مقرر(علم الحيوان Zoo 101- Zoology "مقدمة في الأجنة والخلية والأنسجة والفسيولوجي ") الفرقة الأولى شعبة العلوم البيولوجية (Zoo 101)

أستاذ المقرر

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مقرر (علم الحيوان Zoology –101 Zoo"جزء الفسيولوجي") لطلاب الفرقة الأولى

شعبة العلوم البيولوجية (Zoo 101)

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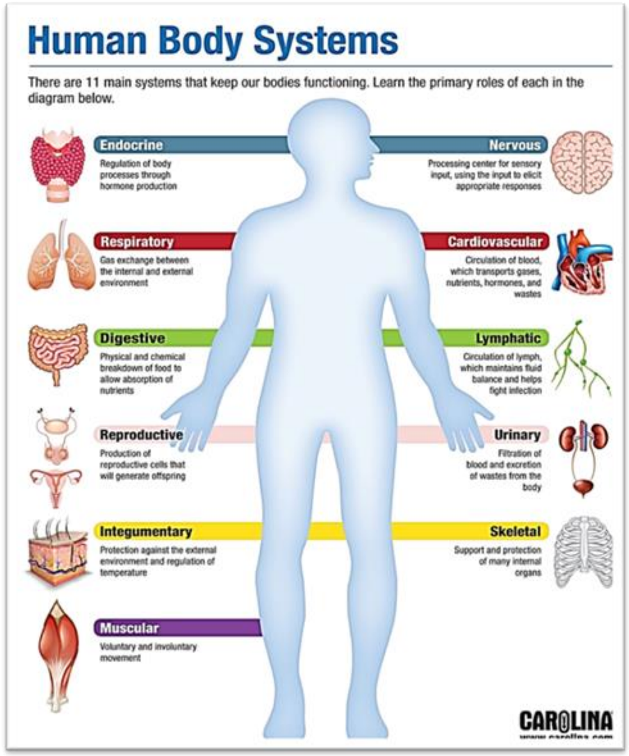

Human Body Systems
There are 11 main systems that keep our bodies functioning. Learn the primary roles of each in the diagram below.
Endocrine
Regulation of body processes through hormone production
Nervous
Processing center for sensory input, using the input to elicit appropriate responses
Respiratory
Gas exchange between the internal and external environment
Cardiovascular
Circulation of blood, which transports gases, nutrients, hormones, and wastes
Digestive
Physical and chemical breakdown of food to allow absorption of nutrients
Lymphatic
Circulation of lymph, which maintains fluid balance and helps fight infection
Reproductive
Production of reproductive cells that will generate offspring
Urinary
Filtration of blood and excretion of wastes from the body
Integumentary
Protection against the external environment and regulation of temperature
Skeletal
Support and protection of many internal organs
Muscular
Voluntary and involuntary movement
CAROLINA

Physiology content:

- **An introduction of general physiology.**
- **Nutrition and Digestion.**
- **Absorption.**
- **Metabolism.**
- **Excretion.**
- **Respiration.**
- **Circulation system, Blood and Lymph.**
- **Reproductive system.**
- **Nervous System.**
- **Endocrine System and hormone's function.**

Physiology and life processes

Physiology tells us how our bodies work structurally and functionally.

The most important life processes of human:

Metabolism: includes catabolism and anabolism that provides energy and body components.

Excitability: ability to sense changes in and around us.

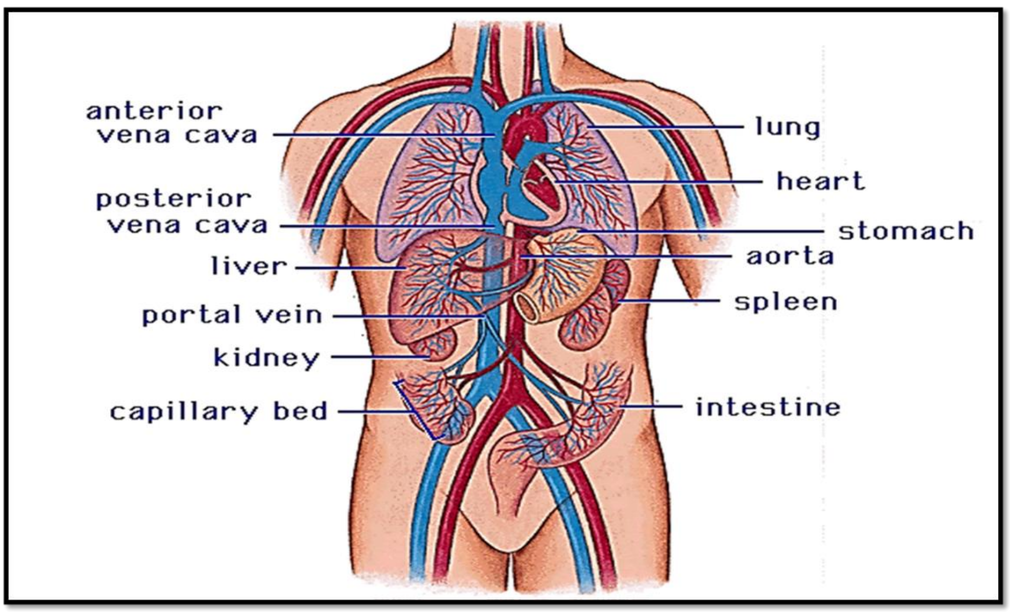
Conductivity: ability to carry the effects of stimulus from part of a cell to another.

Contractility: ability to contract in response to stimulus.

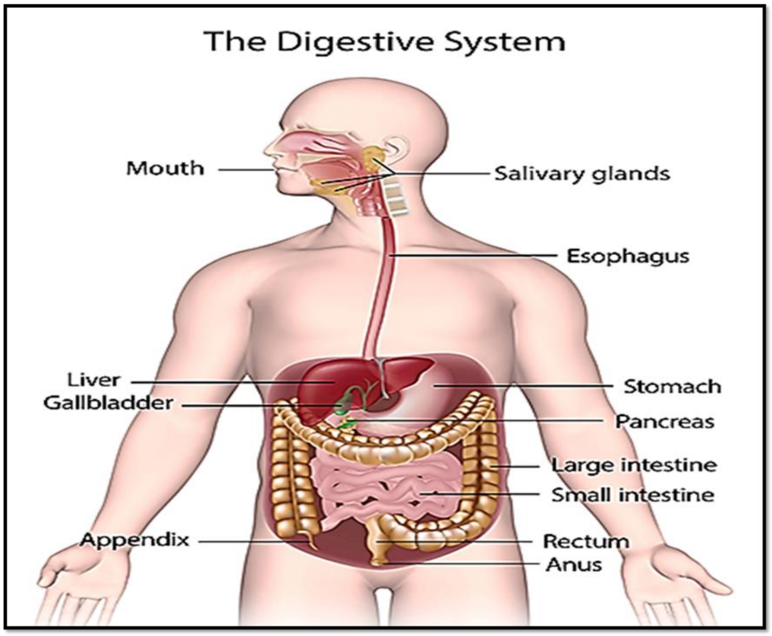
Growth

Reproduction

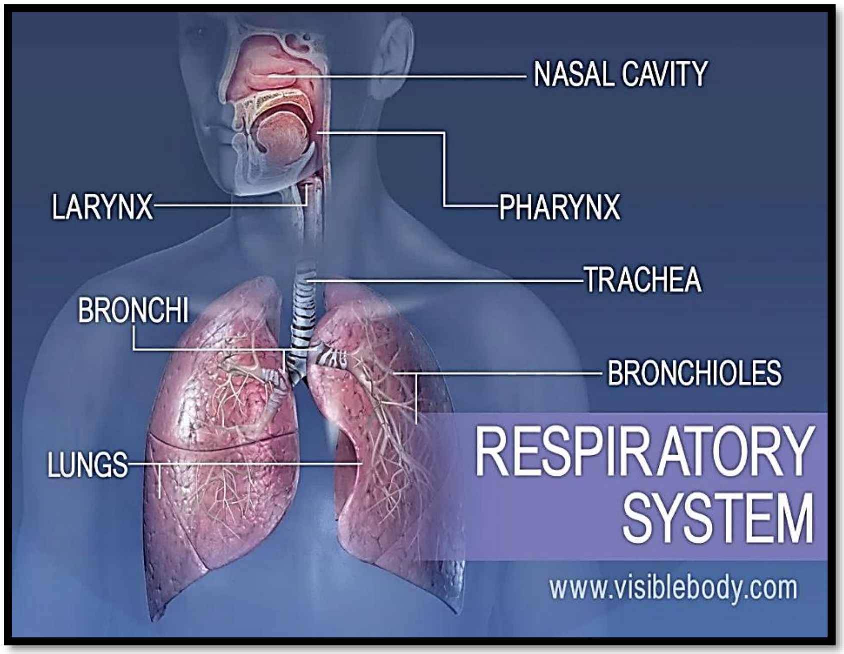
Components of body system



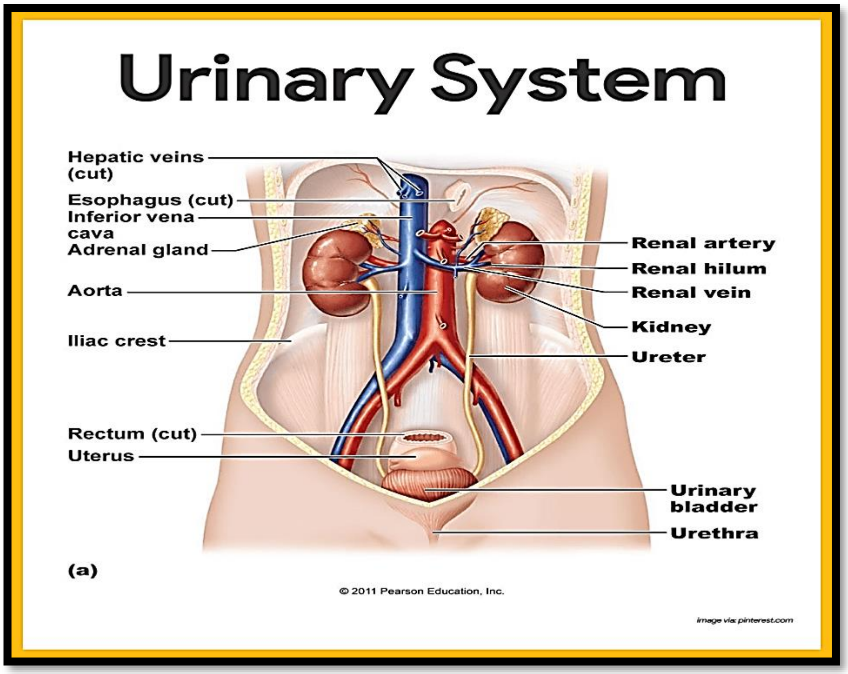
Circulatory system



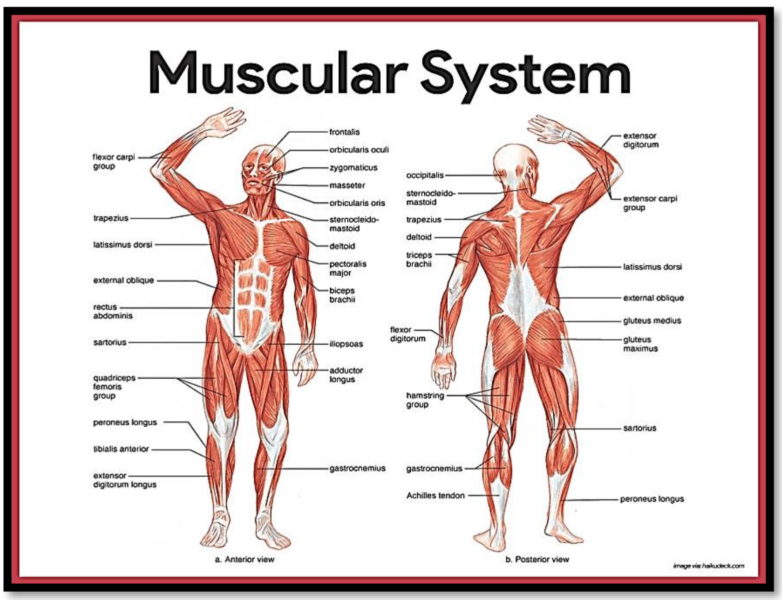
Digestive System



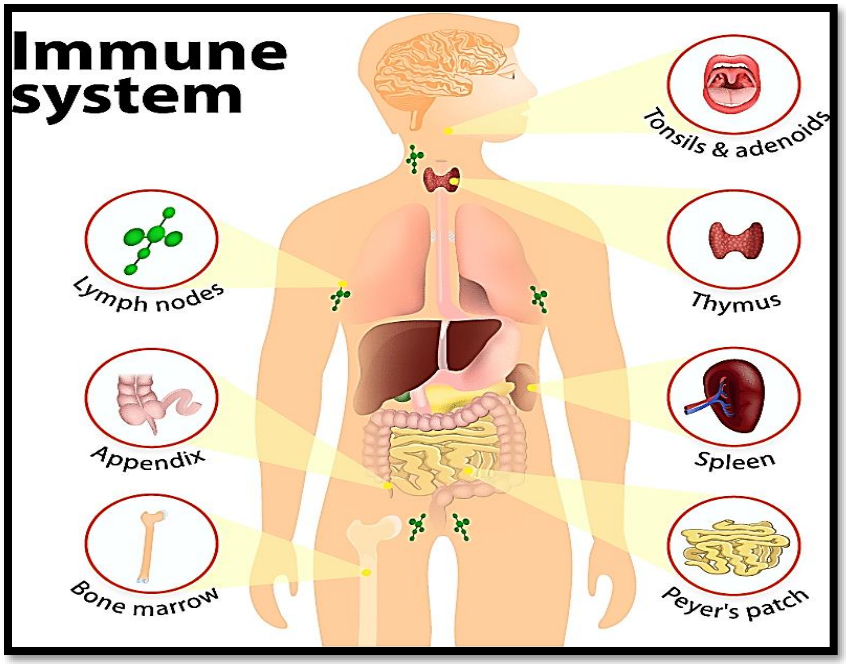
Respiratory system



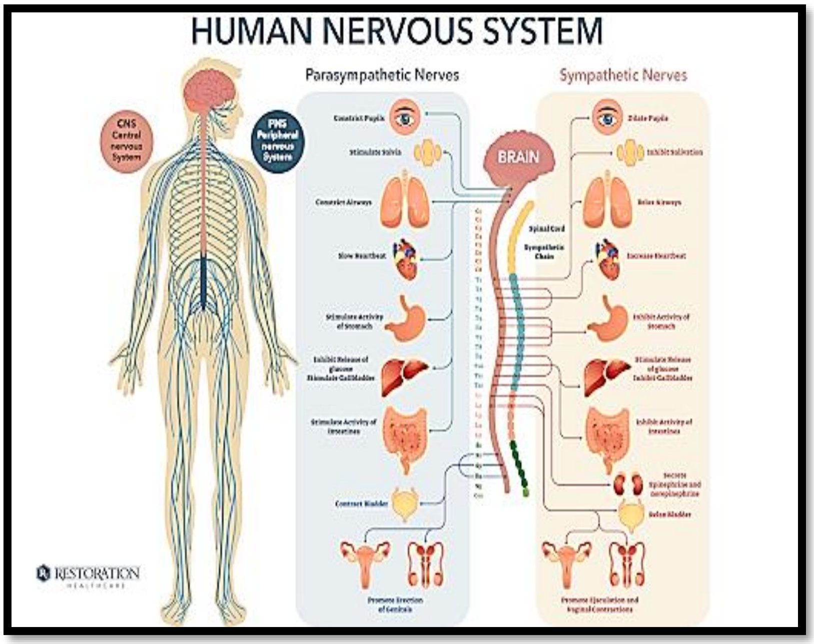
Urinary system



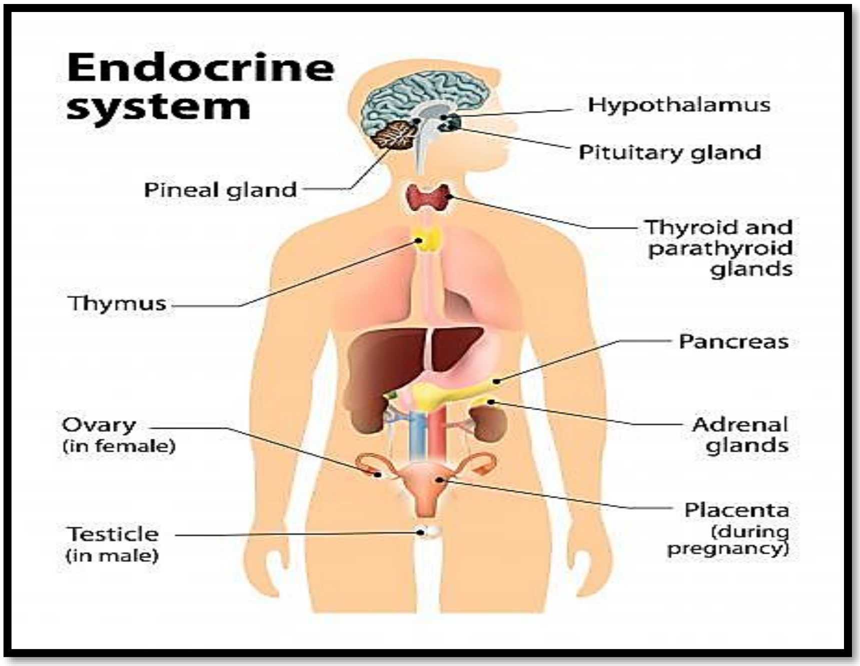
Muscular system



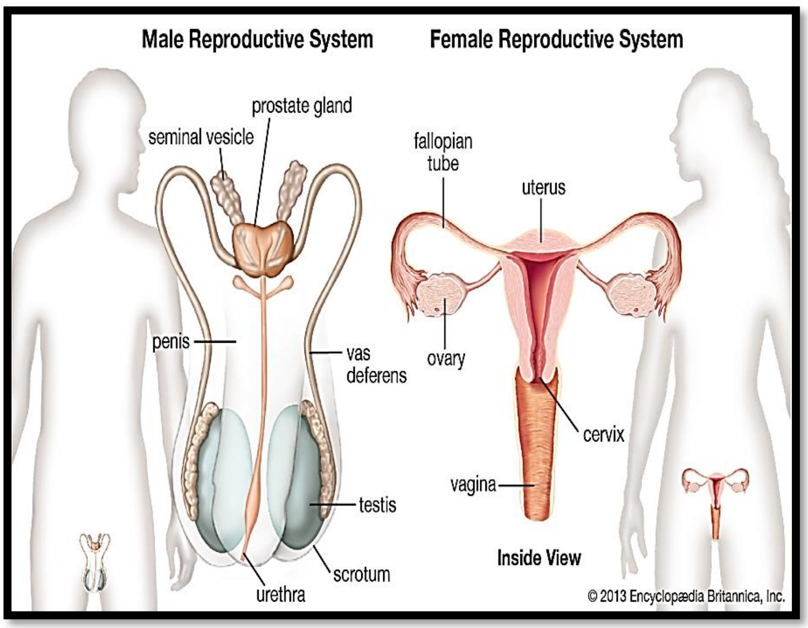
Immune system



Nervous system

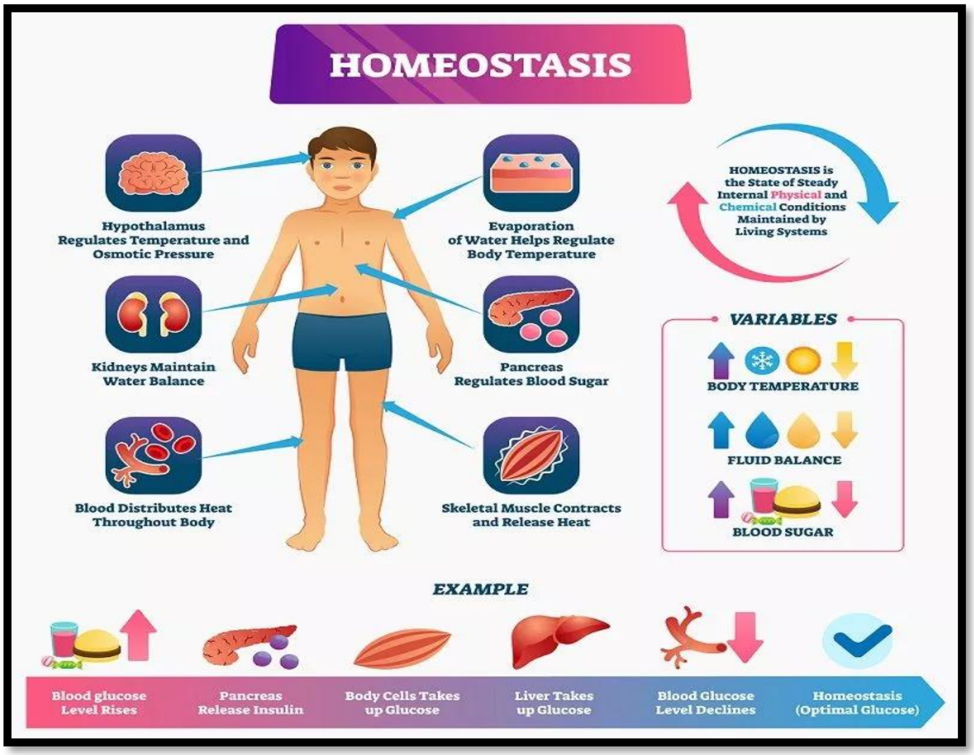


Endocrine system



Reproductive system

Homeostasis



Role of body system in maintaining homeostasis:

Nervous system:

Information from the external environment, also acts through electrical signals to control rapid responses for higher functions such as concentration, memory, and creativity.

Endocrine system:

Acts by hormones secreted into the blood to control processes that require duration rather than speed, such as metabolic activity, water and electrolytes balances.

Circulatory system:

Transports nutrients, oxygen, CO_2, wastes, electrolytes and hormones through the body.

Respiratory system:

Obtains oxygen and eliminates CO_2 to the external environment; helps regulate pH by adjusting the rate of removal of acid-forming carbon dioxide.

Urinary system:

Important in regulating the volume, electrolyte composition, and pH of the internal environment; removes waste and excess water, salt, acid and other electrolytes from the plasma and eliminate them into the urine.

Digestive system:

Obtains nutrients, water and electrolytes from the external environment and transfers them into the plasma; eliminates undigested food residues to the external environment.

Muscular and skeletal system:

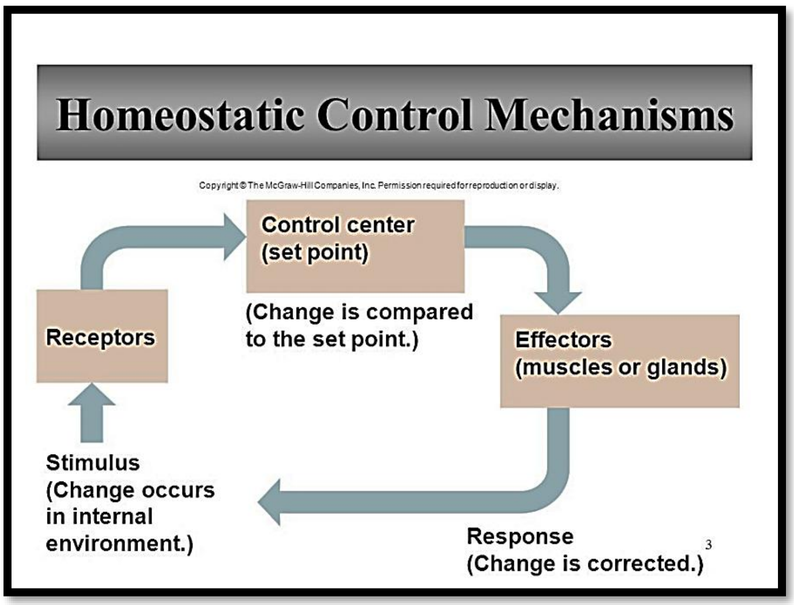
Supports and protects body parts and allows body movements, heat generated by muscular contraction are important in temperature regulation, calcium stored in the bones.

Immune system:

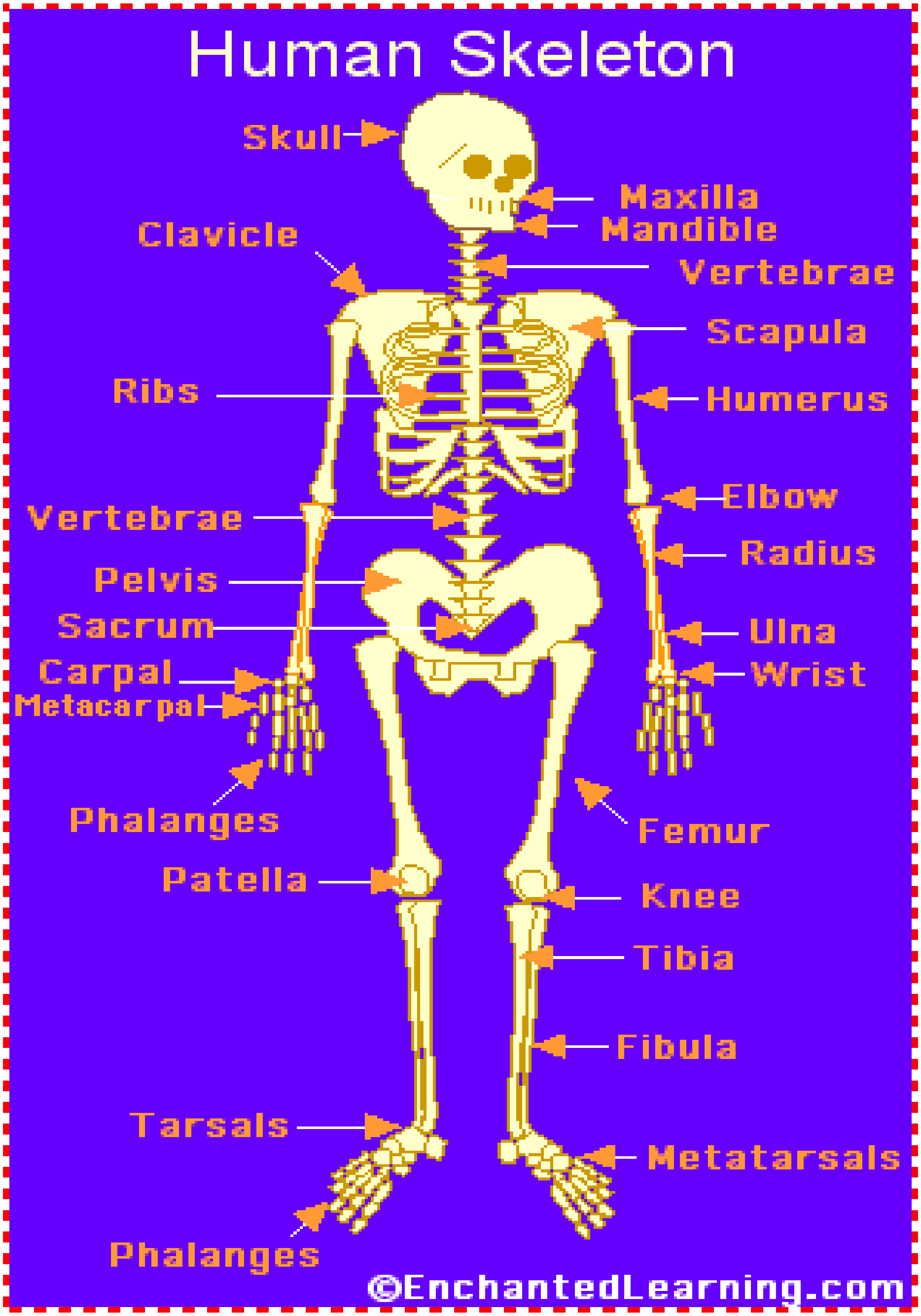
Defense against foreign invaders and cancer cells; tissue repair.

Integumentary system:

Keeps internal fluids in and foreign materials out serves as a protective barrier between the external environment and the remainder of the body; temperature regulation.



The skeletal system



The skeletal system is composed of bones and cartilage connected by ligaments to form a framework for the rest of the body tissues. There are two parts to the skeleton:

- **Axial skeleton** – bones along the axis of the body, including the skull, vertebral column and ribcage;
- **Appendicular skeleton** – appendages, such as the upper and lower limbs, pelvic girdle and shoulder girdle.

Function

As well as contributing to the body's overall shape, the skeletal system has several key functions, including:

- Support and movement;
- Protection;
- Mineral homeostasis;
- Blood-cell formation;
- Triglyceride storage.

Support and movement

Bones are a site of attachment for ligaments and tendons, providing a skeletal framework that can produce movement through the coordinated use of levers, muscles, tendons and ligaments. The bones act as levers, while the muscles generate the forces responsible for moving the bones.

Protection

Bones provide protective boundaries for soft organs: the cranium around the brain, the vertebral column surrounding the spinal cord, the ribcage containing the heart and lungs, and the pelvis protecting the urogenital organs.

Mineral homoeostasis

As the main reservoirs for minerals in the body, bones contain approximately 99% of the body's calcium, 85% of its phosphate and 50% of its magnesium (Bartl and Bartl, 2017). They are essential in maintaining homoeostasis of minerals in the blood with minerals stored in the bone are released in response to the body's demands, with levels maintained and regulated by hormones, such as parathyroid hormone.

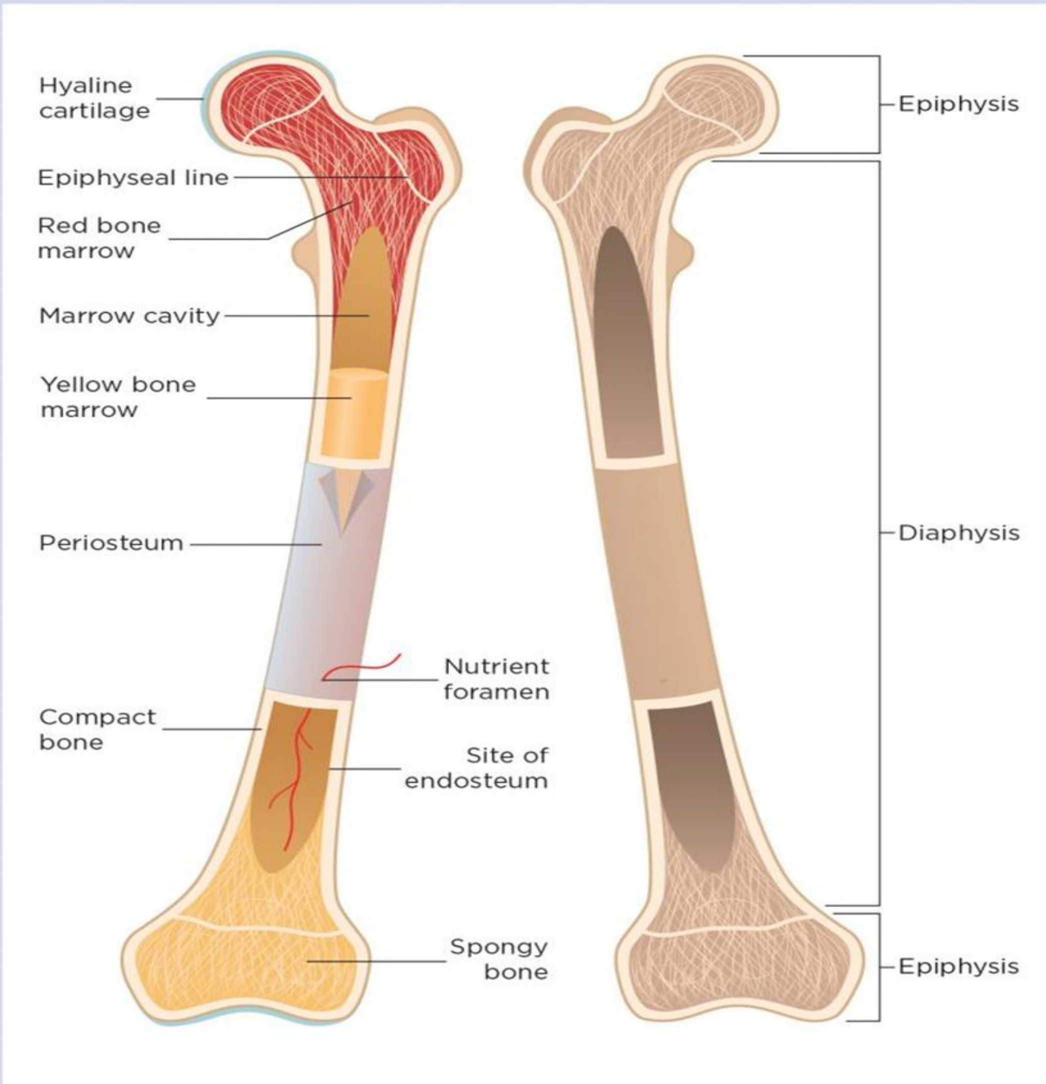
Blood-cell formation (haemopoiesis)

Blood cells are formed from haemopoietic stem cells present in red bone marrow. Babies are born with only red bone marrow; over time this is replaced by yellow marrow due to a decrease in erythropoietin, the hormone responsible for stimulating the production of erythrocytes (red blood cells) in the bone marrow. By adulthood, the amount of red marrow has halved, and this reduces further to around 30% in older age (Robson and Syndercombe Court, 2018).

Triglyceride storage

Yellow bone marrow (Fig 1) acts as a potential energy reserve for the body; it consists largely of adipose cells, which store triglycerides (a type of lipid that occurs naturally in the blood) (Tortora and Derrickson, 2009).

Fig 1. **Bone structure**



Development and structure of the skeleton

Infants are born with about 300 separate bones, a nonprofit children's health provider. As a child grows, some of those bones fuse together until growth stops, typically by the age of 25, leaving the skeleton with 206 bones.

