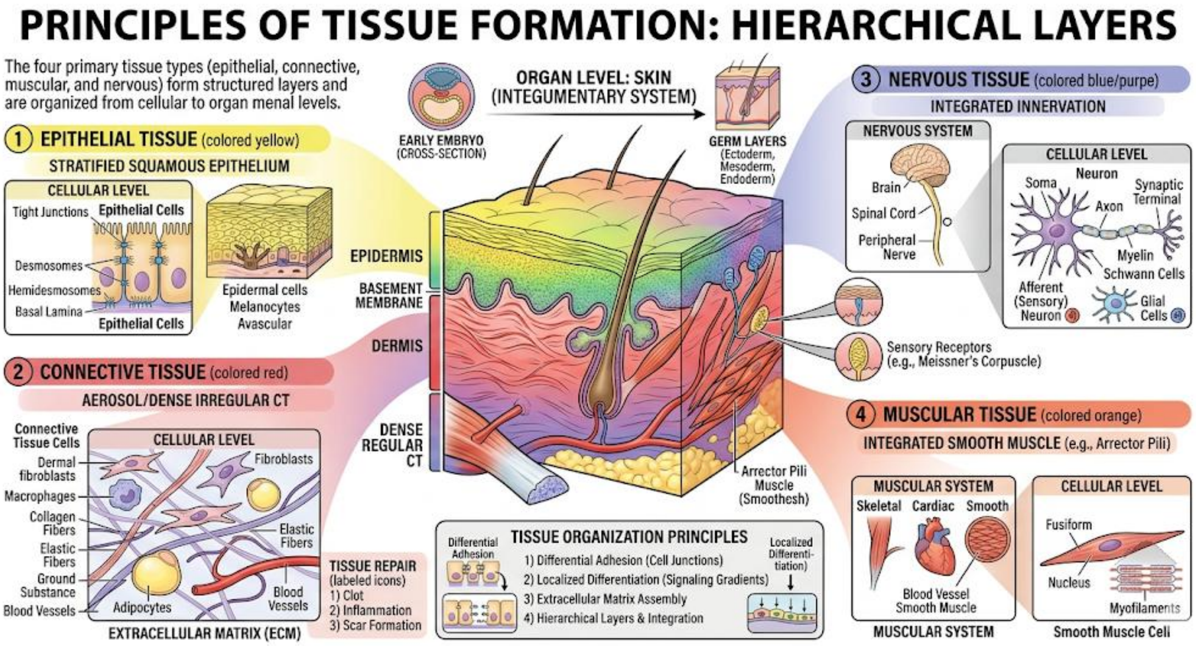
1.2.1 Principles of tissue formation

Tissue formation refers to the process by which groups of specialised cells come together to perform collective functions. Cells organise themselves into layers or clusters, depending on their roles. For example, epithelial cells form protective linings, while connective tissue cells provide support and structure.

The organisation of tissues is guided by cell adhesion molecules, which help cells stick together, and extracellular matrix components, which provide a scaffold. This ensures that tissues are not just random collections of cells but structured units with defined roles.

Short description: Diagram showing epithelial, connective, and nervous tissues forming structured layers.

Caption: **Figure 1.3 Principles of tissue formation**



Fill in the blank: The scaffold that supports tissue organisation is called the ______ matrix.

1.2.2 Cell communication and coordination

Cell communication is the exchange of signals between cells that allows tissues to function as integrated systems. Cells communicate through chemical messengers, direct contact, or electrical signals. This coordination ensures that tissues respond appropriately to changes in their environment.

For instance, in nervous tissue, electrical impulses transmit information rapidly, while in endocrine tissues, hormones act as chemical messengers. Without effective communication, tissues would fail to maintain homeostasis and proper function.

Box 1.4 Cell communication in tissue organisation

Category	Process / Focus	Key Stages or Components	Practical Application
Developmental Biology	**Gametogenesis**	**Male:** Spermatogonia $\rightarrow$ Spermatocytes	Foundations of reproductive biology and fertility studies.

Category	Process / Focus	Key Stages or Components	Practical Application
		$\rightarrow$ Spermatids $\rightarrow$ **Spermatozoa**. **Female:** Oogonia $\rightarrow$ Oocytes $\rightarrow$ Polar Bodies $\rightarrow$ **Mature Ovum**.	
Developmental Biology	**Embryogenesis**	Zygote $\rightarrow$ Cleavage $\rightarrow$ **Blastula** $\rightarrow$ **Gastrulation**.	Foundational milestones in early life development.
Cellular Biology	**Differentiation**	Multipotent cells $\rightarrow$ Specialized **Muscle**, **Nerve**, and **Skin** cells.	Histology, tissue engineering, and anatomy.
Field Entomology	**Collection Methods**	**Handpicking**, **Sweeping Nets**, and **Beating Trays**.	Biodiversity sampling and vector monitoring.
Field Entomology	**Safety & PPE**	Respiratory protection, gloves, and branch/tick/snake protection.	Fieldwork risk management and safe chemical handling.
Specimen Curation	**Preservation**	**Pinning** (Thorax/Elytra), **Wing Spreading** (Lepidoptera), and **Labelling**.	Museum archiving and systematic research collections.
Taxonomy & ID	**Morphology**	**Mouthparts** (Siphoning, Lapping), **Wings** (Elytra, Scaled), and **Antennae**.	Traditional species classification and morphological keys.

Category	Process / Focus	Key Stages or Components	Practical Application
Modern Technology	**Advanced ID**	**Digital Imaging** and **DNA Barcoding** (PCR sequencing).	High-accuracy molecular and digital archiving.

Fill in the blank: Hormones act as _______ messengers in tissue communication.

Pilot questions 1.2

What is tissue formation?
What role does the extracellular matrix play in tissue organisation?
Name one type of cell adhesion molecule.
How do cells communicate within tissues?
Give one example of chemical communication in tissues.

1.3 Integration Into Organ Systems

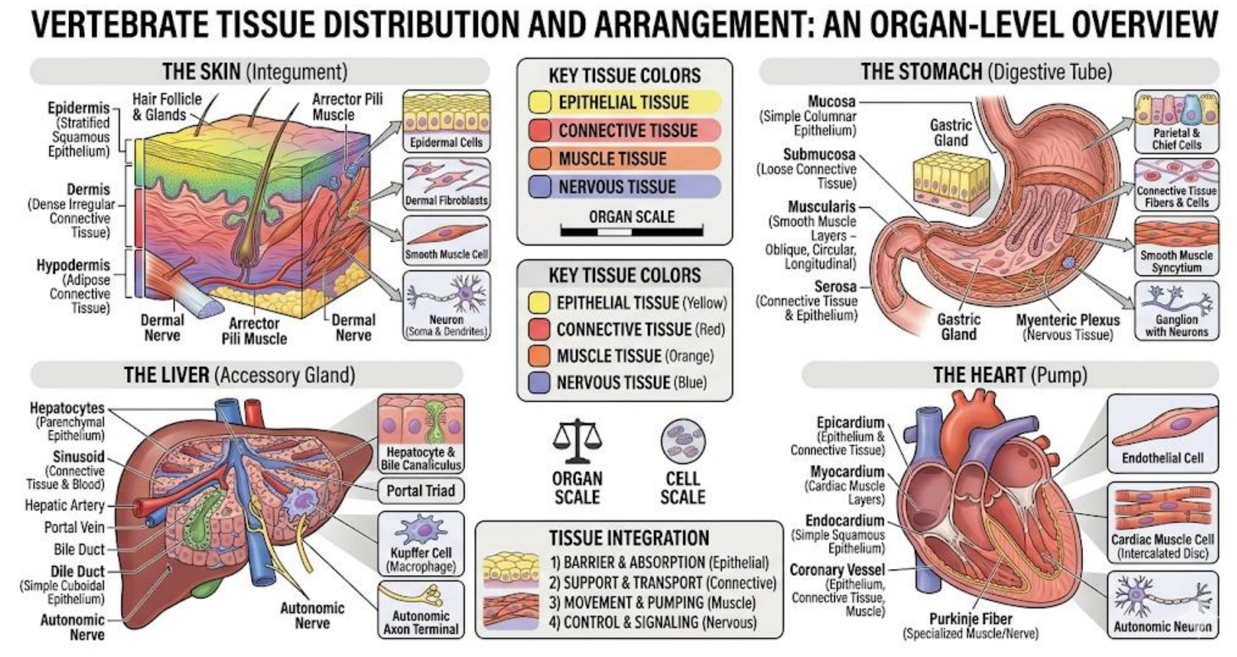
1.3.1 Distribution and structural arrangement of vertebrate tissues

The integration of tissues into organ systems begins with their **distribution** and **structural arrangement**. Vertebrate tissues are organised in specific ways to ensure that organs can perform their functions effectively. For example, epithelial tissue lines surfaces to provide protection and regulate exchange, connective tissue supports and binds structures, muscle tissue enables movement, and nervous tissue coordinates responses.

The arrangement of these tissues within organs is not random but highly ordered. Each organ has a unique structural pattern that reflects its function. For instance, the kidney contains epithelial cells arranged into tubules for filtration, while the heart has muscle fibres aligned to contract rhythmically.

Short description: Diagram showing distribution of epithelial, connective, muscle, and nervous tissues in vertebrate organs.

Caption: **Figure 1.5 Distribution and arrangement of vertebrate tissues**



Fill in the blank: The kidney contains epithelial cells arranged into ______ for filtration.

1.3.2 Functional organisation within organ systems

Functional organisation refers to how tissues work together within organs to support the overall role of an organ system. Each system, such as the digestive, circulatory, or nervous system, relies on coordinated tissue functions.

For example, in the digestive system, epithelial tissue absorbs nutrients, muscle tissue enables peristalsis, and connective tissue provides structural support. In the circulatory system, muscle tissue in the heart pumps blood, while connective tissue forms blood vessels. This integration ensures that organ systems operate efficiently and maintain homeostasis.

Box 1.6 Functional organisation of organ systems

Category	Process / Focus	Key Stages or Components	Practical Application
Developmental Biology	**Gametogenesis**	**Male:** Spermatogonia $\rightarrow$ Spermatocytes	Foundations of reproductive biology and fertility studies.

Category	Process / Focus	Key Stages or Components	Practical Application
		$\rightarrow$ Spermatids $\rightarrow$ **Spermatozoa**. **Female:** Oogonia $\rightarrow$ Oocytes $\rightarrow$ Polar Bodies $\rightarrow$ **Mature Ovum**.	
Developmental Biology	**Embryogenesis**	Zygote $\rightarrow$ Cleavage $\rightarrow$ **Blastula** $\rightarrow$ **Gastrulation**.	Key milestones in early life development.
Cellular Biology	**Differentiation**	Multipotent cells $\rightarrow$ Specialized **Muscle**, **Nerve**, and **Skin** cells.	Histology, anatomy, and tissue engineering.
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Field Entomology	**Safety & PPE**	Respiratory protection, gloves, and protection from thorns/ticks/snakes.	Fieldwork risk management and safe sampling.
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Taxonomy & ID	**Morphology**	**Mouthparts** (Siphoning, Lapping), **Wings** (Elytra, Scaled), and **Antennae**.	Traditional species classification and morphological keys.

Category	Process / Focus	Key Stages or Components	Practical Application
Modern Tech	**Advanced ID**	**Digital Imaging** (High-mag) and **DNA Barcoding** (PCR sequencing).	High-accuracy molecular and digital archiving.

Fill in the blank: In the digestive system, muscle tissue enables ______ to move food along the tract.

Pilot questions 1.3

What does distribution of vertebrate tissues mean?
Give one example of tissue arrangement in the kidney.
How do tissues cooperate in the digestive system?
What role does connective tissue play in the circulatory system?
Why is functional organisation important in organ systems?

Series Summary

This Series introduced the cellular basis of tissue formation and organisation, which is fundamental to histology. We began by examining how cells differentiate and specialise, guided by gene regulation, and then considered the stability of the differentiated state that ensures tissues maintain their identity. Following that, we explored the organisation of tissues, focusing on the principles of tissue formation and the importance of cell communication in coordinating functions. Finally, we looked at how tissues integrate into organ systems, highlighting their distribution, arrangement, and functional cooperation.

By completing this Series, you should now be able to explain cellular differentiation, analyse the stability of specialised states, describe how tissues are formed, evaluate the role of communication in tissue organisation, explain the distribution of vertebrate tissues, and assess how tissues integrate into organ systems. These achievements align with the Series Learning Outcomes, equipping you with a strong foundation for studying histology.

Glossary of Terms

Cell communication: The exchange of signals between cells that allows tissues to function as integrated systems.
Cell differentiation: The process by which unspecialised cells acquire distinct structures and functions.
Cell adhesion molecules: Proteins that help cells stick together during tissue formation.

Extracellular matrix: A scaffold of proteins and other molecules that supports tissue organisation.
Functional organisation: The way tissues cooperate within organs to support the role of an organ system.
Gene expression: The activation or silencing of specific genes that determines cell function.
Stability of the differentiated state: Mechanisms that preserve a cell's specialised identity over time.
Tissue formation: The process by which groups of specialised cells organise into structured units.

Concept Check Questions 1

Objective questions

Although all cells contain the same DNA, only certain ______ are expressed in each cell type. (Linked to SLO 1.1)
DNA methylation and histone modification are examples of ______ mechanisms that stabilise cell identity. (Linked to SLO 1.2)
The scaffold that supports tissue organisation is called the ______ matrix. (Linked to SLO 1.3)
Hormones act as ______ messengers in tissue communication. (Linked to SLO 1.4)
The kidney contains epithelial cells arranged into ______ for filtration. (Linked to SLO 1.5)

Short-answer questions
6. What is cell differentiation? (Linked to SLO 1.1)
7. Why is stability of the differentiated state important? (Linked to SLO 1.2)
8. What role does the extracellular matrix play in tissue organisation? (Linked to SLO 1.3)
9. Give one example of chemical communication in tissues. (Linked to SLO 1.4)
10. How do tissues cooperate in the digestive system? (Linked to SLO 1.6)

Long-answer questions
11. Explain how gene regulation leads to cellular differentiation. (Linked to SLO 1.1)
12. Analyse the mechanisms that maintain stability of the differentiated state. (Linked to SLO 1.2)
13. Evaluate the importance of cell communication in tissue organisation. (Linked to SLO 1.4)
14. Discuss how tissues integrate into organ systems, using examples from the circulatory and digestive systems. (Linked to SLO 1.5, 1.6)

Answers to Concept Check Questions 1

Objective questions

Genes.
Epigenetic.
Extracellular.
Chemical.

Tubules.

Short-answer questions
6. The process by which unspecialised cells acquire distinct structures and functions.
7. It ensures cells maintain their identity and continue performing their roles.
8. It provides structural support and scaffolding for tissue organisation.
9. Hormones.
10. Epithelial tissue absorbs nutrients, muscle tissue enables peristalsis, and connective tissue provides support.

Long-answer questions
11. **Basic response**: Gene regulation activates or silences specific genes, leading to specialised cell functions.
Value-added response: Regulatory networks and transcription factors coordinate gene activity, ensuring diversity of cell types.

Basic response: Epigenetic mechanisms preserve cell identity.
Value-added response: DNA methylation and histone modifications stabilise gene expression patterns, preventing dedifferentiation.
Basic response: Communication allows tissues to function as integrated systems.
Value-added response: Chemical, electrical, and contact-based signals coordinate responses, maintaining homeostasis and efficiency.
Basic response: Tissues cooperate to support organ systems.
Value-added response: In the circulatory system, muscle tissue pumps blood while connective tissue forms vessels; in the digestive system, epithelial tissue absorbs nutrients while muscle tissue enables peristalsis.

Answers to Pilot Questions 1

Part 1.1

The process by which unspecialised cells acquire distinct structures and functions.
By activating or silencing specific genes.
It ensures cells maintain their specialised identity.
DNA methylation or histone modification.
Muscle cells produce contractile proteins, nerve cells produce neurotransmitters.

Part 1.2

The process by which groups of specialised cells form structured units.
It provides scaffolding and support for tissue organisation.
Cadherins.
Through chemical messengers, electrical signals, or direct contact.
Hormones.

Part 1.3

The arrangement of tissues within organs.
Tubules.
Epithelial tissue absorbs nutrients, muscle tissue enables peristalsis.
It forms blood vessels.
It ensures organs function efficiently and maintain homeostasis.

References And Attributions 1

Figures and Boxes suggested in Series 1:

Figure 1.1 Gene regulation in cellular differentiation
Box 1.2 Stability of the differentiated state
Figure 1.3 Principles of tissue formation
Box 1.4 Cell communication in tissue organisation
Figure 1.5 Distribution and arrangement of vertebrate tissues
Box 1.6 Functional organisation of organ systems

AI prompt suggestions used for illustration placeholders:

Diagrams showing gene regulation, tissue formation, and tissue distribution.
Boxes summarising epigenetic mechanisms, communication methods, and functional organisation.

Open Educational Resource (OER) search strings suggested:

"cell differentiation gene regulation diagram OER"
"epigenetic mechanisms stability differentiated cells OER"
"principles of tissue formation diagram OER"
"cell communication tissue organisation OER"
"vertebrate tissue distribution arrangement diagram OER"
"functional organisation tissues organ systems OER"

General references (APA style):

Alberts, B., Johnson, A., Lewis, J., et al. (2015). *Molecular Biology of the Cell*. Garland Science.

Gilbert, S. F. (2010). *Developmental Biology*. Sinauer Associates.

OER Commons. (n.d.). *Resources on tissue formation and organisation*. Retrieved from https://www.oercommons.org

ZOO316 Series 2 Structure And Function Of Vertebrate Tissues

Introduction

In the last Series, we explored how cells differentiate, organise, and integrate into organ systems. Building on that foundation, this Series focuses on the structure and function of vertebrate tissues, which are the basic building blocks of organs. By studying these tissues, you will gain insight into how specialised cells work together to maintain life processes.

The aim of this Series is to describe the structure and classification of epithelial, connective, and nervous tissues, and to explain their functions and roles in vertebrate systems.

We shall commence this Series by examining epithelial tissues, looking at their structure, classification, and functions. Next, we will move on to connective tissues, considering their types and roles in support and transport. Finally, we will conclude with nervous tissues, exploring the structure of neurons and supporting cells, as well as their functions in coordination and communication.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 2.1 describe the structure and classification of epithelial tissues,
SLO 2.2 explain the functions and locations of epithelial tissues,
SLO 2.3 identify the types of connective tissues,
SLO 2.4 analyse the roles of connective tissues in support and transport,
SLO 2.5 describe the structure of neurons and supporting cells, and
SLO 2.6 evaluate the functions of nervous tissues in coordination and communication.