Our bones are separated into two categories based on the purpose and location of the bones: The axial skeleton and the appendicular skeleton, according to "Anatomy & Physiology."

The axial skeleton contains 80 bones, including the skull, spine and rib cage. It forms the central structure of the skeleton, with the function of protecting the brain, spinal cord, heart and lungs.

The remaining 126 bones make up the appendicular skeleton; they include the arms, legs, shoulder girdle and pelvic girdle. The lower portion of the appendicular skeleton protects the major organs associated with digestion and reproduction and provides

stability when a person is walking or running. The upper portion allows for a greater range of motion when lifting and carrying objects.
Bones are further classified by their shape: long, short, flat, irregular or sesamoid, according to "Anatomy & Physiology".

- Long bones are found in the arms, legs, fingers and toes. These bones are longer than they are wide and are cylindrical. They move when the muscles around them contract, and they are the most mobile parts of the skeleton.
- Short bones are found in the wrists and ankles and are about equal in their length, width and thickness.
- Flat bones make up the skull, shoulder blades, sternum and ribs. These curved, thin bones protect internal organs and provide an anchor for muscles.
- Irregular bones are those in the spinal cord and face, which, because of their unique dimension, don't fit in any of the other shape categories.
- Sesamoid bones are found in the hands, wrists, feet, ears and knees. These small, round bones are embedded in tendons and protect them from the great pressure and force they encounter.

There are some variations between male and female skeletons. For example, the female pelvis is typically more broad, thin, and round than the male pelvis, according to "Anatomy & Physiology."

What's inside your bones?

All about your body's skeleton, the framework of bones that keeps you together.
Three main types of material make up every bone in your body: compact bone, spongy bone and bone marrow.
Approximately 80% of every bone is compact bone, which is the hardest and strongest type of bone and is what allows the body to support its weight. Compact bone makes up the outer layers of the bone and protects the inner parts of the bones where many vital functions occur, such as bone marrow production. Compact bone consists primarily of cells called osteocytes. Microscopic passages in between the cells to allow nerves and blood vessels to pass through.
About 20% of each bone is spongy bone, which is filled with large holes and passages. Most often found toward the ends of individual bones, the spongy bone material is filled with bone marrow, nerves and blood vessels.
Two types of bone marrow fill the pores in spongy bone. Approximately half is red bone marrow, which is found mainly within flat bones such as shoulder blades and ribs. This is where all red and white blood cells and platelets (cells that help a cut stop bleeding) are made. Infant's bones contain all red bone marrow to produce enough blood cells to keep up with the youngsters' growth.
The other half of marrow is yellow bone marrow, which is found in long bones, such as thigh bones, and consists primarily of fat. Blood vessels run through both types of bone marrow to deliver nutrients and remove waste from the bones.
There are four main types of cells within bones: Osteoblasts, osteocytes, osteoclasts and lining cells.

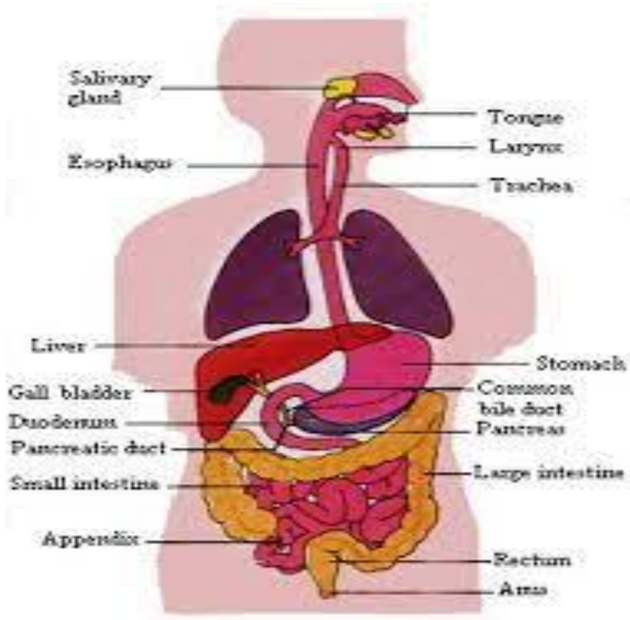
Osteoblasts are cells that create new or repair existing bone material as the bones grow or break. The cells create a flexible material called osteoid and then fortify it with minerals to harden and strengthen it. When osteoblasts successfully finish their job, they retire to become osteocytes or lining cells.
Osteocytes, found in the compact bone, are responsible for exchanging minerals and communicating with other cells in the vicinity. They are formed from old osteoblasts that have gotten stuck in the center of bones.
Osteoclasts break down existing bone material and reabsorb it. These cells often work with osteoblasts to heal and reshape bone after a break (the osteoclasts break down the extra callus formed by the healing process) to make room for new blood vessels and nerves and to make bones thicker and stronger.
Lining cells are flat bone cells that completely cover the outside surface of bones. Their primary function is controlling the movement of minerals, cells and other materials into and out of the bones.

Diseases of the skeletal system

As with any part of the human body, bones are susceptible to injury and disease.
Some of the most common diseases that can affect the skeletal system include:

- Osteoporosis is a disease that causes the density and strength of bones to decrease because bone loss occurs faster than bone growth. It can be caused by genetics or unhealthy lifestyle habits (such as lack of calcium or vitamin D, and heavy smoking or drinking with little exercise).
- Leukemia is a type of cancer that starts in the bone marrow and the lymphatic system. Several types of leukemia affect various blood cells and other systems of the body.
- Osteoarthritis is a disease that causes the breakdown of the cartilage that protects the ends of bones in joints. This lack of cartilage leads to bone-on-bone rubbing, which can cause significant pain, damage to the bones and connective tissues, inflammation of the surrounding tissue and restricted motion.

The Digestive System



the digestive system uses mechanical and chemical activities to break food down into absorbable substances during its journey through the digestive system. Table 1 provides an overview of the basic functions of the digestive organs.

Main function of digestive system: The main function of the digestive system is to turn the food into simple sugars, amino acids, and carbohydrates. This is fuel for the human body.

Table 1: Functions of the Digestive Organs

Organ	Major functions	Other functions
Mouth	• Ingests food • Chews and mixes food • Begins chemical breakdown of carbohydrates • Moves food into the pharynx • Begins breakdown of lipids via lingual lipase	• Moistens and dissolves food, allowing you to taste it • Cleans and lubricates the teeth and oral cavity • Has some antimicrobial activity
Pharynx	• Propels food from the oral cavity to the esophagus	• Lubricates food and passageways
Esophagus	• Propels food to the stomach	• Lubricates food and passageways
Stomach	• Mixes and churns food with gastric juices to form chyme • Begins chemical breakdown of proteins • Releases food into the duodenum as	• Stimulates protein-digesting enzymes • Secretes intrinsic factor required for vitamin B_{12} absorption in small intestine

Organ	Major functions	Other functions
	chyme • Absorbs some fat-soluble substances (for example, alcohol, aspirin) • Possesses antimicrobial functions	
Small intestine	• Mixes chyme with digestive juices • Propels food at a rate slow enough for digestion and absorption • Absorbs breakdown products of carbohydrates, proteins, lipids, and nucleic acids, along with vitamins, minerals, and water • Performs physical digestion via segmentation	• Provides optimal medium for enzymatic activity
Accessory organs	• Liver: produces bile salts, which emulsify lipids, aiding their digestion and absorption • Gallbladder: stores, concentrates, and releases bile • Pancreas: produces digestive enzymes and bicarbonate	• Bicarbonate-rich pancreatic juices help neutralize acidic chyme and provide optimal environment for enzymatic activity
Large intestine	• Further breaks down food residues • Absorbs most residual water, electrolytes, and vitamins produced by enteric bacteria • Propels feces toward rectum • Eliminates feces	• Food residue is concentrated and temporarily stored prior to defecation • Mucus eases passage of feces through colon

Functions of the Digestive System

1- ingestion – the oral cavity allows food to enter the digestive tract and have mastication (chewing) occurs, and the resulting food bolus is swallowed.

2- Digestion:

♣ Mechanical digestion – muscular movement of the digestive tract (mainly in the oral cavity and stomach) physically break down food into smaller particles.

♣ chemical digestion – hydrolysis reactions aided by enzymes (mainly in the stomach and small intestine) chemically break down food particles into nutrient molecules, small enough to be absorbed.

♣Secretion – enzymes and digestive fluids secreted by the digestive tract and its accessory organs facilitate chemical digestion.

♣ Absorption – passage of the end – products (nutrients) of chemical digestion from the digestive tract into blood or lymph for distribution to tissue cells.

♣ Elimination (defecation) – undigested material will be released through the rectum and anus by defecation.

Digestive Processes

The processes of digestion include six activities: ingestion, propulsion, mechanical or physical digestion, chemical digestion, absorption, and defecation.

The first of these processes, **ingestion**, refers to the entry of food into the alimentary canal through the mouth. There, the food is chewed and mixed with saliva, which contains enzymes that begin breaking down the carbohydrates in the food plus some lipid digestion via lingual lipase. Chewing increases the surface area of the food and allows an appropriately sized bolus to be produced.

Food leaves the mouth when the tongue and pharyngeal muscles propel it into the esophagus. This act of swallowing, the last voluntary act until defecation, is an example of propulsion, which refers to the movement of food through the digestive tract. It includes both the voluntary process of swallowing and the involuntary process of peristalsis. Peristalsis consists of sequential, alternating waves of contraction and relaxation of alimentary wall smooth muscles, which act to propel food along (Figure 1). These waves also play a role in mixing food with digestive juices. Peristalsis is so powerful that foods and liquids you swallow enter your stomach even if you are standing on your head.

Peristalsis

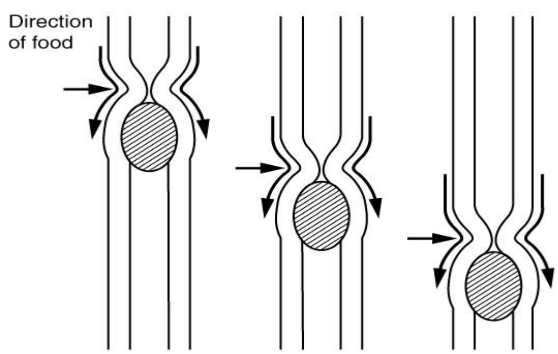


Figure 1: Peristalsis moves food through the digestive tract with alternating waves of muscle contraction and relaxation.

Digestion includes both mechanical and chemical processes.

Mechanical digestion is a purely physical process that does not change the chemical nature of the food. Instead, it makes the food smaller to increase both surface area and mobility. It includes mastication, or chewing, as well as tongue movements that help break food into smaller bits and mix food with saliva. Although there may be a tendency to think that mechanical digestion is limited to the first steps of the digestive process, it occurs after the food leaves the mouth, as well. The mechanical churning of food in the stomach serves to further break it apart and expose more of its surface area to digestive juices, creating an acidic "soup" called chyme. Segmentation, which occurs mainly in the small intestine, consists of localized contractions of circular muscle of the muscularis layer of the alimentary canal. These contractions isolate small sections of the intestine, moving their contents back and forth while continuously subdividing, breaking up, and mixing the contents. By moving food back and forth in the intestinal lumen, segmentation mixes food with digestive juices and facilitates absorption.

chemical digestion, starting in the mouth, digestive secretions break down complex food molecules into their chemical building blocks (for example, proteins into separate amino acids). These secretions vary in composition, but typically contain water, various enzymes, acids, and salts. The process is completed in the small intestine.

Food that has been broken down is of no value to the body unless it enters the bloodstream and its nutrients are put to work. This occurs through the process of absorption, which takes place primarily within the small intestine. There, most nutrients are absorbed from the lumen of the alimentary canal into the bloodstream through the epithelial cells that make up the mucosa. Lipids are absorbed into lacteals and are transported via the lymphatic vessels to the bloodstream (the subclavian veins near the heart). The details of these processes will be discussed later.

defecation, the final step in digestion, undigested materials are removed from the body as feces.

in some cases, a single organ is in charge of a digestive process. For example, ingestion occurs only in the mouth and defecation only in the anus. However, most digestive processes involve the interaction of several organs and occur gradually as food moves through the alimentary canal (Figure 2).

Digestive Processes

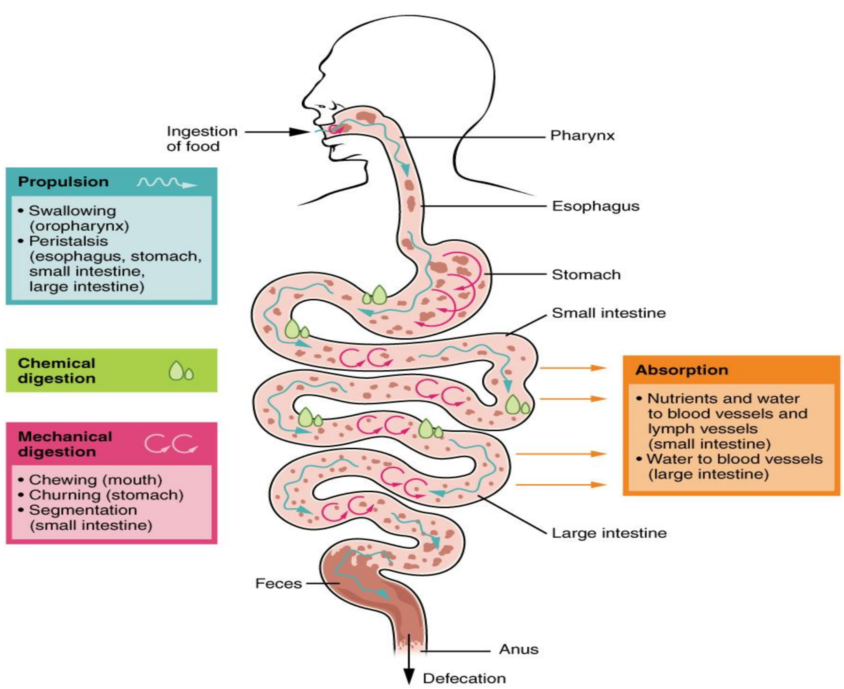


Figure 2: The digestive processes are ingestion, propulsion, mechanical digestion, chemical digestion, absorption, and defecation.

Some chemical digestion occurs in the mouth. Some absorption can occur in the mouth and stomach, for example, alcohol and aspirin.

Regulatory Mechanisms

Neural and endocrine regulatory mechanisms work to maintain the optimal conditions in the lumen needed for digestion and absorption. These regulatory mechanisms, which stimulate digestive activity through mechanical and chemical activity, are controlled both extrinsically and intrinsically.

Neural Controls

The walls of the alimentary canal contain a variety of sensors that help regulate digestive functions. These include mechanoreceptors, chemoreceptors, and osmoreceptors, which are capable of detecting mechanical, chemical, and osmotic stimuli, respectively. For example, these receptors can sense when the presence of food has caused the stomach to expand, whether food particles have been sufficiently broken down, how much liquid is present, and the type of nutrients in the food (lipids, carbohydrates, and/or proteins). Stimulation of these receptors provokes an appropriate reflex that furthers the process of digestion. This may entail sending a message that activates the glands that secrete digestive juices into the lumen, or it may mean the stimulation of muscles within the alimentary canal, thereby activating peristalsis and segmentation that move food along the intestinal tract.

The walls of the entire alimentary canal are embedded with nerve plexuses that interact with the central nervous system and other nerve plexuses—either within the same digestive organ or in different ones. These interactions prompt several types of reflexes. Extrinsic nerve plexuses orchestrate long reflexes, which involve the central and autonomic nervous systems and work in response to stimuli from outside the digestive system. Short reflexes, on the other hand, are orchestrated by intrinsic nerve plexuses within the alimentary canal wall. These two plexuses and their connections were introduced earlier as the enteric nervous system. Short reflexes regulate activities in one area of the digestive tract and may coordinate local peristaltic movements and stimulate digestive secretions. For example, the sight, smell, and taste of food initiate long reflexes that begin with a sensory neuron delivering a signal to the medulla oblongata. The response to the signal is to stimulate cells in the stomach to begin secreting digestive juices in preparation for incoming food. In contrast, food that distends the stomach initiates short reflexes that cause cells in the stomach wall to increase their secretion of digestive juices.

Hormonal Controls

A variety of hormones are involved in the digestive process. The main digestive hormone of the stomach is gastrin, which is secreted in response to the presence of food. Gastrin stimulates the secretion of gastric acid by the parietal cells of the stomach mucosa. Other GI hormones are produced and act upon the gut and its accessory organs. Hormones produced by the duodenum include secretin, which stimulates a watery secretion of bicarbonate by the pancreas; cholecystokinin (CCK), which stimulates the secretion of pancreatic enzymes and bile from the liver and release of bile from the gallbladder; and gastric inhibitory peptide, which inhibits gastric secretion and slows gastric emptying and motility. These GI hormones are secreted by specialized epithelial cells, called endocrinocytes, located in the mucosal epithelium of the stomach and small intestine. These hormones then enter the bloodstream, through which they can reach their target organs.

The Circulatory System

(The Heart, Blood Vessels, Blood Types)

Circulatory systems generally have three main features:

- Fluid (blood or lymph) that transports materials.
- System of blood vessels.
- A heart to pump the fluid through the vessels.

Types of circulatory systems:

- Animals that have a circulatory system have one of two kinds:

Open: fluid is circulated through an open body chamber.
Closed: fluid is circulated through blood vessels.

Function

- Transport materials needed by cells (Oxygen- Glucose).
- Remove waste materials from cells (Carbon dioxide- Urea)

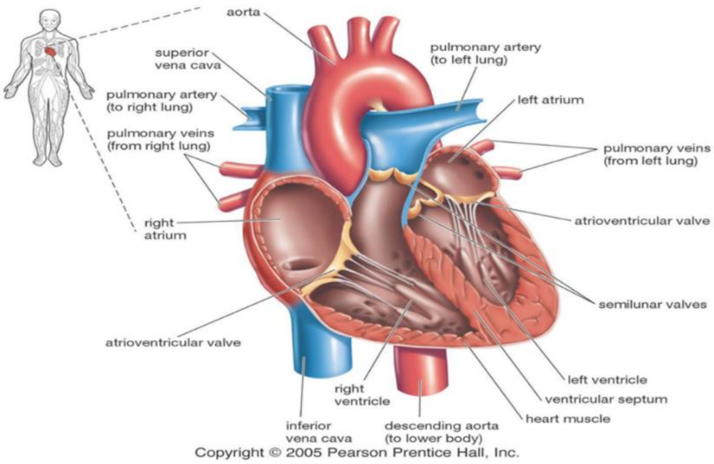
Major Components

Blood: Fluid that fills the circulatory system
Pump (heart): Continuously circulates blood
Network of tubes (blood vessels)

- Arteries- blood away from heart
- Veins- blood back to the heart
- Capillaries- link Arteries with Veins

1-The Heart

The human heart has four chambers (Left and right ventricle - Left and right atrium).
The left side of the heart pumps oxygenated blood to the body while the right side of the heart pumps deoxygenated blood to the lungs where oxygen can be absorbed by the hemoglobin carrying red blood cells.



Functions of the Heart

- Generating blood pressure.
- Routing blood.
- Heart separates pulmonary and systemic circulations.
- Ensuring one-way blood flow.
- Heart valves ensure one-way flow.
- Regulating blood supply.

Size, Shape, Location of the Heart

Shape:

Apex: Blunt rounded point of cone.
Base: Flat part at opposite of end of cone.

- Size of a closed fist
- Located in thoracic cavity between tow lungs

External Anatomy

- **Four chambers**

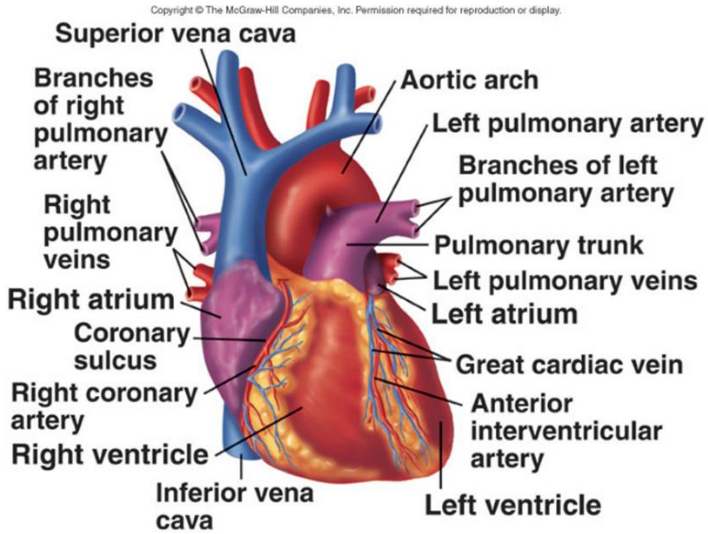
2 atria
2 ventricles

- **Major veins**

Superior and inferior vena cava
Pulmonary veins

- **Major arteries**

Aorta
Pulmonary trunk



<u>Heart Valves</u>

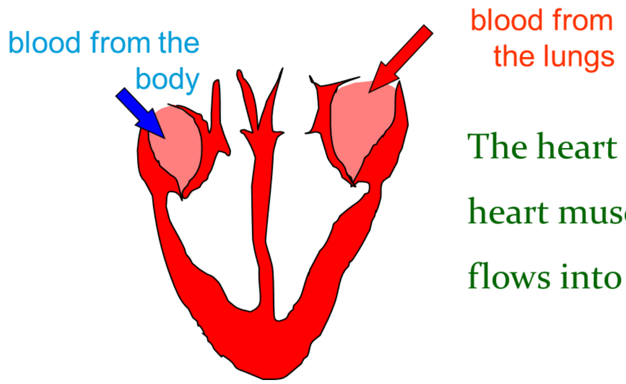
- **Atrioventricular valves**

Tricuspid
Bicuspid or mitral

- **Semilunar valves**

Aortic
Pulmonary
Prevent blood from flowing back

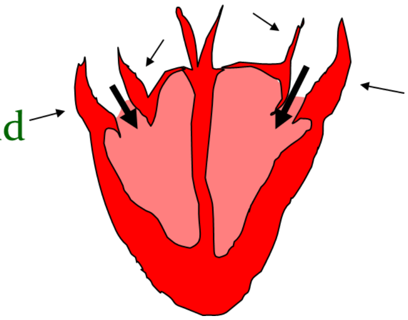
How does the Heart work? **Step one**



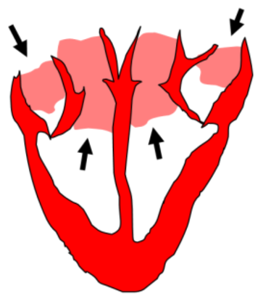
The heart beat begins when the heart muscles **relax** and blood flows into the atria.

STEP TWO

The atria then **contract** and the valves **open** to allow blood into the ventricles.



STEP THREE



The valves **close** to stop blood flowing backwards.

The ventricles **contract** forcing the blood to leave the heart.

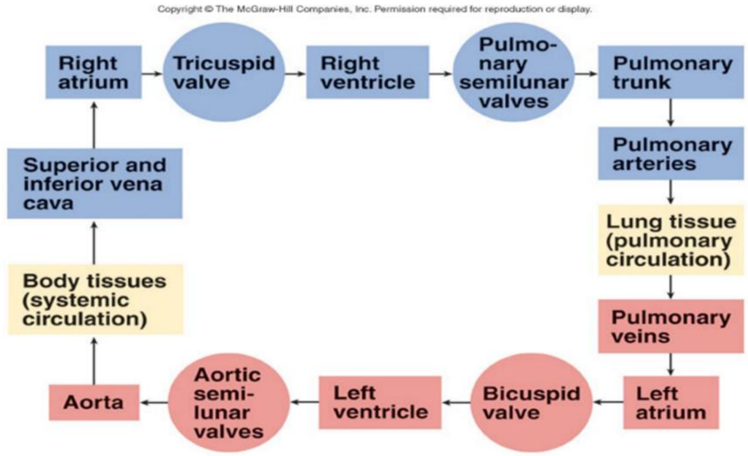
At the same time, the atria are **relaxing** and once again filling with blood

.

The cycle then repeats itself.

Circulation

After passing through the capillaries of the lungs, the blood which is now oxygenated returns to the heart in the pulmonary veins. The left atrium receives blood from the pulmonary vein. Blood passes through the mitral valve into the left ventricle. Contraction of the left ventricle pushes blood through the aortic semilunar valve into the aorta. Blood travels to all regions of the body where it feeds cells with oxygen picked up from the lungs and nutrients from the digestive tract. Deoxygenated blood returns from the rest of the body through the superior and inferior vena cava. Contraction of the right ventricle pushes blood through the pulmonary semilunar valve into the pulmonary arteries in which it travels to the lungs.



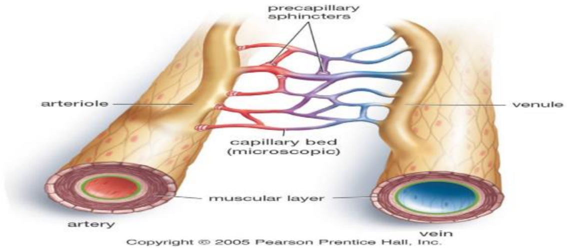
Blood Pressure

Blood pressure is a measure of the force exerted by the blood on the wall of the arteries. An example is 120/80 (systolic pressure/diastolic pressure. Systolic pressure is the result of the contraction of the ventricles (normal 110-140). Diastolic pressure is during the ventricle relaxation (normal 70-90)

2-Blood Vessels:

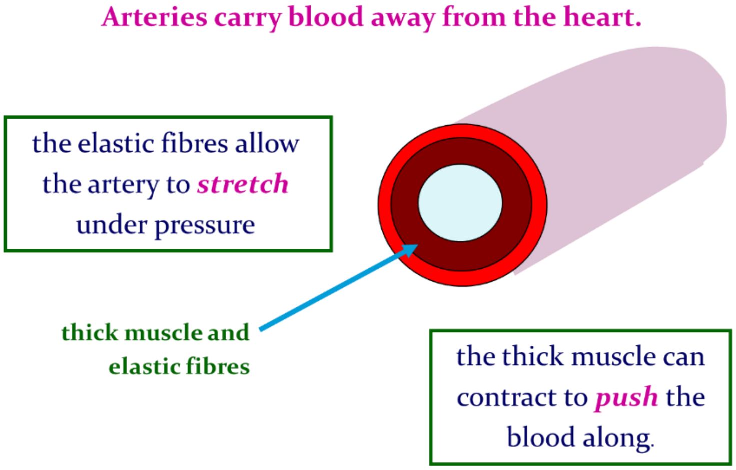
Blood vessels fall into three major classes:

- Arteries and arterioles carry blood away from the heart.
- Veins and venules carry blood to the heart.
- Capillaries allow exchange of nutrients, wastes and gases.



a-The ARTERY

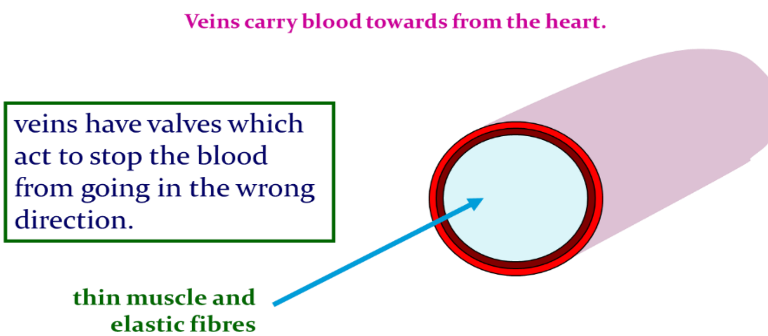
Arteries are thick-walled and lined with smooth muscle. How does the structure of an artery help with its function?



Arteries carry blood away from the heart.

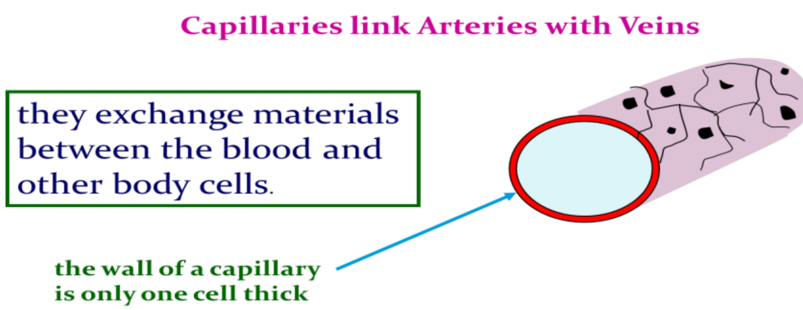
b-The Vein

Veins have thinner walls than arteries. Veins have fewer smooth muscle cells but do have valves. How do valves and the skeletal muscles help vein's function?



c- The Capillary

Body tissues contain a vast network of thin capillaries. Capillary walls are only one cell thick, allowing exchange of gases, nutrients, and wastes.



3- Blood Components:

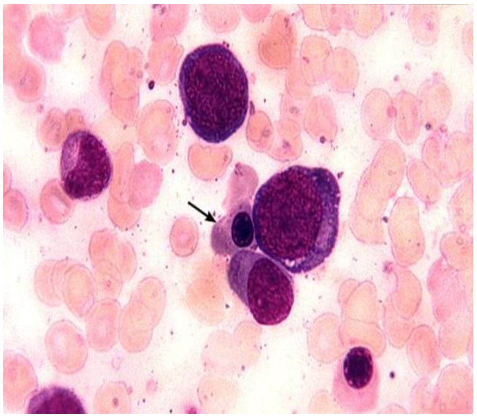
Blood is made up of four major components. What do each of these do?

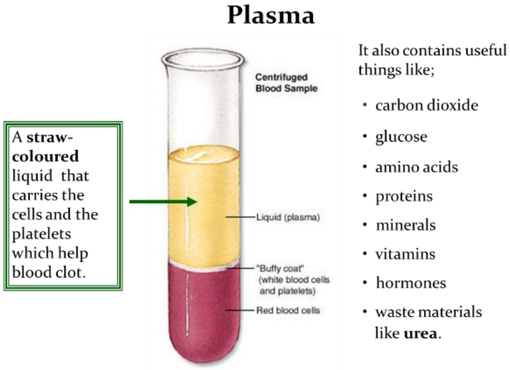
- Plasma: the liquid portion.

- Red blood cells (RBCs).
- White blood cells (WBCs).
- Platelets (PLT).

A-) Plasma

Liquid portion of the blood. Contains clotting factors, hormones, antibodies, dissolved gases, nutrients, and waste.





B.) Red Blood Cells

- A biconcave disc that is round and flat.

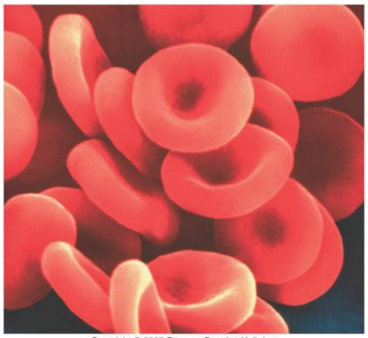
- Carry hemoglobin and oxygen. Do not have a nucleus and live only about 120 days.

- Can change shape to an amazing extent, without breaking, as it squeezes single file through the capillaries.

- Cannot repair themselves.

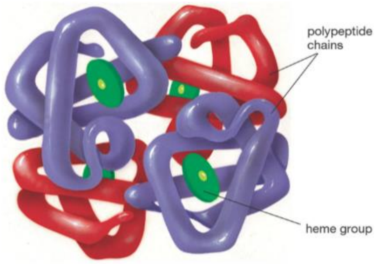
- Make up about 99% of the blood's cellular component.

- Red color is due to hemoglobin.



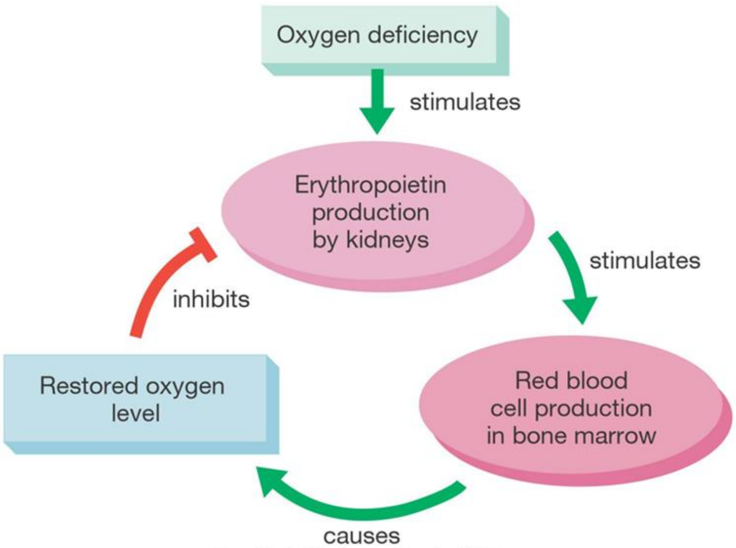
Hemoglobin

Hemoglobin is a complex protein made up of four protein strands, plus iron-rich heme groups. Each hemoglobin molecule can carry four oxygen atoms. The presence of oxygen turns hemoglobin bright red.



RBC lifespan

RBCs live about 4 months. Iron from hemoglobin is recycled in the liver and spleen. The hormone erythropoietin, made by the kidneys, stimulates the production of RBCs in red bone marrow.