2.1 Epithelial Tissues

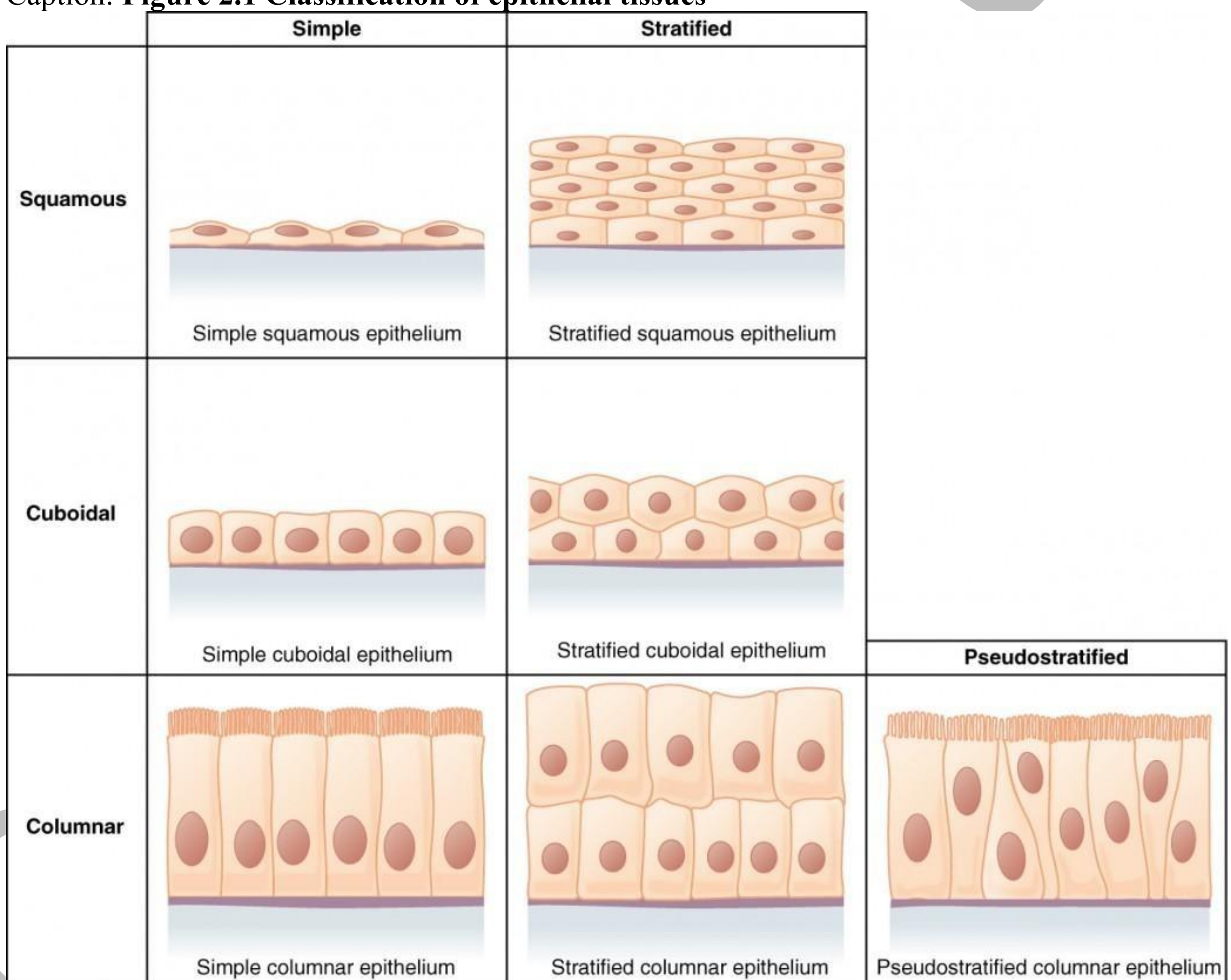
2.1.1 Structure and classification of epithelial tissues

Epithelial tissue is a type of tissue that covers body surfaces, lines cavities, and forms glands. It consists of closely packed cells with minimal extracellular material, creating protective barriers and specialised surfaces for absorption and secretion.

Epithelial tissues are classified based on the number of cell layers and the shape of the cells. **Simple epithelium** has a single layer of cells, while **stratified epithelium** has multiple layers. Cell shapes include squamous (flat), cuboidal (cube-like), and columnar (tall). This classification helps in identifying their roles in different organs.

Short description: Diagram showing types of epithelial tissues (simple squamous, cuboidal, columnar, stratified).

Caption: **Figure 2.1 Classification of epithelial tissues**



Fill in the blank: A single layer of cube-shaped cells is called ______ epithelium.

2.1.2 Functions and locations of epithelial tissues

Epithelial tissues perform several vital functions. They provide **protection** against mechanical injury and pathogens, enable **absorption** of nutrients, facilitate **secretion** of substances such as enzymes and hormones, and allow **exchange** of gases in organs like the lungs.

Their locations vary according to function. For example, simple squamous epithelium lines the alveoli of the lungs for gas exchange, cuboidal epithelium is found in kidney tubules for absorption and secretion, and stratified squamous epithelium forms the skin's outer layer for protection.

Box 2.2 Functions and locations of epithelial tissues

Category	Process / Concept	Key Characteristics	Examples
Cleavage Patterns	**Holoblastic**	Total division of the egg; occurs in eggs with little-to-moderate yolk.	Amphibians (Frogs), Mammals
	Meroblastic	Partial division; cleavage occurs only in a small disk of cytoplasm.	Birds (Chicks), Reptiles
Germ Layer Fates	**Ectoderm**	Outer layer; forms the "outer" and "thinking" parts.	Skin (epidermis), Nervous system
	Mesoderm	Middle layer; forms the "structural" and "moving" parts.	Muscles, Skeleton, Circulatory system
	Endoderm	Inner layer; forms the "internal plumbing."	Digestive tract, Respiratory lining
Cell Signaling	**Morphogens**	Signaling molecules that form gradients to dictate cell fate.	Shh (Sonic Hedgehog), BMP, Wnt
	Induction	Interaction where one cell group influences the development of another.	Notochord inducing the Neural Plate

Category	Process / Concept	Key Characteristics	Examples
Tissue Stability	**Homeostasis**	The dynamic balance between cell division and cell death.	Skin renewal, Liver regeneration
	Apoptosis	Programmed, "clean" cell death; no inflammation.	Development of fingers/toes
Pathology	**Necrosis**	Accidental, "messy" cell death; causes inflammation.	Infarction (Tissue death), Infection
	Benign Tumour	Localized, encapsulated, slow-growing, well-differentiated.	Adenoma, Lipoma
	Malignant Tumour	Invasive, metastatic (spreads), poorly differentiated.	Carcinoma, Sarcoma

Fill in the blank: The alveoli of the lungs are lined by simple ______ epithelium for gas exchange.

Pilot questions 2.1

What is epithelial tissue?
How are epithelial tissues classified?
Name the three main shapes of epithelial cells.
Give one function of epithelial tissue.
Where is stratified squamous epithelium commonly found?

2.2 Connective Tissues

2.2.1 Types of connective tissues

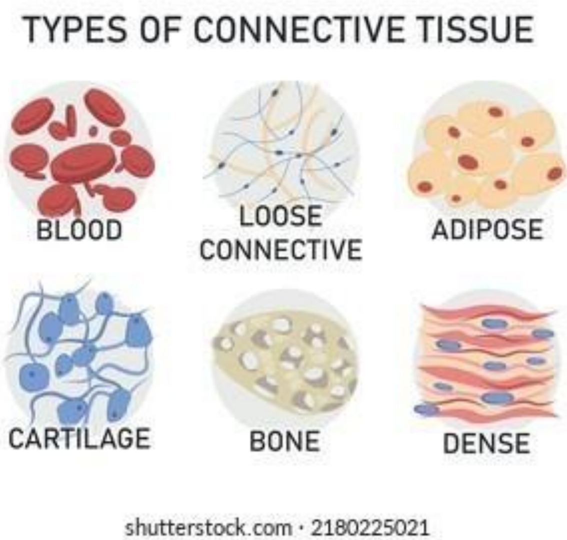
Connective tissue is a diverse group of tissues that provide support, bind structures together, and play roles in transport and defence. Unlike epithelial tissue, connective tissue has abundant **extracellular matrix**, which consists of fibres and ground substance surrounding the cells.

The main types of connective tissues include:

- **Loose connective tissue**, which holds organs in place and attaches epithelial tissue to underlying structures.
- **Dense connective tissue**, which contains tightly packed fibres and provides strength, as seen in tendons and ligaments.
- **Cartilage**, a flexible tissue that supports structures such as the nose and ear.
- **Bone**, a rigid tissue that provides structural support and protection.
- **Blood**, a fluid connective tissue that transports nutrients, gases, and wastes.

Short description: Diagram showing types of connective tissues (loose, dense, cartilage, bone, blood).

Caption: **Figure 2.3 Types of connective tissues**



Fill in the blank: Tendons and ligaments are examples of ______ connective tissue.

2.2.2 Roles of connective tissues in support and transport

Connective tissues perform essential roles in the body. They provide **support** by forming the framework of organs and maintaining their shape. For example, bone tissue supports the skeleton, while cartilage provides flexibility in joints.

They also play a role in **transport**. Blood, as a connective tissue, circulates oxygen, nutrients, and hormones throughout the body, while removing waste products. Connective tissues are also involved in defence, as white blood cells within blood protect against pathogens.

Box 2.4 Roles of connective tissues

Category	Process / Concept	Key Characteristics	Examples
Cleavage Patterns	**Holoblastic**	Total division of the egg; occurs in eggs with little-to-moderate yolk.	Amphibians (Frogs), Mammals
	Meroblastic	Partial division; cleavage occurs only in a small disk of cytoplasm.	Birds (Chicks), Reptiles
Germ Layer Fates	**Ectoderm**	Outer layer; forms the "outer" and "thinking" parts.	Skin (epidermis), Nervous system
	Mesoderm	Middle layer; forms the "structural" and "moving" parts.	Muscles, Skeleton, Circulatory system
	Endoderm	Inner layer; forms the "internal plumbing."	Digestive tract, Respiratory lining
Cell Signaling	**Morphogens**	Signaling molecules that form gradients to dictate cell fate.	Shh (Sonic Hedgehog), BMP, Wnt
	Induction	Interaction where one cell group influences the development of another.	Notochord inducing the Neural Plate
Tissue Stability	**Homeostasis**	The dynamic balance between cell division and cell death.	Skin renewal, Liver regeneration
	Apoptosis	Programmed, "clean" cell death; no inflammation.	Development of fingers/toes
Pathology	**Necrosis**	Accidental, "messy" cell death; causes inflammation.	Infarction (Tissue death), Infection
	Benign Tumour	Localized, encapsulated, slow-growing, well-defined.	Adenoma, Lipoma

Category	Process / Concept	Key Characteristics	Examples
	Malignant Tumour	Invasive, metastatic (spreads), poorly differentiated.	Carcinoma, Sarcoma

Fill in the blank: Blood is a connective tissue specialised for ______ of nutrients and gases.

Pilot questions 2.2

What is connective tissue?
Name two types of connective tissue.
Which connective tissue provides flexibility in joints?
What role does bone tissue play in the body?
How does blood function as a connective tissue?

2.3 Nervous Tissues

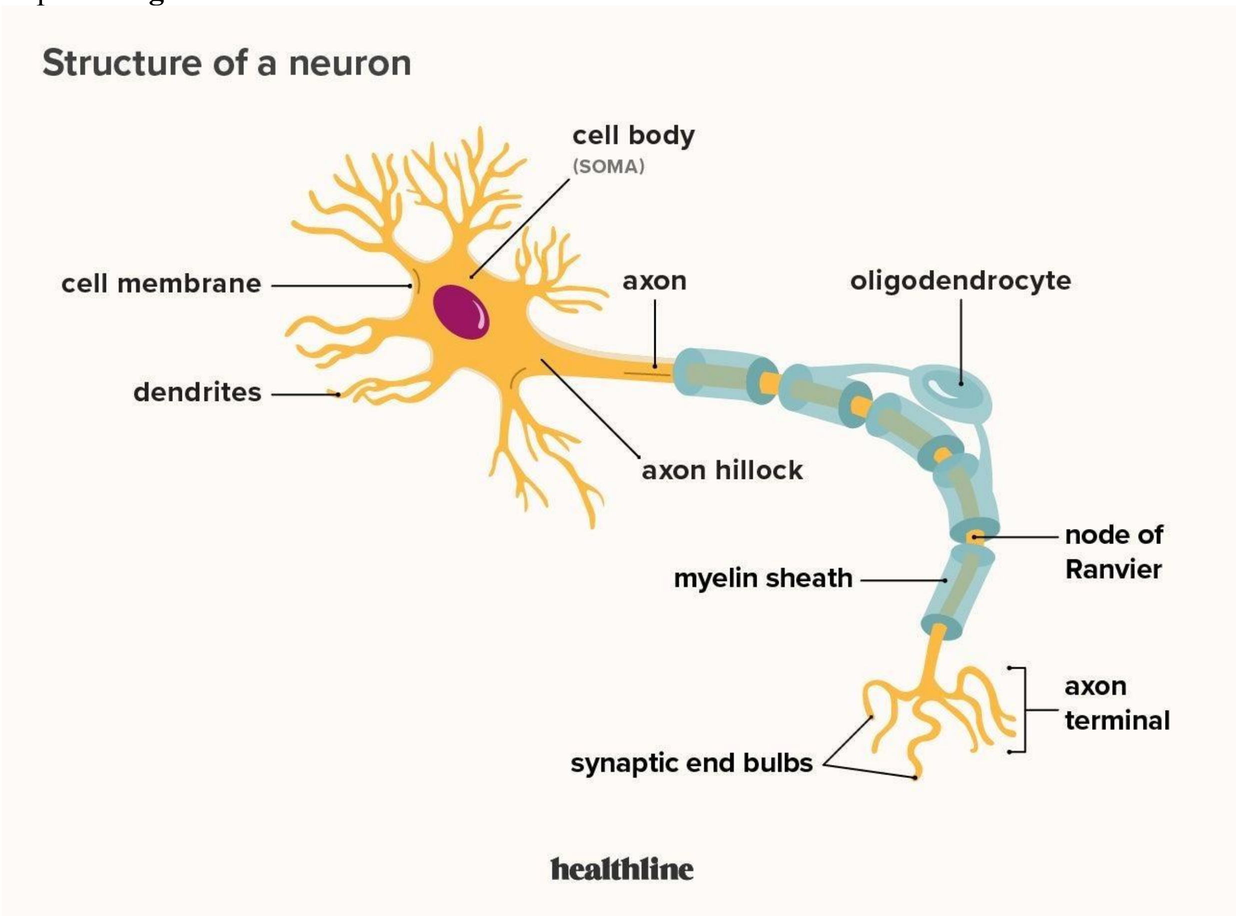
2.3.1 Structure of neurons and supporting cells

Nervous tissue is specialised for transmitting information and coordinating body functions. It is composed of **neurons**, which are the primary signalling cells, and **supporting cells** (also called glial cells), which provide protection, nourishment, and structural support.

A neuron typically consists of three main parts: the **cell body**, which contains the nucleus and organelles; **dendrites**, which receive signals from other cells; and the **axon**, which transmits signals away from the cell body. Supporting cells, such as astrocytes, oligodendrocytes, and Schwann cells, play crucial roles in maintaining the environment around neurons and facilitating efficient signal transmission.

Short description: Diagram showing the structure of a neuron with cell body, dendrites, and axon.

Caption: **Figure 2.5 Structure of a neuron**



Fill in the blank: The part of the neuron that transmits signals away from the cell body is the ______.

2.3.2 Functions of nervous tissues in coordination and communication

The primary function of nervous tissue is **coordination and communication**. Neurons transmit electrical impulses rapidly, allowing the body to respond to stimuli. For example, sensory neurons detect changes in the environment, while motor neurons send signals to muscles to initiate movement.

Supporting cells enhance this process by insulating axons, regulating the chemical environment, and protecting neurons from damage. Together, neurons and supporting cells ensure that the nervous system maintains homeostasis and enables complex behaviours such as learning and memory.

Box 2.6 Functions of nervous tissue

Function	Mechanism and Role
Sensory Input	**Detection:** Specialized neurons (receptors) detect internal and external environmental changes (stimuli), such as light, sound, temperature, or chemical concentrations.
Data Integration	**Processing:** The Central Nervous System (CNS)—the brain and spinal cord—analyzes sensory signals, compares them to stored memories, and determines the appropriate physiological response.
Motor Output	**Response:** The tissue transmits "commands" via efferent neurons to effector organs, such as **muscles** (for movement) or **glands** (for secretion).
Fast Communication	**Electrochemical Signaling:** Rapid transmission of **action potentials** along axons and chemical signaling across **synapses** ensures near-instantaneous communication across long distances in the body.
Coordination	**Homeostasis:** Nervous tissue coordinates the activities of different organ systems (e.g., matching heart rate to respiratory rate during exercise) to maintain a stable internal environment.

Fill in the blank: Supporting cells that insulate axons and enhance signal transmission are called _______ cells.

Pilot questions 2.3

What are the main components of a neuron?
Name two types of supporting cells in nervous tissue.
What is the primary function of nervous tissue?
How do sensory neurons differ from motor neurons?
Give one role of supporting cells in nervous tissue.

Series Summary

This Series focused on the structure and function of vertebrate tissues, which form the foundation of organ systems. We began with epithelial tissues, exploring their structure, classification, and functions in protection, absorption, secretion, and exchange. Then we examined connective tissues, considering their diverse types such as loose, dense, cartilage, bone, and blood, and their roles in support, transport, and defence. Finally, we studied nervous tissues, analysing the structure of neurons and supporting cells, and evaluating their functions in coordination and communication.

By completing this Series, you should now be able to describe and classify epithelial tissues, explain their functions and locations, identify types of connective tissues, analyse their roles in support and transport, describe the structure of neurons and supporting cells, and evaluate the functions of nervous tissues. These achievements align with the Series Learning Outcomes and provide you with a clear understanding of how vertebrate tissues underpin organ systems.

Glossary of Terms

- **Axon**: The part of a neuron that transmits signals away from the cell body.
- **Cartilage**: A flexible connective tissue that supports structures such as the nose and ear.
- **Cell body**: The central part of a neuron containing the nucleus and organelles.
- **Connective tissue**: A group of tissues with abundant extracellular matrix that provide support, transport, and defence.
- **Cuboidal epithelium**: Epithelial tissue made up of cube-shaped cells, often found in kidney tubules.
- **Dense connective tissue**: Connective tissue with tightly packed fibres, providing strength in tendons and ligaments.
- **Dendrites**: Branch-like extensions of a neuron that receive signals from other cells.
- **Epithelial tissue**: Tissue that covers body surfaces, lines cavities, and forms glands.
- **Extracellular matrix**: The scaffold of fibres and ground substance surrounding cells in connective tissue.
- **Neuron**: A specialised cell in nervous tissue responsible for transmitting electrical signals.
- **Simple epithelium**: A single layer of epithelial cells.
- **Stratified epithelium**: Multiple layers of epithelial cells, often providing protection.

Concept Check Questions 2

Objective questions

- A single layer of cube-shaped cells is called ______ epithelium. (Linked to SLO 2.1)
- The alveoli of the lungs are lined by simple ______ epithelium for gas exchange. (Linked to SLO 2.2)
- Tendons and ligaments are examples of ______ connective tissue. (Linked to SLO 2.3)
- Blood is a connective tissue specialised for ______ of nutrients and gases. (Linked to SLO 2.4)
- The part of the neuron that transmits signals away from the cell body is the ______. (Linked to SLO 2.5)

Short-answer questions

6. What is epithelial tissue? (Linked to SLO 2.1)
7. Name the three main shapes of epithelial cells. (Linked to SLO 2.1)

8. What role does bone tissue play in the body? (Linked to SLO 2.4)
9. Name two types of supporting cells in nervous tissue. (Linked to SLO 2.5)
10. What is the primary function of nervous tissue? (Linked to SLO 2.6)

Long-answer questions
11. Describe the classification of epithelial tissues and explain how their structure relates to function. (Linked to SLO 2.1, 2.2)
12. Analyse the roles of connective tissues in support and transport, giving examples. (Linked to SLO 2.3, 2.4)
13. Discuss the structure of neurons and supporting cells, and evaluate their functions in coordination. (Linked to SLO 2.5, 2.6)

Answers to Concept Check Questions 2

Objective questions

Simple cuboidal.
Squamous.
Dense.
Transport.
Axon.

Short-answer questions
6. Tissue that covers surfaces, lines cavities, and forms glands.
7. Squamous, cuboidal, columnar.
8. Provides structural support and protection.
9. Astrocytes and Schwann cells.
10. Coordination and communication.

Long-answer questions
11. **Basic response**: Epithelial tissues are classified by layers and cell shape, which determine their functions.
Value-added response: Simple squamous epithelium allows diffusion, cuboidal epithelium supports absorption and secretion, and stratified epithelium provides protection.

Basic response: Connective tissues support organs and transport materials.
Value-added response: Bone supports the skeleton, cartilage provides flexibility, and blood transports nutrients and gases while defending against pathogens.
Basic response: Neurons transmit signals, and supporting cells protect and nourish them.
Value-added response: Dendrites receive input, axons transmit signals, and glial cells insulate axons, regulate the environment, and enable efficient communication.

Answers to Pilot Questions 2

Part 2.1

Tissue that covers surfaces, lines cavities, and forms glands.
By layers (simple, stratified) and cell shape (squamous, cuboidal, columnar).
Squamous, cuboidal, columnar.
Protection, absorption, secretion, or exchange.
Skin.

Part 2.2

Tissue with abundant extracellular matrix that supports, binds, and transports.
Loose and dense connective tissue.
Cartilage.
Provides structural support and protection.
Transports nutrients, gases, and wastes.

Part 2.3

Cell body, dendrites, axon.
Astrocytes, oligodendrocytes, Schwann cells.
Coordination and communication.
Sensory neurons detect stimuli, motor neurons send signals to muscles.
Insulating axons and regulating the environment.

References And Attributions 2

Figures and Boxes suggested in Series 2:
Figure 2.1 Classification of epithelial tissues
Box 2.2 Functions and locations of epithelial tissues
Figure 2.3 Types of connective tissues
Box 2.4 Roles of connective tissues
Figure 2.5 Structure of a neuron
Box 2.6 Functions of nervous tissue

AI prompt suggestions used for illustration placeholders:
Diagrams showing epithelial tissue types, connective tissue types, and neuron structure.
Boxes summarising functions and roles of epithelial, connective, and nervous tissues.

Open Educational Resource (OER) search strings suggested:
"epithelial tissue classification diagram OER"
"epithelial tissue functions and locations OER"
"types of connective tissue diagram OER"
"roles of connective tissue support transport OER"
"neuron structure diagram OER"
"functions of nervous tissue coordination communication OER"

General references (APA style):
Alberts, B., Johnson, A., Lewis, J., et al. (2015). *Molecular Biology of the Cell*. Garland Science.

Ross, M. H., & Pawlina, W. (2015). *Histology: A Text and Atlas*. Wolters Kluwer.
OER Commons. (n.d.). *Resources on vertebrate tissues*. Retrieved from https://www.oercommons.org

ZOO316 Series 3 Histological Study Of Mammalian Organs

Part 3.1 Digestive organs
3.1.1 Histological structure and function of the liver
3.1.2 Histological structure and function of the intestine
3.1.3 Histological structure and function of the pancreas
Part 3.2 Lymphoid and excretory organs
3.2.1 Histological structure and function of the spleen
3.2.2 Histological structure and function of the kidney
Part 3.3 Endocrine organs
3.3.1 Histological structure and function of the pituitary gland
3.3.2 Histological structure and function of the thyroid gland
3.3.3 Histological structure and function of the adrenal glands
Part 3.4 Reproductive organs

3.4.1 Histological structure and function of the testis
3.4.2 Histological structure and function of the ovary

Introduction

In the previous Series, we examined the structure and function of vertebrate tissues, which form the foundation of organs. Building on that knowledge, this Series focuses on the histological study of mammalian organs. By exploring their microscopic structures, you will gain a deeper understanding of how tissues combine to form organs and how these organs carry out essential physiological functions.

The aim of this Series is to describe the histological features of major mammalian organs, explain their functions, and analyse how tissue organisation supports organ activity.

We shall commence this Series by studying digestive organs, beginning with the liver, intestine, and pancreas. Next, we will move on to lymphoid and excretory organs, focusing on the spleen and kidney. Following that, we will examine endocrine organs, including the pituitary, thyroid, and adrenal glands. Finally, we will conclude with reproductive organs, considering the histological structures of the testis and ovary.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 3.1 describe the histological structure and function of the liver, intestine, and pancreas,
SLO 3.2 explain the histological features of the spleen and kidney,
SLO 3.3 analyse the histological organisation of the pituitary, thyroid, and adrenal glands,
SLO 3.4 describe the histological structure of the testis and ovary, and
SLO 3.5 evaluate how tissue organisation supports the physiological functions of mammalian organs

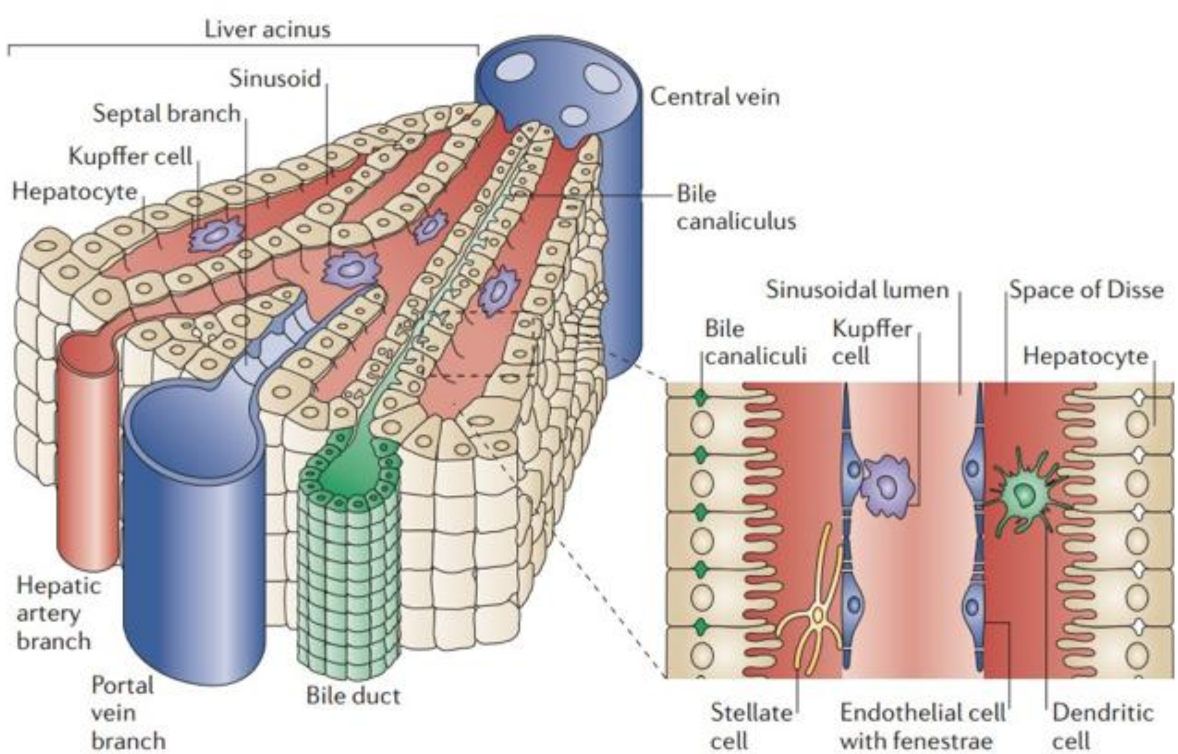
3.1 Digestive Organs

3.1.1 Histological structure and function of the liver

The **liver** is a vital organ responsible for metabolism, detoxification, and secretion of bile. Histologically, it is composed of **lobules**, which are hexagonal units centred around a central vein. Within each lobule, hepatocytes (liver cells) are arranged in plates radiating from the central vein, with sinusoids (specialised capillaries) running between them.

Hepatocytes perform multiple functions, including storing glycogen, synthesising proteins, and detoxifying harmful substances. The liver also produces bile, which aids in fat digestion.

Short description: Diagram showing the histological structure of a liver lobule with hepatocytes, sinusoids, and central vein.
Caption: **Figure 3.1 Histological structure of the liver lobule**



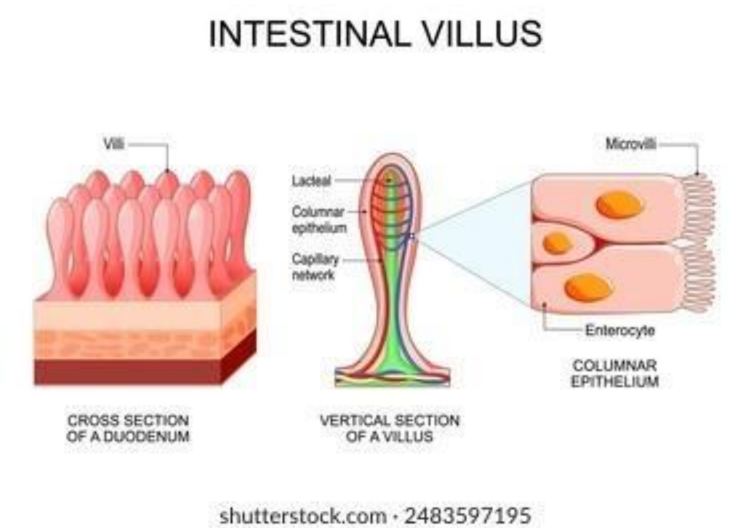
Fill in the blank: The functional unit of the liver is called a ______.

3.1.2 Histological structure and function of the intestine

The **intestine** is specialised for digestion and absorption of nutrients. Histologically, its lining is composed of **villi**, which are finger-like projections that increase the surface area for absorption. Each villus contains epithelial cells, connective tissue, blood vessels, and lymphatic vessels.

The small intestine has simple columnar epithelium with absorptive cells and goblet cells that secrete mucus. The large intestine, in contrast, has fewer villi and more goblet cells, reflecting its role in water absorption and faeces formation.

Short description: Diagram showing villi structure in the small intestine with epithelial lining and blood vessels.
Caption: **Figure 3.2 Histological structure of intestinal villi**



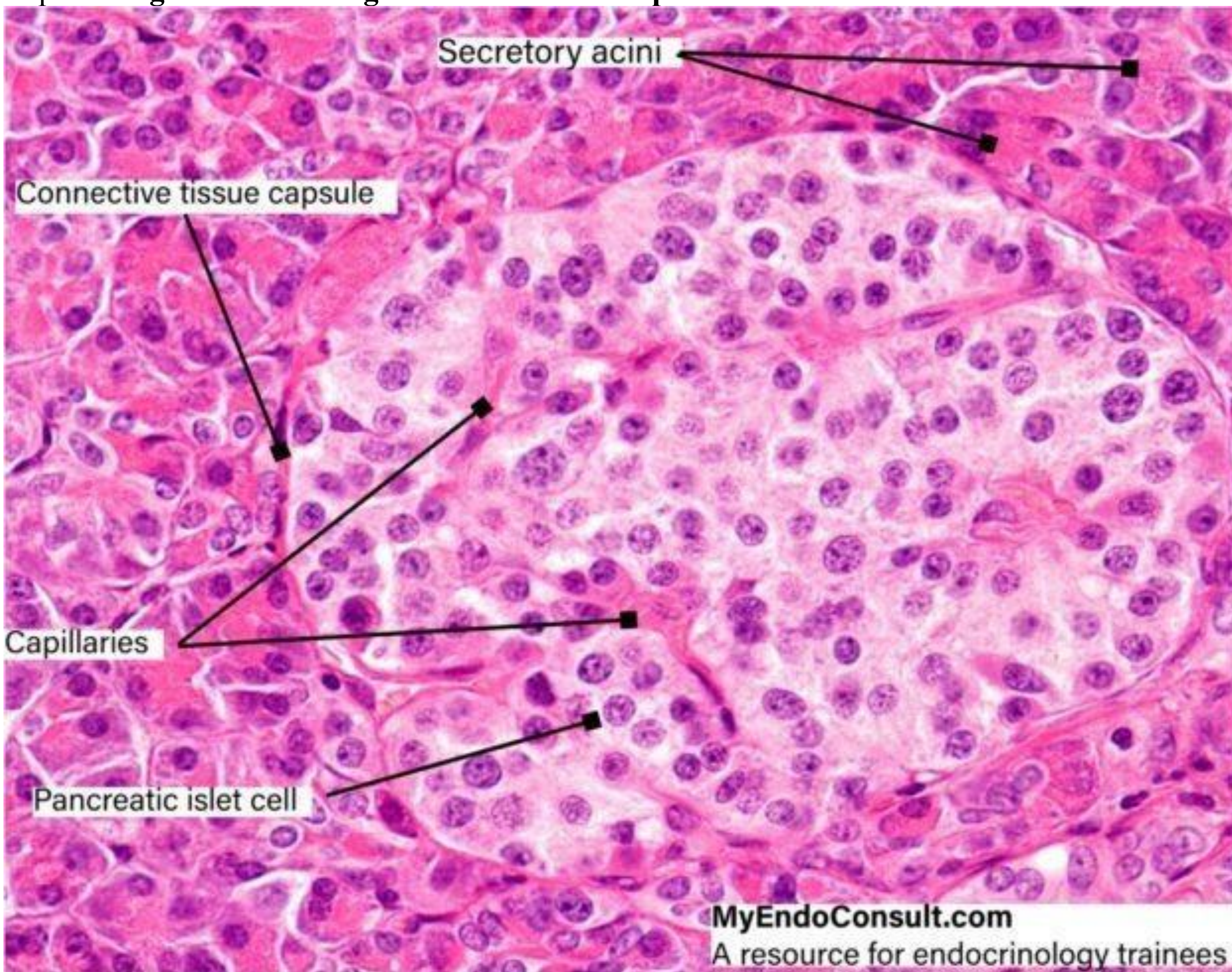
Fill in the blank: Finger-like projections that increase the surface area of the intestine are called ______.

3.1.3 Histological structure and function of the pancreas

The **pancreas** has both exocrine and endocrine functions. Histologically, the exocrine portion consists of **acini**, clusters of cells that secrete digestive enzymes into ducts. The endocrine portion is made up of the **islets of Langerhans**, which contain different cell types that secrete hormones such as insulin and glucagon.

Acinar cells produce enzymes like amylase and lipase, which aid in digestion, while the islets regulate blood glucose levels. This dual role makes the pancreas essential for both digestion and metabolic regulation.

Short description: Diagram showing pancreatic acini and islets of Langerhans.
Caption: **Figure 3.3 Histological structure of the pancreas**



Fill in the blank: The endocrine portion of the pancreas consists of the islets of ______.

Pilot questions 3.1

What is the functional unit of the liver?
Name one function of hepatocytes.
What are villi, and what is their role in the intestine?
Which cells in the pancreas secrete digestive enzymes?
What hormones are secreted by the islets of Langerhans?

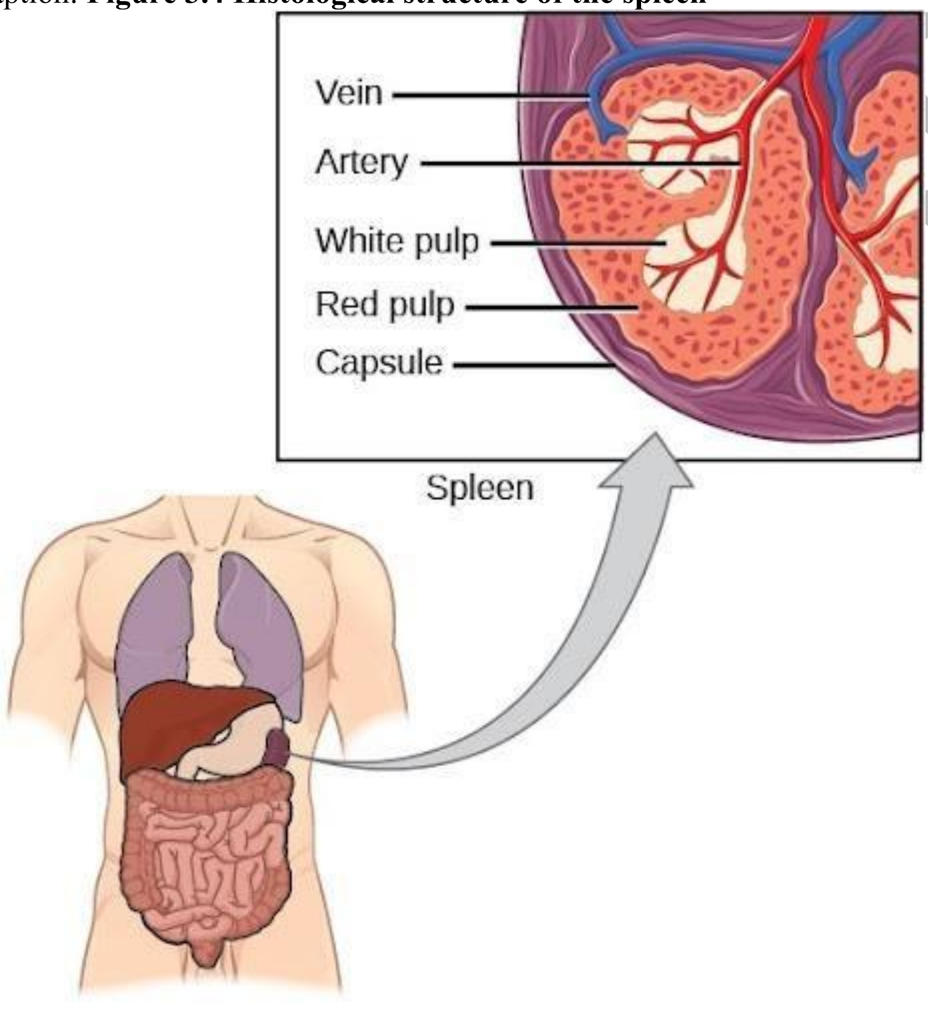
3.2 Lymphoid And Excretory Organs

3.2.1 Histological structure and function of the spleen

The **spleen** is a lymphoid organ that plays a role in immune defence and blood filtration. Histologically, it is divided into **white pulp** and **red pulp**. The white pulp contains lymphocytes organised around central arteries, which are crucial for immune responses. The red pulp consists of sinusoids and splenic cords, which filter blood, remove old red blood cells, and recycle iron.

The spleen also acts as a reservoir for blood and contributes to the production of lymphocytes. Its dual role in immunity and blood maintenance makes it essential for overall health.

Short description: Diagram showing spleen histology with white pulp and red pulp.
Caption: **Figure 3.4 Histological structure of the spleen**



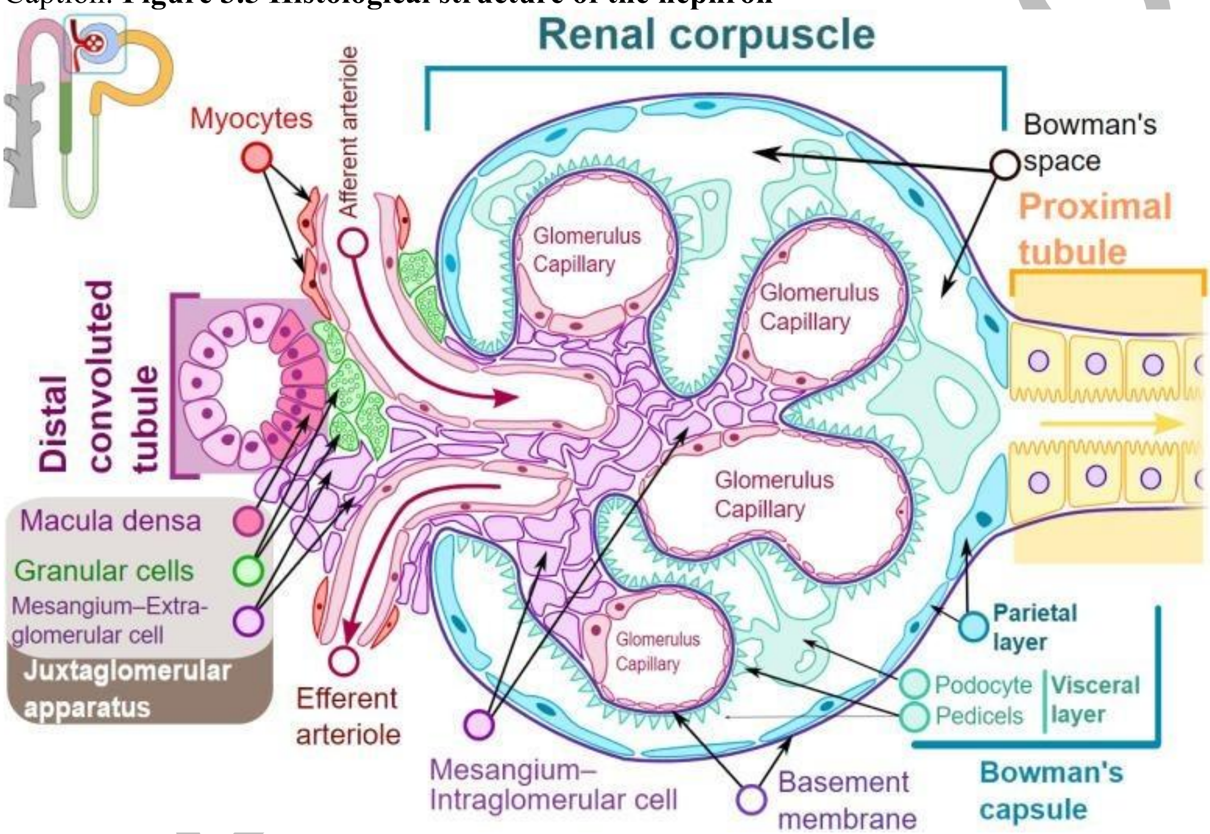
Fill in the blank: The spleen's white pulp contains clusters of ______ that support immune responses.