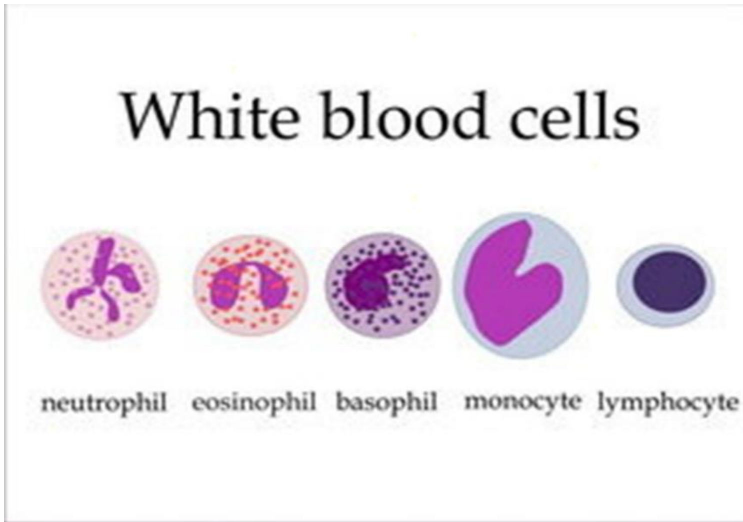
C.) White Blood cells

- Fight infection and are formed in the bone marrow.

- White blood cells defend against disease by recognizing proteins that do not belong to the body.

-White cells can ooze through the walls of capillaries to patrol the tissues and reach the lymph system

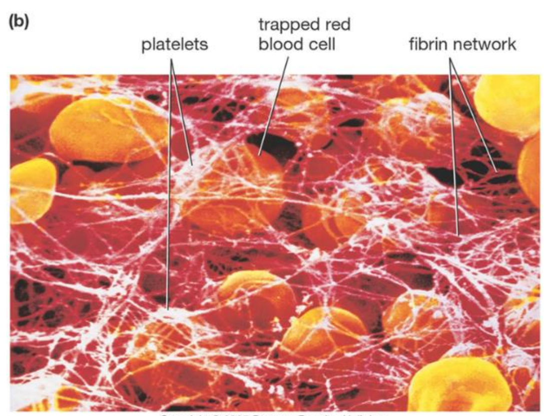
-Have five types (neutrophils, lymphocytes, eosinophils, basophils, and monocytes).



the two main ones are the lymphocytes and the macrophages, macrophages ‘eat’ and digest micro-organisms, some lymphocytes fight disease by making antibodies to destroy invaders by dissolving them. other lymphocytes make antitoxins to break down poisons.

D) Platelets

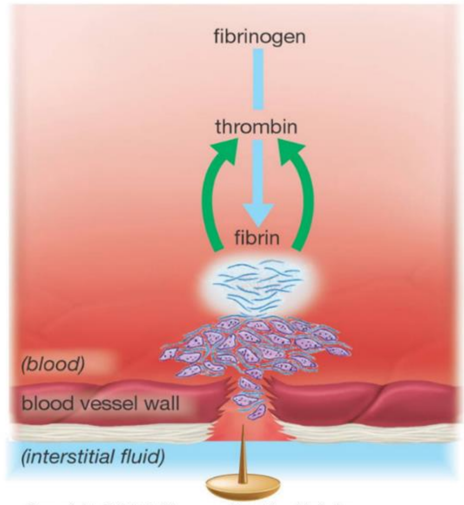
Platelets are cell fragments used in blood clotting. Platelets are derived from megakaryocytes. Because they lack a nucleus, platelets have a short lifespan, usually about 10 days.



<u>Blood clotting</u>

1- Platelets aggregate at the site of a wound.
2- Broken cells and platelets release chemicals to stimulate thrombin production.
3- Thrombin converts the protein fibrinogen into sticky fibrin, which binds the clot.

(a)



Disorders of the Circulatory System

- Anemia - lack of iron in the blood, low RBC count.
- Leukemia - white blood cells proliferate wildly, causing anemia.
- Hemophilia - bleeder's disease, due to lack of fibrinogen in thrombocytes.
- Heart Murmur - abnormal heartbeat, caused by valve problems.
- Heart attack - blood vessels around the heart become blocked with plaque, also called myocardial infarction.

The Neuromuscular System

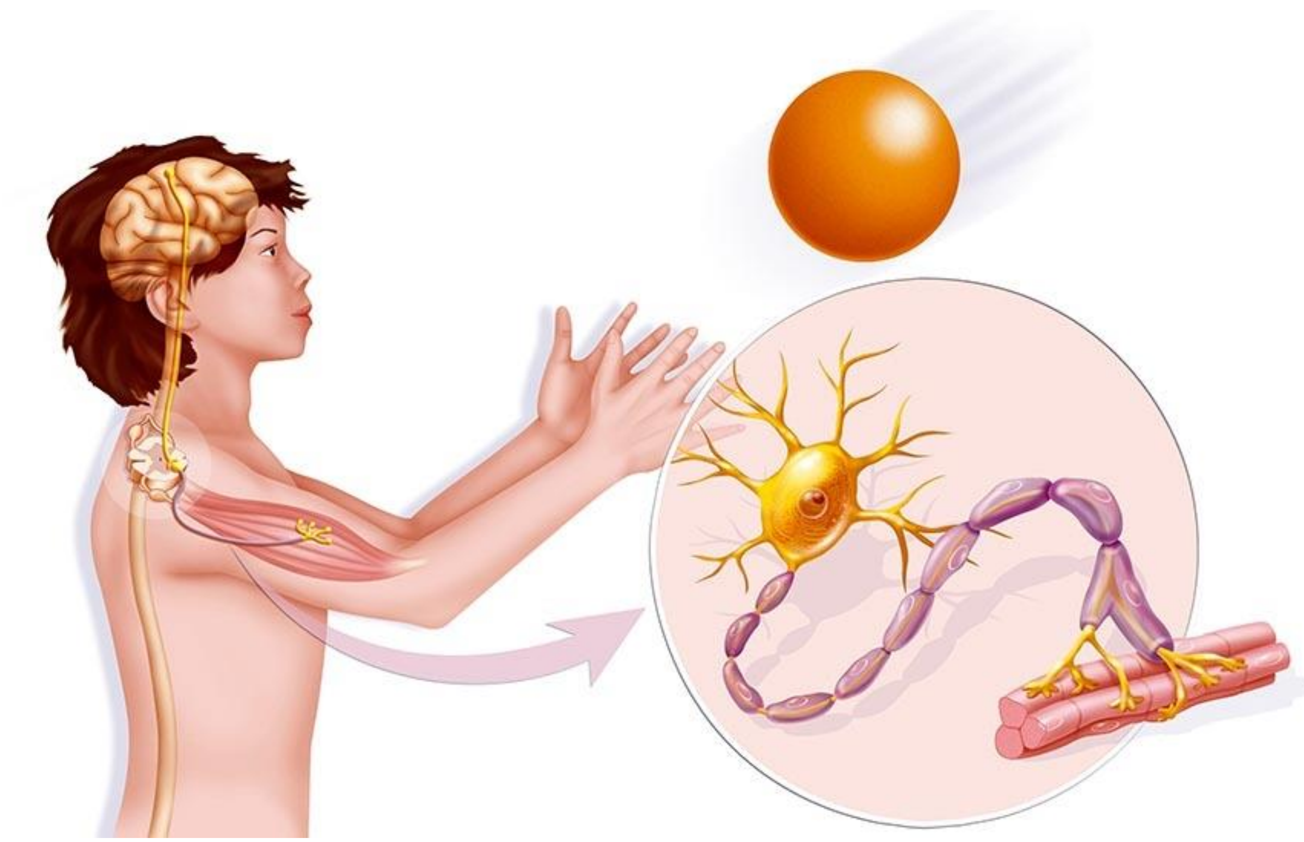
The neuromuscular system includes all the muscles in the body and the nerves serving them. Every movement the body makes requires communication between the brain and the muscles. The nervous system provides the link between thoughts and actions by relaying messages from the brain to other parts of the body.

Nerves and muscles, working together as the neuromuscular system, make the body move as you want it to and also control functions such as breathing.

How does the neuromuscular system work?

Nerves have cells called neurons. Neurons carry messages from the brain via the spinal cord. The neurons that carry these messages to the muscles are called motor neurons.

Each motor neuron ending sits very close to a muscle fibre. Where they sit together is called a neuromuscular junction. The motor neurons release a chemical, which is picked up by the muscle fiber. This tells the muscle fiber to contract, which makes the muscles move.



The Muscular System

The muscular system controls numerous functions, which is possible with the significant differentiation of muscle tissue morphology and ability.

Key Points

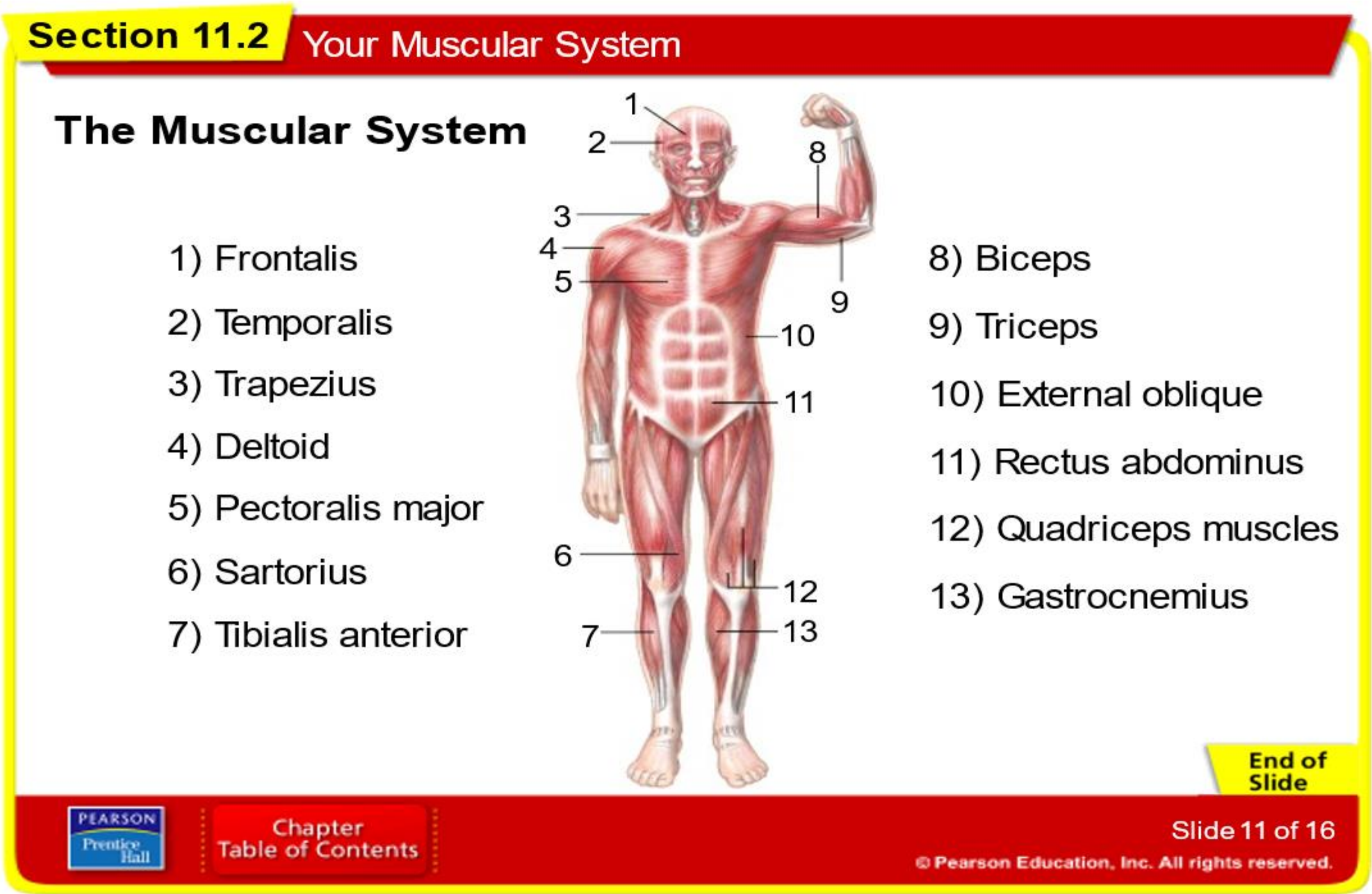
- The muscular system is responsible for functions such as maintenance of posture, locomotion, and control of various circulatory systems.
- Muscle tissue can be divided functionally (voluntarily or involuntarily controlled) and morphologically (striated or non-striated).
- These classifications describe three distinct muscle types: skeletal, cardiac and smooth. Skeletal muscle is voluntary and striated, cardiac muscle is involuntary and striated, and smooth muscle is involuntary and non-striated.

Key Terms

- **myofibril**: A fiber made up of several myofilaments that facilitates the generation of tension in a myocyte.
- **myofilament**: A filament composed of either multiple myosin or actin proteins that slide over each other to generate tension.
- **myosin**: A motor protein which forms myofilaments that interact with actin filaments to generate tension.
- **actin**: A protein which forms myofilaments that interact with myosin filaments to generate tension.
- **striated**: The striped appearance of certain muscle types in which myofibrils are aligned to produce a constant directional tension.
- **voluntary**: A muscle movement under conscious control (e.g. deciding to move the forearm).
- **involuntary**: A muscle movement not under conscious control (e.g. the beating of the heart).
- **myocyte**: A muscle cell.

The Musculoskeletal System

The muscular system is made up of muscle tissue and is responsible for functions such as maintenance of posture, locomotion and control of various circulatory systems. This includes the beating of the heart and the movement of food through the digestive system. The muscular system is closely associated with the skeletal system in facilitating movement. Both voluntary and involuntary muscular system functions are controlled by the nervous system.



Muscle is a highly-specialized soft tissue that produces tension which results in the generation of force. Muscle cells, or myocytes, contain myofibrils comprised of actin and myosin myofilaments which slide past each other producing tension that changes the shape of the myocyte. Numerous myocytes make up muscle tissue and the controlled production of tension in these cells can generate significant force.

Muscle tissue can be classified functionally as voluntary or involuntary and morphologically as striated or non-striated. Voluntary refers to whether the muscle is under conscious control, while striation refers to the presence of visible banding within myocytes caused by the organization of myofibrils to produce constant tension.

Types of Muscle

The above classifications describe three forms of muscle tissue that perform a wide range of diverse functions.

Skeletal Muscle

Skeletal muscle mainly attaches to the skeletal system via tendons to maintain posture and control movement. For example, contraction of the biceps muscle, attached to the scapula and radius, will raise the forearm. Some skeletal muscle can attach directly to other muscles or to the skin, as seen in the face where numerous muscles control facial expression.

Skeletal muscle is under voluntary control, although this can be subconscious when maintaining posture or balance. Morphologically skeletal myocytes are elongated and tubular and appear striated with multiple peripheral nuclei.

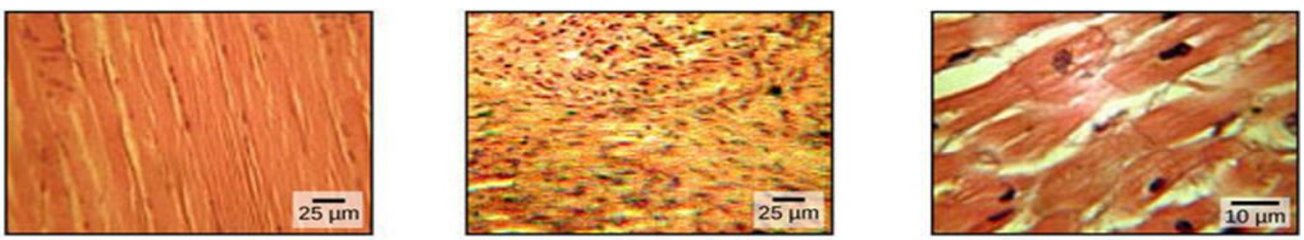
Cardiac Muscle Tissue

Cardiac muscle tissue is found only in the heart, where cardiac contractions pump blood throughout the body and maintain blood pressure.

As with skeletal muscle, cardiac muscle is striated; however it is not consciously controlled and so is classified as involuntary. Cardiac muscle can be further differentiated from skeletal muscle by the presence of intercalated discs that control the synchronized contraction of cardiac tissues. Cardiac myocytes are shorter than skeletal equivalents and contain only one or two centrally located nuclei.

Smooth Muscle Tissue

Smooth muscle tissue is associated with numerous organs and tissue systems, such as the digestive system and respiratory system. It plays an important role in the regulation of flow in such systems, such as aiding the movement of food through the digestive system via peristalsis. Smooth muscle is non-striated and involuntary. Smooth muscle myocytes are spindle shaped with a single centrally located nucleus.



Skeletal muscle | Smooth muscle | Cardiac muscle

Types of muscle: The body contains three types of muscle tissue: skeletal muscle, smooth muscle, and cardiac muscle, visualized here using light microscopy. Visible striations in skeletal and cardiac muscle are visible, differentiating them from the more randomized appearance of smooth muscle.

Function of Muscle Tissue

The main function of the muscular system is movement. Muscles are the only tissue in the body that has the ability to contract and therefore move the other parts of the body.

Related to the function of movement is the muscular system's second function: the maintenance of posture and body position. Muscles often contract to hold the body still or in a particular position rather than to cause movement. The muscles responsible for the body's posture have the greatest endurance of all muscles in the body—they hold up the body throughout the day without becoming tired.

Another function related to movement is the movement of substances inside the body. The cardiac and visceral muscles are primarily responsible for transporting substances like blood or food from one part of the body to another.

The final function of muscle tissue is the generation of body heat. As a result of the high metabolic rate of contracting muscle, our muscular system produces a great deal of waste heat. Many small muscle contractions within the body produce our natural body heat. When we exert ourselves more than normal, the extra muscle contractions lead to a rise in body temperature and eventually to sweating.

The Nervous System

Basic Structure and Function of the Nervous System

the nervous system probably includes the brain, the nervous tissue contained within the cranium, and the spinal cord, the extension of nervous tissue within the vertebral column. That suggests it is made of two organs—and you may not even think of the spinal cord as an organ—but the nervous system is a very complex structure. Within the brain, many different and separate regions are responsible for many different and separate functions.

The Central and Peripheral Nervous Systems

The nervous system can be divided into two major regions: the central and peripheral nervous systems.

The central nervous system (CNS) is the brain and spinal cord, and the peripheral nervous system (PNS) are referred to as ganglia and Nerves. The brain is contained within the cranial cavity of the skull, and the spinal cord is contained within the vertebral cavity of the vertebral column.

Basic Functions of the Nervous System

The nervous system is involved in receiving information about the environment around us (sensation) and generating responses to that information (motor responses).

But there is a third function that needs to be included. Sensory input needs to be integrated with other sensations, as well as with memories, emotional state, or learning (cognition). Some regions of the nervous system are termed integration or association areas. The process of integration combines sensory perceptions and higher cognitive functions such as memories, learning, and emotion to produce a response.

Sensation:

The first major function of the nervous system is sensation—receiving information about the environment to gain input about what is happening outside the body (or, sometimes, within the body). The sensory functions of the nervous system register the presence of a change from homeostasis or a particular event in the environment, known as a stimulus. The senses we think of most are the "big five": taste, smell, touch, sight, and hearing.

Response:

The nervous system produces a response based on the stimuli perceived by sensory structures. An obvious response would be the movement of muscles, such as withdrawing a hand from a hot stove.

Controlling the Body:

The nervous system can be divided into two parts mostly based on a functional difference in responses. The somatic nervous system (SNS) is responsible for conscious perception and voluntary motor responses. Voluntary motor response means the contraction of skeletal muscle,

The autonomic nervous system (ANS) is responsible for involuntary control of the body, usually for the sake of homeostasis (regulation of the internal environment). Sensory input for autonomic functions can be from sensory structures tuned to external or internal environmental stimuli.

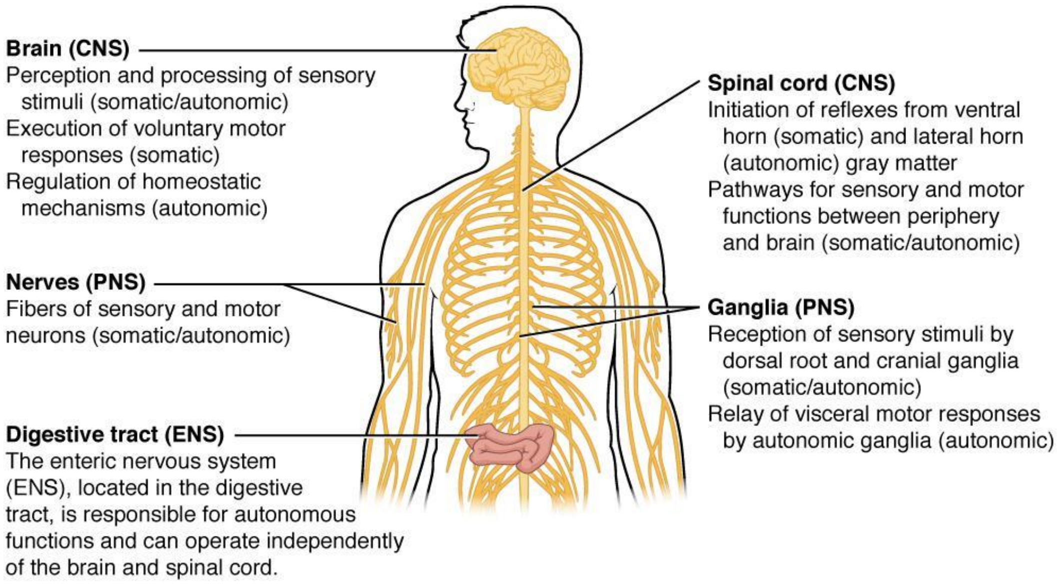


Figure: Somatic, Autonomic, and Enteric Structures of the Nervous System Somatic structures include the spinal nerves, both motor and sensory fibers, as well as the sensory ganglia (posterior root ganglia and cranial nerve ganglia). Autonomic structures are found in the nerves also but include the sympathetic and parasympathetic ganglia. The enteric nervous system includes the nervous tissue within the organs of the digestive tract.

Nervous Tissue:

Nervous tissue is composed of two types of cells, neurons, and glial cells. Neurons are the primary type of cell that most anyone associates with the nervous system.
They are responsible for the computation and communication that the nervous system provides.

Neurons:

Neurons are the cells considered to be the basis of nervous tissue. They are responsible for the electrical signals that communicate information about sensations, and that produce movements in response to those stimuli.

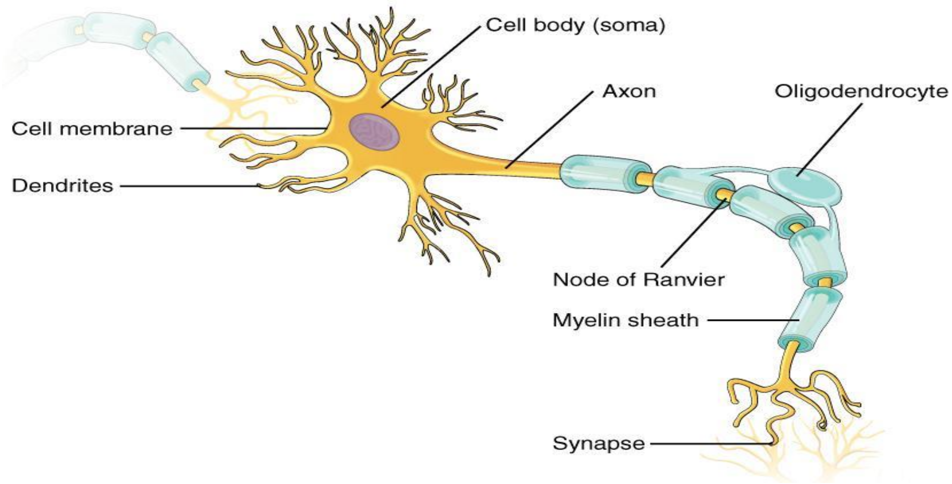
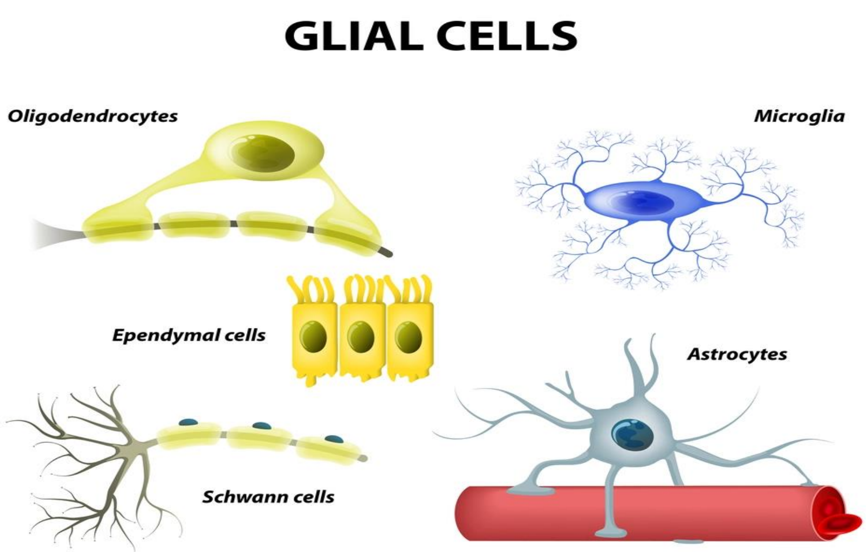


Figure: Parts of a Neuron

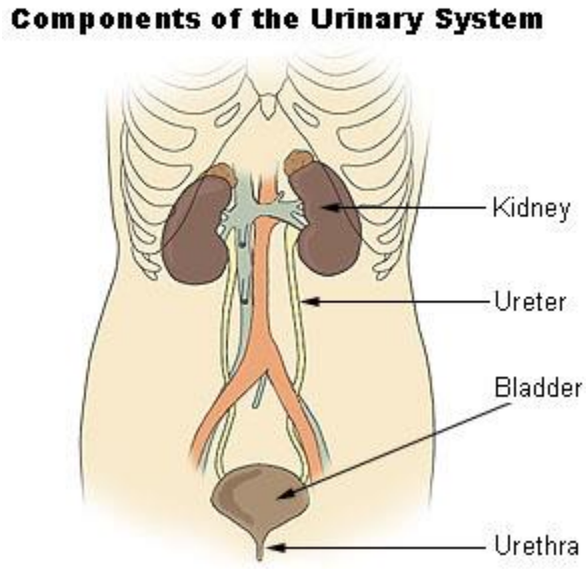
Structure: The major parts of the neuron are labeled on a multipolar neuron from the CNS. Where the axon emerges from the cell body, there is a special region referred to as the axon hillock. This is a tapering of the cell body toward the axon fiber. Within the axon hillock, the cytoplasm changes to a solution of limited components called axoplasm. Because the axon hillock represents the beginning of the axon, it is also referred to as the initial segment.

Glial Cells

Glial cells, or neuroglia or simply glia, are the other type of cell found in nervous tissue. They are supporting cells, and many functions are directed at helping neurons complete their function for communication.



Urinogenital system



1-Urinary System

The Urinary System is a group of organs in the body concerned with filtering out excess fluid and other substances from the bloodstream. The substances are filtered out from the body in the form of urine. Urine is a liquid produced by the kidneys, collected in the bladder and excreted through the urethra. Urine is used to extract excess minerals or vitamins as well as blood corpuscles from the body.

The Urinary organs include the kidneys, ureters, bladder, and urethra. The Urinary system works with the other systems of the body to help maintain homeostasis. The kidneys are the main organs of homeostasis because they maintain the acid base balance and the water salt balance of the blood.

Functions of the Urinary System

One of the major functions of the Urinary system is the process of excretion.

1-Excretion is the process of eliminating, from an organism, waste products of metabolism and other materials that are of no use.

2-The urinary system maintains an appropriate fluid volume by regulating the amount of water that is excreted in the urine. Other aspects of its function include

3-regulating the concentrations of various electrolytes in the body fluids and maintaining normal pH of the blood.

Several body organs carry out excretion, but the kidneys are the most important excretory organ. The primary function of the kidneys is to maintain a stable internal environment (homeostasis) for optimal cell and tissue metabolism. They do this by separating urea, mineral salts, toxins, and other waste products from the blood. They also do the job of conserving water, salts, and electrolytes. At least one kidney must function properly for life to be maintained.

Six important roles of the kidneys are:

Regulation of plasma ionic composition. Ions such as sodium, potassium, calcium, magnesium, chloride, bicarbonate, and phosphates are regulated by the amount that the kidney excretes. Regulation of plasma osmolarity. The kidneys regulate osmolarity because they have direct control over how many ions and how much water a person excretes.

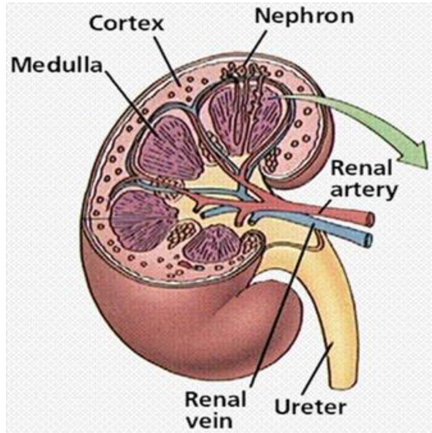
Regulation of plasma volume. Your kidneys are so important they even have an effect on your blood pressure. The kidneys control plasma volume by controlling how much water a person excretes. The plasma volume has a direct effect on the total blood volume, which has a direct effect on your blood pressure. Salt (NaCl)will cause osmosis to happen; the diffusion of water into the blood.

Regulation of plasma hydrogen ion concentration (pH). The kidneys partner up with the lungs and they together control the pH. The kidneys have a major role because they control the amount of bicarbonate excreted or held onto. The kidneys help maintain the blood Ph mainly by excreting hydrogen ions and reabsorbing bicarbonate ions as needed.

Removal of metabolic waste products and foreign substances from the plasma. One of the most important things the kidneys excrete is nitrogenous waste. As the liver breaks down amino acids it also releases ammonia. The liver then quickly combines that ammonia with carbon dioxide, creating urea which is the primary nitrogenous end product of metabolism in humans. The liver turns the ammonia into urea because it is much less toxic. We can also excrete some ammonia, creatinine and uric acid. The creatinine comes from the metabolic breakdown of creatine phosphate (a high-energy phosphate in muscles). Uric acid comes from the breakdown of nucleotides. Uric acid is insoluble and too much uric acid in the blood will build up and form crystals that can collect in the joints and cause gout.

Secretion of Hormones The endocrine system has assistance from the kidney's when releasing hormones. Renin is released by the kidneys. Renin leads to the secretion of aldosterone which is released from the adrenal cortex. Aldosterone promotes the kidneys to reabsorb the sodium (Na+) ions. The kidneys also secrete erythropoietin when the blood doesn't have the capacity to carry oxygen. Erythropoietin stimulates red blood cell production. The Vitamin D from the skin is also activated with help from the kidneys. Calcium (Ca+) absorption from the digestive tract is promoted by vitamin D.

Organs in the Urinary System Kidneys and Their Structure:



The kidneys

The kidneys are a pair of bean shaped, reddish brown organs about the size of your fist. It measures 10-12 cm long. They are covered by the renal capsule, which is a tough capsule of fibrous connective tissue. Adhering to the surface of each kidney is two layers of fat to help cushion them. There is a concaved side of the kidney that has a depression where a renal artery enters, and a renal vein and a ureter exit the kidney. The kidneys are located at the rear wall of the abdominal cavity just above the waistline, and are protected by the ribcage. They are considered retroperitoneal, which means they lie behind the peritoneum. There are three major regions of the kidney, renal cortex, renal medulla and the renal pelvis. The outer, granulated layer is the renal cortex. The cortex stretches down in between a radially striated inner layer. The inner radially striated layer is the renal medulla. This contains pyramid shaped tissue called the renal pyramids, separated by renal columns. The ureters are continuous with the renal pelvis and is the very center of the kidney. 1. Renal pyramid 2. Interlobar artery 3. Renal artery 4. Renal vein 5. Renal hilum 6. Renal pelvis 7. Ureter 8. Minor calyx 9. Renal capsule 10. Inferior renal capsule 11. Superior renal capsule 12. Interlobar vein 13. Nephron 14. Minor calyx 15. Major calyx 16. Renal papilla 17. Renal column.

Renal Vein

The renal veins are veins that drain the kidney. They connect the kidney to the inferior vena cava. Because the inferior vena cava is on the right half of the body, the left renal vein is generally the longer of the two. Unlike the right renal vein, the left renal vein often receives the left gonadal vein (left testicular vein in males, left ovarian vein in females). It frequently receives the left suprarenal vein as well.

Renal Artery

The renal arteries normally arise off the abdominal aorta and supply the kidneys with blood. The arterial supply of the kidneys are variable and there may be one or more renal arteries supplying each kidney. Due to the position of the aorta, the inferior vena cava and the kidneys in the body, the right renal artery is normally longer than the left renal artery. The right renal artery normally crosses posteriorly to the inferior vena cava. The renal arteries carry a large portion of the total blood flow to the kidneys. Up to a third of the total cardiac output can pass through the renal arteries to be filtered by the kidneys.

Ureters

The ureters are two tubes that drain urine from the kidneys to the bladder. Each ureter is a muscular tube about 10 inches (25 cm) long. Muscles in the walls of the ureters send the urine in small spurts into the bladder, (a collapsible sac found on the forward part of the cavity of the bony pelvis that allows temporary storage of urine). After the urine enters the bladder from the ureters, small folds in the bladder mucosa act like valves preventing backward flow of the urine. The outlet of the bladder is controlled by a sphincter muscle. A full bladder stimulates sensory nerves in the bladder wall that relax the sphincter and allow release of the urine. However, relaxation of the sphincter is also in part a learned response under voluntary control. The released urine enters the urethra. Urinary Bladder The urinary bladder is a hollow, muscular and distendible or elastic organ that sits on the pelvic floor (superior to the prostate in males). On its anterior border lies the pubic symphysis and, on its posterior border, the vagina (in females) and rectum (in males).