3.2.2 Histological structure and function of the kidney

The **kidney** is an excretory organ responsible for filtering blood and producing urine. Histologically, it is composed of numerous **nephrons**, which are the functional units. Each nephron includes a renal corpuscle (Bowman's capsule and glomerulus) and a tubular system (proximal tubule, loop of Henle, distal tubule, and collecting duct).

The glomerulus filters blood plasma, while the tubules reabsorb water, ions, and nutrients, and secrete wastes. This organisation ensures the kidney maintains fluid balance, regulates blood pressure, and removes metabolic waste.

Short description: Diagram showing nephron structure with glomerulus, tubules, and collecting duct.
Caption: **Figure 3.5 Histological structure of the nephron**



Fill in the blank: The functional unit of the kidney is the ______.

Pilot questions 3.2

What are the two main regions of the spleen?
What is the role of the red pulp in the spleen?
Which cells are found in the white pulp of the spleen?
What is the functional unit of the kidney?
Name one function of the nephron tubules.

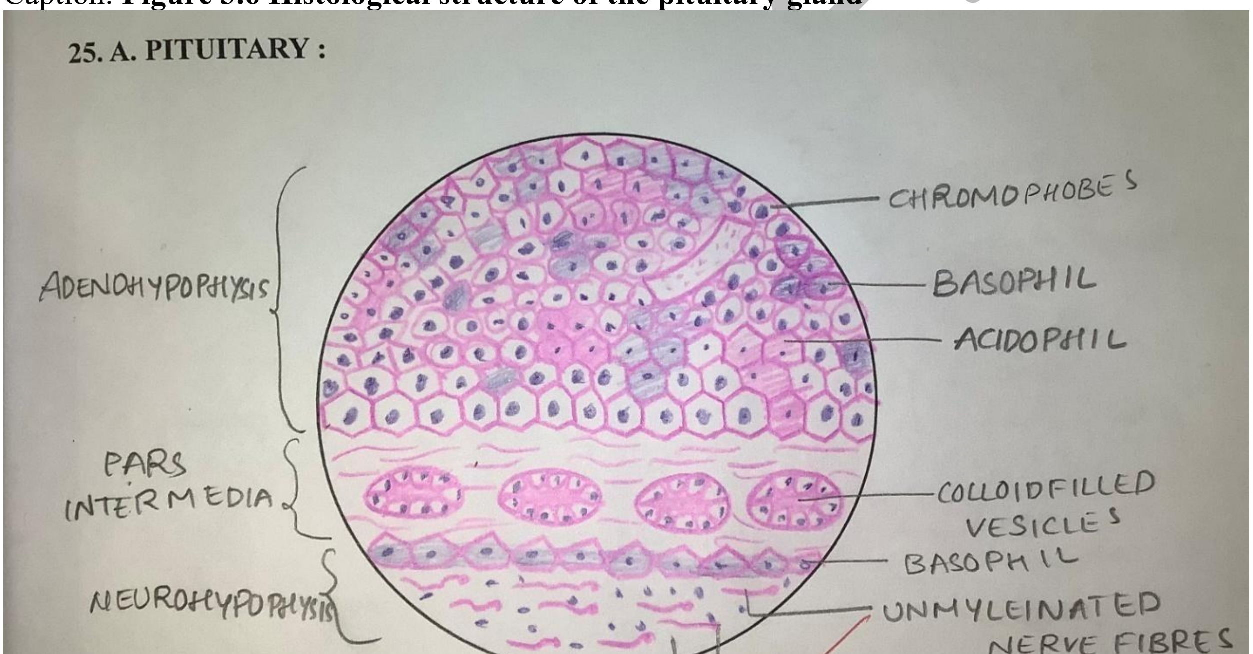
3.3 Endocrine Organs

3.3.1 Histological structure and function of the pituitary gland

The **pituitary gland** is often referred to as the "master gland" because it regulates many other endocrine organs. Histologically, it is divided into the anterior lobe (adenohypophysis) and the posterior lobe (neurohypophysis). The anterior lobe contains endocrine cells that secrete hormones such as growth hormone, prolactin, and thyroid-stimulating hormone. The posterior lobe stores and releases hormones produced by the hypothalamus, including oxytocin and vasopressin.

This dual structure allows the pituitary gland to coordinate growth, reproduction, and water balance.

Short description: Diagram showing anterior and posterior lobes of the pituitary gland.
Caption: **Figure 3.6 Histological structure of the pituitary gland**



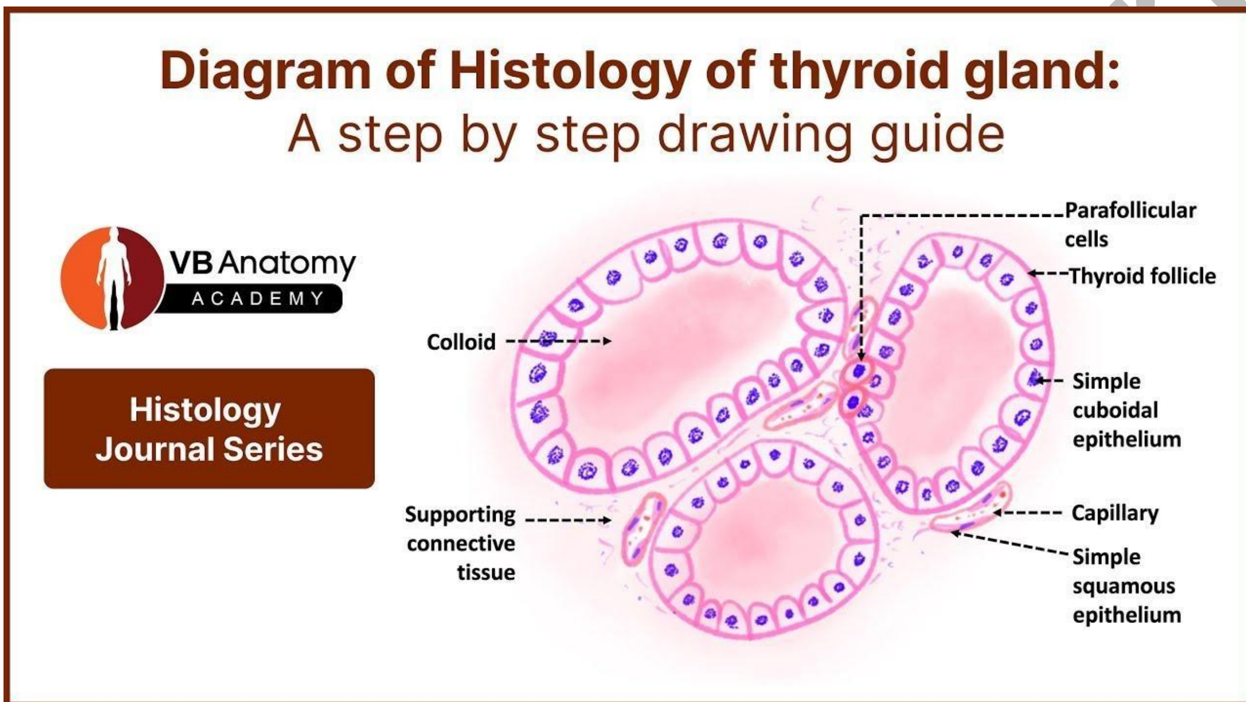
Fill in the blank: The anterior lobe of the pituitary gland is called the ______.

3.3.2 Histological structure and function of the thyroid gland

The **thyroid gland** regulates metabolism and growth. Histologically, it consists of spherical units called **follicles**, which are lined by cuboidal epithelial cells. These cells produce thyroxine (T4) and triiodothyronine (T3), hormones that control metabolic rate. The follicles contain colloid, a storage form of thyroid hormones.

Between the follicles are parafollicular cells, which secrete calcitonin, a hormone that regulates calcium levels.

Short description: Diagram showing thyroid follicles with colloid and parafollicular cells.
Caption: **Figure 3.7 Histological structure of the thyroid gland**



Fill in the blank: Thyroid follicles are filled with ______, which stores thyroid hormones.

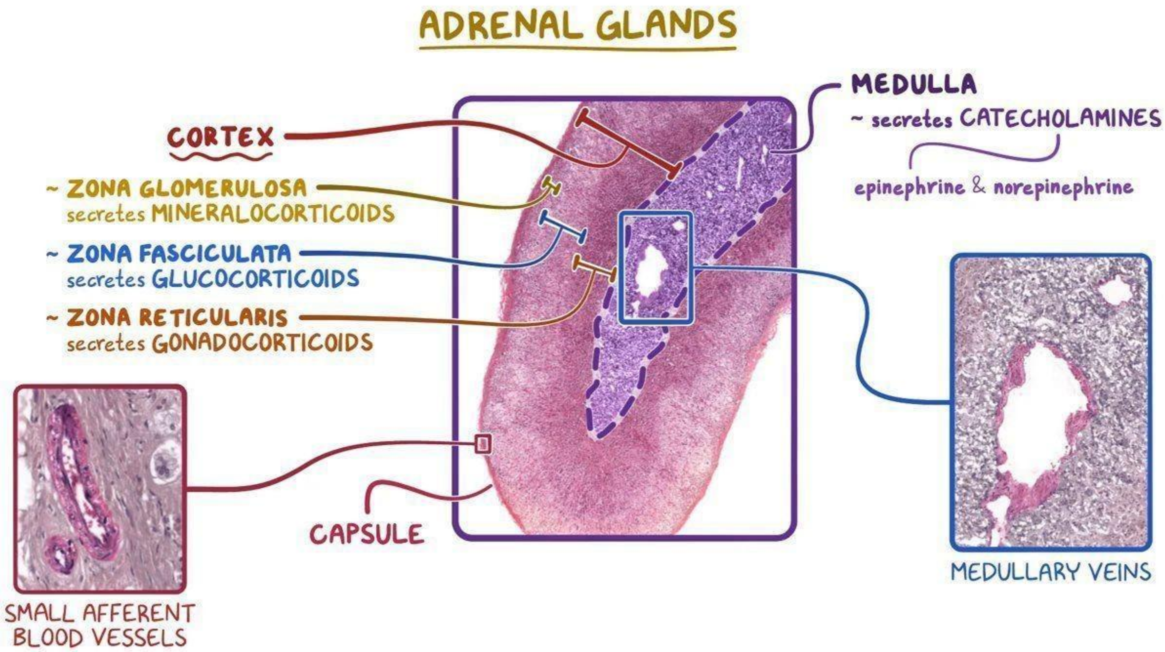
3.3.3 Histological structure and function of the adrenal glands

The **adrenal glands** are located above the kidneys and are divided into the cortex and medulla. The cortex has three zones: zona glomerulosa, which secretes mineralocorticoids (e.g., aldosterone); zona fasciculata, which secretes glucocorticoids (e.g., cortisol); and zona reticularis, which secretes androgens. The medulla contains chromaffin cells that secrete adrenaline and noradrenaline, which prepare the body for stress responses.

This layered organisation ensures that the adrenal glands regulate metabolism, stress responses, and electrolyte balance.

Short description: Diagram showing adrenal cortex zones and medulla.

Caption: **Figure 3.8 Histological structure of the adrenal gland**



Fill in the blank: The zona fasciculata of the adrenal cortex secretes ______, which regulates metabolism and stress responses.

Pilot questions 3.3

What are the two main lobes of the pituitary gland?
Name one hormone secreted by the anterior pituitary.
What is the structural unit of the thyroid gland?
Which hormone is secreted by parafollicular cells?
Name the three zones of the adrenal cortex.

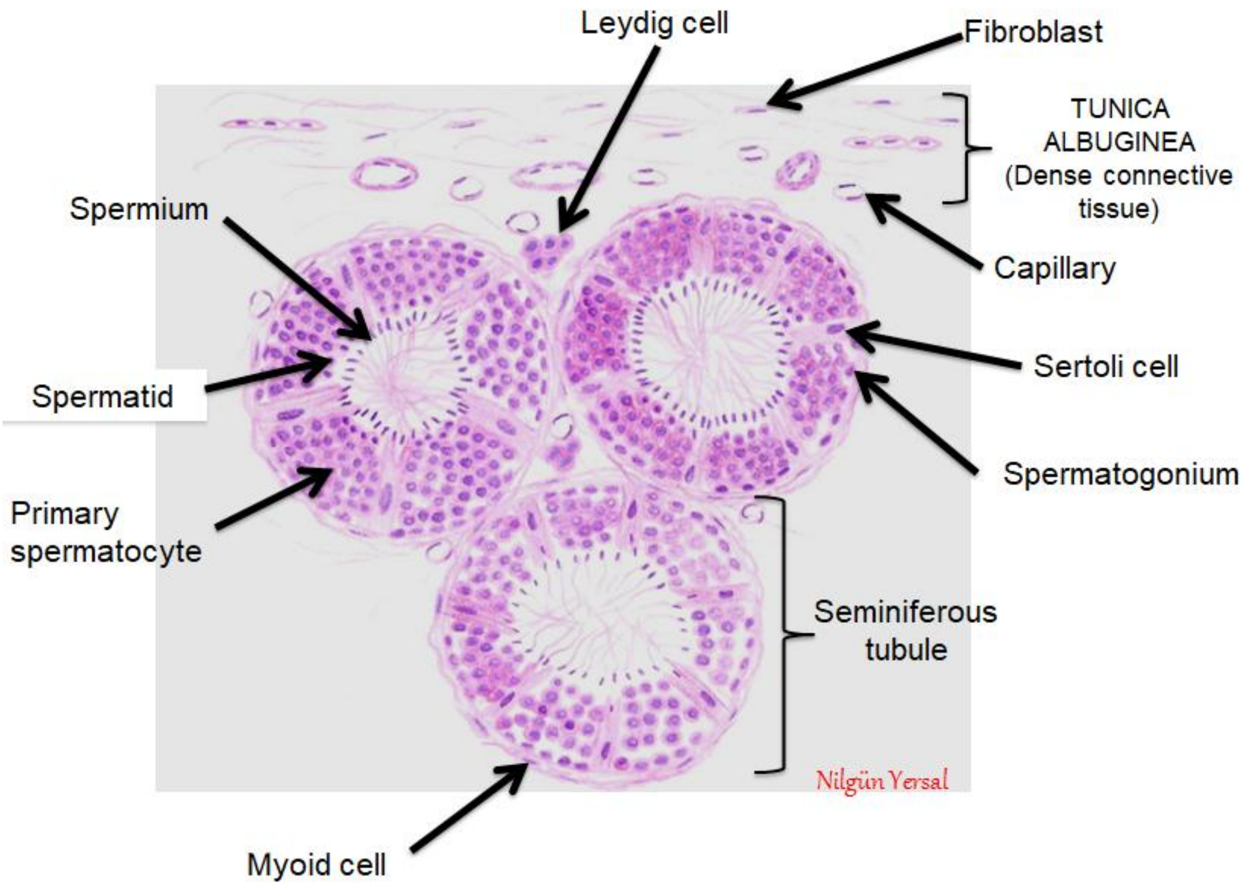
3.4 Reproductive Organs

3.4.1 Histological structure and function of the testis

The **testis** is the male reproductive organ responsible for producing sperm and secreting testosterone. Histologically, it is composed of **seminiferous tubules**, which are tightly coiled structures where spermatogenesis (the formation of sperm) occurs. The tubules are lined by germ cells at different stages of development and supported by Sertoli cells, which provide nourishment and structural support.

Between the seminiferous tubules are **Leydig cells**, which secrete testosterone. This hormone regulates male secondary sexual characteristics and supports sperm production.

Short description: Diagram showing seminiferous tubules with germ cells, Sertoli cells, and Leydig cells.
Caption: **Figure 3.9 Histological structure of the testis**



Fill in the blank: The cells that secrete testosterone in the testis are called ______ cells.

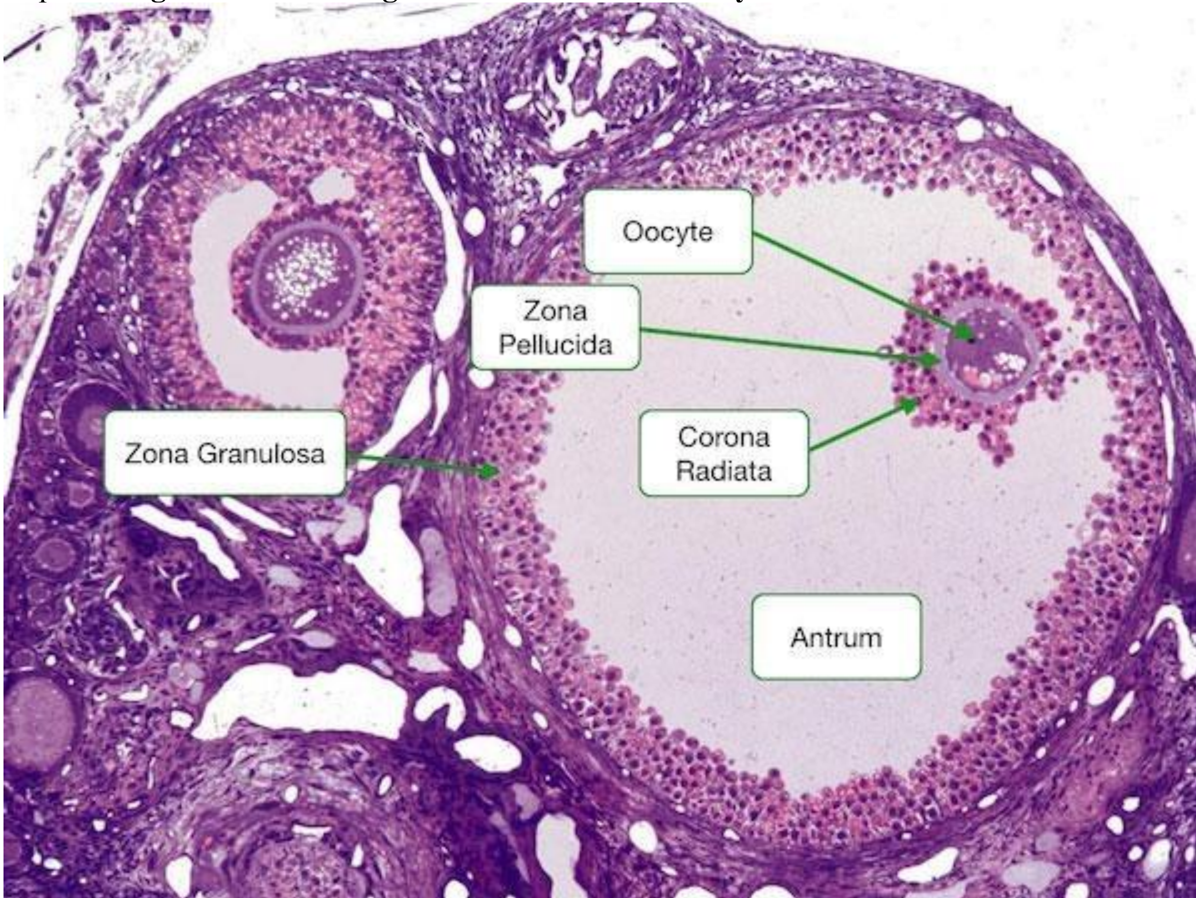
3.4.2 Histological structure and function of the ovary

The **ovary** is the female reproductive organ responsible for producing ova (eggs) and secreting hormones such as oestrogen and progesterone. Histologically, the ovary is divided into the **cortex** and **medulla**. The cortex contains ovarian follicles at different stages of development, while the medulla consists of connective tissue, blood vessels, and nerves.

Follicles progress from primordial to primary, secondary, and mature (Graafian) stages. Each follicle contains an oocyte surrounded by follicular cells. After ovulation, the follicle transforms into the corpus luteum, which secretes progesterone to prepare the uterus for possible implantation.

Short description: Diagram showing ovarian follicles at different stages of development.

Caption: **Figure 3.10 Histological structure of the ovary**



Fill in the blank: After ovulation, the follicle transforms into the corpus ______, which secretes progesterone.

Pilot questions 3.4

What is the role of seminiferous tubules in the testis?
Which cells secrete testosterone?
What are the two main regions of the ovary?
Name the stages of follicle development.
What hormone does the corpus luteum secrete?

Series Summary

This Series focused on the histological study of mammalian organs, building on the earlier exploration of tissues. We began with digestive organs, examining the liver, intestine, and pancreas, and highlighting how their microscopic structures support functions such as metabolism, absorption, and enzyme secretion. We then moved on to lymphoid and excretory organs, considering the spleen's role in immunity and blood filtration, and the kidney's function in excretion and fluid balance. Following that, we studied endocrine organs, including the pituitary, thyroid, and adrenal glands, and analysed how their histological organisation supports hormone production and regulation. Finally, we concluded with reproductive organs, focusing on the testis and ovary, and their roles in gamete production and hormone secretion.

By completing this Series, you should now be able to describe the histological features of major mammalian organs, explain their functions, and evaluate how tissue organisation supports physiological activity. These outcomes align with the Series Learning Objectives and provide you with a comprehensive understanding of organ histology in mammals.

Glossary of Terms

- **Acini**: Clusters of cells in the pancreas that secrete digestive enzymes.
- **Adrenal cortex**: The outer region of the adrenal gland, divided into zones that secrete steroid hormones.
- **Adrenal medulla**: The inner region of the adrenal gland that secretes adrenaline and noradrenaline.
- **Corpus luteum**: A structure formed after ovulation that secretes progesterone.
- **Follicle**: The structural unit of the thyroid gland or ovarian cortex, containing cells and stored material.
- **Hepatocyte**: A liver cell responsible for metabolism, detoxification, and bile secretion.
- **Islets of Langerhans**: Clusters of endocrine cells in the pancreas that secrete insulin and glucagon.
- **Leydig cells**: Cells in the testis that secrete testosterone.
- **Lobule**: The functional unit of the liver, centred around a central vein.
- **Nephron**: The functional unit of the kidney, responsible for filtering blood and producing urine.
- **Seminiferous tubules**: Coiled structures in the testis where sperm are produced.
- **Sinusoids**: Specialised capillaries in the liver and spleen that allow blood filtration.
- **Villi**: Finger-like projections in the intestine that increase surface area for absorption.

Concept Check Questions 3

Objective questions

- The functional unit of the liver is the ______. (Linked to SLO 3.1)
- Finger-like projections that increase the surface area of the intestine are called ______. (Linked to SLO 3.1)
- The endocrine portion of the pancreas consists of the islets of ______. (Linked to SLO 3.1)
- The functional unit of the kidney is the ______. (Linked to SLO 3.2)
- Thyroid follicles are filled with ______, which stores thyroid hormones. (Linked to SLO 3.3)

Short-answer questions

6. Name one function of hepatocytes. (Linked to SLO 3.1)
7. What are the two main regions of the spleen? (Linked to SLO 3.2)
8. Name one hormone secreted by the anterior pituitary. (Linked to SLO 3.3)

9. Which cells secrete testosterone in the testis? (Linked to SLO 3.4)
10. What hormone does the corpus luteum secrete? (Linked to SLO 3.4)

Long-answer questions
11. Describe the histological structure of the liver and explain how it supports its functions. (Linked to SLO 3.1)
12. Analyse the roles of the spleen and kidney, relating their histological features to their functions. (Linked to SLO 3.2)
13. Discuss the histological organisation of the pituitary, thyroid, and adrenal glands, and evaluate their roles in hormone regulation. (Linked to SLO 3.3)
14. Explain the histological structure of the testis and ovary, and assess how they support reproduction. (Linked to SLO 3.4, 3.5)

Answers to Concept Check Questions 3

Objective questions

Lobule.
Villi.
Langerhans.
Nephron.
Colloid.

Short-answer questions
6. Detoxification or bile secretion.
7. White pulp and red pulp.
8. Growth hormone.
9. Leydig cells.
10. Progesterone.

Long-answer questions
11. **Basic response**: The liver is composed of lobules with hepatocytes arranged around a central vein.
Value-added response: Hepatocytes store glycogen, detoxify substances, and secrete bile, while sinusoids allow blood filtration.

Basic response: The spleen filters blood and the kidney produces urine.
Value-added response: White pulp supports immunity, red pulp removes old red blood cells, and nephrons filter plasma and reabsorb nutrients.
Basic response: The pituitary, thyroid, and adrenal glands secrete hormones that regulate body functions.
Value-added response: The pituitary coordinates other glands, thyroid follicles regulate metabolism, and adrenal cortex and medulla manage stress and electrolyte balance.
Basic response: The testis produces sperm and testosterone, while the ovary produces ova and hormones.
Value-added response: Seminiferous tubules support spermatogenesis, Leydig cells

secrete testosterone, ovarian follicles mature into ova, and the corpus luteum secretes progesterone.

Answers to Pilot Questions 3

Part 3.1

Lobule.
Detoxification or bile secretion.
Villi, for nutrient absorption.
Acinar cells.
Insulin and glucagon.

Part 3.2

White pulp and red pulp.
Filters blood and removes old red blood cells.
Lymphocytes.
Nephron.
Reabsorption of water or ions.

Part 3.3

Anterior and posterior lobes.
Growth hormone.
Follicle.
Calcitonin.
Zona glomerulosa, zona fasciculata, zona reticularis.

Part 3.4

Spermatogenesis.
Leydig cells.
Cortex and medulla.
Primordial, primary, secondary, Graafian.
Progesterone.

References And Attributions 3

Figures and Boxes suggested in Series 3:

Figure 3.1 Histological structure of the liver lobule
Figure 3.2 Histological structure of intestinal villi
Figure 3.3 Histological structure of the pancreas
Figure 3.4 Histological structure of the spleen
Figure 3.5 Histological structure of the nephron
Figure 3.6 Histological structure of the pituitary gland

Figure 3.7 Histological structure of the thyroid gland
Figure 3.8 Histological structure of the adrenal gland
Figure 3.9 Histological structure of the testis
Figure 3.10 Histological structure of the ovary

AI prompt suggestions used for illustration placeholders:

Diagrams showing liver lobule, intestinal villi, pancreas, spleen, nephron, pituitary, thyroid, adrenal gland, testis, and ovary.

Open Educational Resource (OER) search strings suggested:

"histology liver lobule diagram OER"
"histology intestinal villi diagram OER"
"histology pancreas acini islets diagram OER"
"histology spleen white pulp red pulp diagram OER"
"histology nephron structure diagram OER"
"histology pituitary gland diagram OER"
"histology thyroid gland follicles diagram OER"
"histology adrenal gland cortex medulla diagram OER"
"histology testis seminiferous tubules diagram OER"
"histology ovary follicles diagram OER"

General references (APA style):

Junqueira, L. C., & Carneiro, J. (2013). *Basic Histology: Text and Atlas*. McGraw-Hill.

Ross, M. H., & Pawlina, W. (2015). *Histology: A Text and Atlas*. Wolters Kluwer.

OER Commons. (n.d.). *Histology resources on mammalian organs*. Retrieved from https://www.oercommons.org

ZOO316 Series 4 Histochemistry And Staining Techniques

Part 4.1 Principles of histochemistry

4.1.1 Definition and scope of histochemistry
4.1.2 Importance of histochemical methods in histology

Part 4.2 General staining techniques

4.2.1 Routine stains (e.g., haematoxylin and eosin)
4.2.2 Special stains for connective and muscle tissues

Part 4.3 Histochemical methods for specific molecules

4.3.1 Carbohydrate staining (e.g., PAS reaction)
4.3.2 Protein and enzyme localisation
4.3.3 Lipid staining methods

Part 4.4 Advanced applications of staining techniques

4.4.1 Immunohistochemistry
4.4.2 Fluorescent staining and modern approaches

Introduction

In the last Series, we explored the histological study of mammalian organs, focusing on how tissues combine to form functional structures. To study these organs in detail, histologists rely on histochemistry and staining techniques, which make microscopic structures visible and distinguishable. Without these methods, the intricate organisation of cells and tissues would remain hidden.

The aim of this Series is to introduce you to the principles of histochemistry and to equip you with knowledge of staining techniques used to highlight different cellular and tissue components.

We shall commence this Series by examining the principles of histochemistry and its importance in histological studies. Next, we will explore general staining techniques, including routine and special stains. Following that, we will consider histochemical methods for specific molecules such as carbohydrates, proteins, enzymes, and lipids. Finally, we will conclude with advanced applications, including immunohistochemistry and fluorescent staining, which represent modern approaches to tissue analysis.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** define histochemistry and explain its scope in histological studies,
- **SLO 4.2** describe the importance of histochemical methods in tissue analysis,
- **SLO 4.3** demonstrate knowledge of routine and special staining techniques,
- **SLO 4.4** apply histochemical methods to identify carbohydrates, proteins, enzymes, and lipids,
- **SLO 4.5** analyse advanced staining techniques such as immunohistochemistry and fluorescent staining, and
- **SLO 4.6** evaluate the relevance of staining techniques in modern histological applications.

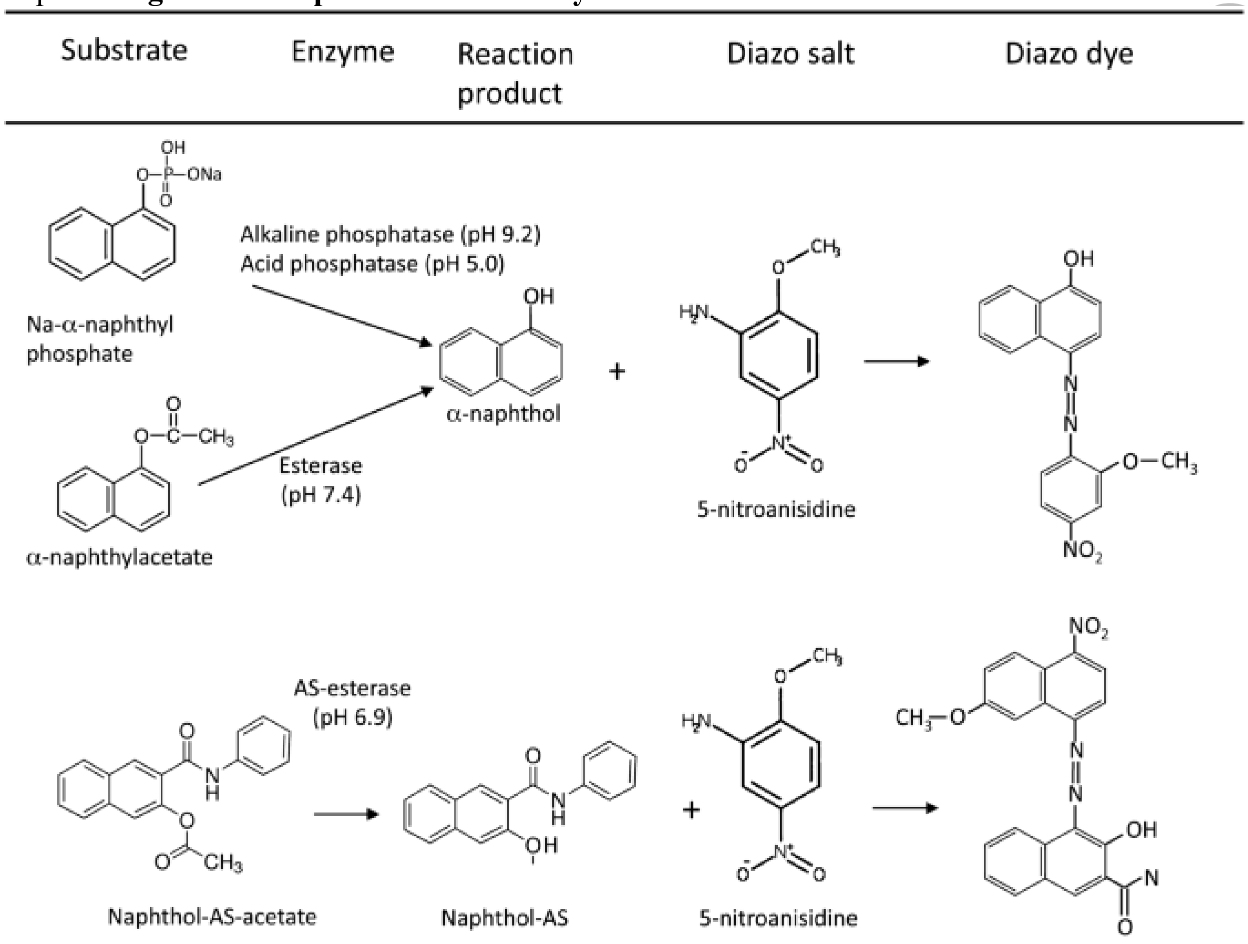
4.1 Principles Of Histochemistry

4.1.1 Definition and scope of histochemistry

Histochemistry is the branch of histology that uses chemical techniques to study the composition of cells and tissues. It involves applying specific stains or reactions to highlight molecules such as proteins, carbohydrates, lipids, and nucleic acids. By doing so, histochemistry allows us to visualise the chemical nature of tissues under the microscope.

The scope of histochemistry extends beyond simple observation. It provides insights into cellular metabolism, disease processes, and the localisation of biomolecules. For example, glycogen can be demonstrated in liver cells using the Periodic Acid–Schiff (PAS) reaction, while lipids can be identified with Sudan dyes.

Short description: Diagram showing histochemical staining highlighting proteins, carbohydrates, and lipids in tissue sections.
Caption: **Figure 4.1 Scope of histochemistry**



Fill in the blank: The PAS reaction is commonly used to demonstrate ______ in tissues.

4.1.2 Importance of histochemical methods in histology

Histochemical methods are important because they make invisible structures visible. Routine microscopy often shows general tissue organisation, but histochemistry reveals the chemical composition and functional state of cells. This is crucial in both teaching and research, as well as in clinical diagnosis.

For instance, histochemical stains can differentiate between normal and diseased tissues. In pathology, they help identify abnormal accumulations such as amyloid deposits or detect enzyme activity in metabolic disorders. In research, histochemistry provides a window into cellular processes, enabling scientists to study how tissues respond to stimuli or injury.

Box 4.2 Importance of histochemical methods

Category	Process / Focus	Key Stages or Components	Practical Application
Developmental Biology	**Gametogenesis**	**Male:** Spermatogonia $\rightarrow$ Spermatocytes $\rightarrow$ Spermatids $\rightarrow$ **Spermatozoa**. **Female:** Oogonia $\rightarrow$ Oocytes $\rightarrow$ Polar Bodies $\rightarrow$ **Mature Ovum**.	Foundations of reproductive biology and fertility studies.
Developmental Biology	**Embryogenesis**	Zygote $\rightarrow$ Cleavage $\rightarrow$ **Blastula** $\rightarrow$ **Gastrulation**.	Foundational milestones in early life development.
Cellular Biology	**Differentiation**	Multipotent cells $\rightarrow$ Specialized **Muscle**, **Nerve**, and **Skin** cells.	Histology, tissue engineering, and anatomy.
Field Entomology	**Collection Methods**	**Handpicking**, **Sweeping Nets**, and **Beating Trays**.	Biodiversity sampling and vector monitoring in ecosystems.
Field Entomology	**Safety & PPE**	Respiratory protection, gloves, and branch/tick/snake protection.	Fieldwork risk management and safe chemical handling.
Specimen Curation	**Preservation**	**Pinning** (Thorax/Elytra), **Wing Spreading** (Lepidoptera), and **Labelling**.	Museum archiving and systematic research collections.

Category	Process / Focus	Key Stages or Components	Practical Application
Taxonomy & ID	**Morphology**	**Mouthparts** (Siphoning, Lapping), **Wings** (Elytra, Scaled), and **Antennae**.	Traditional species classification and morphological keys.
Modern Technology	**Advanced ID**	**Digital Imaging** and **DNA Barcoding** (PCR sequencing).	High-accuracy molecular and digital archiving.

Fill in the blank: Histochemical methods are essential in pathology because they help identify abnormal ______ in tissues.

Pilot questions 4.1

What is histochemistry?
What does the PAS reaction demonstrate?
Name one biomolecule that can be identified using histochemical methods.
Why are histochemical methods important in pathology?
Give one example of how histochemistry is used in research.

4.2 General Staining Techniques

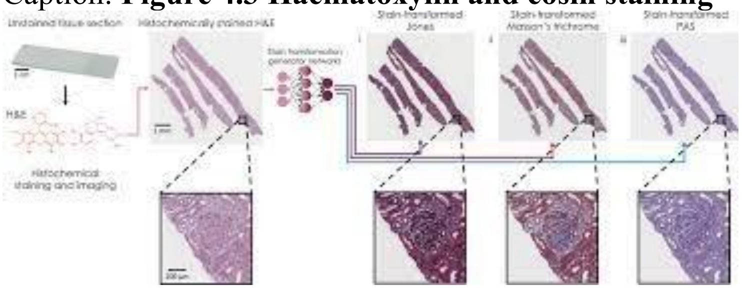
4.2.1 Routine stains (e.g., haematoxylin and eosin)

Routine stains are the most commonly used methods in histology for general tissue examination. The most widely applied is the **haematoxylin and eosin (H&E) stain**. Haematoxylin stains cell nuclei blue or purple, highlighting DNA and nuclear structures, while eosin stains cytoplasm and extracellular components pink. Together, they provide contrast that allows histologists to distinguish between different tissue types and cellular components.

This technique is essential in both teaching and diagnostic pathology, as it provides a clear overview of tissue organisation and abnormalities.

Short description: Diagram showing tissue section stained with haematoxylin and eosin, highlighting nuclei and cytoplasm.

Caption: **Figure 4.3 Haematoxylin and eosin staining**



Fill in the blank: Haematoxylin stains the cell ______ blue or purple.

4.2.2 Special stains for connective and muscle tissues

While routine stains provide general information, **special stains** are used to highlight specific tissue components. For example, **Masson's trichrome stain** differentiates collagen fibres (blue or green), muscle fibres (red), and nuclei (black). This is particularly useful in studying connective tissue disorders or fibrosis.

Another example is **Periodic Acid–Schiff (PAS) stain**, which highlights carbohydrates such as glycogen and mucins in tissues. For muscle tissues, stains like phosphotungstic acid haematoxylin (PTAH) can be used to demonstrate striations in skeletal and cardiac muscle.

Box 4.4 Special stains for connective and muscle tissues

Stain Name	Target Tissue / Component	Resulting Coloration	Primary Application
Masson's Trichrome	Collagen vs. Muscle	**Blue/Green:** Collagen **Red:** Muscle & Cytoplasm	Distinguishing smooth muscle from visceral collagen; staging liver or lung fibrosis.

Stain Name	Target Tissue / Component	Resulting Coloration	Primary Application
		Black: Nuclei	
Verhoeff-Van Gieson (VVG)	Elastic Fibers	**Black:** Elastic fibers **Red:** Collagen **Yellow:** Muscle/Cytoplasm	Identifying atrophy of elastic tissue in emphysema or thinning of vessel walls (e.g., Aneurysms).
Gomori's Reticulin	Reticular Fibers (Type III Collagen)	**Black:** Reticular fibers (Argyrophilic)	Visualizing the structural framework (stroma) of "soft" organs like the liver, spleen, and bone marrow.
Periodic Acid-Schiff (PAS)	Glycogen & Basement Membranes	**Magenta/Hot Pink:** Glycogen, Basement membrane, Fungus	Detecting glycogen storage diseases in muscle or thickening of basement membranes in kidney disease.
Movat's Pentachrome	Multi-component (Collagen, Elastic, Muscle, Mucin)	**Black:** Elastic	Comprehensive study of heart valves and complex vascular structures.

Stain Name	Target Tissue / Component	Resulting Coloration	Primary Application
		Yellow: Collagen **Red:** Muscle **Blue:** Mucin	
Toluidine Blue	Mast Cells (Connective Tissue)	**Red-Purple (Metachromatic):** Mast cell granules **Blue:** Background	Identifying mast cells in connective tissue during allergic or inflammatory response studies.
PTAH (Phosphotungstic Acid Hematoxylin)	Striated Muscle & Fibrin	**Blue-Black:** Striations, Fibrin **Red-Brown:** Collagen	Confirming rhabdomyosarcomas (muscle tumors) by highlighting cross-striations.