The urinary bladder

The urinary bladder can hold approximately 17 to 18 ounces (500 to 530 ml) of urine, however the desire to micturate is usually experienced when it contains about 150 to 200 ml. When the bladder fills with urine (about half full), stretch receptors send nerve impulses to the spinal cord, which then sends a reflex nerve impulse back to the sphincter (muscular valve) at the neck of the bladder, causing it to relax and allow the flow of urine into the urethra. The Internal urethral sphincter is involuntary. The ureters enter the bladder diagonally from its dorsolateral floor in an area called the trigone. The trigone is a triangular shaped area on the postero-inferior wall of the bladder. The urethra exits at the lowest point of the triangle of the trigone. The urine in the bladder also helps regulate body temperature. If the bladder becomes completely void of fluid, it causes the patient to chill.

The urethra

The urethra is a muscular tube that connects the bladder with the outside of the body. The function of the urethra is to remove urine from the body. It measures about 1.5 inches (3.8 cm) in a woman but up to 8 inches (20 cm) in a man. Because the urethra is so much shorter in a woman it makes it much easier for a woman to get harmful bacteria in her bladder this is commonly called a bladder infection or a UTI. The most common bacteria of a UTI is E-coli from the large intestines that have been excreted in fecal matter.

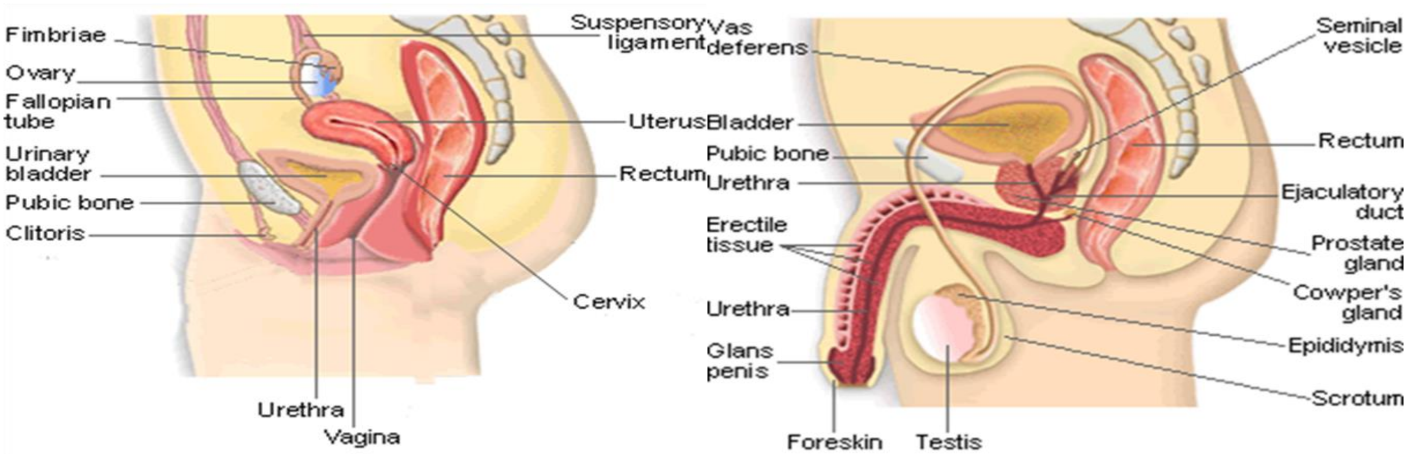
Female urethra in the human female, the urethra is about 1-2 inches long and opens in the vulva between the clitoris and the vaginal opening. Men have a longer urethra than women. This means that women tend to be more susceptible to infections of the bladder (cystitis) and the urinary tract.

Male urethra in the human male, the urethra is about 8 inches long and opens at the end of the head of the penis. The length of a male's urethra, and the fact it contains a number of bends, makes catheterisation more difficult.

The urethral sphincter is a collective name for the muscles used to control the flow of urine from the urinary bladder. These muscles surround the urethra, so that when they contract, the urethra is closed.

• There are two distinct areas of muscle: the internal sphincter, at the bladder neck and • the external, or distal, sphincter. Human males have much stronger sphincter muscles than females, meaning that they can retain a large amount of urine for twice as long, as much as 800mL, i.e

. "hold it".



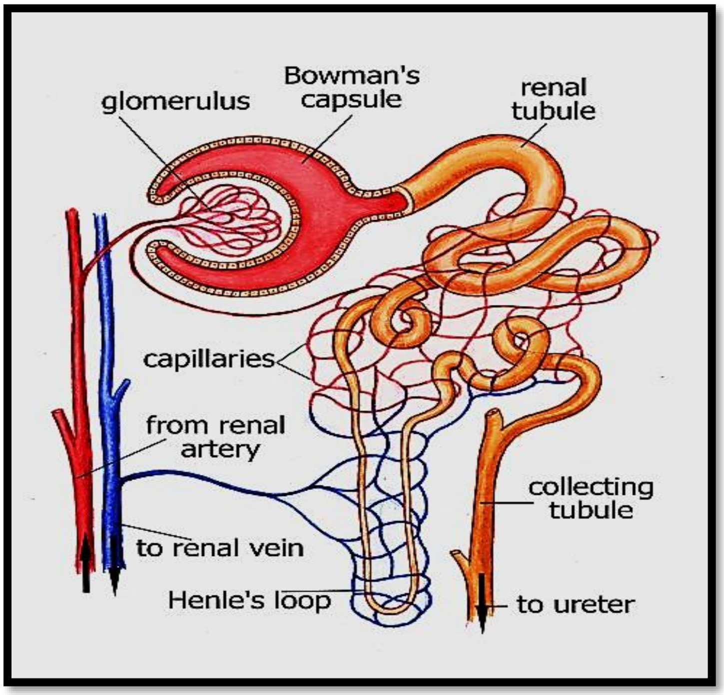
Nephrons

The filtering units of the kidneys is the nephrons. There are approximately one million nephrons in each kidney. The nephrons are located within the cortex and medulla of each kidney.
The tubes of the nephron are surrounded by cells and a network of blood vessels spreads throughout the tissue. Therefore, material that leaves the nephron enters the surrounding cells and returns to the bloodstream by a network of vessels.

Parts of the Nephron

Each nephron consists of the following parts:
1) glomerulus
2) Bowman’s capsule
3) proximal tubule

4) loop of Henle
5) distal tubule
6) collecting duct



The **glomerulus i**s a mass of thin-walled capillaries.
The **Bowman's capsule** is a double-walled, cup-shaped structure.
The **proximal tubule** leads from the Bowman's capsule to the Loop of Henle.
The **loop of Henle** is a long loop which extends into the medulla.
The **distal tubule** connects the loop of Henle to the collecting duct.

Function of the Kidney

The principal function of the kidney is to filter blood to remove cellular waste products from the body. At any given time, 20 % of blood is in the kidneys. Humans can function with one kidney.

The kidney has other functions but it is usually associated with the excretion of cellular waste such as:

1) urea (a nitrogenous waste produced in the liver from the breakdown of protein. It is the main component of urine).
2) uric acid (usually produced from breakdown of DNA or RNA).
3) creatinine (waste product of muscle action).

- All these compounds have nitrogen as a major component.
- The kidneys are more than excretory organs.
- They are one of the major homeostatic organs of the body.
- They control blood pH
- Secrete erythropoietin (a hormone that stimulates red blood cell production)
- Activate vitamin D production in the skin.

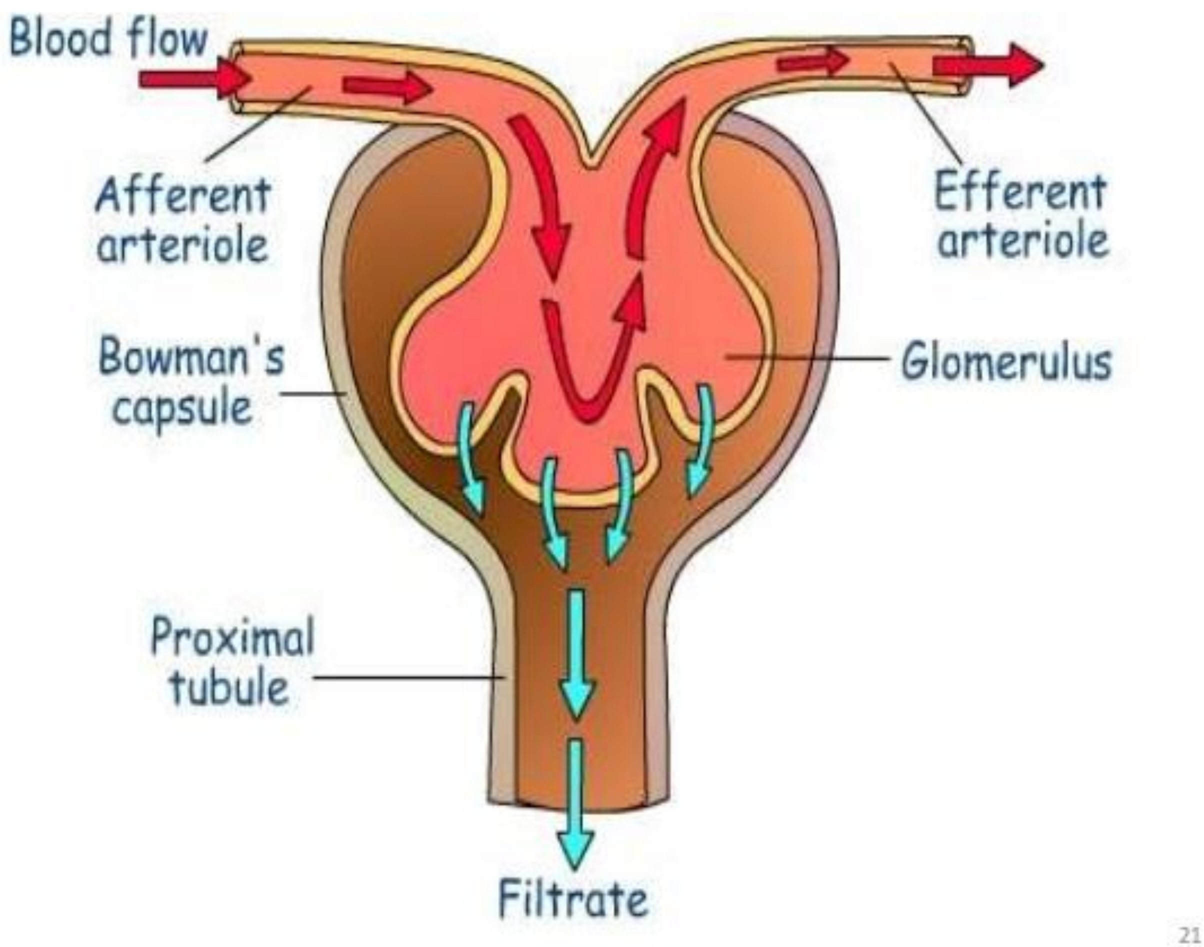
Formation of Urine

Urine is formed in three steps: Filtration, Reabsorption, and Secretion.

Filtration Blood enters the afferent arteriole and flows into the glomerulus. Blood in the glomerulus has both filterable blood components and non-filterable blood components. Filterable blood components move toward the inside of the glomerulus while non-filterable blood components bypass the filtration process by exiting through the efferent arteriole. Filterable Blood components now take on plasma like form called glomerular filtrate. A few of the filterable blood components are water, nitrogenous waste, nutrients and salts (ions). Nonfilterable blood components include formed elements such as blood cells and platelets along with plasma proteins. The glomerular filtrate is not the same consistency as urine, as much of it is reabsorbed into the blood as the filtrate passes through the tubules of the nephron.

Reabsorption Within the peritubular capillary network, molecules and ions are reabsorbed back into the blood. Sodium Chloride reabsorbed into the system increases the osmolarity of blood in comparison to the glomerular filtrate. This reabsorption process allows water (H2O) to pass from the glomerular filtrate back into the circulatory system. Glucose and various amino acids also are reabsorbed into the circulatory system. These nutrients have carrier molecules that claim the glomerular molecule and release it back into the circulatory system. If all of the carrier molecules are used up, excess glucose or amino acids are set free into the urine. A complication of diabetes is the inability of the body to reabsorb glucose. If too much glucose appears in the glomerular filtrate, it increases the osmolarity of the filtrate, causing water to be released into the urine rather than reabsorbed by the circulatory system. Frequent urination and unexplained thirst are warning signs of diabetes, due to water not being reabsorbed. Glomerular filtrate has now been separated into two forms: Reabsorbed Filtrate and Non-reabsorbed Filtrate. Non-reabsorbed filtrate is now known as tubular fluid as it passes through the collecting duct to be processed into urine.

Secretion Some substances are removed from blood through the peritubular capillary network into the distal convoluted tubule or collecting duct. These substances are Hydrogen ions, creatinine, and drugs. Urine is a collection of substances that have not been reabsorbed during glomerular filtration or tubular reabsorbtion.



Glomerular filtration

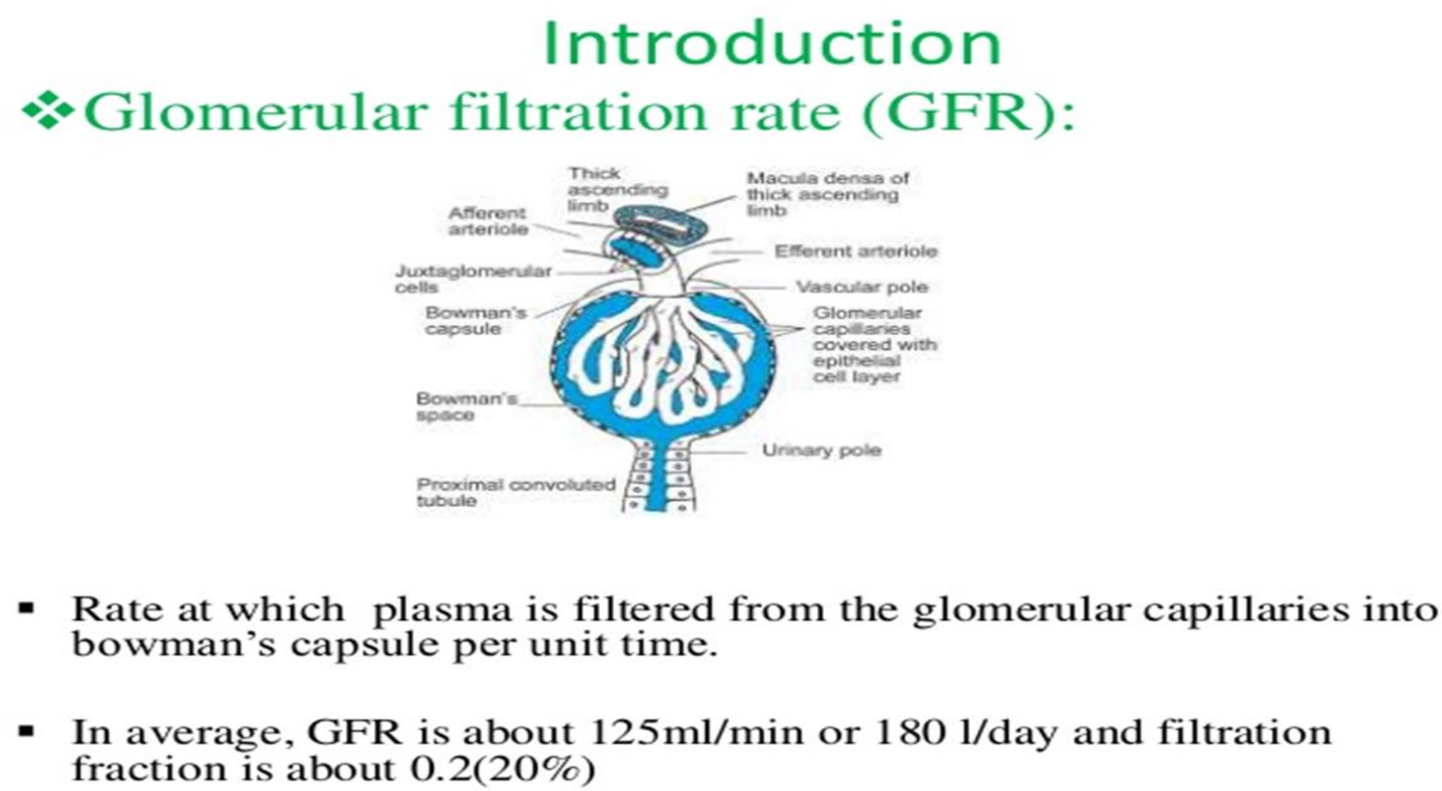
Glomerular filtration occurs when blood enters the glomerulus through the afferent arteriole. Due to glomerular blood pressure, water and small solutes (such as glucose, amino acids, nitrogenous wastes and ions) present in blood move from the glomerulus to the inside of the glomerulus capsule. This is a filtration process because large molecules (such as proteins) and formed elements (blood cells and platelets) are unable to pass through the capillary wall. The filtered fluid (called the glomerular filtrate) is essentially protein-free and devoid of cells. On an average, the daily volume of glomerular filtrate is about 180 L in adult males and 150 L in adult females. More than 99% of the glomerular filtrate returns to the bloodstream via tubular reabsorption, so only 1-1.5 L is excreted as urine. The volume of fluid filtered by the renal corpuscle is much larger than in other capillaries of the body for three reasons:

1. Glomerular capillaries present a large surface area for filtration because they are long.
2. The filtration membrane (the endothelial cells of glomerular capillaries and the podocytes, which completely encircle the capillaries, form a leaky barrier known as the filtration membrane) is thin and pores.

3. Glomerular capillary blood pressure is high. Because the efferent arteriole is smaller in diameter than the afferent arteriole.

Glomerular filtration rate (GFR)

The amount of filtrate formed in all the renal corpuscles of both kidneys per minute is called GFR. The GFR in a healthy individual is approximately 125 ml/minute (7.5 L/hr or 180 L/day). The GFR is determined by the net filtration pressure and the glomerular filtration coefficient. The net filtration pressure represents the sum of the hydrostatic and colloid osmotic pressures that either favour or oppose filtration across the glomerular capillaries. Glomerular hydrostatic pressure is the blood pressure in glomerular capillaries. It is about 55 mm Hg. It promotes filtration by forcing water and solutes present in blood plasma to pass through the filtration membrane. Capsular hydrostatic pressure is the hydrostatic pressure exerted against the filtration membrane by fluid already present in the capsular space. It opposes filtration. Its value is about 15 mm Hg. Blood colloid osmotic pressure is the pressure develops due to the pressure of proteins such as albumin, globulins and fibrinogen in blood plasma. Because plasma proteins cannot be filtered, they are in the glomerular capillaries but not in Bowman's capsule. Blood colloid osmotic pressure also opposes filtration. Its value in glomerular capillaries is about 30 mm Hg. Net filtration pressure: The force favoring filtration is the glomerular hydrostatic pressure which is about 55 mm Hg. The total of the two forces opposing filtration is about 45 mm Hg. The net difference favoring filtration (about 10 mm Hg) is called net filtration pressure.



Regulation of Glomerular filtration rate (GFR)

The mechanisms that regulate glomerular filtration rate operate in two main ways: (1) By adjusting blood flow into and out of the glomerulus. GFR increases when blood flow into the glomerular capillaries increases. (2) By altering the glomerular capillary surface area available for filtration. Coordinated control of the diameter of both afferent and efferent arterioles regulates glomerular blood flow. Constriction of the afferent arteriole decreases blood flow into the glomerulus; dilation of the afferent arteriole increases it. Three mechanisms control GFR: renal autoregulation, neural regulation, and hormonal regulation. (A) Renal autoregulation The kidneys themselves help maintain a constant renal blood flow and GFR despite normal, everyday changes in blood pressure, like those that occur during exercise. This capability is called renal autoregulation and consists of two mechanisms— the myogenic mechanism and tubuloglomerular feedback. A1. Myogenic autoregulation: Myogenic constriction of the afferent arteriole occurs due to the ability of the smooth muscle to sense and respond to an increase in arterial pressure. As blood pressure rises, GFR also rises because renal blood flow increases. However, the elevated blood pressure stretches the walls of the afferent arterioles. In response, smooth muscle fibers in the wall of the afferent arteriole contract, which narrows the arteriole's lumen. As a result, renal blood flow decreases, thus reducing GFR to its previous level. Conversely, when arterial blood pressure drops, the smooth muscle cells are stretched less and thus relax. The afferent arterioles dilate, renal blood flow increases, and GFR increases. The myogenic mechanism normalizes renal blood flow and GFR within seconds after a change in blood pressure. A2. Tubuloglomerular feedback: It is so named because part of the renal tubules—the macula densa—provides feedback to the glomerulus. When GFR is above normal due to elevated systemic blood pressure, filtered fluid flows more rapidly along the renal tubules. As a result, the proximal convoluted tubule and loop of Henle have less time to reabsorb Na+ , Cl- , and water. Macula densa cells are thought to detect the increased delivery of Na+ , Cl- , and water and to inhibit release of nitric oxide (NO) from cells in the juxtaglomerular apparatus (JGA). 5 Because NO causes vasodilation, afferent arterioles constrict when the level of NO declines. As a result, less blood flows into the glomerular capillaries, and GFR decreases. When blood pressure falls, causing GFR to be lower than normal, the opposite sequence of events occurs, although to a lesser degree. Tubuloglomerular feedback operates more slowly than the myogenic mechanism. (B) Neural regulation All the blood vessels of the kidneys, including the afferent and the efferent arterioles, are richly innervated by sympathetic nerve fibres. Activation of renal sympathetic nerves releases norepinephrine. Norepinephrine causes vasoconstriction of afferent arterioles and thus decreases the GFR. (C) Hormonal regulation Two hormones contribute to regulation of GFR. Angiotensin II reduces GFR; atrial natriuretic peptide (ANP) increases GFR. Angiotensin II is a very potent vasoconstrictor that narrows both afferent and efferent arterioles and reduces renal blood flow, thereby decreasing GFR. Cells in the atria of the heart secrete atrial natriuretic peptide (ANP). Stretching of the atria, as occurs when blood volume increases, stimulates secretion of ANP. By causing relaxation of the glomerular mesangial cells, ANP increases the capillary surface area available for filtration. Glomerular filtration rate rises as the surface area increases.

مقرر(علم الحيوان Zoo 101- Zoology I "جزء الخلية والأنسجة ") لطلاب الفرقة

الأولي بكلية العلوم شعبة العلوم البيولوجية للعام الدراسي2023/2024

الفصل الدراسى الأول

د /عبيده فوزى -المدرس بقسم علم الحيوان

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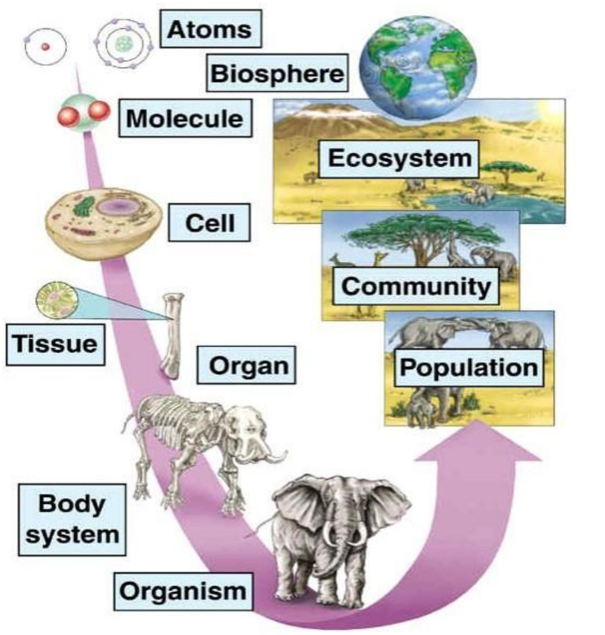
Levels of Organization in BIOLOGY…



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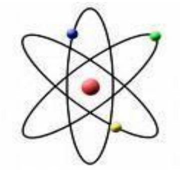
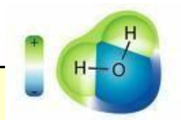
From the smallest level.



1. ATOMS

The smallest unit of matter that cannot be broken down into anything simpler by chemical means.

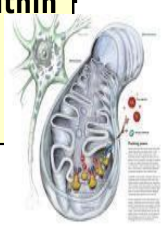
2. Molecules



The smallest units of most compounds formed by the chemical bonding of atoms.

3. Organelles

Specialized structures that perform important cellular functions within cell

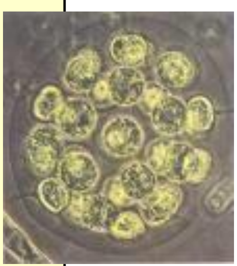


4. Cell

The smallest unit of life

collections of living matter

enclosed by a barrier that separates them from the surroundings.



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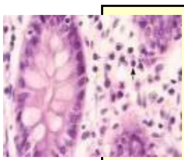
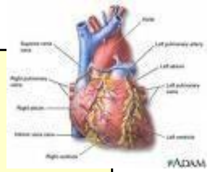


5. Tissues

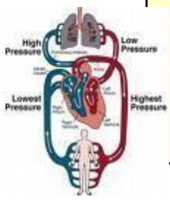
Groups of similar cellL that perform a particular function.

6. Organs



GroupL of tissues that work together to perform closely related functions.

7. Organ Systems



Groups of organs that work together to perform closely related functions.

8. Organisms

Living things composed cells (multicellular organiLmL).

Species =a group of organisms so similar to one another that they can breed and produce FERTILE OFFSPRING.

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...tO the largest leve

9.Population

Groups of individuals of the same species that live in the same area.

10. Community

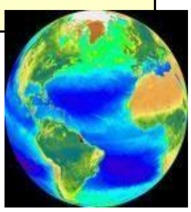
GroupsL different populations that live together in a defined area.

11.Ecosystem

Groups of all the organisms that live in a particular place, together with their nonliving environment.

12. Biome

Groups of ecosystems that have the Lame climate and similar dominant communities



13. Biosphere

Part of the Earth in which life exists including land,water,air and atmoLphere.

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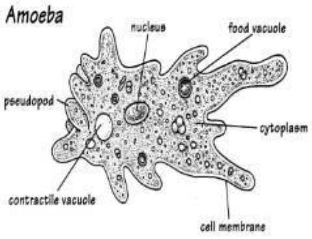
Cytology

Organisms and Cells



- Some organisms are unicellular.
  - This means they are made of only one cell.
  - Examples: bacteria, yeast

- Some organisms are multicellular.
  - This means they are made of many cells.
  - Examples: humans, trees

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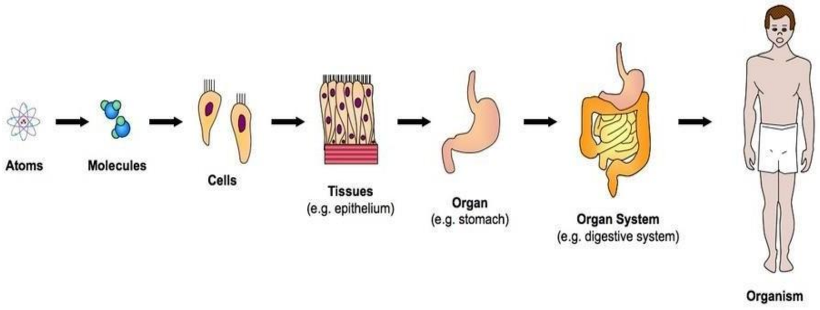
Organisms and Cells

- Unicellular organisms have nothing but a single cell.

- However, multicellular organisms have many more levels of organization to make sure the whole body can work correctly, even when it is doing many things at the same time.



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There are 5 Levels of Organization in Multicellular Organisms:

- 1. Cells
- 2. Tissues
- 3. Organs
- 4. Organ Systems
- 5. Organisms

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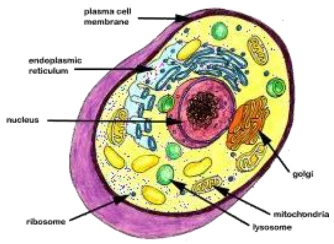
The CELL

The **cell** is the basic unit of life.

Cells are specialized by size and shape for the job they do.

Example: skin cell

The paramecium above is made of only one cell and it must perform all the jobs of the organism.



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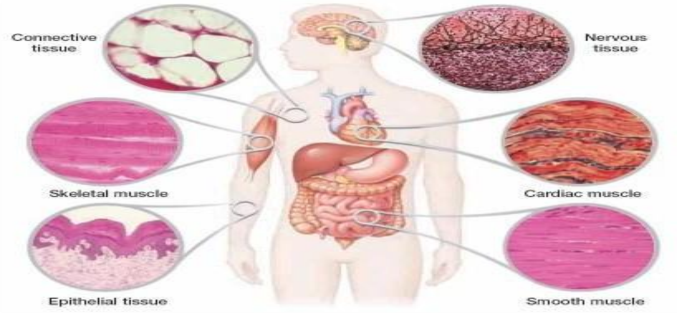
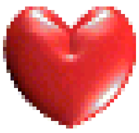
T I S S U E S

Tissues are made of the same type of cells grouped together to do a specific job.

Human Body Tissues



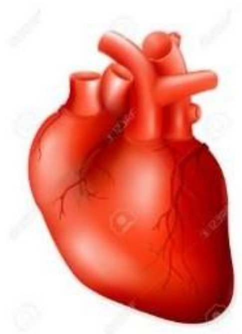
Example: Humans have four kinds of tissue in their Bodies: Epithelia, Muscle, Connective, and Nerve.



Organs

Organs are made up of different tissues that work together to do a job.

Example: a heart is an organ .



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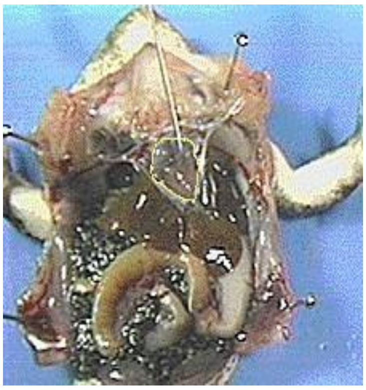
Organ Systems

An organ system is a group of organs working together.

Examples:

- Human organ systems include circulatory, reproductive, digestive, nervous, respiratory.

- Plant organ system-roots, stems, leaves= transport system.



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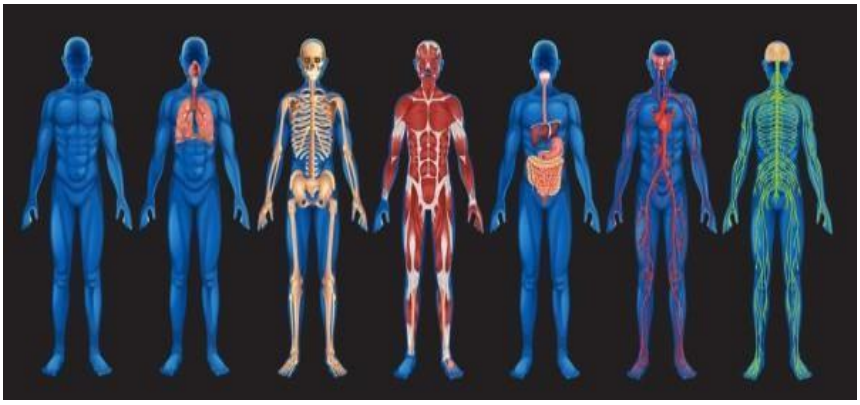
Organisms

All cells, tissues, organs and organ systems working together makes an organism.



Example: a human

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The Cell Theory

The cell theory (proposed independently in1838 and 1839) is a cornerstone of biology.

All organisms are composed of one or more cells.

Cells are the smallest living things.

Cells arise only by division of previously existing cells.

All organisms living today aredescendents of an ancestral cell.

Schleiden

Schwann

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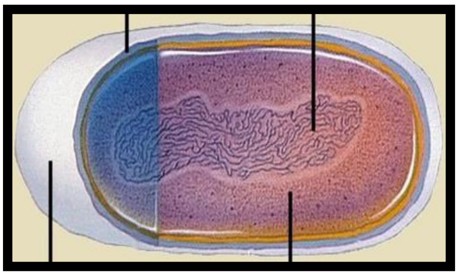
Two Fundamentally Different Types of Cells



A prokaryotic cell

A eukaryotic cell

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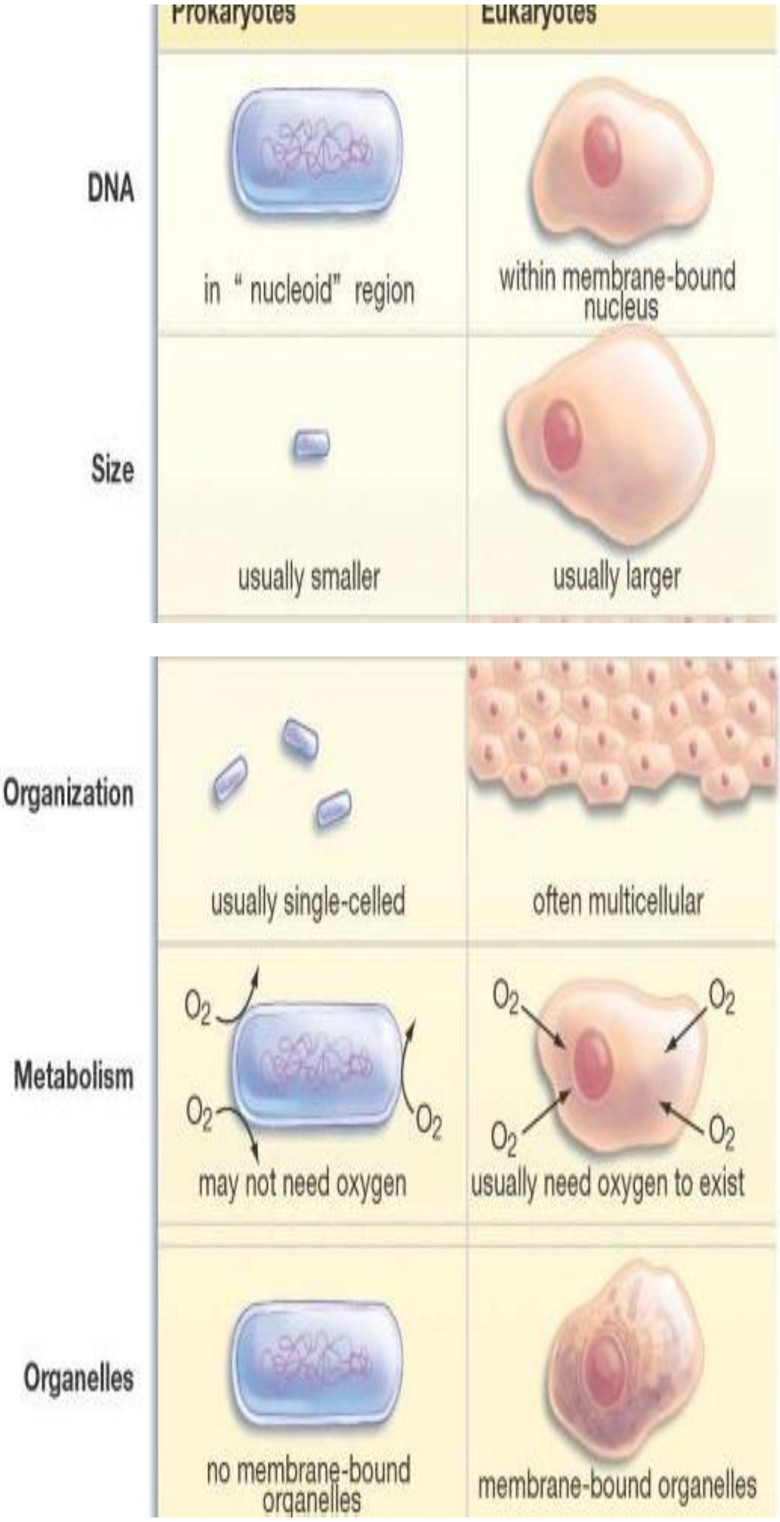
Us *vs.* Them -Eukaryotes and Prokaryotes



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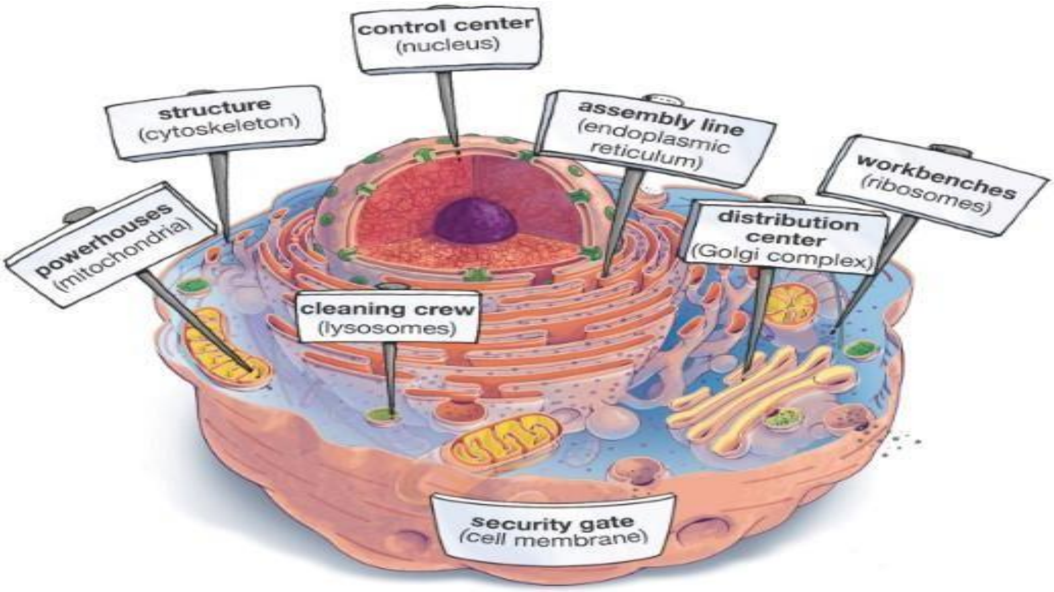
An Idealized Animal Cell



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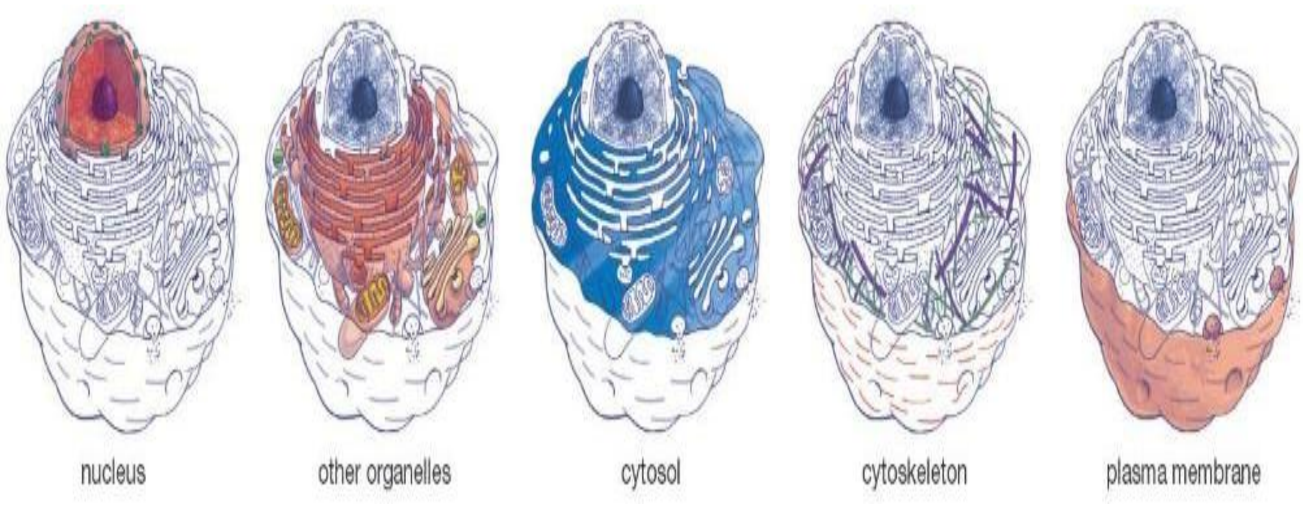
Major Divisions of the Eukaryotic Cell



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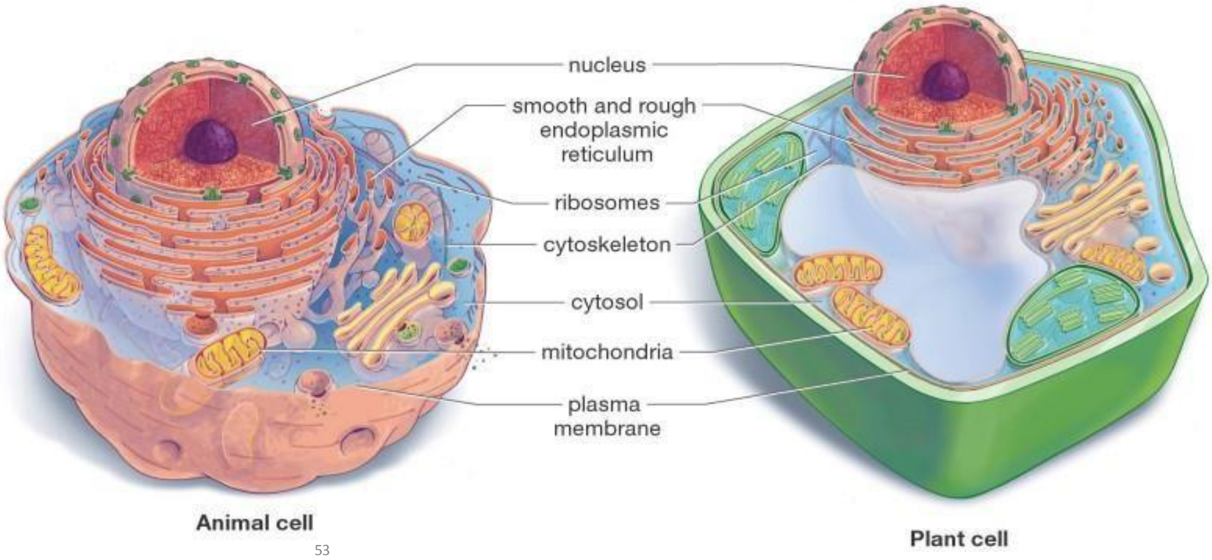
Animal and Plant Cells Have More Similarities Than Differences



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• Give the function (job) of each organelle below

a. Nucleus
b. Cell membrane
c. Mitochondrion
d. Endoplasmic reticulum
e. Golgi body
f. Vacuole
g. Lysosome
h. Cytoskeleton

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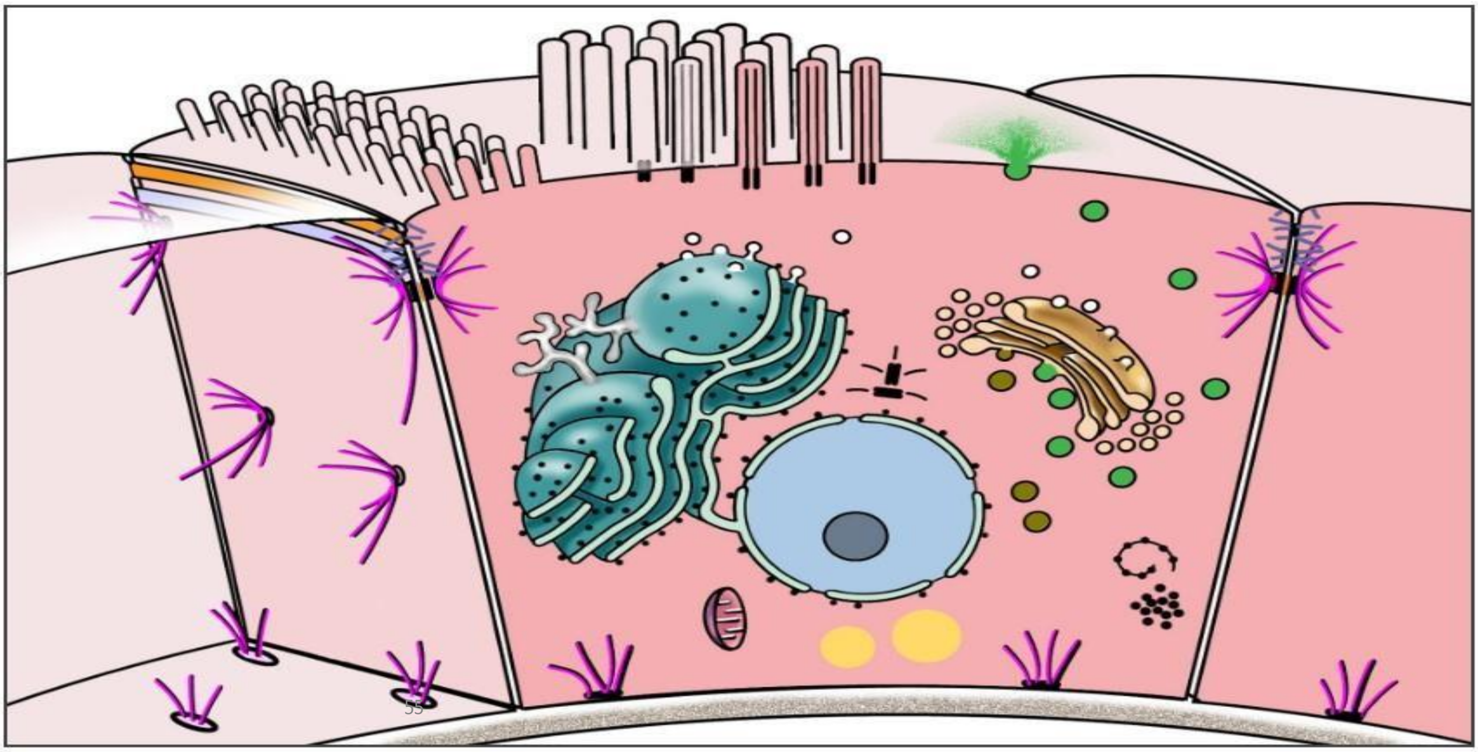
- **Overview of cell structures**

- The cell consists of two major compartments, cytoplasm and nucleus. Located throughout the cytoplasm are membranous organelles, e.g., endoplasmic reticulum, lysosomes and mitochondria, as well as non -membranous organelles, e.g., polysomes and centrioles. The nucleus is surrounded by two membranes which are continuous with the endoplasmic reticulum.



- **Cells are the structural units of all living organisms .**
- Although there are approximately 200 different cell types in the body, cells are more alike than different. Specialization of function, (e.g., glandular cells for secretion or muscle cells for contraction) is really an emphasis of a function that all cells possess to some degree. In some cases, cells have become so specialized that some functions are lost altogether (e.g., cell proliferation).
- Cells vary in size and shape according to location and function .
- Cells widely vary in diameter, from the largest, the mature human ovum (120 microns) to the smallest, the red blood cell (7-8 microns).
- Cells vary in internal structure depending upon their function . Specialized cells possess abundant internal structures related to their specific function, e.g., contractile filaments in muscle cells or secretory granules in gland cells.
- Cells vary in their life history, for example, rates of cell renewal.

Functions of cells

As you already know that a cell is a structural and functional unit of living. Let us study 6 of the most vital functions performed by a cell.

1- Structure and Support

You know a house is made of bricks. Similarly, an organism is made up of cells. Though there are certain cells such as collenchyma and sclerenchyma are present for offering structural support however in general too, all cells generally provide the structural basis of all organisms.

2- Growth

In complex organisms such as humans, the tissues grow by simple multiplication of cells. Hence, cells are responsible for the growth of the organism. The entire thing takes place via a process of mitosis.

3- Transport

Cells import the nutrients that are used in the different chemical process which take place inside them. As a result of these processes, a waste product is produced. Cells then work to get rid of this waste. In this manner, the small molecules like such as oxygen, carbon dioxide, and ethanol pass through the cell membrane by diffusion. This method is known as passive transport. On the other hand, the larger molecules like the proteins and polysaccharides, go in and out of the cell via active transport.

4- Energy Production

Organisms need energy to perform different chemical reactions. In plants, the energy comes from the process of photosynthesis while in the animals the energy comes via respiration.

5- Metabolism

Cell is responsible for metabolism that includes all the chemical reactions that take place inside an organism to keep it alive.

6- **Reproduction**

A cell helps in reproduction by the processes of mitosis (in more evolved organisms) and meiosis.

- **Chemical Composition of the Cell**

Chemical compounds in the cell can be divided into two major groups : Organic and Inorganic compounds

Organic compounds are chemical compounds that contain the element carbon. Organic compounds in the cell include carbohydrates, protein, lipids and nucleic acids. Some of these compounds are synthesized by the cell itself.

Water is an inorganic compound which is composed of hydrogen and oxygen . It is an important compound in the cell.

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Table : inorganic chemical compounds in the cell.

Percentage of Body Weight	Element	Usage
65%	Oxygen	This element is obviously the most important element in the human body. Oxygen atoms are present in water, which is the compound most common in the body, and other compounds that make up tissues. It is also found in the blood and lungs due to respiration.
18.6%	Carbon 60	Carbon is found in every organic molecule in the body, as well as the waste product of respiration (carbon dioxide). It is typically ingested in food that is eaten.

9.7%	Hydrogen	Hydrogen is found in all water molecules in the body as well as many other compounds making up the various tissues.
3.2%	Nitrogen	Nitrogen is very common in proteins and organic compounds. It is also present in the lungs due to its abundance in the atmosphere.
1.8%	Calcium	Calcium is a primary component of the skeletal system, including the teeth. It is also found in the nervous system, muscles, and the blood.
1.0%	Phosphorus	This element is common in the bones and teeth, as well as nucleic acids.
0.4%	Potassium	Potassium is found in the muscles, nerves, and certain tissues.
0.2%	Sodium	Sodium is excreted in sweat, but is also found in muscles and nerves.
0.2%	Chlorine	Chlorine is present in the skin and facilitates water absorption by the cells.
0.06%	Magnesium	Magnesium serves as a cofactor for various enzymes in the body.
0.04%	Sulfur	Sulfur is present in many amino acids and proteins.
0.007%	Iron	Iron is found mostly in the blood since it facilitates the transportation of oxygen.
0.0002%	Iodine	Iodine is found in certain hormones in the thyroid gland.

- **The Importance of Organic Compounds in the Cell**
- **Carbohydrates**
  - Supply energy for cell processes
- A means of storing energy
- Give structural support to cell walls
- **Lipids**
- Store large amounts of energy over long periods of time
- Act as an energy source
- Play a major role in the structureof the cell membranes
- Act as a source of metabolic water
- Reduce the loss of water by evaporation

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- **Proteins**
  - Act as building blocks of many structural components of the cell ; required for growth
- Form enzymes which catalyze chemical reactions
- Form hormones which control growth and metabolism
- **Nucleic acids**
- Contain the genetic information of cells
- Play a vital role in protein synthesis

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- **The importanceof waterin the cell**
- Water is important for life because its chemical and physical propertiesallow it to sustain life.
- Water is a polar molecule which consistsof 2 hydrogen atoms and 1 oxygen atom. A polar molecule is a molecule with an unequal distributionof charges. Each molecule has a positively charged and a negatively charged end. Polar moleculesattract one another as well as ions. Because of this property,water is consideredthe solvent of life.
- It is the transport medium in the blood.
- It acts as a medium for biochemicalreactions.
- Water helps in the maintenance of a stable internal environment within a living organism. The concentration of water and inorganic salts that dissolve in water is important in maintaining the osmoticbalance between the blood and interstitialfluid.
- It helps in lubrication.
- Water moleculeshave very high cohesion. Water moleculestend to stick to each other and move in long unbroken columns through the vascular tissuesin plants.

Quick review

Definition of a cell	Smallest functional unit within a living organism that can function independently
Components	Plasma membrane, cytoplasm, nucleus, membranous organelles, non-membranous organelles
Membranous organelles	Nucleus, Endoplasmic reticulum,Golgi apparatus, mitochondria, peroxisomes, lysosomes, transport vesicles
Non-membranous organelles	Ribosomes, microtubules, cytoskeleton (actin filaments, intermediate filaments, centrioles)

- ✓ The cell is the structural and functional unit of all tissues. It consists of a mass of protoplasm divided into nucleus and cytoplasm. The cytoplasm is the part of protoplasm located around the nucleus designed to perform synthetic and metabolic activities.
- ✓ The cytolplasmic matrix (cytosol) is the non-organelle component of the cytoplasm occupying the intracellular spaces between organelles and inclusions. It contains any soluble proteins, lipids, carbohydrates and small ions.
- ✓ Cytoplasmic Organelles

They are permanent, living cytoplasmic structures that perform specific functions. Two types of cytoplasmic organelles are recognized: membranous and non-membranous organelles.

► Membranous organelles

The membranous organelles are cytoplasmic organelles that possess a bounding membrane of their own and they include cell membrane, mitochondria, endoplasmic reticulum, Golgi apparatus, lysosomes, and peroxisomes.

1- Cell membrane

The cell membrane (plasmalemma or plasmamembrane) is the outer membrane of the cell that acts as a barrier between its internal and external environment.

With light microscope (LM) it is too thin (8-10 nm) to be seen. The cell boundary that is often seen is mainly due to condensation of cytoplasm on the inner aspect of the cell membrane, condensation of the stain (such as silver or PAS) on the carbohydrate-rich coat and obliquity of the sections.

With electron microscope (EM) it appears as a trilaminar structure consisting of outer and inner electron-dense layers separated by an intermediate electron-lucent layer.

The molecular structure of the cell membrane

The most recent and currently acceptable model for the cell membrane is the

Fluid mosaic model

According to this model, the cell membrane is made up of three major components phospholipids, proteins, and carbohydrates.

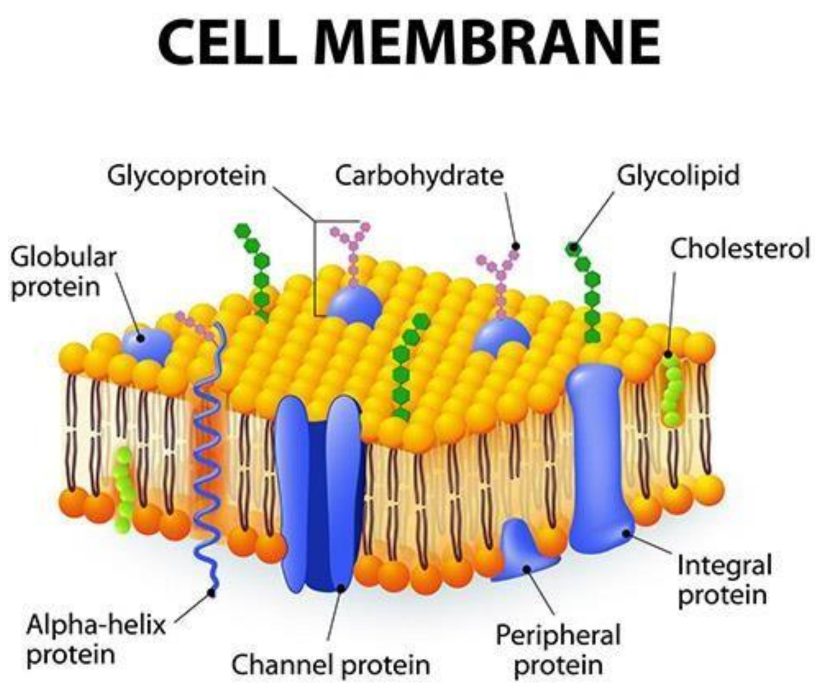
The phospholipids molecules form a central bimolecular layer. Each molecule is formed of two ends; polar or hydrophilic (has affinity with water) end, and non-polar or hydrophobic (has no affinity with water) tail. The phospholipids molecules are arranged with their hydrophilic ends are directed outward, while hydrophobic tails are directed inward toward the center of the membrane.

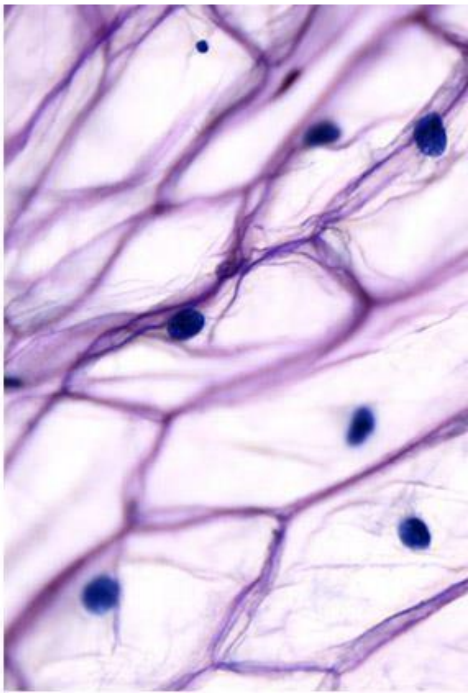
The protein is the second major constituent of the cell membrane. The protein molecules are arranged as globules moving freely within the lipid layer. Two types of protein globules are recognized: intrinsic or integral protein and extrinsic or peripheral proteins.

The intrinsic proteins are firmly attached to the lipid bilayer. Some of them extend throughout the entire thickness of the membrane and constitute transmembrane channels for the passage of water-soluble ions and molecules

The extrinsic or peripheral proteins are only partially embedded to either aspect of the membrane.

The carbohydrate fractions are conjugated with the protein (glycoprotein) and lipid (glycolipid) molecules of the cell membrane. These glycoproteins and glycolipids project from the outer surface of the cell membrane as cell coat or glycocalyx.





Functions of the cell membrane

The cell membrane is the part of the cell that regulate the exchange of molecules and ions between its internal and external environment. This occurs by several ways:

1. Passive Diffusion*:* this involves the entrance of small molecules into the cytoplasm. It depends on the presence of a concentration gradient across the plasmalemma (e.g., diffusion of lipid soluble substances, oxygen, CO2, water and small ions).
2. Facilitated Diffusion*:* this type of diffusion is also concentration-dependent and involves the transport of large water-soluble molecules such as glucose and amino acids. It requires the presence of carriers to which the molecules have to bind in order to pass through the plasmalemma.
3. Active Transport*:* this process requires the utilization of energy provided as ATP. (e.g., sodium-potassium pump).
4. Selective transport*:* it depends on the presence of specific cell surface receptors to pick up specific molecules into the cytoplasm (e.g., hormones).

5. Endocytosis and Exocytosis

Endocytosis involves either the engulfment of solid particles (phagocytosis) or minute droplet of fluid (pinocytosis). The engulfed material is surrounded first by cytoplasmic extensions called pseudopodia. When the particles become surrounded, the plasma membrane fuses and the membrane surrounding the engulfed particles forms a vesicle, known as a phagosome or endocytotic vesicle, which detaches from the cell membrane to float freely within the cytoplasm.

Once the phagosome enters the cytoplasm it fuses with the lysosomes and their contents are subjected to enzymatic digestion.

6. Exocytosis

Exocytosis (Exo = out) is the process by which some membranous vesicles located within the cytoplasm fuse with the plasma membrane and release their contents outside the cell. It occurs in many secretory processes.

Functions of the cell coat (Glycocalyx)

- Mechanical and chemical protection the cell membrane.
- Aids in the induction of immunological (antigen-antibody) response.
- Site for binding of hormones.
- Shares in the formation of intercellular adhesions.
- Contributes to the formation of the basement membrane.
- Cell recognition.

Other functions of the cell membrane include

- Transmission of nerve impulses in muscle and nerve cells.
- Myelin sheath formation (Schwan cell around peripheral nerves).
- Share in the formation of microvilli, cilia, flagella and cell junctions.

2- Mitochondria

Mitochondria are membranous organelles involved primarily in cell respiration and energy production.

With LM, they appear as granules, rod-like or thread-like. Their size rage from 5-10 mm length and 0.5-1 mm in diameter. The number is highly variable according to the energy requirements of the cells. Liver cells (active cells) contain as many as 1000 mitochondria. Small lymphocytes (inactive cells) contain very few.

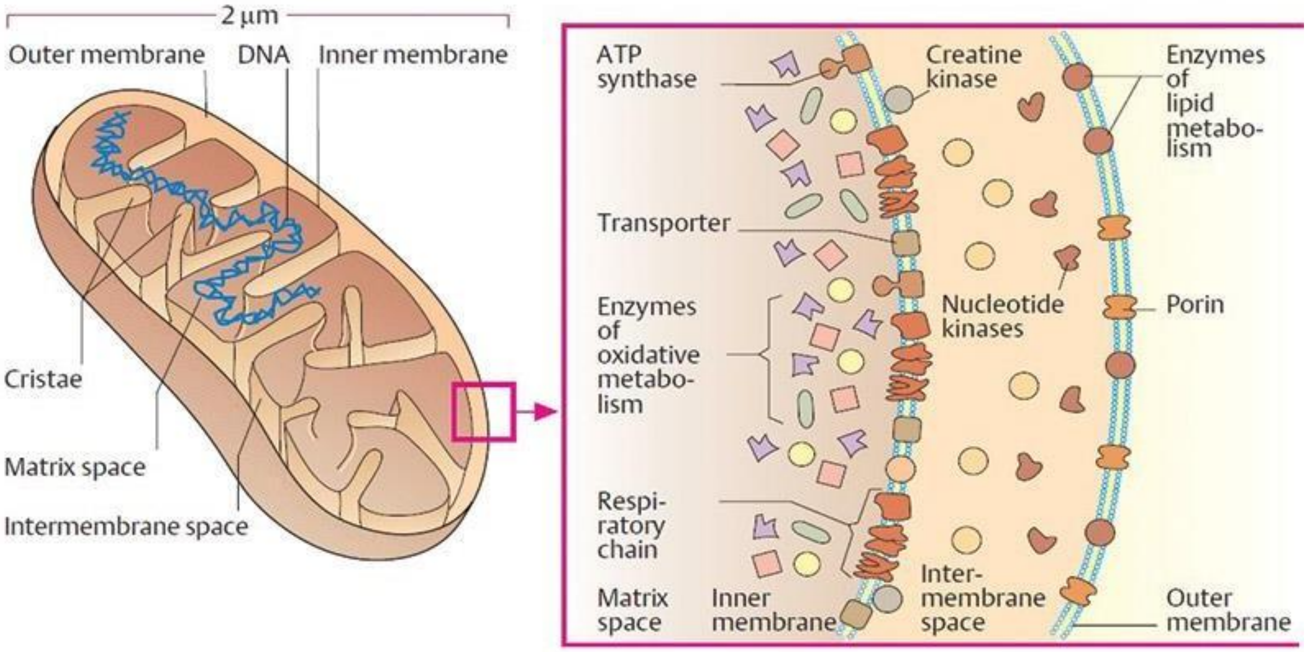
They are motile organelles and localize at intracellular sites of high-energy requirements such as basal regions of ion-transporting cells.

They could be selectively stained with iron hematoxylin, Janus green B in supravital staining of living cells.

With EM, they appear as ovoid or elongated structures bounded by two membranes. The outer membrane is smooth. The inner membrane is thrown into folds called cristae projecting into the inner cavity that is filled with an amorphous substance called matrix. The number of the cristae seen in mitochondria is directly related to the energy requirement of cell.

The inner membrane is covered with tiny spherical projections about 9 mm in diameter supported at narrow stalks. These are called inner membrane spheres or elementary particles and are believed to represent an enzyme known as F1, which couple electron transport to the phosphorylation of ADP.

The mitochondrial matrix is also containing many electron-dense granules called matrix granules that are the sites for Ca^{++} ions storage. The mitochondrial matrix contains DNA and RNA that explain the mitochondrial ability to grow, divide and synthesis some of their proteins.



Functions

- They house the chains of enzymes that catalyze reactions that provide the cells with most of its ATP (adenosine triphosphate).
- On demands, the ATP yields its high-energy phosphate bond to another molecule and become transformed into ADP.
- Within the mitochondrial matrix, ADP is transformed again into ATP. These processes take place within the mitochondrial matrix and inner mitochondrial membranes.
- The matrix contains enzymes of Krebs cycle and fatty acid oxidation. The inner membrane contains the cytochromes and the enzymes involved in ATP production.
- Due to their role in energy production, the mitochondria are likened to powerhouses of the cells.
- Participate in regulation of calcium level within the cytosol.

3- Endoplasmic reticulum (ER)

The Endoplasmic reticulum (Endo=inside; plasm=cytoplasm; reticulum = network*)* is an irregular network of branching and anastomosing tubules, cisternae and vesicles. Two types of ER are recognized, rough and smooth.

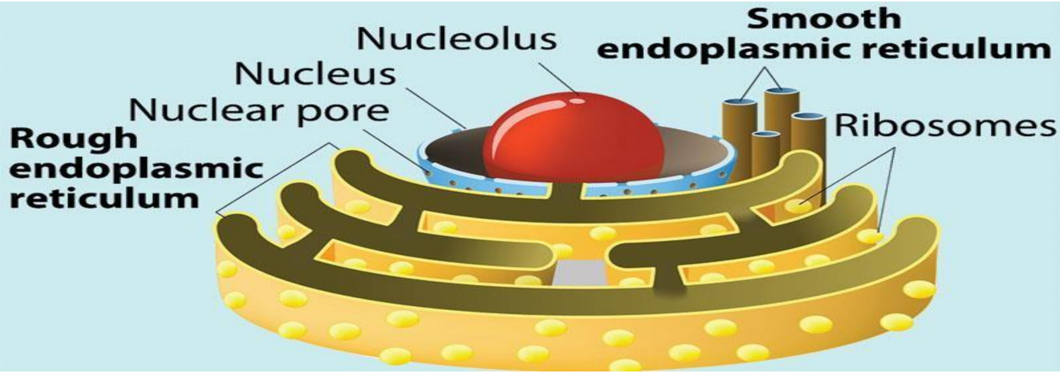
Rough endoplasmic reticulum (rER)

The rough endoplasmic reticulum is a membranous organelle concerned principally with synthesis and secretion of proteins. It is called rough due to the presence of large number of ribosomes attached to its limiting membrane. With LM, it appears as basophilic cytoplasmic areas that are referred to as the ergastoplasm or chromidial substances. The cytoplasmic basophilia may be diffuse (plasma cells), localized (pancreatic acinar cells) or arranged into clumps (Nissl granules in nerve cells) . Aggregates of rER appear basophilic mainly due to the presence of ribosomes on their outer surface .

With EM, it consists of an anastomosing network of tubules, vesicles and flattened cisternae that ramifies throughout the cytoplasm. Much of the surface of the rER is studded with ribosomes giving the reticulum a rough or granular appearance.

Functions:

- Synthesis of proteins for extracellular use (secretory proteins, lysosomal proteins and membrane proteins).
- Glycosylation of proteins to form glycoproteins.



Smooth endoplasmic reticulum (sER)

The smooth endoplasmic reticulum is a membranous organelle consists primarily of a network of branching and anastomosing tubules and vesicles.

It differs from the rER in that its limiting membrane is smooth and devoid of ribosomes. With LM, it does not appear. The cytoplasm of the cells contained abundant sER usually appears acidophilic.

With EM, it appears as irregular network of membranous tubules and vesicles devoid of ribosomes in contrast to the flattened ribosome-studded cisternae of rER. The sER tubules may be continuous with those of rER and Golgi apparatus .

Functions

- Steroid hormone synthesis in the testicular interstitial cells, the cells of the corpus luteum and adrenal cortex cells.
- Drug detoxification in liver cells.
- Lipid synthesis in the intestinal absorptive cells.
- Release and storage of Ca^{++} ions in striated muscle cells.
- Production of HCL in gastric parietal cells.