Fill in the blank: Masson's trichrome stain colours collagen fibres ______ or green.

Pilot questions 4.2

What is the most widely used routine stain in histology?
Which structures are stained by haematoxylin?
Name one special stain used for connective tissue.
What does PAS stain highlight in tissues?
Which stain can be used to demonstrate striations in muscle fibres?

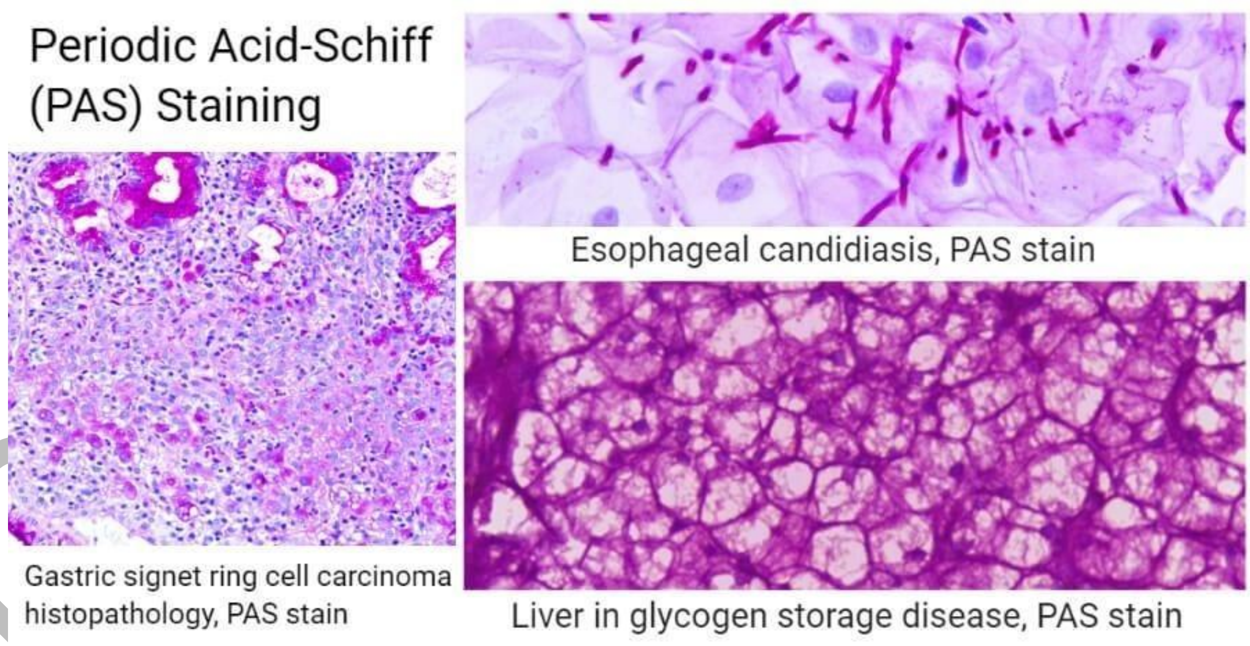
4.3 Histochemical Methods For Specific Molecules

4.3.1 Carbohydrate staining (e.g., PAS reaction)

Carbohydrates in tissues can be demonstrated using the **Periodic Acid–Schiff (PAS) reaction**. This method oxidises carbohydrate molecules to form aldehydes, which then react with Schiff's reagent to produce a magenta colour. It is particularly useful for identifying glycogen, mucins, and basement membranes.

The PAS reaction is widely applied in pathology to detect abnormal carbohydrate deposits, such as those seen in certain storage diseases.

Short description: Diagram showing PAS staining highlighting glycogen in liver cells.
Caption: **Figure 4.5 PAS staining of carbohydrates**



Fill in the blank: The PAS reaction produces a ______ colour when carbohydrates are present.

4.3.2 Protein and enzyme localisation

Proteins and enzymes can be identified using histochemical methods that rely on their chemical activity. For example, enzyme histochemistry involves incubating tissue sections with substrates that produce coloured products when acted upon by specific enzymes.

An example is the demonstration of alkaline phosphatase activity, which produces a coloured precipitate at sites where the enzyme is active. This helps in studying metabolic processes and diagnosing enzyme deficiencies.

Box 4.6 Protein and enzyme localisation methods

Category	Process / Concept	Key Characteristics	Examples
Cleavage Patterns	**Holoblastic**	Total division of the egg; occurs in eggs with little-to-moderate yolk.	Amphibians (Frogs), Mammals
	Meroblastic	Partial division; cleavage occurs only in a small disk of cytoplasm.	Birds (Chicks), Reptiles
Axis & Patterning	**Morphogen Gradients**	Concentration-dependent signaling molecules that dictate cell fate.	Sonic Hedgehog (Shh), Wnt, BMP
	Induction	One group of cells influencing the development of adjacent cells.	Neural tube formation via the Notochord
Germ Layer Fates	**Ectoderm**	Outer layer; forms "attractiveness" and "intelligence."	Skin (epidermis), Nervous system
	Mesoderm	Middle layer; forms "means of movement."	Muscles, Skeleton, Circulatory system
	Endoderm	Inner layer; forms "internal plumbing."	Digestive tract, Respiratory lining

Category	Process / Concept	Key Characteristics	Examples
Tissue Stability	**Homeostasis**	The balance between cell division (mitosis) and programmed death.	Skin renewal, Liver regeneration
	Apoptosis	"Clean" programmed cell death; no inflammation.	Finger webbing disappearance in utero
Pathology	**Necrosis**	"Messy" accidental cell death; causes inflammation.	Infarction (heart attack), Infections
	Benign Tumour	Localized, encapsulated, slow-growing, well-differentiated.	Adenoma, Lipoma
	Malignant Tumour	Invasive, metastatic (spreads), poorly differentiated.	Carcinoma, Sarcoma

Fill in the blank: Enzyme histochemistry demonstrates activity by producing a coloured ______ at the site of reaction.

4.3.3 Lipid staining methods

Lipids are visualised using stains that dissolve in fat droplets and impart colour. Common methods include **Sudan dyes** (Sudan III, Sudan IV, and Sudan Black), which stain lipids in orange, red, or black. Another method is **Oil Red O**, which highlights neutral lipids in red.

These stains are important in identifying fat deposits in tissues, studying metabolic disorders, and detecting pathological changes such as fatty liver disease.

Short description: Diagram showing lipid staining with Sudan dyes in adipose tissue.

Caption: **Figure 4.7 Lipid staining in adipose tissue**

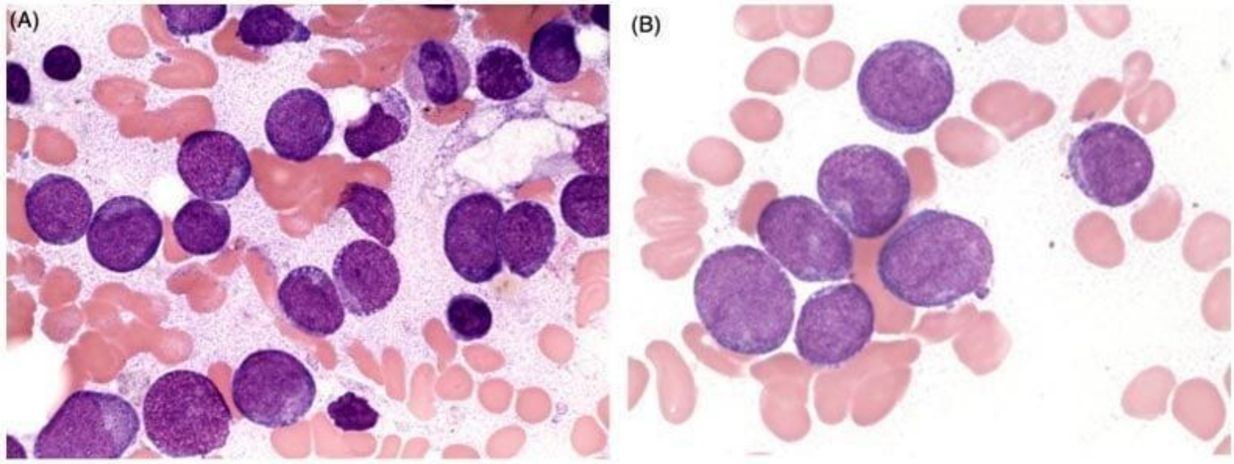


Figure - AML (Acute Myeloid Leukemia) without maturation (AML-M1)

Bone marrow smear (A) and blood smear (B) showing numerous blast cells with scant nongranular basophilic cytoplasm, round, or slightly irregular nuclei, fine chromatin, and one or more prominent nucleoli.

Fill in the blank: Oil Red O is used to stain ______ lipids red.

Pilot questions 4.3

What does the PAS reaction demonstrate?
What colour is produced by PAS staining?
How is enzyme histochemistry carried out?
Name one enzyme that can be demonstrated histochemically.
Which stains are commonly used to identify lipids?

4.4 Advanced Applications Of Staining Techniques

4.4.1 Immunohistochemistry

Immunohistochemistry (IHC) is a technique that uses antibodies to detect specific antigens in tissue sections. Antibodies are tagged with markers such as enzymes or fluorescent dyes, which produce a visible signal when they bind to their target. This allows precise localisation of proteins within cells and tissues.

IHC is widely used in medical diagnostics, particularly in identifying tumour markers, infectious agents, and abnormal protein expression. It also plays a crucial role in research, helping scientists study signalling pathways and cellular interactions.

Short description: Diagram showing immunohistochemistry with antibody binding to antigen in tissue.
Caption: **Figure 4.8 Immunohistochemistry principle**

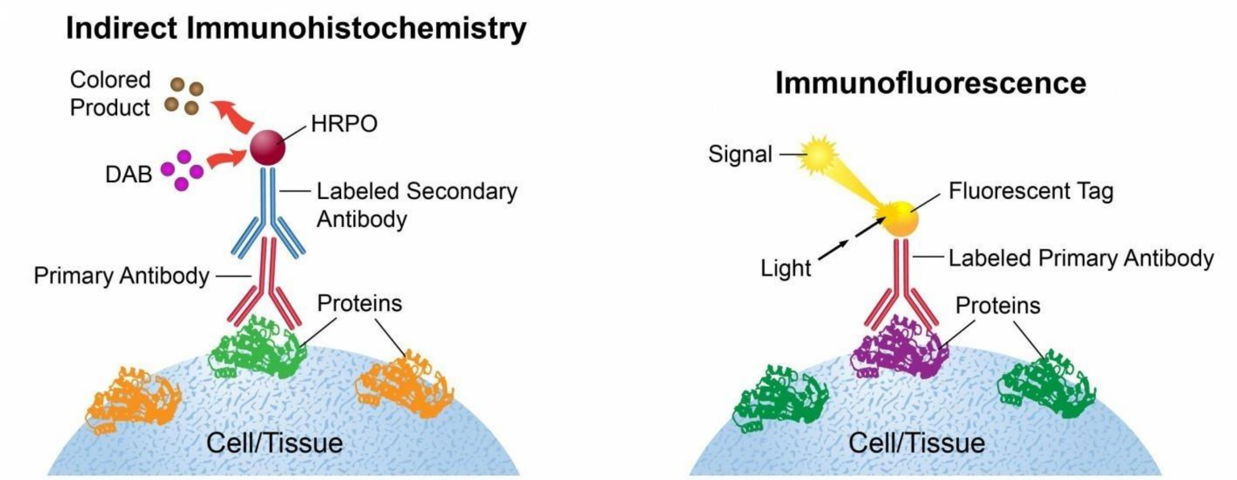


Diagram 1: *Illustration of Indirect Immunohistochemistry and Immunofluorescence methods.*

Fill in the blank: Immunohistochemistry uses ______ to detect specific antigens in tissues.

4.4.2 Fluorescent staining and modern approaches

Fluorescent staining involves using dyes or labelled antibodies that emit light when exposed to specific wavelengths. Under a fluorescence microscope, these signals appear as bright colours, allowing detailed visualisation of cellular structures. Common dyes include DAPI, which binds to DNA and stains nuclei blue, and fluorescein, which can be conjugated to antibodies for protein detection.

Modern approaches combine fluorescent staining with advanced imaging techniques such as confocal microscopy, which provides high-resolution three-dimensional images. These methods are invaluable in neuroscience, cancer research, and molecular biology, as they allow scientists to track cellular processes in real time.

Short description: Diagram showing fluorescent staining of cells with DAPI and fluorescein-labelled antibodies.

Caption: **Figure 4.9 Fluorescent staining of cells**

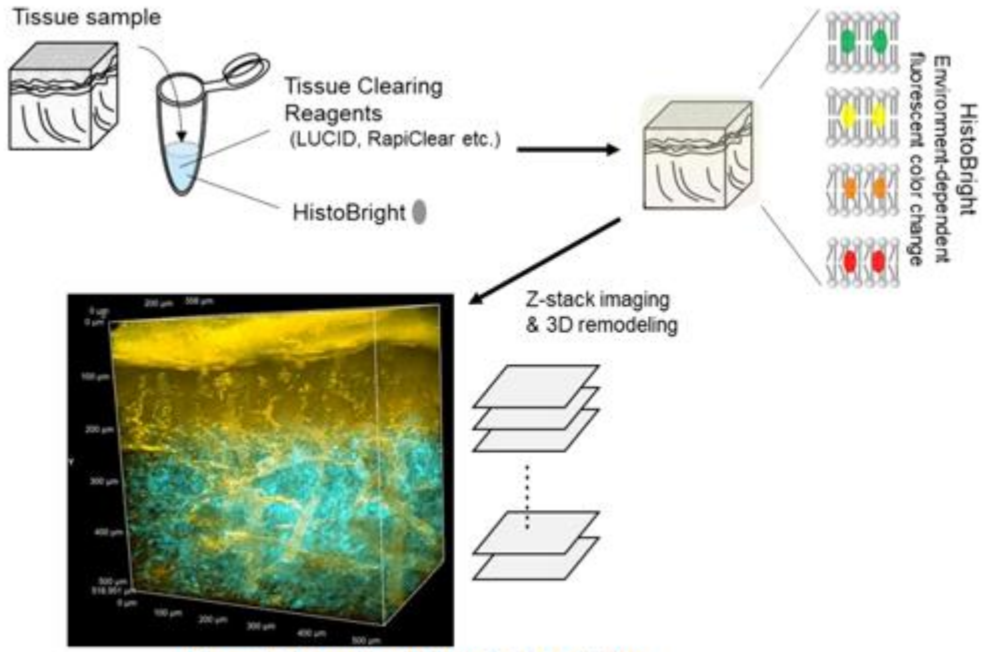


Figure 1 Overview of HistoBright staining

Fill in the blank: DAPI is a fluorescent dye that binds to ______ and stains nuclei blue.

Pilot questions 4.4

What is immunohistochemistry used to detect?
How are antibodies visualised in immunohistochemistry?
Name one application of immunohistochemistry in medicine.
What does DAPI stain in cells?
Which modern imaging technique provides three-dimensional views of fluorescently stained tissues?

Series Summary

This Series explored histochemistry and staining techniques, which are essential tools for revealing the chemical composition and organisation of tissues. We began by defining histochemistry and considering its scope and importance in histological studies. We then examined general staining techniques, focusing on routine stains such as haematoxylin and eosin, and special stains for connective and muscle tissues. Following that, we studied histochemical methods for specific molecules, including carbohydrates, proteins, enzymes, and lipids. Finally, we concluded with advanced applications such as immunohistochemistry and fluorescent staining, which represent modern approaches to tissue analysis.

By completing this Series, you should now be able to define histochemistry, describe its importance, demonstrate knowledge of routine and special stains, apply histochemical methods for identifying biomolecules, analyse advanced staining techniques, and evaluate their relevance in modern histological applications. These achievements align with the Series Learning Outcomes and provide you with practical and theoretical skills for studying tissues at the microscopic level.

Glossary of Terms

- **Alkaline phosphatase**: An enzyme demonstrated histochemically to study metabolic activity.
- **Colloid**: Stored material inside thyroid follicles containing thyroid hormones.
- **DAPI**: A fluorescent dye that binds to DNA and stains nuclei blue.
- **Haematoxylin and eosin (H&E)**: Routine stain used to highlight nuclei (blue/purple) and cytoplasm (pink).
- **Histochemistry**: The study of chemical composition of tissues using staining techniques.
- **Immunohistochemistry (IHC)**: A technique using antibodies to detect specific antigens in tissues.
- **Oil Red O**: A stain used to highlight neutral lipids in red.
- **PAS reaction**: A staining method that demonstrates carbohydrates such as glycogen and mucins.
- **PTAH stain**: A special stain used to demonstrate striations in muscle fibres.
- **Sudan dyes**: Lipid stains that colour fat droplets orange, red, or black.

Concept Check Questions 4

Objective questions

- The PAS reaction produces a ______ colour when carbohydrates are present. (Linked to SLO 4.4)
- Haematoxylin stains the cell ______ blue or purple. (Linked to SLO 4.3)
- Oil Red O is used to stain ______ lipids red. (Linked to SLO 4.4)
- Immunohistochemistry uses ______ to detect specific antigens in tissues. (Linked to SLO 4.5)
- DAPI is a fluorescent dye that binds to ______. (Linked to SLO 4.5)

Short-answer questions

6. Define histochemistry. (Linked to SLO 4.1)
7. Why are histochemical methods important in pathology? (Linked to SLO 4.2)
8. Name one special stain used for connective tissue. (Linked to SLO 4.3)
9. What does enzyme histochemistry demonstrate? (Linked to SLO 4.4)
10. Name one modern imaging technique used with fluorescent staining. (Linked to SLO 4.6)

Long-answer questions

11. Describe the principles of histochemistry and explain its scope in histological studies. (Linked to SLO 4.1, 4.2)

12. Analyse routine and special staining techniques, giving examples of their applications. (Linked to SLO 4.3)
13. Discuss histochemical methods for carbohydrates, proteins, enzymes, and lipids, and evaluate their importance. (Linked to SLO 4.4)
14. Explain immunohistochemistry and fluorescent staining, and assess their relevance in modern histological applications. (Linked to SLO 4.5, 4.6)

Answers to Concept Check Questions 4

Objective questions

Magenta.
Nucleus.
Neutral.
Antibodies.
DNA.

Short-answer questions
6. The study of chemical composition of tissues using staining techniques.
7. They help identify abnormal deposits and differentiate diseased tissues.
8. Masson's trichrome.
9. Enzyme activity.
10. Confocal microscopy.

Long-answer questions
11. **Basic response**: Histochemistry uses chemical reactions to study tissue composition.
Value-added response: It reveals biomolecules such as glycogen, lipids, and proteins, supporting both research and diagnosis.

Basic response: Routine stains like H&E highlight nuclei and cytoplasm, while special stains target specific tissues.
Value-added response: Masson's trichrome differentiates collagen and muscle fibres, PAS highlights carbohydrates, and PTAH shows muscle striations.
Basic response: PAS demonstrates carbohydrates, enzyme histochemistry shows enzyme activity, and Sudan dyes highlight lipids.
Value-added response: These methods are crucial in detecting storage diseases, metabolic disorders, and pathological changes.
Basic response: Immunohistochemistry uses antibodies, and fluorescent staining uses dyes to visualise structures.
Value-added response: IHC identifies tumour markers and abnormal proteins, while fluorescent staining with confocal microscopy provides high-resolution imaging for advanced research.

Answers to Pilot Questions 4

Part 4.1

The study of chemical composition of tissues using staining techniques.
Glycogen.
Lipids, proteins, carbohydrates, nucleic acids.
Abnormal deposits.
Studying tissue responses or enzyme activity.

Part 4.2

Haematoxylin and eosin (H&E).
Nuclei.
Masson's trichrome.
Carbohydrates such as glycogen.
PTAH.

Part 4.3

Carbohydrates.
Magenta.
By incubating tissue with substrates that produce coloured products.
Alkaline phosphatase.
Sudan dyes or Oil Red O.

Part 4.4

Specific antigens.
Enzymes or fluorescent dyes.
Identifying tumour markers.
DNA.
Confocal microscopy.