4- Golgi Apparatus (Golgi complex)

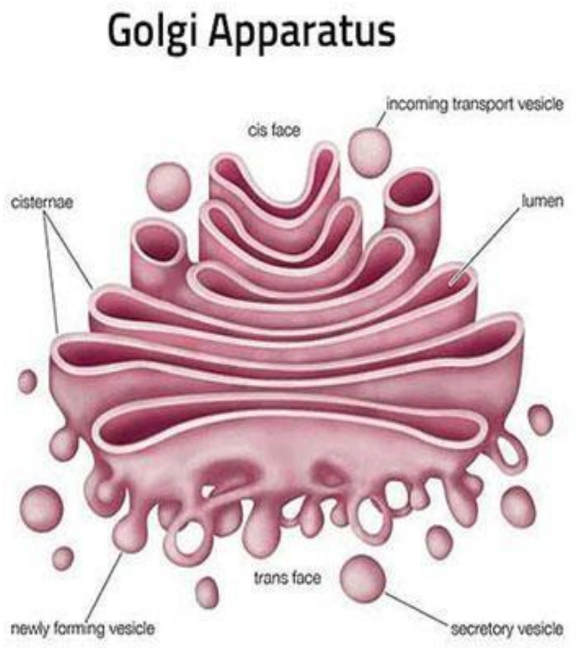
The Golgi apparatus is a membranous organelle concerned principally with synthesis, concentration, packaging and release of the secretory products.

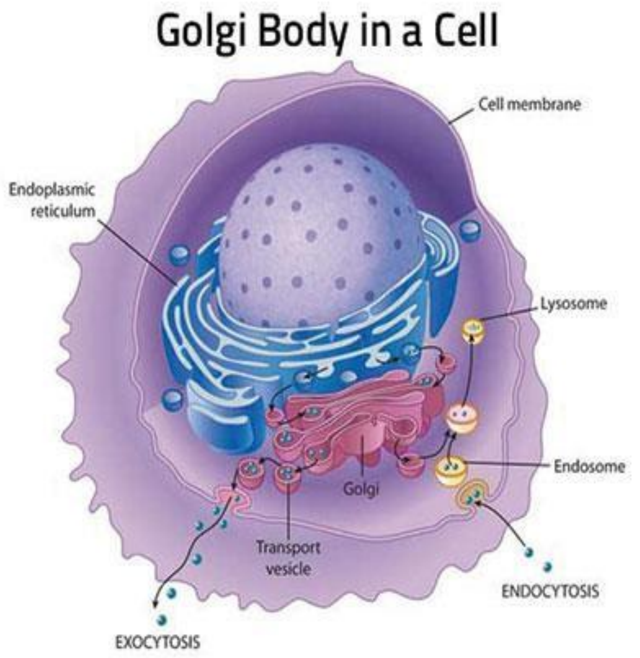
With LM, it can be selectively stained with silver salts or osmium where it appears as a black network located near the nucleus. In H&E sections, it may be visible as a lighter-stained region called negative Golgi image. It is seen to great advantage in secretory cells such as osteoblasts.

With EM, the main structure unit of the Golgi apparatus is a flattened membranous vesicle called Golgi saccule.

The Golgi saccules are arranged in Golgi stacks that contain from 3-10 saccules. Most cell types possess several stacks of Golgi saccules forming an elaborate ramifying network termed the Golgi complex.

Each stack of saccules has 1) a forming face or Cis face that is convex in shape. 2) a maturing face or trance face that is concave. The Cis face is usually associated with a number of small transfer vesicles. The trance face characterized by being associated with much larger secretory granules.





Functions

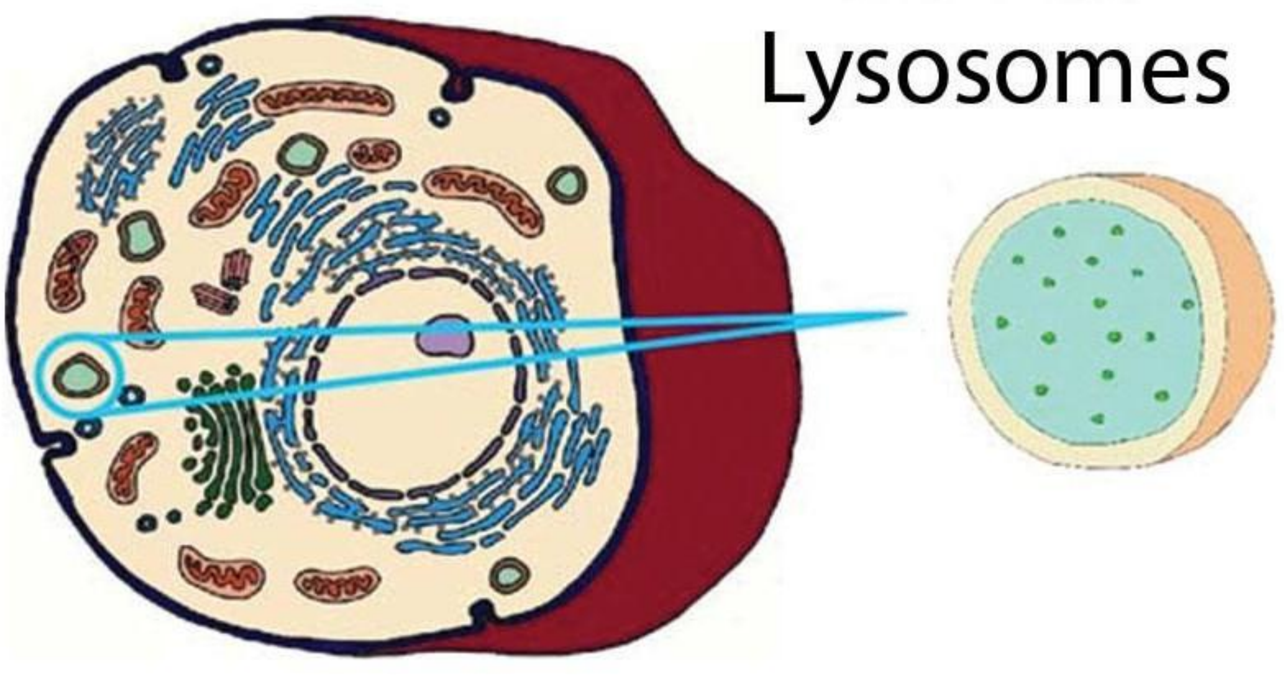
- Packaging and concentration of secretions.
- Modification of the secretory products such as glycosylation and sulfation of proteins to for glycoproteins and sulfated glycoproteins (mucus).
- Production of primary lysosomes.

5- Lysosomes

They are membrane-bounded vesicles (0.2-0.4μm) containing a number (more than 40) of hydrolytic enzymes that are active at acid pH (acid hydrolases) maintained within their interior. This group of enzymes can destroy all the major macromolecules (e.g., proteins and lipids) of the cells.

LM provides no direct evidence for the existence of lysosomes. The lysosomes are resolved at the LM level when their enzyme contents (e.g., acid phosphatase) are stained by histochemical methods.

With EM, the lysosomes appear as spherical membrane-bounded vacuoles with there contents showing varying degree of electron density.



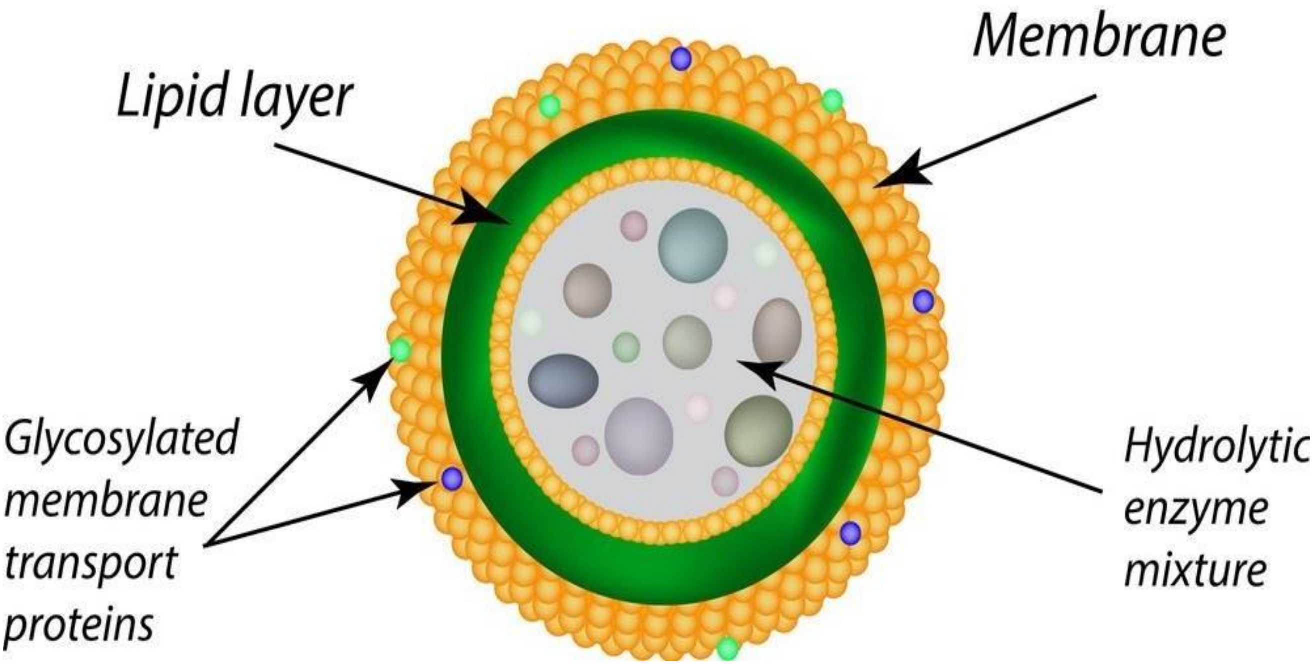
Types of lysosomes

Primary lysosomes are lysosomes freshly formed from the Golgi or sER. They contain nothing but hydrolytic enzymes.

Secondary lysosomes formed as the result of fusion of primary lysosomes with phagosomes. A phagosome is a membrane-bounded vesicle containing either exogenous material (e.g., bacteria) and it is called heterophagosome or endogenous material (e.g., damaged organelle) and it is called autophagosome.

Multivesicular bodies are spherical forms of heterophagosomes. They are membrane-bounded vesicles containing a number of smaller vesicles.

Residual bodies are debris containing vacuoles representing the terminal stage of lysosomal activities. Their contents may either be extruded from the cell by exocytosis or accumulate in the cytoplasm as lipofuscin pigments.



Functions

- Degradation of any exogenous macromolecules (phagocytosis and pinocytosis).
- Disposition of any organelles or cell constituents that are no longer useful to the cell (autophagy).

6- Peroxisomes

Peroxisomes are spherical, membrane-bounded organelles containing peroxide forming enzymes and catalase that are involved in the formation and degradation of intracellular hydrogen peroxide.

With LM, it does not appear. With EM, they are membrane-bounded vacuoles, vary in size and appearance depending on species and cell types. They are relatively large in hepatocytes and kidney cells and small in intestinal cells (microperoxisomes).

In human cell, they contain finely granular matrix of moderate density. In many other species, they have crystalline core called a nucleoid.

Such nucleoid is absent from liver peroxisomes from reptiles, birds, and human being which are species that lack urate oxidase, an enzyme that degrades urates.

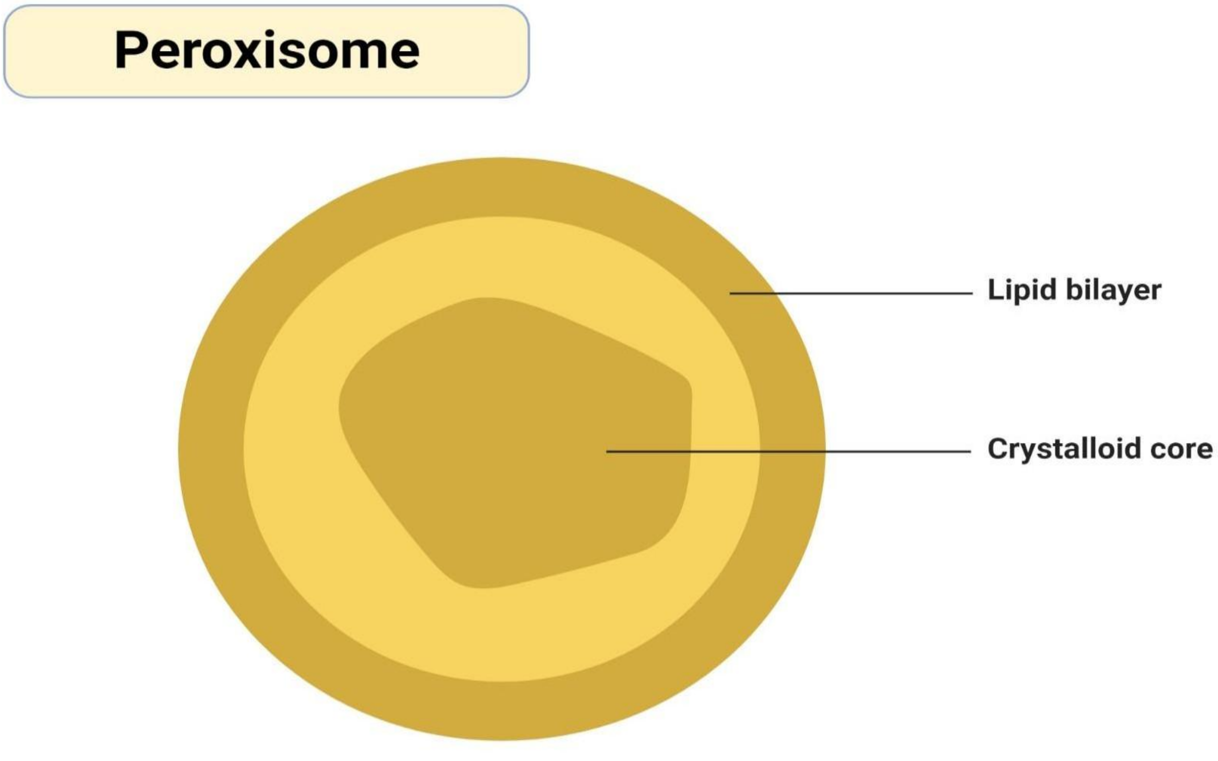


Figure: Peroxisome, Image Copyright © Sagar Aryal, www.microbenotes.com

Functions

- Peroxisomes contain at least three oxidase (D-amino acid oxidase, urate oxidase and catalase).
- The D-amino acid oxidase, urate oxidases are responsible for the production of hydrogen peroxide (H2O2).
- The catalase then utilizes the H2O2 in oxidation (and therefor, detoxification) of various toxic substances such as phenol, alcohol and fatty acids.

1. Non-membranous organelles

They are cytoplasmic organelles that possess no bounding membrane of their own. They include ribosomes, and centrioles.

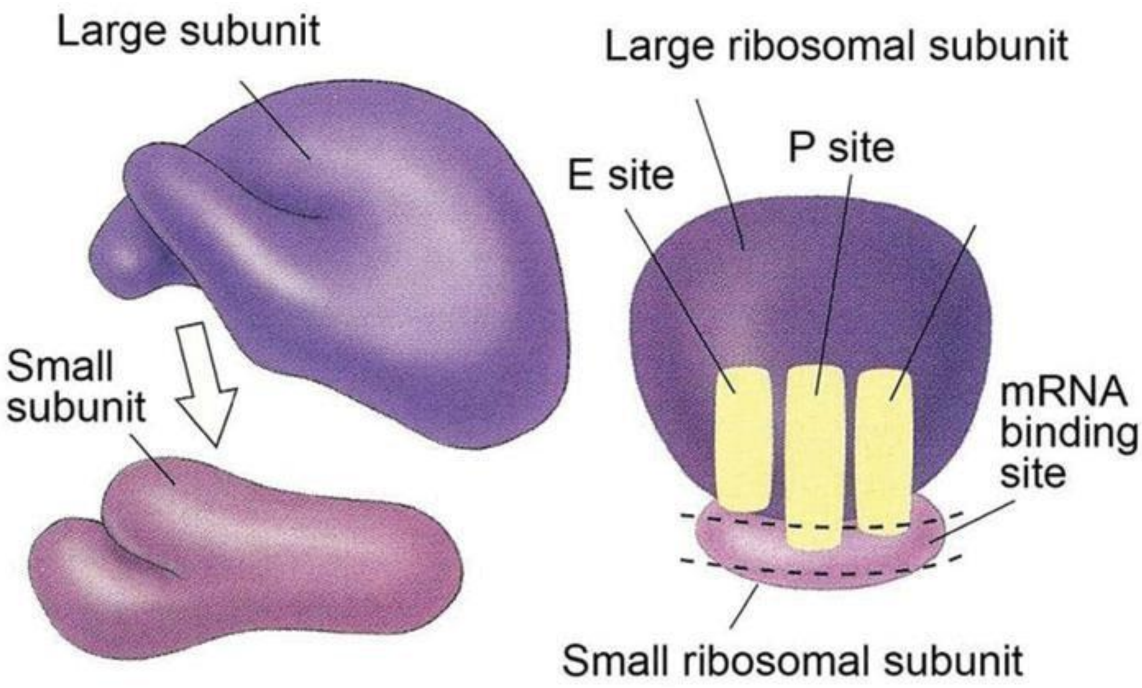
7- Ribosomes

They are rounded ribonucleoprotein particles, 20-30 nm in diameter that provide the intracellular sites where amino acids are linked together to form polypeptide chains (proteins).

With LM they are too small to be seen. However, cell containing abundant ribosomes usually has basophilic cytoplasm. Such cytoplasmic basophilia is largely due to the strong affinity of rRNA for hematoxylin.

With EM, the ribosomes are seen free in the cytoplasm either as separate entities or attached to messenger RNA molecules in small aggregation called polyribosomes or polysomes. Polyribosomes may also be attached to the surface of rER.

Each ribosome composed of a large and a small subunit that are made of rRNA and different types of proteins.



Functions

Free ribosomes are responsible for synthesis of proteins for internal use (cytoplasmic proteins and enzymes).

Attached ribosomes are responsible for synthesis of proteins for external use (secretory or lysosomal enzymes).

8- Centrosome and Centrioles

The centrosome is a specialized zone of cytoplasm contains a pair of centrioles together known as a diplosome, spherical bodies, procentrioles organizer and centriolar satellites that function as microtubular organization center.

With LM, the centrioles are selectively stained with iron hematoxylin where they appear as two tiny dots located close to the nucleus. In some epithelial cells, centrioles are located in the apical cytoplasm immediately beneath the ciliated surface. Such apical centrioles are called basal bodies and from which cilia originate.

With EM, each centriole is a hollow cylinder, closed at one end. The two centrioles of each diplosome are arranged with their long axes at right angles to each

other. The wall of each centriole is made up of nine triplet of parallel microtubules connected to each other by a fine filaments, the protein link.

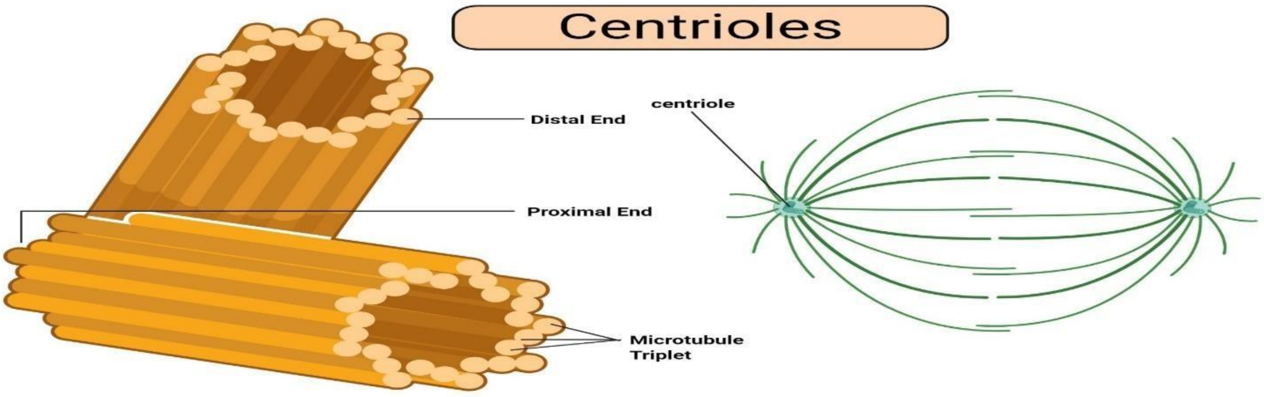


Figure: Centrioles, Image Copyright © Sagar Aryal, www.microbenotes.com

Functions

Formation of mitotic spindle during cell division.

Microtubular organization center

Ciliogenesis by the formation of procentrioles from the procentrioles organizer.

9- Cytoskeleton

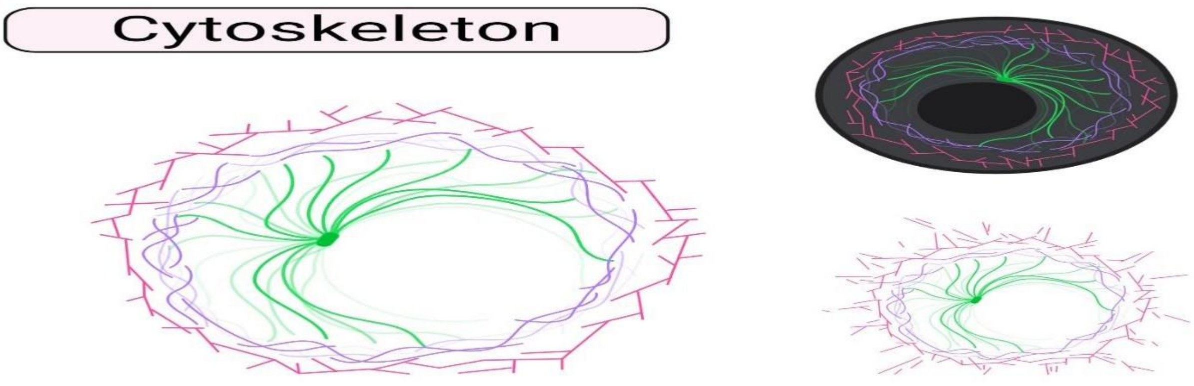
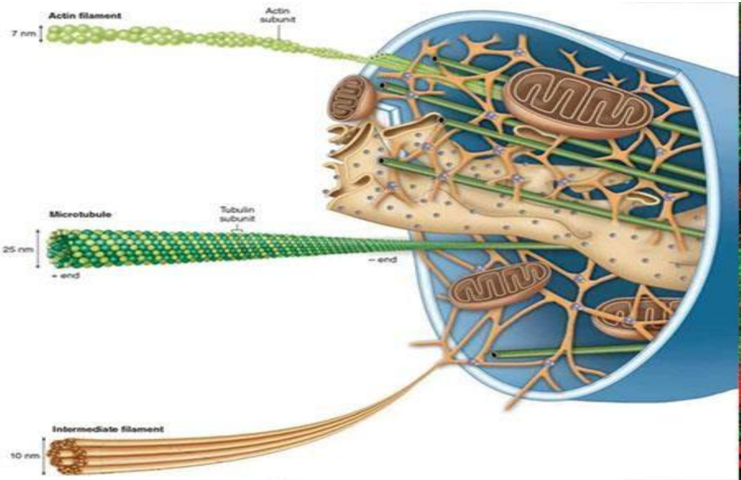
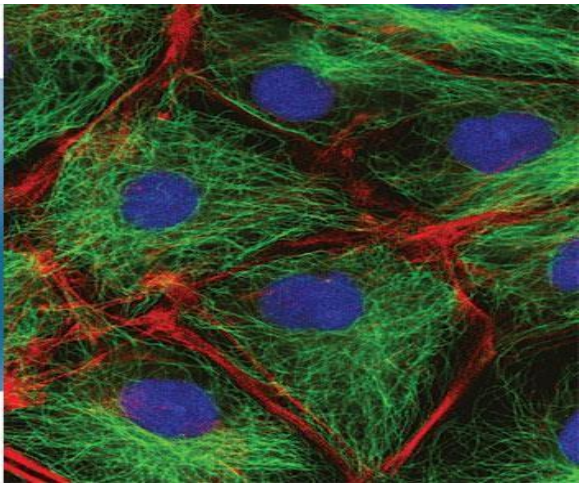


Figure: Cytoskeleton, Image Copyright © Sagar Aryal, www.microbenotes.com

The cytoskeleton is a complex network of minute filaments and tubules located within every cell, that maintain cell shape and stability and are responsible for some cell functions. It includes cytofilaments and microtubules.





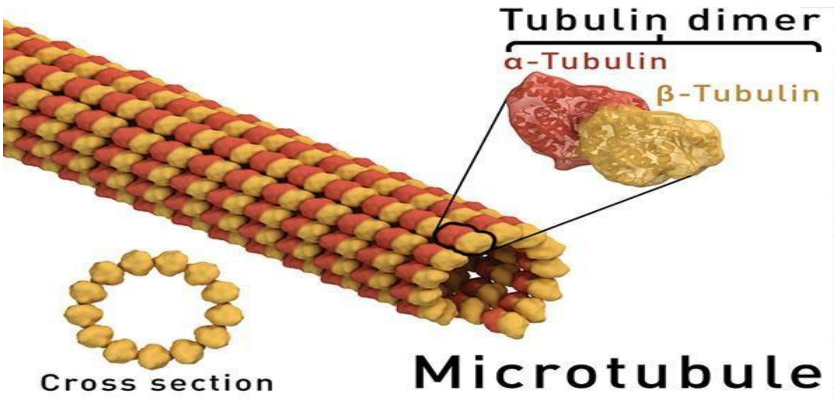
Cytofilaments: are minute thread-like structures of three types:

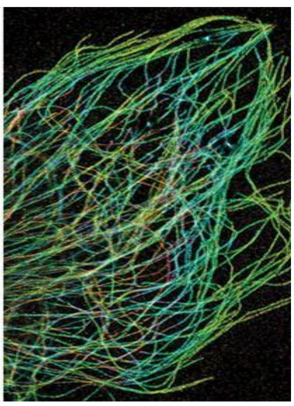
The Actin (thin filaments) is found in muscle cell, in the core of each microvillus, in motile cells such as macrophages and in developing nerve cells. Their diameter is about 5 nm.

The Myosin (thick filaments) occurs mainly in muscle cells in association with actin filaments. They have a diameter of 15 nm.

The Intermediate filaments are 10 nm in diameter and include neurofilaments in neurons, glial filaments in astrocytes and tonofilaments in epithelial cells.

Microtubules





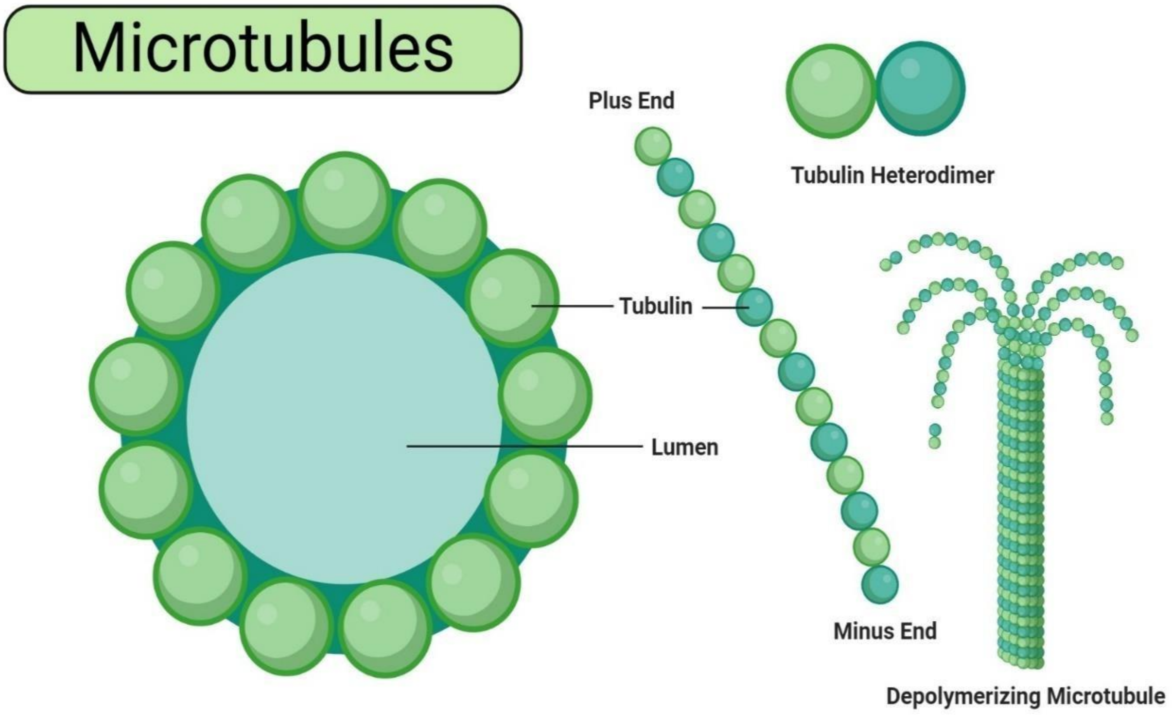


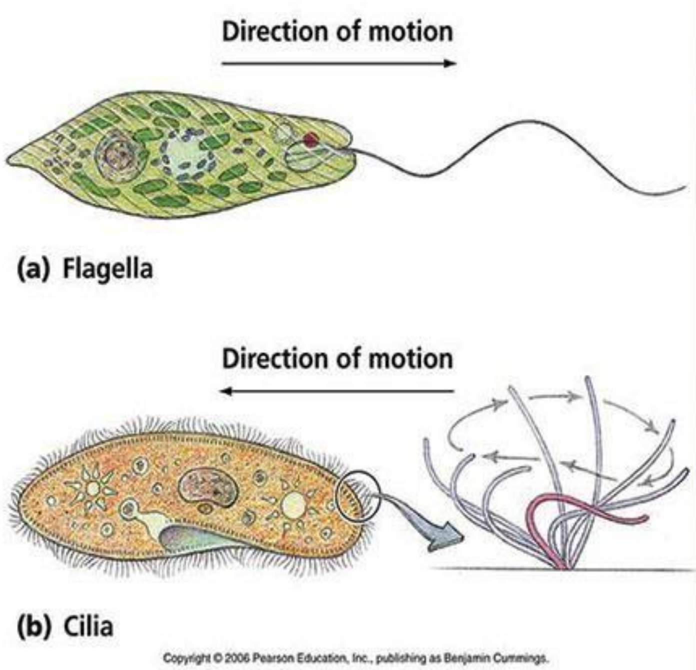
Figure: Microtubules, Image Copyright © Sagar Aryal, www.microbenotes.com

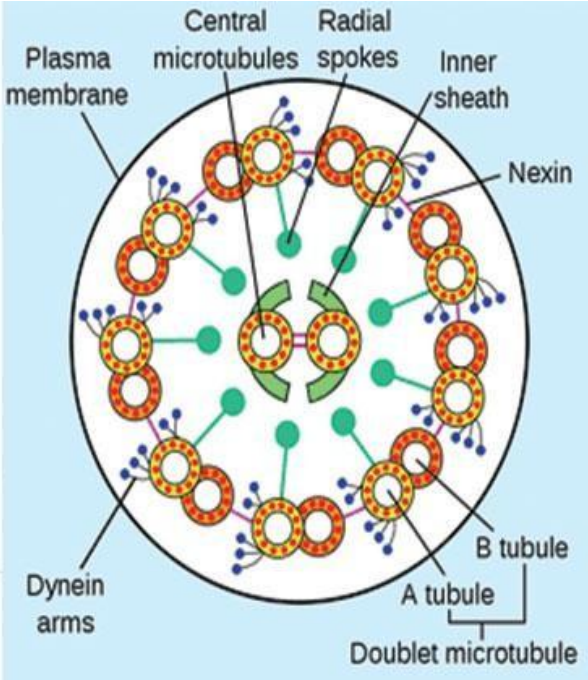
They are hollow tubular structures of variable length with a constant diameter of 25nm. Microtubules are stable permanent structures in cilia, flagella, centrioles and basal bodies. Each microtubule is made up of protein molecules (tubulin) that appear to organize into protofilaments that run parallel to the length of the tubule. A total of 13 protofilaments comprise the wall of a microtubule.

Functions of the cytoskeleton

- It provides the structural support for the plasmalemma, cellular organelles and some cytosol enzyme system.
- It provides the means for the movement of intracellular organelles within the cytoplasm.

- It plays an essential role in cell motility as well as provides the framework of motile structures such as cilia and flagella.
- It is responsible for contractility of the muscle cells.
- It plays an important role in epithelial cell adhesion as well as cell division.





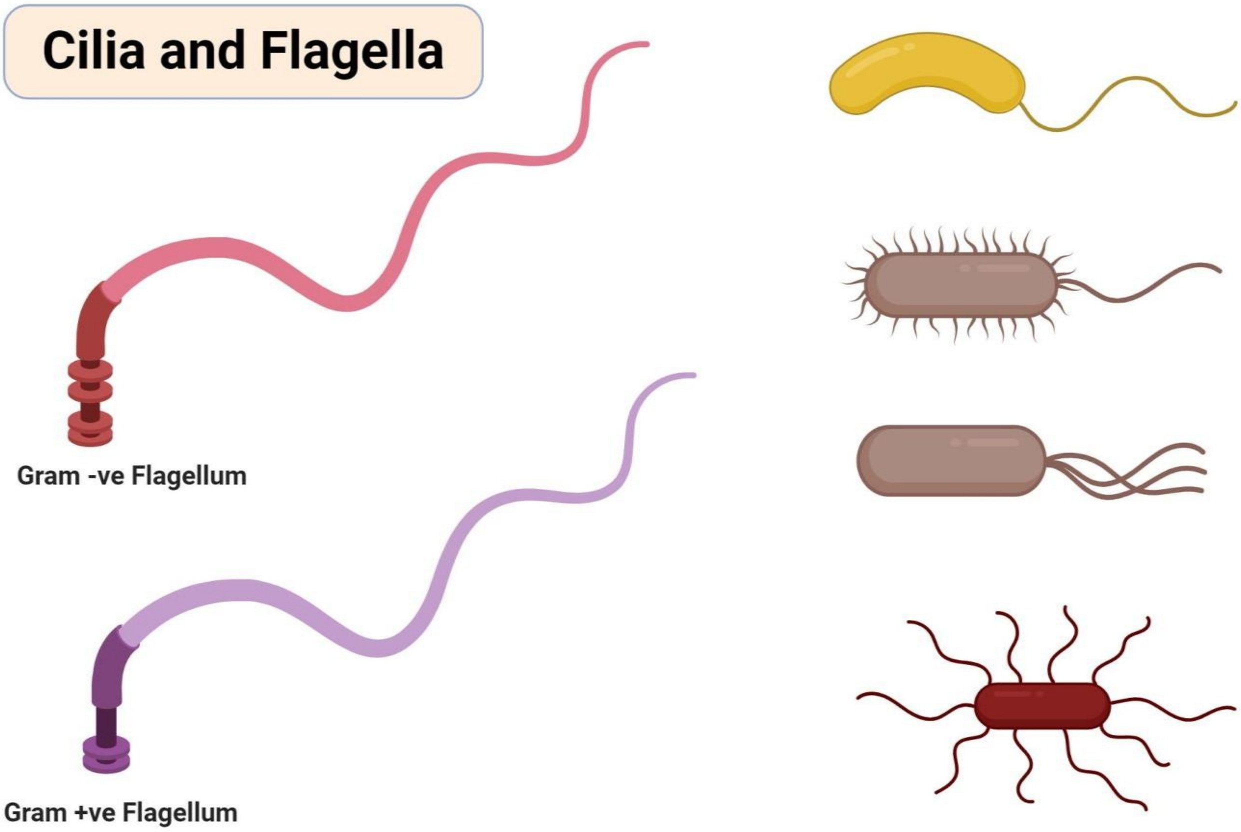


Figure: Cilia and Flagella, Image Copyright © Sagar Aryal, www.microbenotes.com

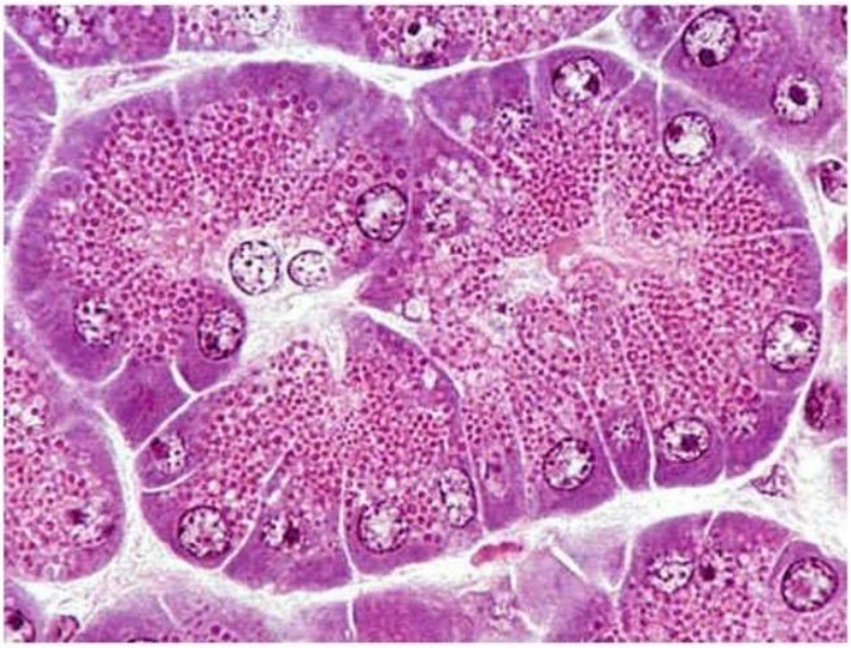
	Microfilaments	Microtubules	Intermediate filaments
1- diameter	7 nm.	25 nm.	10 nm.
2- LM	Seen only by immunohistochemistry.	Seen only by immunohistochemistry	Seen only by immunohistochemistry
3- EM	Thin electron dense filaments.	Fine tubules.	Thicker electron dense filaments.
4- Structural proteins	Monomers of G actin polymerize to form F actin.	Tubulin dimer polymerize to protofilaments. 13 protofilaments form a microtubule,	Woven ropes.
5- Functions	Dynamic 1– Muscle contraction. 2– Contractile ring in cell division. 3– Pseudopodia in migration. 4– Microvilli. 5– Cytoplasmic streaming. 	Dynamic. 1– Transport of organelles& vesicles. 2– Formation of centrioles, cilia & flagella. 	Not dynamic. Structural support.

10- Cytoplasmic Inclusions

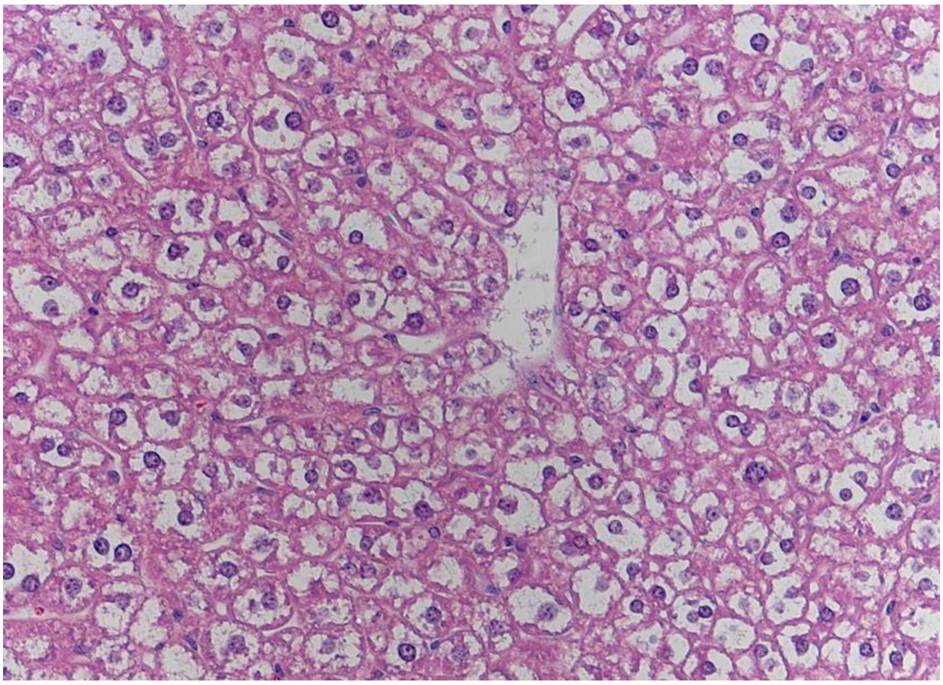
They are temporary lifeless accumulation of metabolites or cell products, such as stored food, pigments and crystals.

1. Stored food

Pancreas – Secretory acini w/ zymogen granules



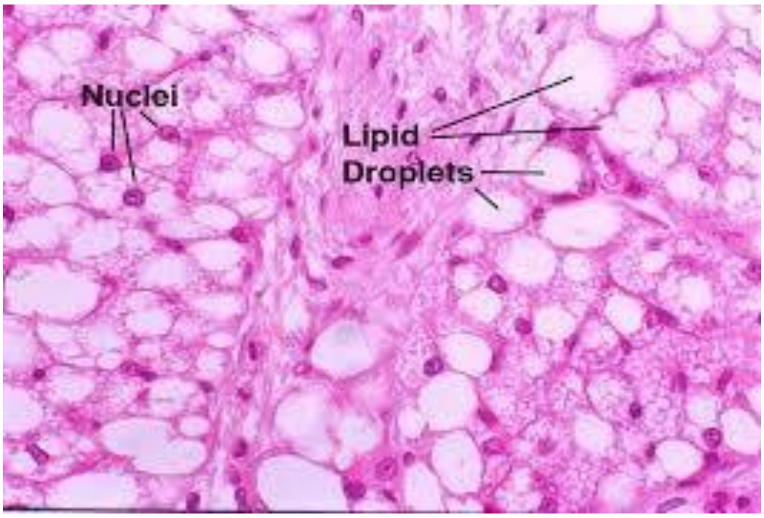
2. Glycogen



3. Lipids

The fat cells of adipose tissues and the fat storing cells of the liver store the lipids. Routine processing generally extracts lipids from tissue and therefore, in H&E sections, lipid droplets within cells appear as unstained vacuoles.

Lipids are best demonstrated in frozen sections stained by specific lipid methods such as osmium or sudan III with which lipids are stained black and orange respectively.



4. Pigments

They are substances that have their own color in their nature state.

a. Exogenous pigments

The exogenous pigments are those that have been produced outside the body. They include carotenes, dusts, minerals and tattoo marks.

1. Carotenes

Carotenes are a family of fat-soluble compound found in vegetable such as carrots, tomatoes and vegetable juice. When animals fed on carotene-containing vegetables, it colors its body fat yellow. Carotenes are provitamens and may be converted into vitamin A.

Ingestion of large amount of carotenes cause the skin of the body to appear yellow or even reddish color due to its great contents of carotenes. This condition is called carotenemia (increase carotene level in the blood). It might be confused with the more serious pathological condition called jaundice (caused by increase bilirubin level in the blood).

2. **Dusts**

The lungs of heavy smokers usually blackened due to accumulation of carbon particles in the alveolar macrophages located in the wall of the lung alveoli.

3. **Minerals**

Silver causes a gray pigmentation of the body. Lead can impart a blue line to the gum.

4. **Tattoo marks**

They are inorganic pigments inserted deeply into the skin with needles.

The pigments are ingested by the subcutaneous macrophages and remain permanently within their cytoplasm.

b. Endogenous pigments

They include hemoglobin, hemosiderin, bilirubin, melanin and lipofuscin.

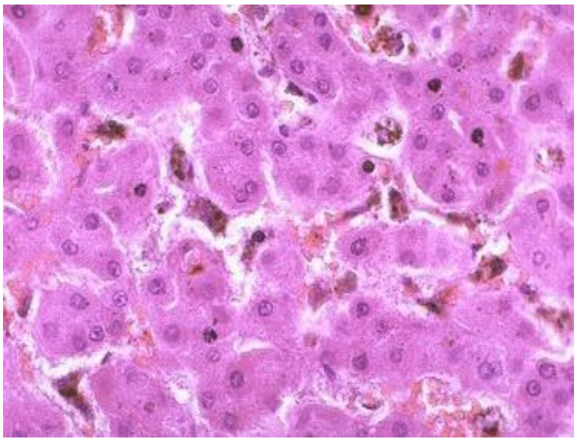
1. **Hemoglobin**

he hemoglobin is an iron-containing pigment of erythrocytes has the function of oxygen transport throughout the body.

2. **Hemosiderin and bilirubin**

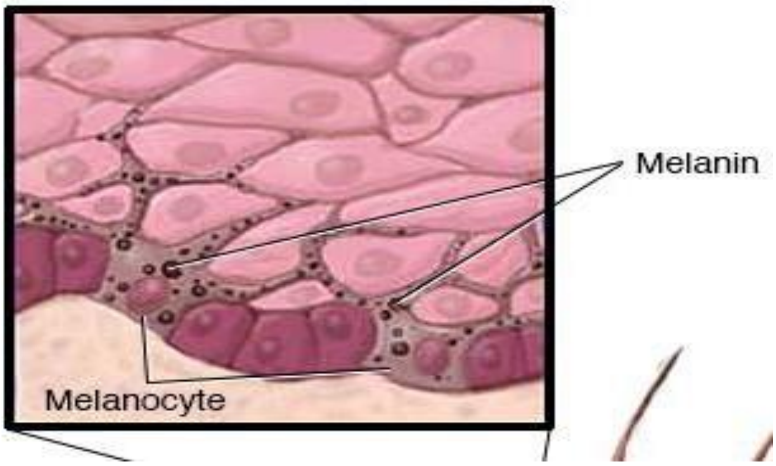
They are formed as the result of degradation of old erythrocytes by the spleen macrophages. Hemoglobin is degraded into hemosiderin and bilirubin. The hemosiderin is a golden brown iron-containing pigment usually seen within the cytoplasm of the splenic macrophages.

The bilirubin is yellowish-brown pigment. It has to be removed from the blood stream by the liver and excreted in bile.



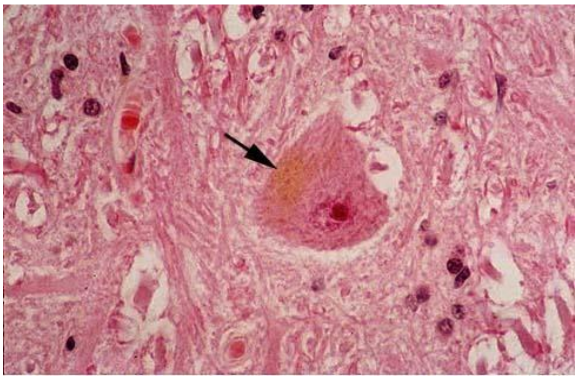
3. **Melanin**

The melanin is a brown-to-black pigment presents in skin, hair and eyes. There is two type of melanin: eumelanin, which has a brownish black color, and phaeomelanin that has a reddish-yellow color.



4. Lipofuscin

The lipofuscin is a golden-brown intracellular pigment represents a normal product of organelle's degradation. It accumulates with increasing age particularly in long-lived cells such as neurons and cardiac muscle cells (hence, they are referred to as age pigments or wear and tear pigments).



c. Crystals

Such as calcium oxalate and calcium carbonate crystals can be seen in the cytoplasm during certain disease conditions.

11. Nucleus

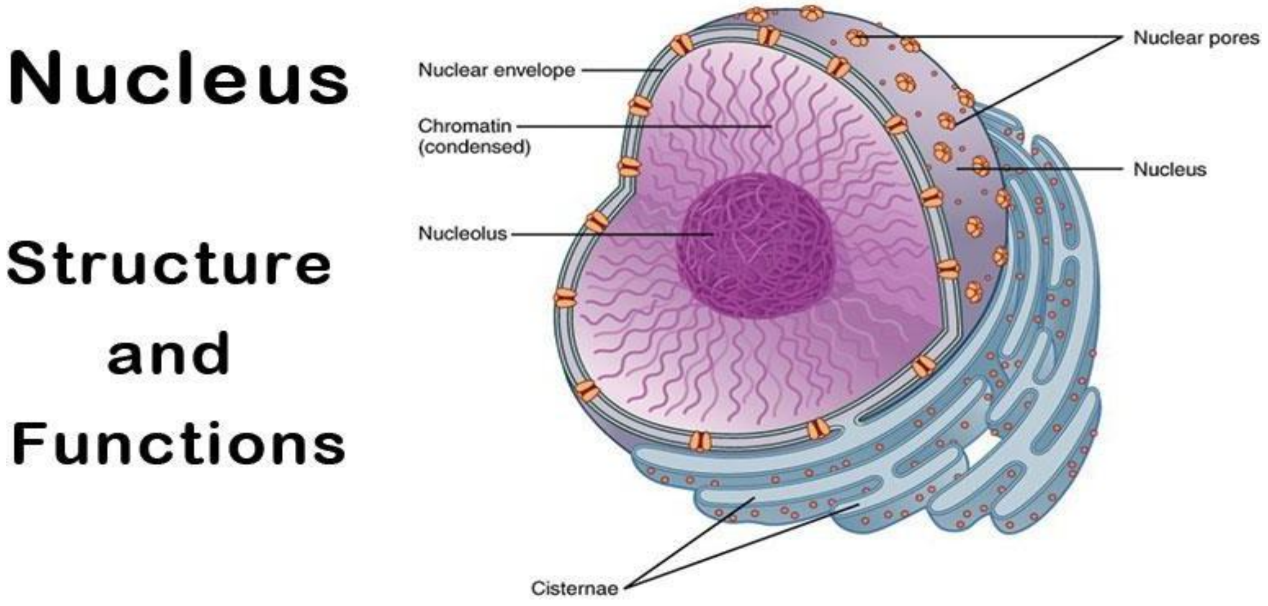
The nucleus is the archive of the cell that carries the genetic information necessary to regulate the different cell functions. It consists primarily of DNA (20% of its mass), DNA-binding proteins, and some RNA.

The DNA-binding proteins are of two major type histones and non-histones. The histones are involved in the folding of DNA strands and regulation of DNA activity. The non-histones are involved in the regulation of gene activity.

The nuclear RNA represents newly synthesized transfer and ribosomal RNA that has not yet passed into the cytoplasm.

With LM, the nuclei appear as basophilic structure located either centrally, eccentric or in a peripheral position. Most commonly nuclei are spherical or ovoid but they may be spindle-shaped (smooth muscle), bean or kidney-shaped (monocytes), or multilobulated (neutrophils).

Most often, cells are mononucleated. Some however, may be binucleated or even multinucleated. The interphase (not engaged in cell division) nucleus consists of nuclear envelope, chromatin, nucleolus and nuclear sap (karyolymph).



1. **Nuclear envelope**

With LM, it appears as a single basophilic line due to the presence of condensed chromatin adherent to its inner surface (peripheral chromatin) as well as ribosomes on the outer surface of the nuclear envelope.

With EM, he nuclear envelope consists of two membranes separated by a perinuclear space 25nm wide.

The outer membrane is continuous with the membranes of both the rER and sER and it may be studded with ribosomes. At the inner surface of the inner membrane, a layer of condensed chromatin known as granular lamina is usually encountered.

Numerous pores through which the nucleus communicates with the cytoplasm interrupt the nuclear envelope. The nuclear pore is guarded by two annuli, an outer and an inner annulus, each with eight globular subunits 15-20 nm diameter, projecting inwards from them are eight radially arranged spokes. In the center of the pore there is a central granule or plug. Such structure is called nuclear pore complex.

2. **Chromatin**

wo types of chromatin are distinguished: heterochromatin and euchromatin.

Heterochromatin

The heterochromatins consist of tightly coiled portions of chromosomes. The genes are repressed and transcription does not occur. It predominates in inactive cells.

With LM, they appear as fine and coarse basophilic granules scattered throughout the different regions of the nucleus.

With EM, it appears as electron-dense areas tend to be clumped around the periphery of the nucleus (peripheral chromatin), around the nucleolus (nucleolus associated chromatin) and also forms irregular clumps throughout the nucleus (chromatin islets).

In females, the inactive X-chromosome forms a small mass located at the edge of the nucleus and is called Barr body.

Euchromatin

The euchromatin is the extended, uncoiled portions of chromosomes in which the transcription of DNA is active. This type of chromatin is found in active cells. With LM, euchromatin is invisible because they are very thin and extended. With EM, they appear as electron-dense nuclear materials represent the parts of the DNA that are active in RNA synthesis.

	Heterochromatin	Euchromatin
1- LM	Dense basophilic clumps .	Lightly stained basophilic areas.
2- EM	Electron dense filaments or granules distriibnu:ted 1– around nucleolus . 2– associated with inner nuclear membrane . 3– swimming in nuclear sap.	Dispersed fine filaments or granules.
3- Function	Inactive part acts as a reserve (transformedeuinchtoromatinwhen needed).	Active part (transcribed into RNA).
4- Site	Inactive cells .	Active cellse.g.dividing cells .

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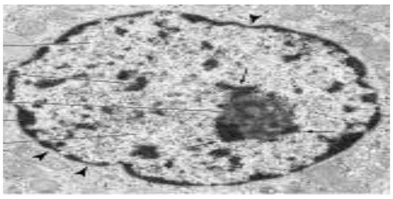


3. Nucleolus

It is a conspicuous, spherical, basophilic structure that is primary concerned with synthesis of ribosomal RNA.

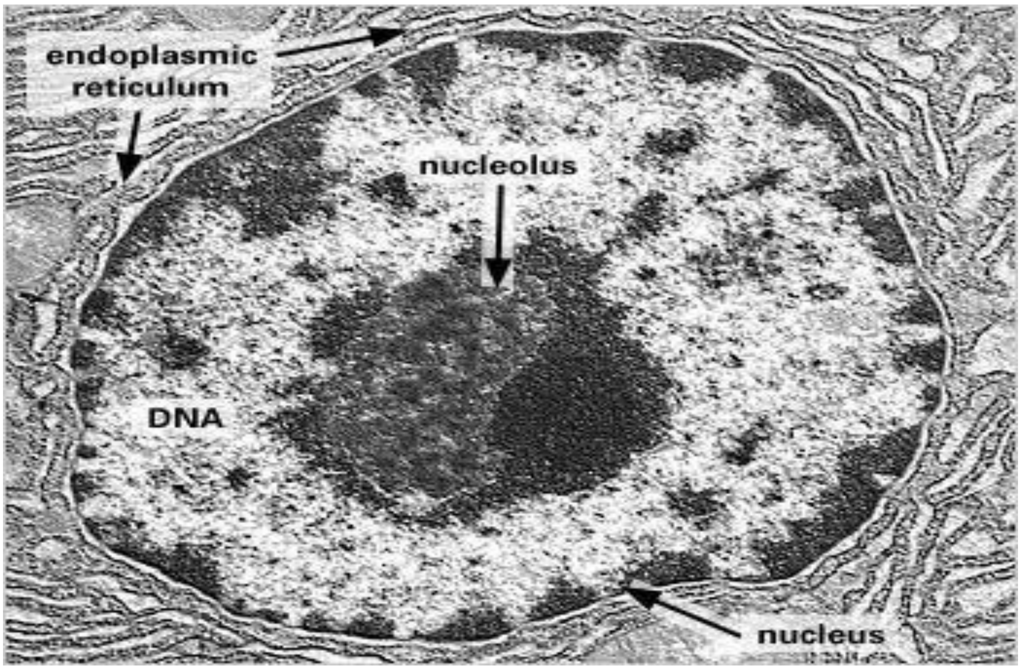
With LM, usually one, sometimes several nucleoli are seen. They are usually basophilic mainly due to nucleolus associated chromatin.

With EM, the nucleolus consists of a sponge showing dark materials of granular (pars granulosa) and fibrillar (pars fibrosa) both form the nucleonema which is ribonucleoprotein permeated by dispersed filaments of DNA (pars amorpha).

The primary function of the nucleolus is the synthesis of ribosomal RNA (rRNA). The genes that code for rRNA are known as nucleolar genes that lie along five different pairs of chromosomes.

4. **Nuclear sap (karyolymph)**

The nuclear sap is a colloidal solution in which chromatins are suspended. It helps in the movement of RNA (rRNA, tRNA, and mRNA) toward the nuclear pores.



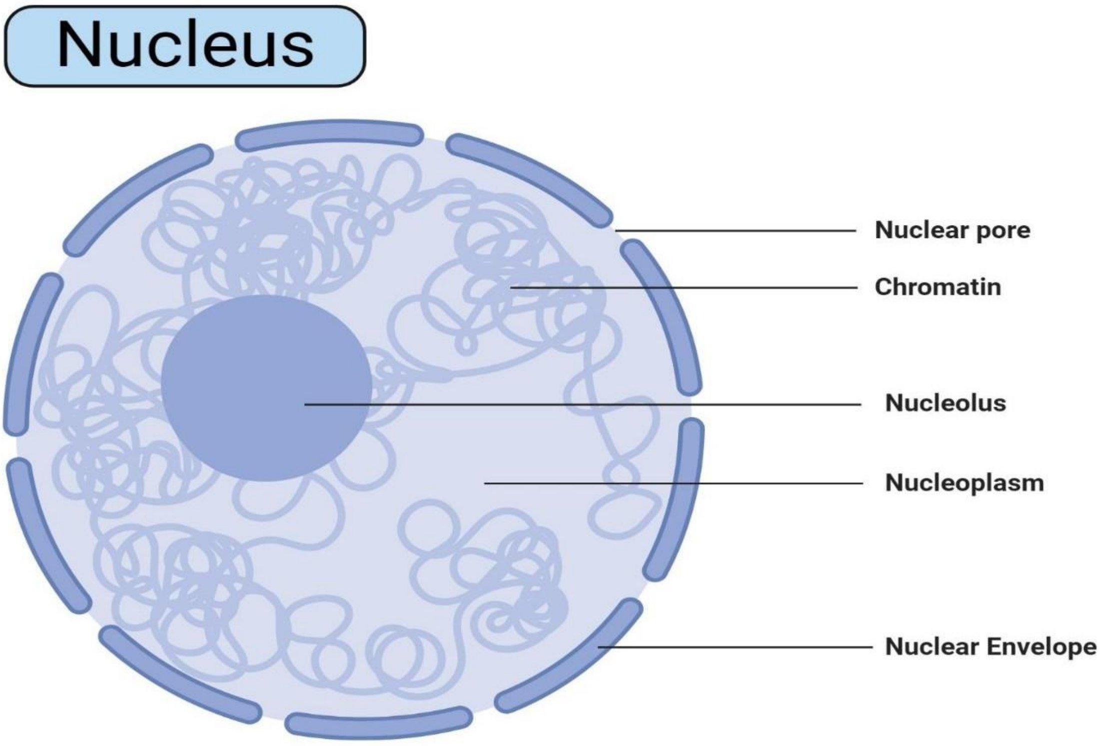
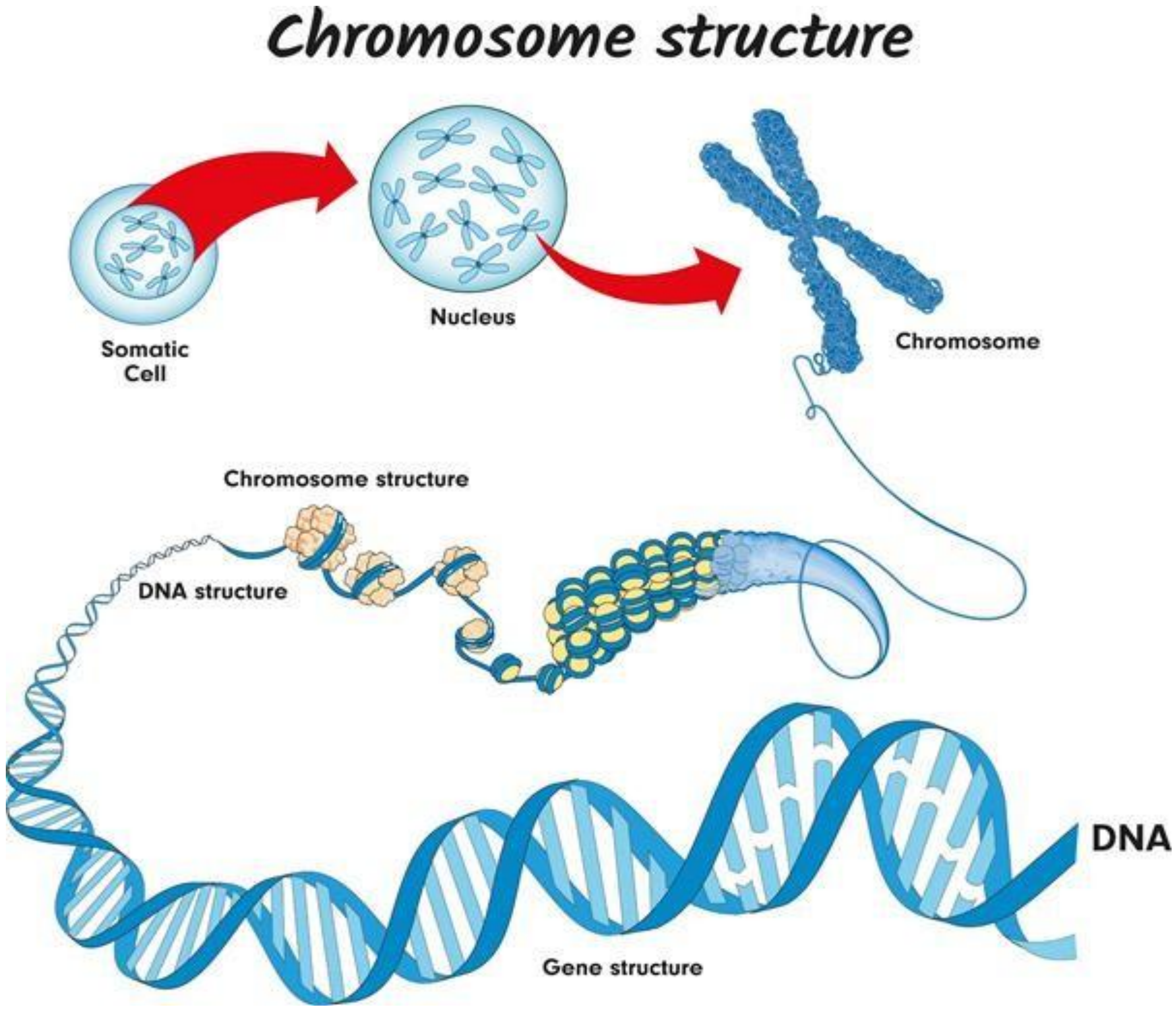


Figure: Nucleus, Image Copyright © Sagar Aryal, www.microbenotes.com

DNA and chromosomes

Inside the nucleus of a cell, there are thread-like structures called chromosomes. Each chromosome is made out of a long, coiled up strand of DNA (genetic material), which means that each chromosome contains many genes.

Normally, there are 46 chromosomes inside the nucleus of each human body cell. Chromosomes are usually found in pairs.



A **diploid** cell contains two complete sets of chromosomes in its nucleus, one from each parent. In humans, all body cells are diploid cells. Human diploid cells have 23 pairs of chromosomes (46 in total). The diploid number is often represented as **2n**, with n being the number of chromosomes. In humans, 2n = 46.

The word **haploid** means half. It describes a cell that contains a single set of chromosomes. The symbol **n** is often used to show the haploid number. In humans, n = 23. Human sex cells (egg and sperm cells) contain a single set of chromosomes, so they are haploid cells.

- Sex cells are also called **gametes**

12- Vacuoles

A vacuole may be described as a space inside the cell that does not contain cytoplasm. It is surrounded by a membrane and filled with a fluid. Vacuoles store various molecules including enzymes, waste products of the cell, water, and even food material depending on the type of cell.

In cases where vacuoles contain waste products of the cell, they are also involved in the exportation of waste from the cell thus protecting the cell from toxicity.

Some vacuoles also play a role in maintaining the internal hydrostatic pressure of the cell as well as regulating pH.

- **Other features of a cell include:**
- **Cell Wall**
- Some books do not consider the cell wall to be an organelle. However, it's one of the most important components of plant cells. The cell wall surrounds the cell membrane and serves to strengthen and protect the cell.
- For instance, in the cells of plant roots, the cell wall protects the cell as they grow deeper in the soil. The cell wall also serves as a filter that controls the movement of molecules in and out of the cell.
- **Cytoplasm** is also not considered as an organelle in some books. However, it is an important component of the cell. Cell cytoplasm is composed of protoplasm in which all the other cell organelles are suspended. Many of the cell processes

(protein synthesis, respiration etc) take place in the cytoplasm. The cytoplasm also plays an important role in the movement of various materials around the cell.

Cell cycle & division

- Definition: it is the alternation between interphase and mitosis.

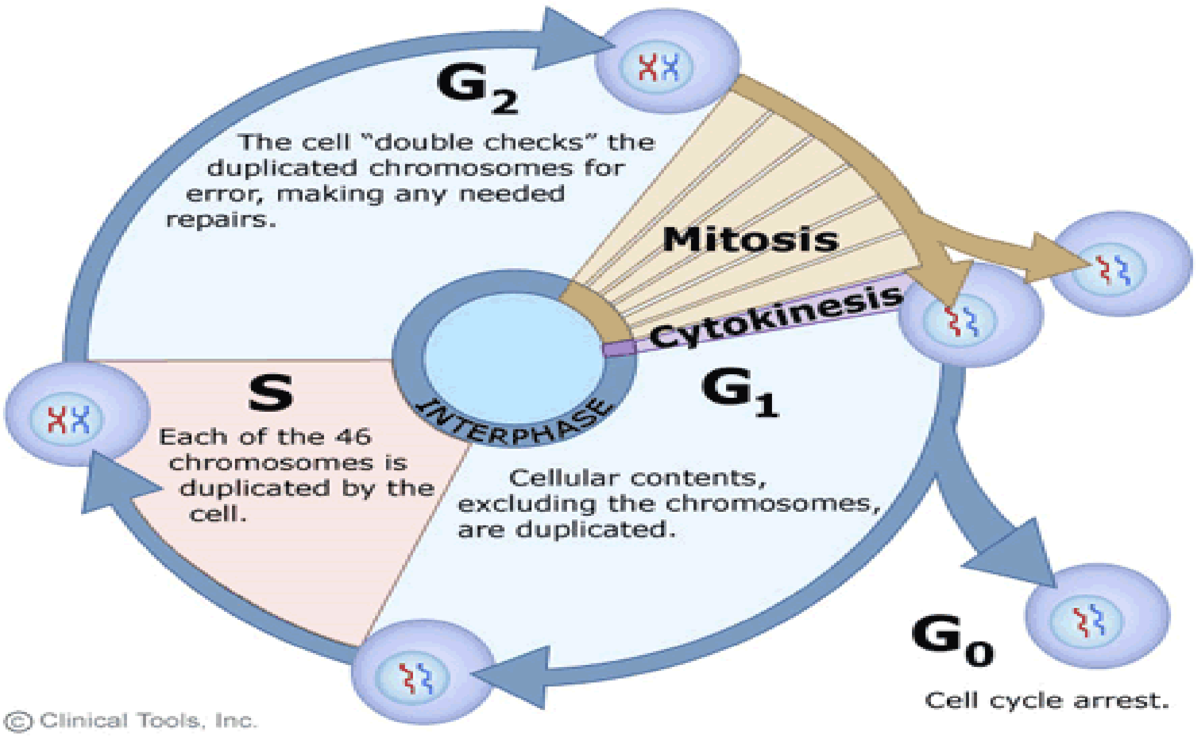
I-Interphase: a longer period:

1- The cell increases in size.