References And Attributions 4

Figures and Boxes suggested in Series 4:

Figure 4.1 Scope of histochemistry
Box 4.2 Importance of histochemical methods
Figure 4.3 Haematoxylin and eosin staining
Box 4.4 Special stains for connective and muscle tissues
Figure 4.5 PAS staining of carbohydrates
Box 4.6 Protein and enzyme localisation methods
Figure 4.7 Lipid staining in adipose tissue
Figure 4.8 Immunohistochemistry principle
Figure 4.9 Fluorescent staining of cells

AI prompt suggestions used for illustration placeholders:

Diagrams showing H&E staining, PAS reaction, lipid staining, immunohistochemistry, and fluorescent staining.
Boxes summarising importance of histochemistry and special stains.

Open Educational Resource (OER) search strings suggested:

"histochemistry scope diagram OER"
"importance of histochemistry OER"
"H&E stain histology diagram OER"
"special stains connective muscle tissue OER"
"PAS stain histology glycogen OER"
"enzyme histochemistry alkaline phosphatase OER"
"Sudan stain lipid histology OER"
"immunohistochemistry principle diagram OER"
"fluorescent staining histology diagram OER"

General references (APA style):

Bancroft, J. D., & Gamble, M. (2008). *Theory and Practice of Histological Techniques*. Churchill Livingstone.

Kiernan, J. A. (2015). *Histological and Histochemical Methods: Theory and Practice*. Scion Publishing.

OER Commons. (n.d.). *Histology and staining resources*. Retrieved from https://www.oercommons.org

ZOO316 Series 5 Histopathology And Tissue Stability

Part 5.1 Principles of histopathology
- 5.1.1 Definition and scope of histopathology
- 5.1.2 Importance of histopathology in medicine and research

Part 5.2 Pathological changes in tissues
- 5.2.1 Degeneration and necrosis
- 5.2.2 Inflammation and repair
- 5.2.3 Neoplasia (tumour formation)

Part 5.3 Tissue stability and homeostasis
- 5.3.1 Mechanisms of tissue stability
- 5.3.2 Cellular adaptation to stress
- 5.3.3 Role of stem cells in tissue renewal

Part 5.4 Applications of histopathology

5.4.1 Diagnostic applications in clinical practice
5.4.2 Research applications in disease studies

Introduction

In the last Series, we explored histochemistry and staining techniques, which provided us with tools to visualise the chemical composition of tissues. Building on that foundation, this Series introduces histopathology and tissue stability, focusing on how tissues respond to injury, disease, and stress. Histopathology is central to medical practice, as it helps clinicians diagnose conditions and understand disease progression.

The aim of this Series is to explain the principles of histopathology, describe pathological changes in tissues, and analyse mechanisms of tissue stability and homeostasis. It also seeks to highlight the diagnostic and research applications of histopathology.

We shall commence this Series by examining the principles of histopathology and its importance in medicine and research. Next, we will explore pathological changes in tissues, including degeneration, necrosis, inflammation, repair, and neoplasia. Following that, we will consider tissue stability and homeostasis, focusing on cellular adaptation and the role of stem cells. Finally, we will conclude with applications of histopathology in clinical diagnosis and research.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** define histopathology and explain its scope,
- **SLO 5.2** describe the importance of histopathology in medicine and research,
- **SLO 5.3** explain pathological changes such as degeneration, necrosis, inflammation, repair, and neoplasia,
- **SLO 5.4** analyse mechanisms of tissue stability and cellular adaptation to stress,
- **SLO 5.5** evaluate the role of stem cells in tissue renewal, and
- **SLO 5.6** apply knowledge of histopathology to diagnostic and research contexts.

5.1 Principles Of Histopathology

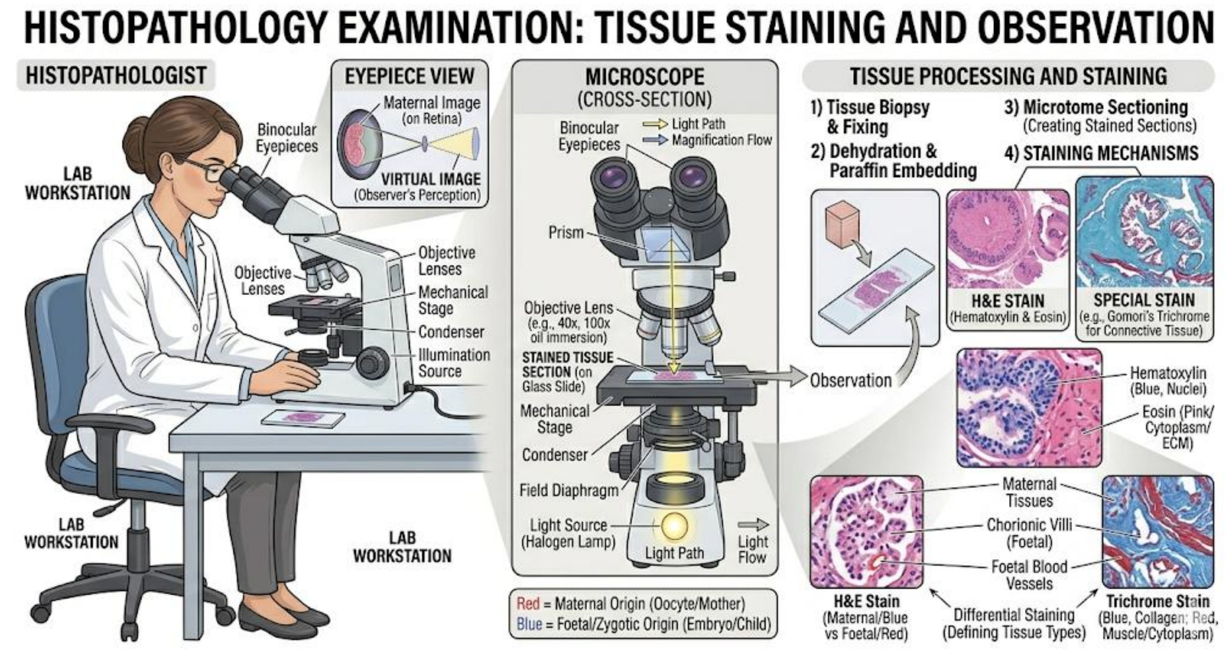
5.1.1 Definition and scope of histopathology

Histopathology is the branch of pathology that studies the microscopic changes in tissues caused by disease. It involves examining stained tissue sections under a microscope to identify structural alterations that indicate injury, degeneration, inflammation, or abnormal growth.

The scope of histopathology extends across medicine and research. In clinical practice, it is used to diagnose conditions such as cancers, infections, and autoimmune disorders. In research, histopathology helps scientists understand disease mechanisms and evaluate the effects of new treatments.

Short description: Diagram showing a histopathologist examining stained tissue sections under a microscope.

Caption: **Figure 5.1 Scope of histopathology**



Fill in the blank: Histopathology studies the ______ changes in tissues caused by disease.

5.1.2 Importance of histopathology in medicine and research

Histopathology is important because it provides definitive evidence of disease at the cellular level. While clinical symptoms and imaging can suggest a diagnosis, histopathology confirms it by revealing the actual tissue changes. For example, a biopsy examined histologically can distinguish between benign and malignant tumours.

In research, histopathology is vital for studying how tissues respond to injury, infection, or experimental treatments. It also supports drug development by showing how new therapies affect tissue structure and stability.

Box 5.2 Importance of histopathology

Category	Process / Focus	Key Stages or Components	Practical Application
Developmental Biology	**Gametogenesis**	**Male:** Spermatogonia $\rightarrow$ Spermatocytes	Foundations of reproductive biology and fertility studies.

Category	Process / Focus	Key Stages or Components	Practical Application
		$\rightarrow$ Spermatids $\rightarrow$ **Spermatozoa**. **Female:** Oogonia $\rightarrow$ Oocytes $\rightarrow$ Polar Bodies $\rightarrow$ **Mature Ovum**.	
Developmental Biology	**Embryogenesis**	Zygote $\rightarrow$ Cleavage $\rightarrow$ **Blastula** $\rightarrow$ **Gastrulation**.	Key milestones in early life development.
Cellular Biology	**Differentiation**	Multipotent cells $\rightarrow$ Specialized **Muscle**, **Nerve**, and **Skin** cells.	Histology, anatomy, and tissue engineering.
Field Entomology	**Collection Methods**	**Handpicking**, **Sweeping Nets**, and **Beating Trays**.	Biodiversity sampling and vector monitoring.
Field Entomology	**Safety & PPE**	Respiratory protection, gloves, and protection from thorns/ticks/snakes.	Fieldwork risk management.
Specimen Curation	**Preservation**	**Pinning** (Thorax/Elytra), **Wing Spreading** (Lepidoptera), and **Labelling**.	Museum archiving and long-term research.
Taxonomy & ID	**Morphology**	**Mouthparts** (Siphoning, Lapping), **Wings** (Elytra, Scaled), and **Antennae**.	Traditional species classification keys.

Category	Process / Focus	Key Stages or Components	Practical Application
Modern Tech	**Advanced ID**	**Digital Imaging** (High-mag) and **DNA Barcoding** (PCR sequencing).	High-accuracy molecular and digital archiving.

Fill in the blank: A biopsy examined histologically can distinguish between benign and ______ tumours.

Pilot questions 5.1

What is histopathology?
What does histopathology study in tissues?
Name one medical application of histopathology.
Why is histopathology important in research?
What type of tumour can histopathology help distinguish?

5.2 Pathological Changes In Tissues

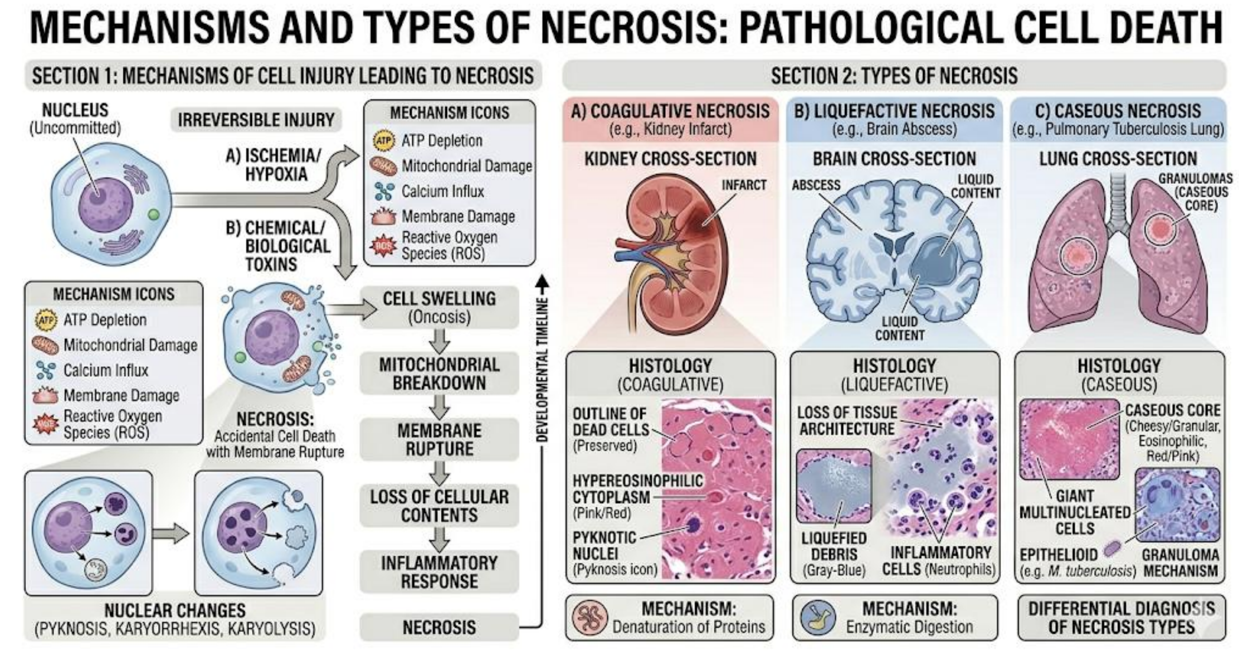
5.2.1 Degeneration and necrosis

Degeneration refers to the deterioration of cells or tissues due to injury, ageing, or disease. It often involves changes such as swelling, fatty infiltration, or pigment accumulation. **Necrosis**, on the other hand, is the irreversible death of cells within living tissue, usually caused by lack of blood supply, toxins, or trauma.

Different types of necrosis exist, including coagulative necrosis (seen in heart attacks), liquefactive necrosis (common in brain tissue), and caseous necrosis (associated with tuberculosis). Recognising these changes is crucial in histopathology, as they provide clues about the underlying disease process.

Short description: Diagram showing types of necrosis (coagulative, liquefactive, caseous).

Caption: **Figure 5.3 Types of necrosis**



Fill in the blank: Necrosis is the irreversible ______ of cells within living tissue.

5.2.2 Inflammation and repair

Inflammation is the body's protective response to injury or infection. It involves redness, swelling, heat, pain, and loss of function. Histologically, inflammation is characterised by the presence of immune cells such as neutrophils, macrophages, and lymphocytes.

Repair follows inflammation and involves regeneration of damaged tissue or replacement with scar tissue. Regeneration occurs when surviving cells proliferate to restore normal structure, while fibrosis results in scar formation. The balance between regeneration and fibrosis determines the quality of tissue healing.

Box 5.4 Inflammation and repair

Category	Process / Focus	Key Stages or Components	Practical Application
Developmental Biology	**Gametogenesis**	**Male:** Spermatogonia $\rightarrow$ Spermatocytes	Foundations of reproductive biology and fertility studies.

Category	Process / Focus	Key Stages or Components	Practical Application
		$\rightarrow$ Spermatids $\rightarrow$ **Spermatozoa**. **Female:** Oogonia $\rightarrow$ Oocytes $\rightarrow$ Polar Bodies $\rightarrow$ **Mature Ovum**.	
Developmental Biology	**Embryogenesis**	Zygote $\rightarrow$ Cleavage $\rightarrow$ **Blastula** $\rightarrow$ **Gastrulation**.	Foundational milestones in early life development.
Cellular Biology	**Differentiation**	Multipotent cells $\rightarrow$ Specialized **Muscle**, **Nerve**, and **Skin** cells.	Histology, tissue engineering, and anatomy.
Field Entomology	**Collection Methods**	**Handpicking**, **Sweeping Nets**, and **Beating Trays**.	Biodiversity sampling and vector monitoring.
Field Entomology	**Safety & PPE**	Respiratory protection, gloves, and branch/tick/snake protection.	Fieldwork risk management and safe chemical handling.
Specimen Curation	**Preservation**	**Pinning** (Thorax/Elytra), **Wing Spreading** (Lepidoptera), and **Labelling**.	Museum archiving and systematic research collections.
Taxonomy & ID	**Morphology**	**Mouthparts** (Siphoning, Lapping), **Wings** (Elytra, Scaled), and **Antennae**.	Traditional species classification and morphological keys.

Category	Process / Focus	Key Stages or Components	Practical Application
Modern Technology	**Advanced ID**	**Digital Imaging** and **DNA Barcoding** (PCR sequencing).	High-accuracy molecular and digital archiving.

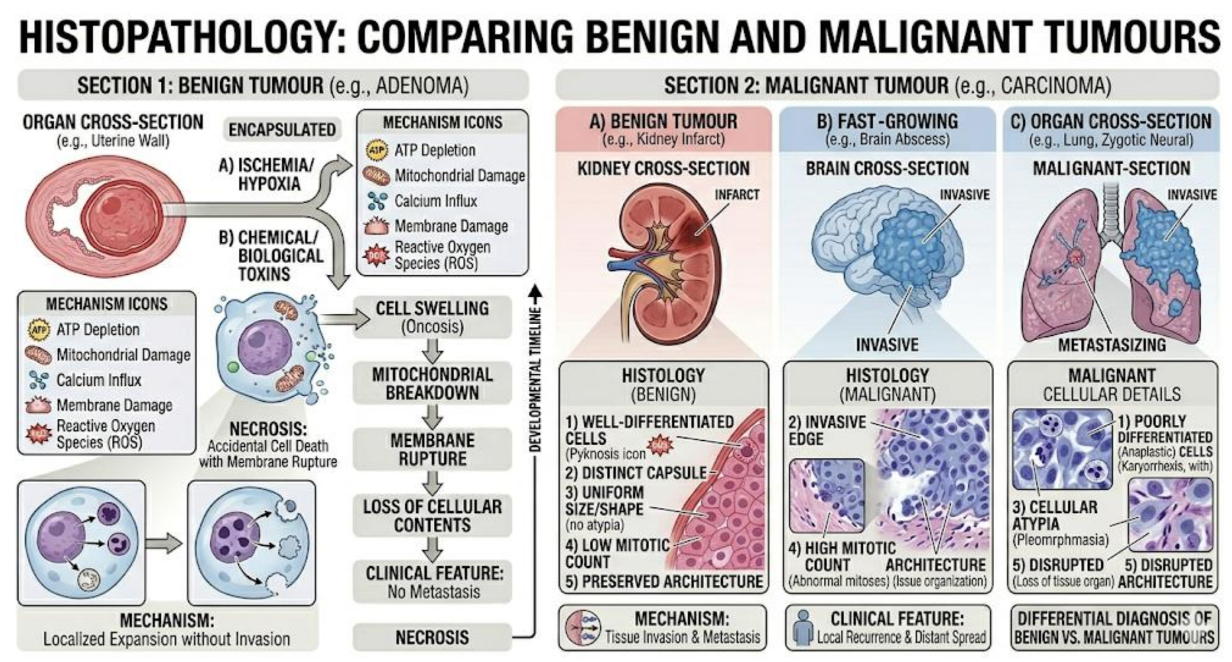
Fill in the blank: The replacement of damaged tissue with scar tissue is called ______.

5.2.3 Neoplasia (tumour formation)

Neoplasia refers to the abnormal and uncontrolled growth of cells, resulting in a tumour. Tumours can be **benign**, meaning they grow slowly and remain localised, or **malignant**, meaning they invade surrounding tissues and may spread to distant sites (metastasis).

Histopathology plays a vital role in distinguishing between benign and malignant tumours by examining features such as cell shape, organisation, and rate of division. This distinction is critical for determining treatment and prognosis.

Short description: Diagram comparing benign and malignant tumours.
Caption: **Figure 5.5 Benign versus malignant tumours**



Fill in the blank: Malignant tumours can spread to distant sites through a process called ______.

Pilot questions 5.2

What is degeneration in tissues?
Name one type of necrosis.
What are the five cardinal signs of inflammation?
What is the difference between regeneration and fibrosis?
How does histopathology distinguish between benign and malignant tumours?

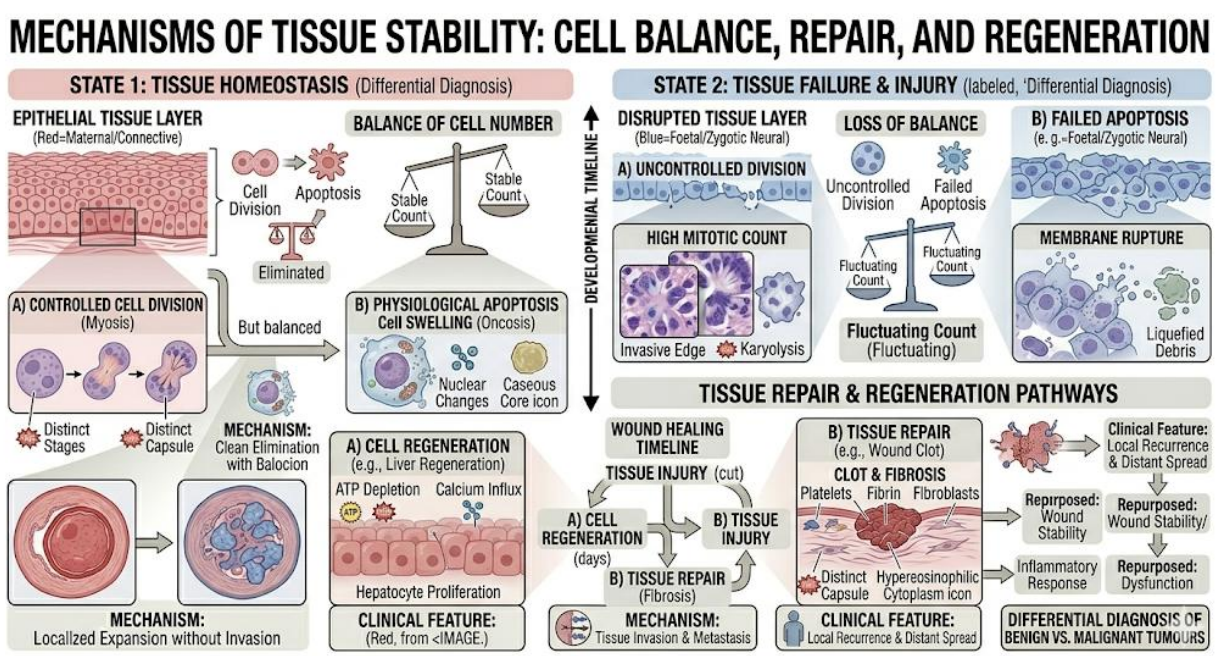
5.3 Tissue Stability And Homeostasis

5.3.1 Mechanisms of tissue stability

Tissue stability refers to the ability of tissues to maintain their structure and function despite external stress or injury. This stability is achieved through mechanisms such as balanced cell division, controlled cell death (apoptosis), and effective repair processes. Stable tissues can adapt to minor changes without losing their essential roles.

For example, the liver demonstrates remarkable stability by regenerating after partial removal, while the skin maintains stability through continuous renewal of its epithelial layers.

Short description: Diagram showing mechanisms of tissue stability including cell division, apoptosis, and repair.
Caption: **Figure 5.6 Mechanisms of tissue stability**



Fill in the blank: Controlled cell death that maintains tissue stability is called ______.

5.3.2 Cellular adaptation to stress

Cellular adaptation is the process by which cells adjust their structure or function in response to stress. Common adaptations include **hypertrophy** (increase in cell size), **hyperplasia** (increase in cell number), **atrophy** (decrease in cell size or function), and **metaplasia** (replacement of one cell type with another).

These adaptations allow tissues to cope with increased demands or adverse conditions. However, if stress persists or becomes severe, adaptation may fail, leading to injury or disease.

Box 5.7 Types of cellular adaptation

Category	Process / Focus	Key Stages or Components	Practical Application
Developmental Biology	**Gametogenesis**	**Male:** Spermatogonia $\rightarrow$ Spermatocytes $\rightarrow$ Spermatids $\rightarrow$ **Spermatozoa**. **Female:** Oogonia $\rightarrow$ Oocytes $\rightarrow$ Polar Bodies $\rightarrow$ **Mature Ovum**.	Foundations of reproductive biology and fertility studies.
Developmental Biology	**Embryogenesis**	Zygote $\rightarrow$ Cleavage $\rightarrow$ **Blastula** $\rightarrow$ **Gastrulation**.	Foundational milestones in early life development.
Cellular Biology	**Differentiation**	Multipotent cells $\rightarrow$ Specialized **Muscle**, **Nerve**, and **Skin** cells.	Histology, tissue engineering, and anatomy.

Category	Process / Focus	Key Stages or Components	Practical Application
Field Entomology	**Collection Methods**	**Handpicking**, **Sweeping Nets**, and **Beating Trays**.	Biodiversity sampling and vector monitoring.
Field Entomology	**Safety & PPE**	Respiratory protection, gloves, and branch/tick/snake protection.	Fieldwork risk management and safe chemical handling.
Specimen Curation	**Preservation**	**Pinning** (Thorax/Elytra), **Wing Spreading** (Lepidoptera), and **Labelling**.	Museum archiving and systematic research collections.
Taxonomy & ID	**Morphology**	**Mouthparts** (Siphoning, Lapping), **Wings** (Elytra, Scaled), and **Antennae**.	Traditional species classification and morphological keys.
Modern Technology	**Advanced ID**	**Digital Imaging** and **DNA Barcoding** (PCR sequencing).	High-accuracy molecular and digital archiving.

Fill in the blank: An increase in the number of cells in a tissue is called ______.

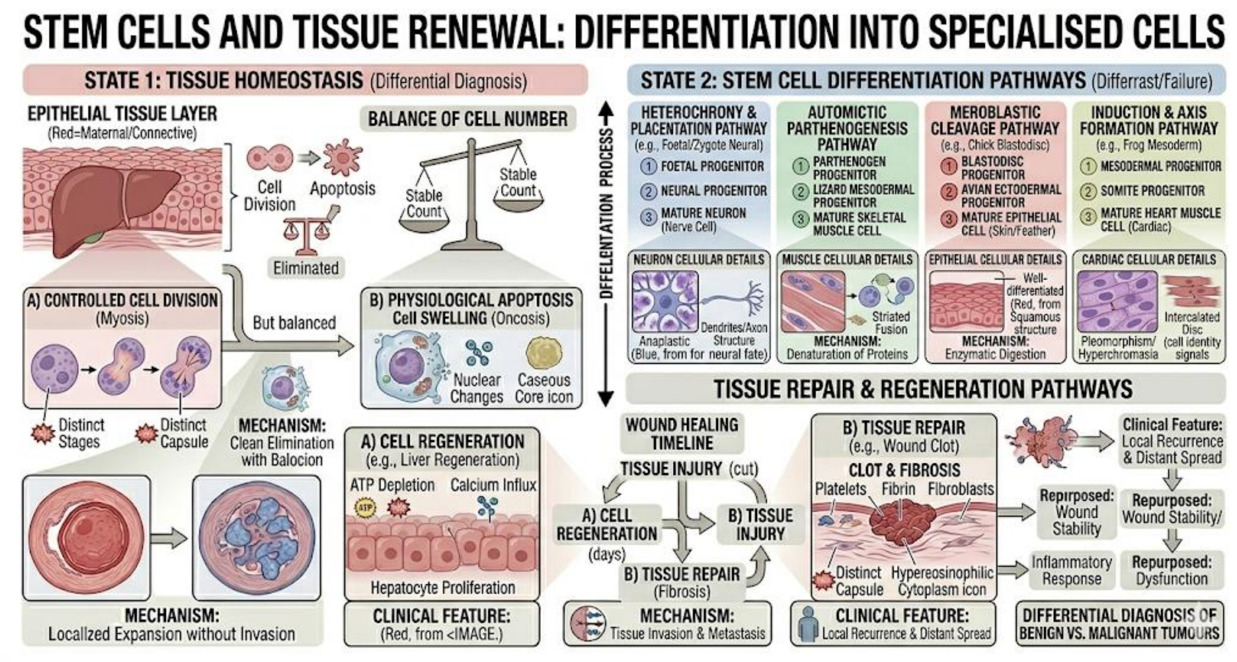
5.3.3 Role of stem cells in tissue renewal

Stem cells are undifferentiated cells capable of self-renewal and differentiation into specialised cell types. They play a vital role in maintaining tissue stability by replacing damaged or ageing cells.

In tissues such as the skin, intestine, and bone marrow, stem cells ensure continuous renewal. In pathology, stem cell dysfunction can lead to impaired healing or contribute to tumour formation. Their study is therefore crucial in both regenerative medicine and cancer research.

Short description: Diagram showing stem cells differentiating into specialised tissue cells.

Caption: **Figure 5.8 Role of stem cells in tissue renewal**



Fill in the blank: Stem cells maintain tissue stability by replacing ______ or ageing cells.

Pilot questions 5.3

What is tissue stability?
Name one mechanism that maintains tissue stability.
Define hypertrophy and hyperplasia.
What is metaplasia?
Why are stem cells important in tissue renewal?

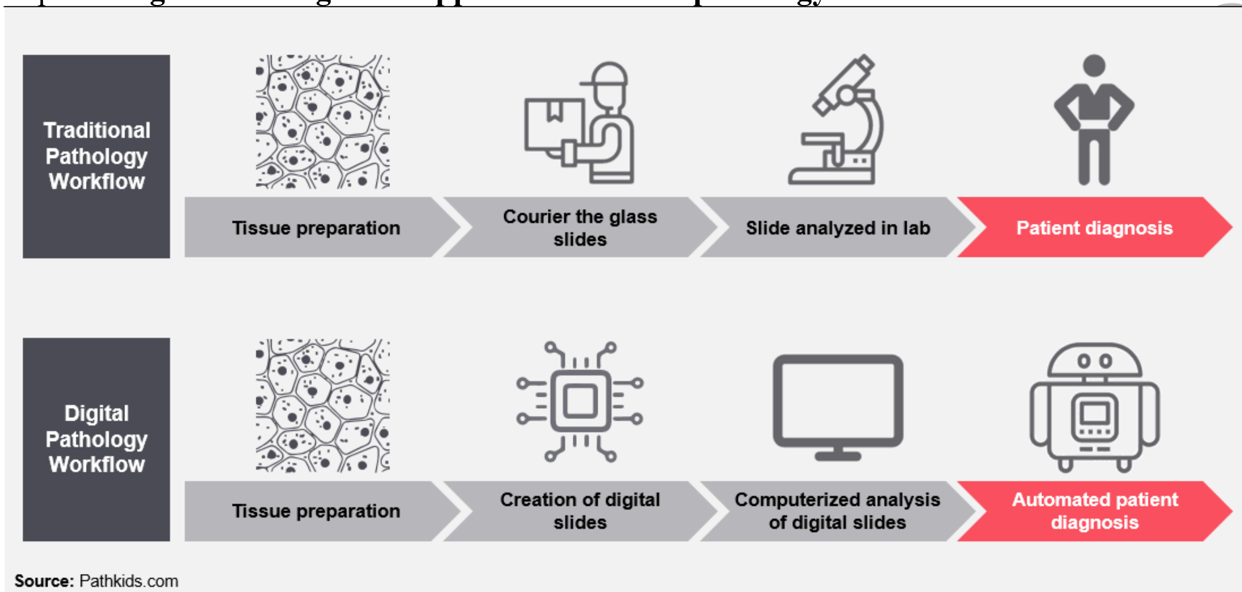
5.4 Applications Of Histopathology

5.4.1 Diagnostic applications in clinical practice

Histopathology is central to clinical diagnosis because it provides direct evidence of disease at the tissue level. By examining biopsies and surgical specimens, pathologists can identify structural changes that confirm or rule out conditions such as cancer, infections, and autoimmune disorders.

For example, histopathology can distinguish between benign and malignant tumours, identify the presence of microorganisms in infected tissues, and reveal inflammatory changes in chronic diseases. This makes it indispensable for accurate diagnosis, prognosis, and guiding treatment decisions.

Short description: Diagram showing the diagnostic workflow of histopathology from biopsy to microscopic examination.
Caption: **Figure 5.9 Diagnostic applications of histopathology**



Fill in the blank: Histopathology can confirm whether a tumour is benign or ______.

5.4.2 Research applications in disease studies

Histopathology also plays a vital role in research, helping scientists understand how diseases develop and progress. By studying tissue samples, researchers can identify cellular changes associated with genetic mutations, environmental factors, or experimental treatments.

In addition, histopathology supports drug development by showing how new therapies affect tissue structure and stability. It is also used in experimental pathology to model diseases in animals, providing insights that can be applied to human medicine.

Box 5.10 Research applications of histopathology

Category	Process / Focus	Key Stages or Components	Practical Application
Developmental Biology	**Gametogenesis**	**Male:** Spermatogonia \$\rightarrow\$ Spermatocytes	Reproductive biology, fertility studies, and historical theories (e.g., Preformation).

Category	Process / Focus	Key Stages or Components	Practical Application
		$\rightarrow$ Spermatids $\rightarrow$ **Spermatozoa**. **Female:** Oogonia $\rightarrow$ Oocytes $\rightarrow$ Polar Bodies $\rightarrow$ **Mature Ovum**.	
Developmental Biology	**Embryogenesis**	Zygote $\rightarrow$ Cleavage $\rightarrow$ **Blastula** $\rightarrow$ **Gastrulation**.	Foundational milestones in early life development.
Cellular Biology	**Differentiation**	Multipotent cells $\rightarrow$ Specialized **Muscle**, **Nerve**, and **Skin** cells.	Histology, anatomy, and tissue engineering.
Field Entomology	**Collection Methods**	**Handpicking**, **Sweeping Nets**, and **Beating Trays**.	Biodiversity sampling and vector monitoring in ecosystems.
Field Entomology	**Safety & PPE**	Respiratory protection, gloves, and protection from thorns/ticks/snakes.	Fieldwork risk management and safe specimen handling.
Specimen Curation	**Preservation**	**Pinning** (Thorax/Elytra), **Wing Spreading** (Lepidoptera), and **Labelling**.	Museum archiving and long-term research documentation.
Taxonomy & ID	**Morphology**	**Mouthparts** (Siphoning, Lapping), **Wings** (Elytra, Scaled), and **Antennae**.	Traditional species classification and morphological keys.

Category	Process / Focus	Key Stages or Components	Practical Application
Modern Tech	**Advanced ID**	**Digital Imaging** (High-mag) and **DNA Barcoding** (PCR sequencing).	High-accuracy molecular archiving and database matching.

Fill in the blank: Histopathology supports drug development by showing how new ______ affect tissue structure.

Pilot questions 5.4

Why is histopathology important in clinical diagnosis?
Name one condition that histopathology can confirm.
How does histopathology contribute to prognosis?
What role does histopathology play in disease research?
How does histopathology support drug development?

Series Summary

This Series focused on histopathology and tissue stability, highlighting how tissues respond to injury, disease, and stress. We began by defining histopathology and examining its scope and importance in medicine and research. We then explored pathological changes in tissues, including degeneration, necrosis, inflammation, repair, and neoplasia. Following that, we studied mechanisms of tissue stability, cellular adaptations to stress, and the role of stem cells in tissue renewal. Finally, we considered the diagnostic and research applications of histopathology.

By completing this Series, you should now be able to define histopathology, describe its importance, explain pathological changes, analyse tissue stability mechanisms, evaluate the role of stem cells, and apply histopathology in both diagnostic and research contexts. These outcomes align with the Series Learning Objectives and provide you with a strong foundation for understanding disease processes and tissue resilience.

Glossary of Terms

Apoptosis: Controlled cell death that maintains tissue stability.
Atrophy: Decrease in cell size or function due to reduced demand or adverse conditions.
Benign tumour: A non-cancerous growth that remains localised and grows slowly.
Degeneration: Deterioration of cells or tissues due to injury, ageing, or disease.
Fibrosis: Replacement of damaged tissue with scar tissue.
Histopathology: The study of microscopic changes in tissues caused by disease.
Hyperplasia: Increase in the number of cells in a tissue.

Hypertrophy: Increase in the size of cells due to greater demand.
Inflammation: Protective response of tissues to injury or infection, characterised by redness, swelling, heat, pain, and loss of function.
Malignant tumour: A cancerous growth that invades surrounding tissues and can spread to distant sites.
Metaplasia: Replacement of one cell type with another as an adaptive response.
Necrosis: Irreversible death of cells within living tissue.
Neoplasia: Abnormal and uncontrolled growth of cells forming a tumour.
Stem cells: Undifferentiated cells capable of self-renewal and differentiation into specialised cell types.
Tissue stability: The ability of tissues to maintain structure and function despite stress or injury.

Concept Check Questions 5

Objective questions

Histopathology studies the ______ changes in tissues caused by disease. (Linked to SLO 5.1)
Necrosis is the irreversible ______ of cells within living tissue. (Linked to SLO 5.3)
The replacement of damaged tissue with scar tissue is called ______. (Linked to SLO 5.3)
Malignant tumours can spread to distant sites through a process called ______. (Linked to SLO 5.3)
Controlled cell death that maintains tissue stability is called ______. (Linked to SLO 5.4)

Short-answer questions
6. Define histopathology. (Linked to SLO 5.1)
7. Why is histopathology important in clinical diagnosis? (Linked to SLO 5.2)
8. Name one type of necrosis. (Linked to SLO 5.3)
9. What are the five cardinal signs of inflammation? (Linked to SLO 5.3)
10. Why are stem cells important in tissue renewal? (Linked to SLO 5.5)

Long-answer questions
11. Explain the scope of histopathology and its importance in medicine and research. (Linked to SLO 5.1, 5.2)
12. Describe pathological changes in tissues, including degeneration, necrosis, inflammation, repair, and neoplasia. (Linked to SLO 5.3)
13. Analyse mechanisms of tissue stability and cellular adaptation to stress. (Linked to SLO 5.4)
14. Evaluate the role of stem cells in tissue renewal and their relevance in pathology. (Linked to SLO 5.5)
15. Discuss the diagnostic and research applications of histopathology. (Linked to SLO 5.6)

Answers to Concept Check Questions 5

Objective questions

Microscopic.

Death.
Fibrosis.
Metastasis.
Apoptosis.

Short-answer questions
6. The study of microscopic changes in tissues caused by disease.
7. It provides definitive evidence of disease at the cellular level.
8. Coagulative necrosis.
9. Redness, swelling, heat, pain, and loss of function.
10. They replace damaged or ageing cells and maintain tissue stability.

Long-answer questions
11. **Basic response**: Histopathology studies tissue changes caused by disease.
Value-added response: It is essential for diagnosis, prognosis, and research, helping clinicians and scientists understand disease processes.

Basic response: Pathological changes include degeneration, necrosis, inflammation, repair, and neoplasia.
Value-added response: Each change has distinct features, such as caseous necrosis in tuberculosis or fibrosis in chronic injury, which aid diagnosis.
Basic response: Tissue stability is maintained by cell division, apoptosis, and repair.
Value-added response: Cells adapt through hypertrophy, hyperplasia, atrophy, and metaplasia, allowing tissues to cope with stress.
Basic response: Stem cells renew tissues by differentiating into specialised cells.
Value-added response: They are crucial in regenerative medicine and cancer research, as dysfunction can impair healing or contribute to tumours.
Basic response: Histopathology is used in diagnosis and research.
Value-added response: It distinguishes tumour types, supports drug development, and models diseases in experimental pathology.

Answers to Pilot Questions 5

Part 5.1

The study of microscopic changes in tissues caused by disease.
Microscopic changes.
Cancer diagnosis.
It helps study disease mechanisms and treatment effects.
Malignant.

Part 5.2

Deterioration of cells or tissues.
Coagulative necrosis.
Redness, swelling, heat, pain, loss of function.

Regeneration restores normal structure, fibrosis forms scar tissue.
By examining cell shape, organisation, and division.

Part 5.3

The ability of tissues to maintain structure and function despite stress.
Apoptosis.
Hypertrophy is increased cell size; hyperplasia is increased cell number.
Replacement of one cell type with another.
They replace damaged or ageing cells.

Part 5.4

It provides direct evidence of disease at the tissue level.
Cancer.
It helps predict disease outcome.
It reveals cellular changes in disease progression.
By showing how therapies affect tissue structure.

References And Attributions 5

Figures and Boxes suggested in Series 5:

- Figure 5.1 Scope of histopathology
- Box 5.2 Importance of histopathology
- Figure 5.3 Types of necrosis
- Box 5.4 Inflammation and repair
- Figure 5.5 Benign versus malignant tumours
- Figure 5.6 Mechanisms of tissue stability
- Box 5.7 Types of cellular adaptation
- Figure 5.8 Role of stem cells in tissue renewal
- Figure 5.9 Diagnostic applications of histopathology
- Box 5.10 Research applications of histopathology

AI prompt suggestions used for illustration placeholders:

- Diagrams showing necrosis types, tumour comparison, tissue stability, stem cell differentiation, and diagnostic workflow.
- Boxes summarising importance of histopathology, inflammation and repair, cellular adaptation, and research applications.

Open Educational Resource (OER) search strings suggested:

- "histopathology scope diagram OER"
- "importance of histopathology OER"
- "histopathology necrosis types diagram OER"
- "histopathology inflammation repair OER"
- "histopathology benign malignant tumour diagram OER"
- "histopathology tissue stability diagram OER"
- "histopathology cellular adaptation OER"
- "stem cells tissue renewal diagram OER"

“histopathology diagnostic workflow diagram OER”
“histopathology research applications OER”

General references (APA style):

Kumar, V., Abbas, A. K., & Aster, J. C. (2020). *Robbins and Cotran Pathologic Basis of Disease*. Elsevier.

Rosai, J. (2011). *Rosai and Ackerman’s Surgical Pathology*. Elsevier.

OER Commons. (n.d.). *Histopathology resources*. Retrieved from https://www.oercommons.org