2- Performs its normal functions.

3- Replicates its DNA for preparing itself for division.

II-Mitosis*:* a shorter period during which parent cell gives 2 daughter cells each containing the same number of chromosomes (identical to the parent cell =46 chromosomes).



I-Interphase

First gap phase (G_1 phase)

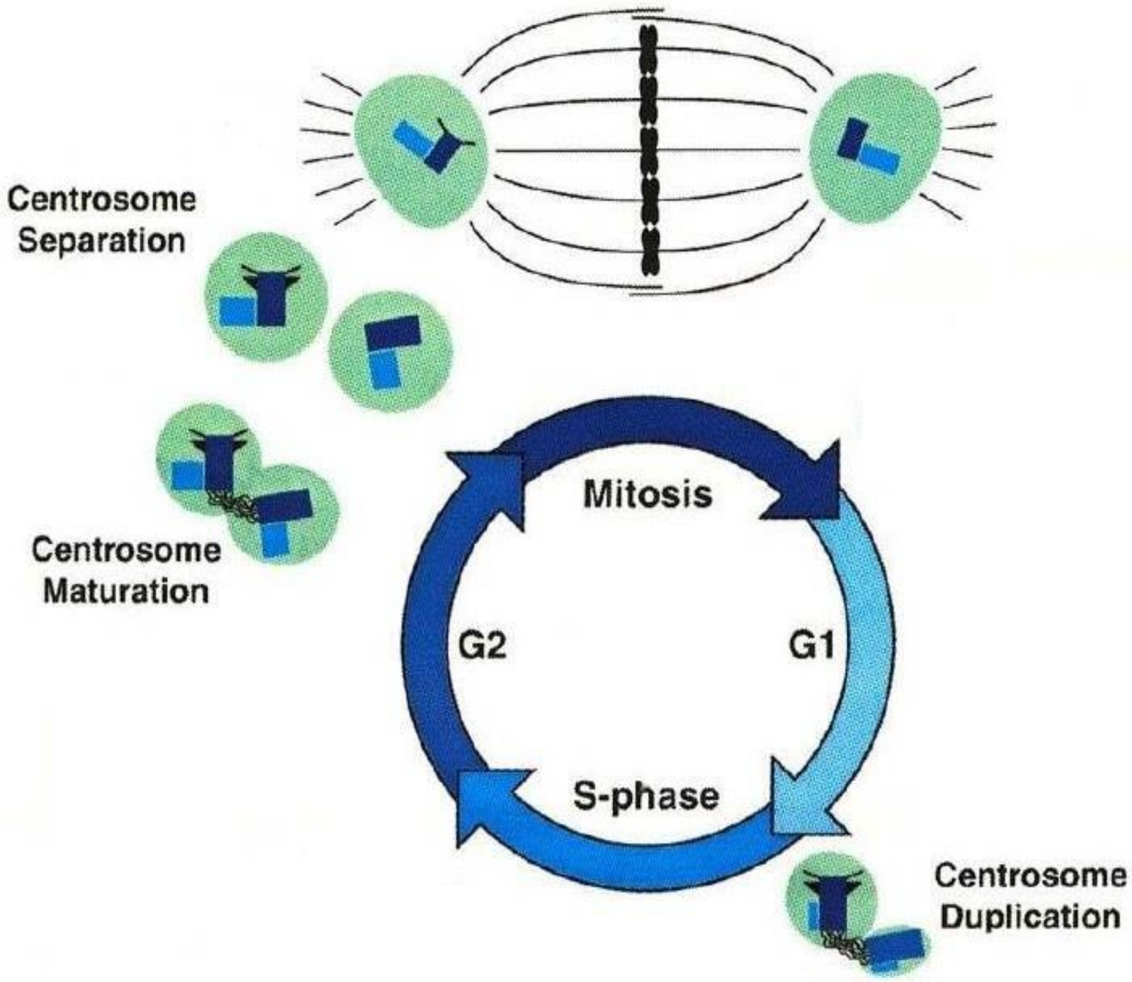
- It is *the longest period* of the cell cycle between the end of mitosis and the beginning of DNA replication:

1- The RNA and protein synthesis occurs.

2- The cell attains its full size.

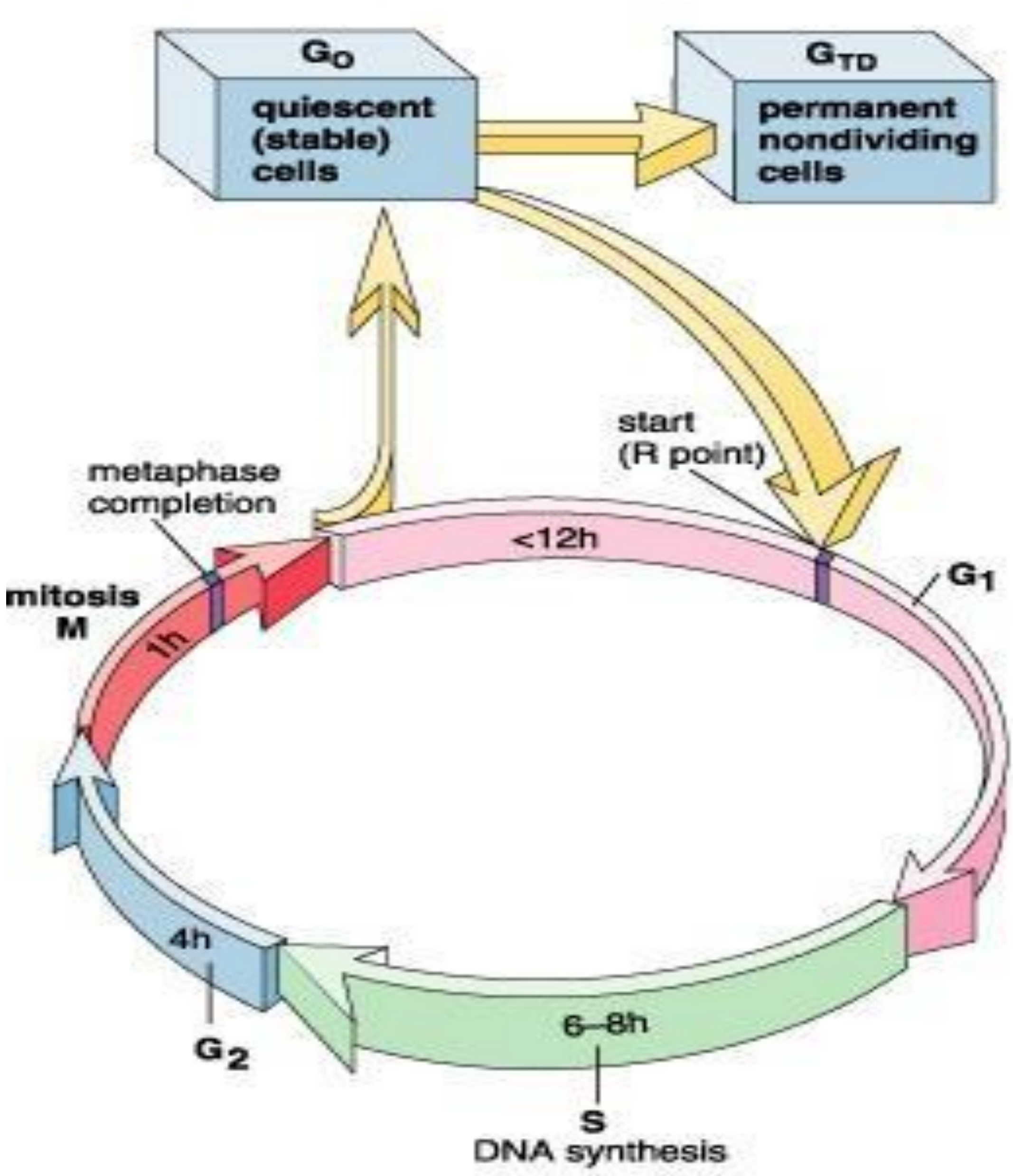
3- The cell performs its function.

4-Duplication of centrosomes occurs near the transition between G_1 and S phase.



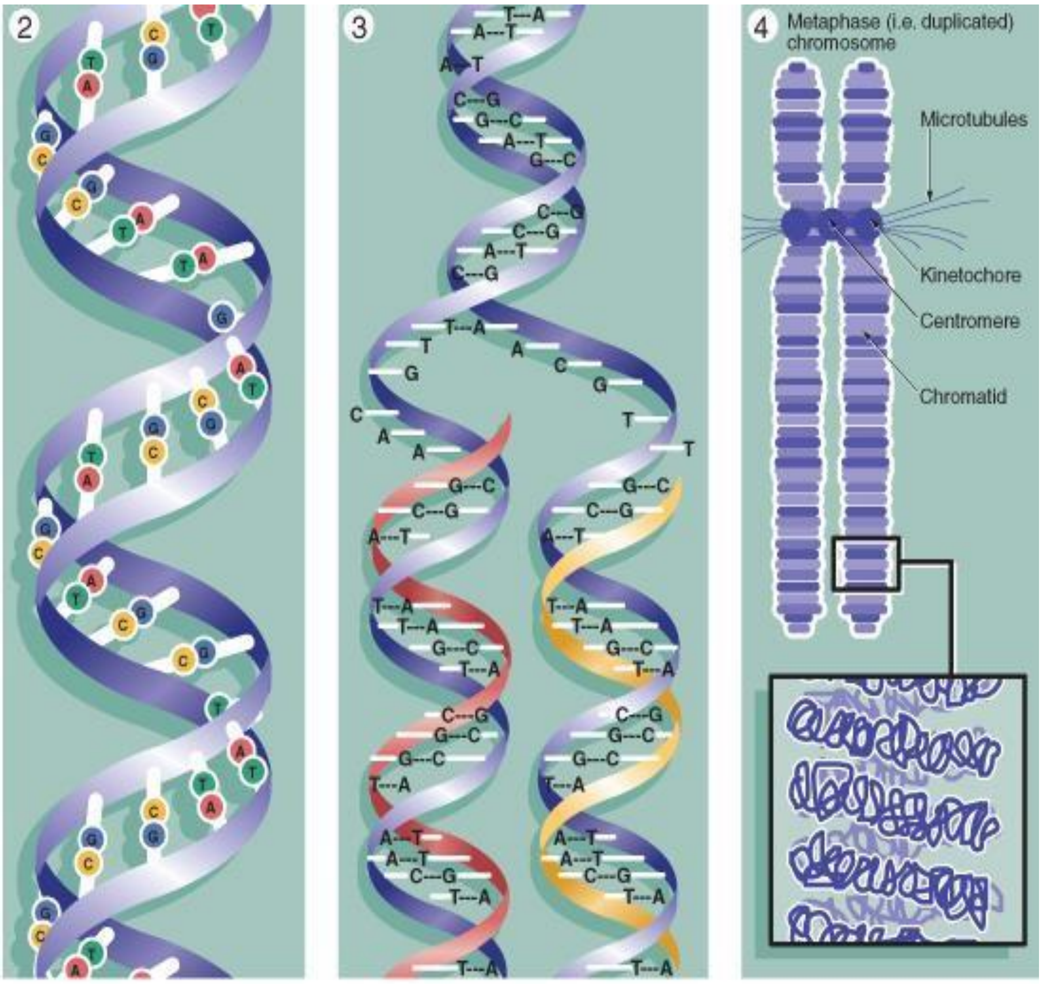
GO Phase

- **Definition**: Differentiation of the cell to carry out specialized function and no longer divide (*outside the cycle*).
- GO may be *permanent* or *temporary*.



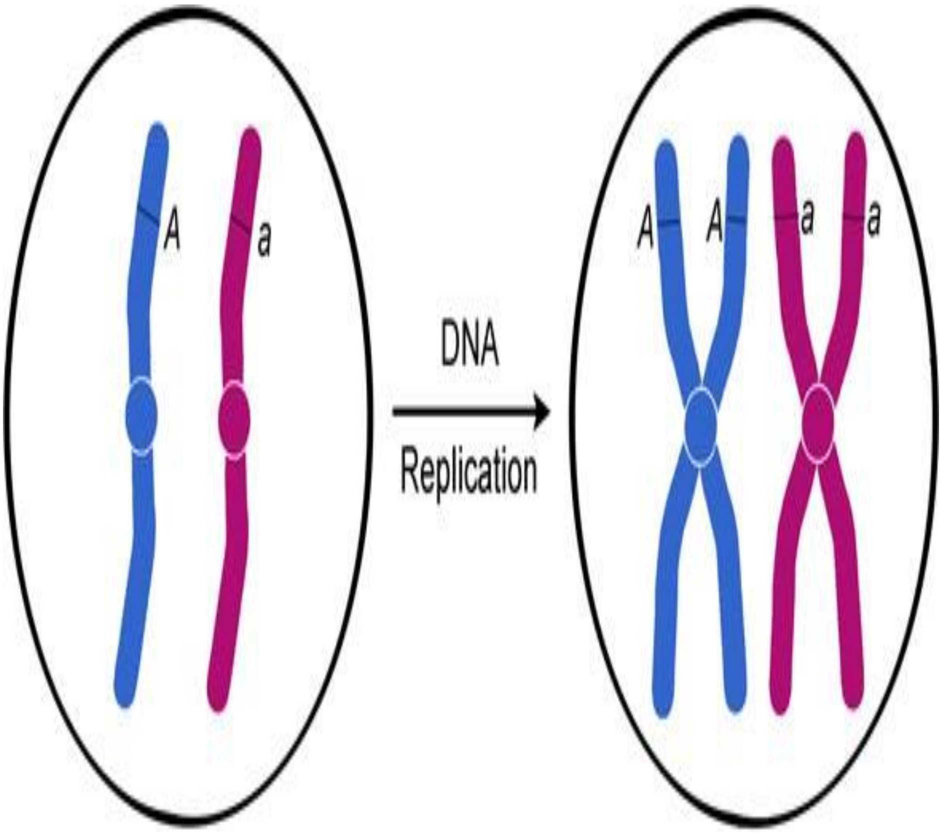
DNA synthesis phase (S phase)

- Replication of DNA, thus the amount of DNA is doubled but *not the total chromosomal number*.



- **Types of chromosomes s-chromosomes** made of one DNA molecule (interphase chromosomes = chromatin or chromatids).

- **d-chromosomes (mitotic chromosomes):** are formed during the S phase. Each d-chromosome is formed of two chromatids, linked at the centromere. Each chromatid is made of a DNA molecule.


A
a
DNA
Replication
A
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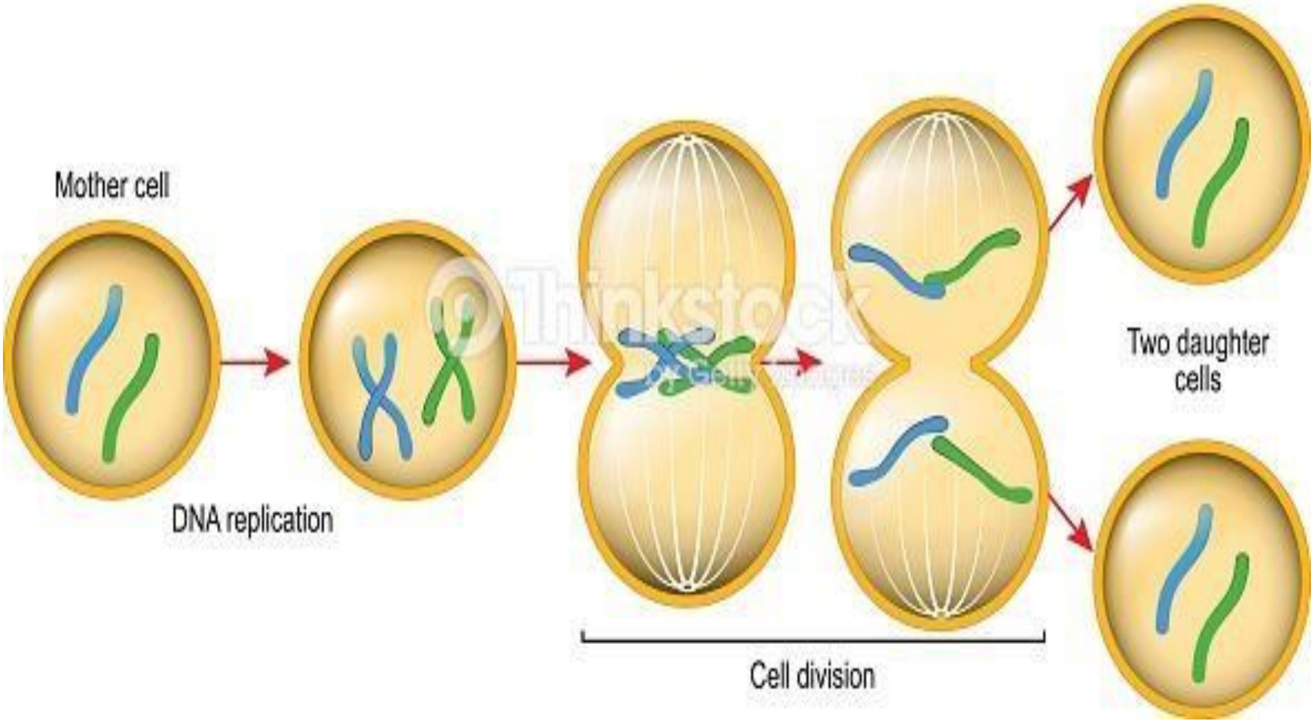
MITOSIS

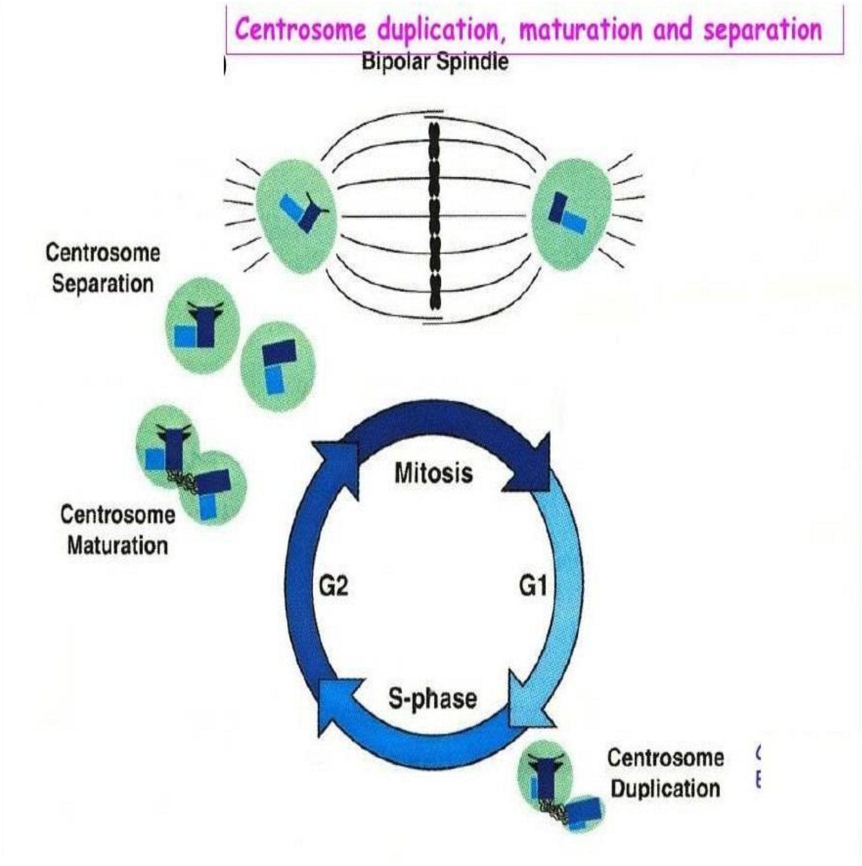

Mother cell
DNA replication
Cell division
Two daughter cells

Second gap phase (G_2 phase)

- It starts by the end of the DNA replication and lasts until the beginning of mitosis.

  1- Proteins and energy essential to mitosis are stored.

  2- Duplication of the centrosome is *completed*.



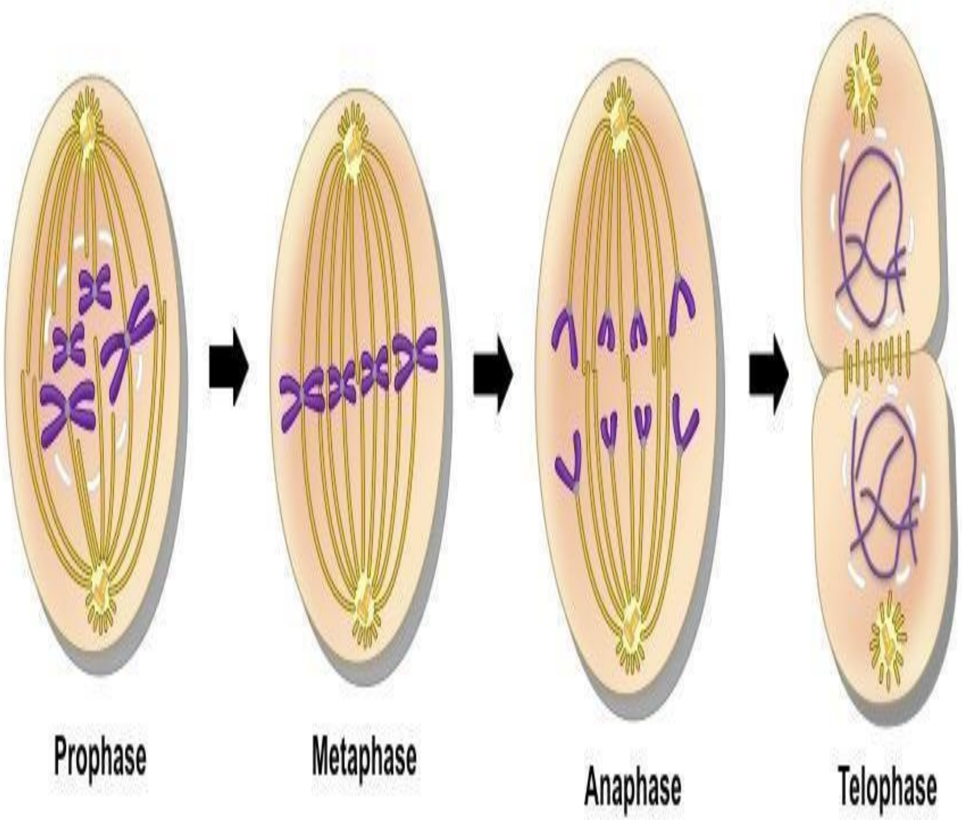
Cell division

Mitosis

- Definition: division of the somatic cell into two daughter cells identical to the mother cell.
- **Function:**

1- Growth and development of the organism.

2- Renewal and repair of cells.



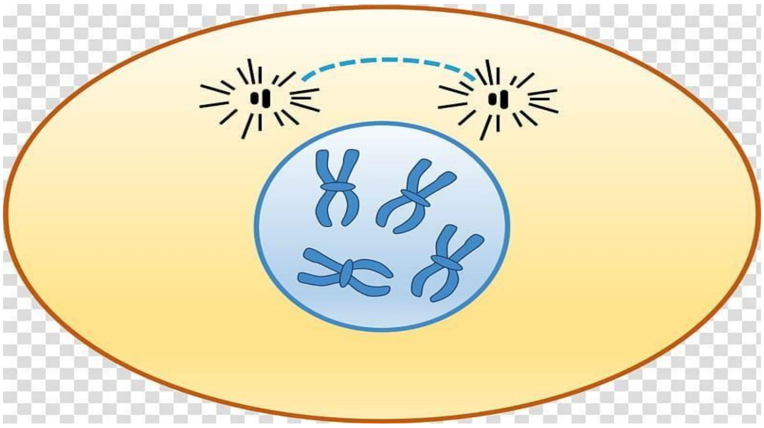
I-Prophase

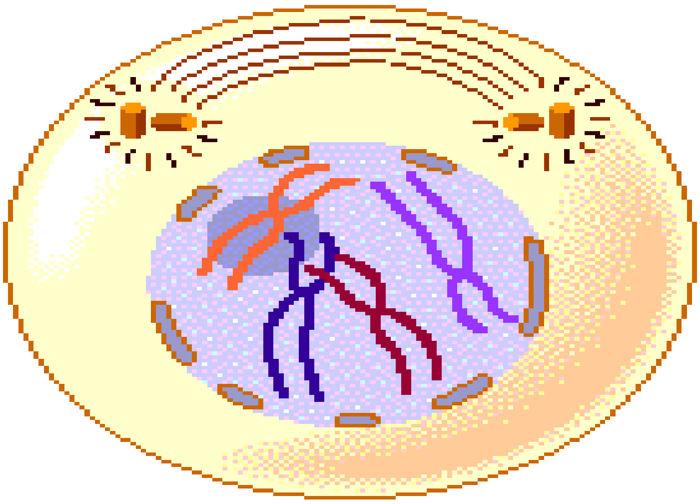
1- The *nucleolus* disappears.

2- Condensation of *chromatin* gives rise to 46 rod-shaped short d-chromosomes.

3- Each pair of *centrioles* migrates to opposite pole of the cell forming the mitotic spindles.

4- The *nuclear envelope* breaks up into small vesicles



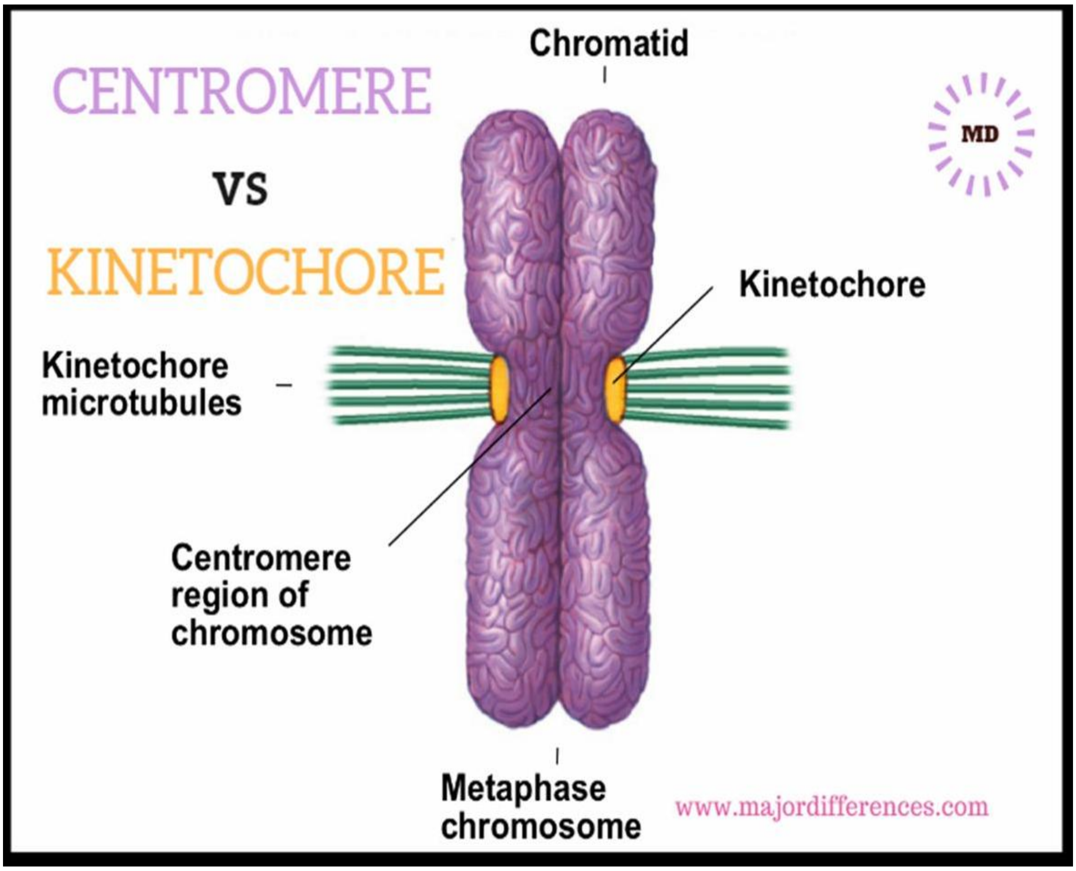


2-Metaphase

1- The 46 d-chromosomes become maximally condensed.

2- The chromosomes *aligned at the equatorial plate* of the cell.

- Each pair of sister chromatid is attached to the mitotic spindles at *the kinetochore*.

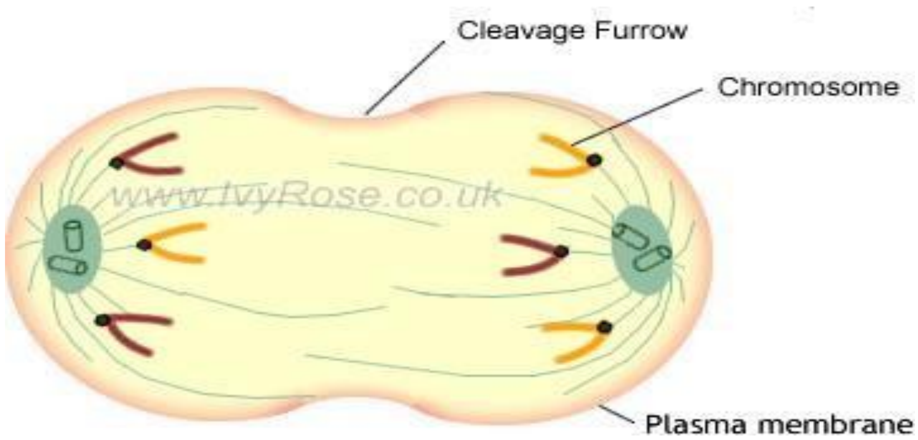


3- Anaphase

1- *Division of the centromere* results in the separation of the sister chromatids.

2- Each 46 chromatids migrate toward the opposite poles of the cell.

3- In late anaphase, *a constriction (cleavage furrow)* develops at the equatorial plate of the cell.



4- Telophase

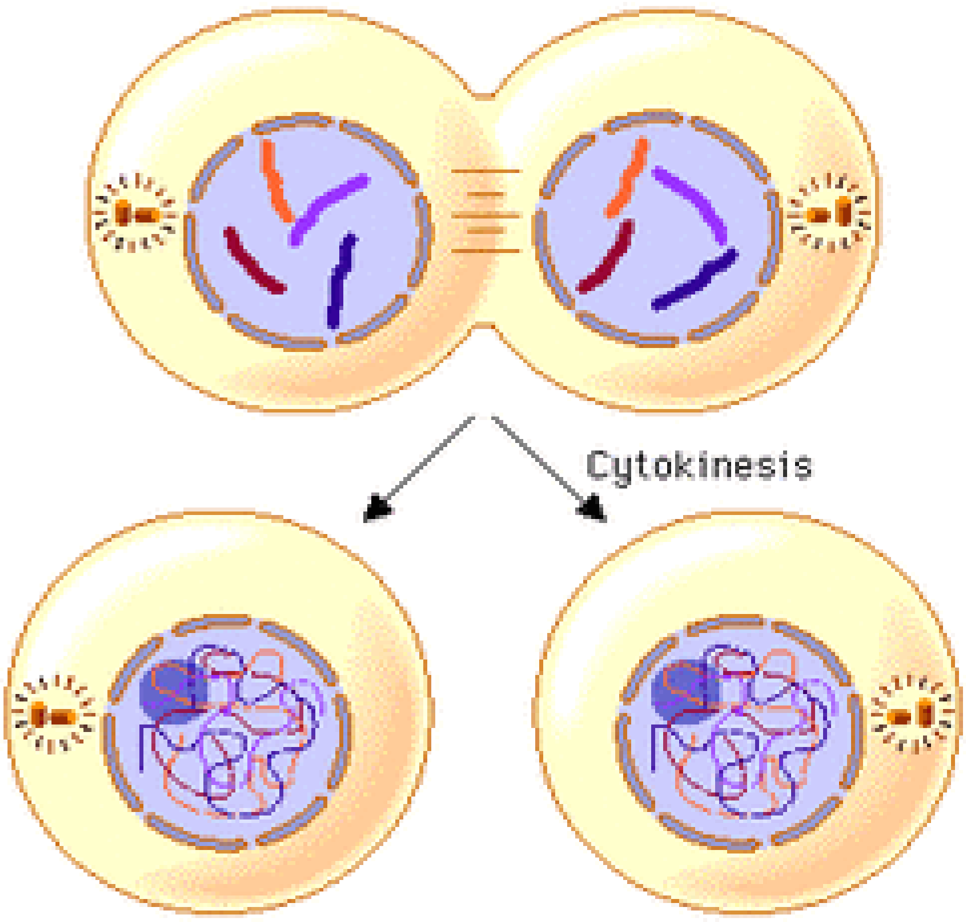
1- The *mitotic spindle* disappears.

2- The *nucleolus* reappears.

3- The *chromosomes* start uncoiling (46 s-chromosomes).

4- The *nuclear envelope* is reformed around the new sets of chromosomes.

5- Division of the *cytoplasm* (cytokinesis): the cleavage furrow becomes deeper due to the formation of a contractile ring of microfilaments until it divides the cytoplasm and its organelles in half resulting into two daughter cells.



Regulation of the cell cycle

- The cell cycle is regulated by growth factors that control cell proliferation to keep its coordination with the needs of the living organism.
- Several ***checkpoints*** control the transition between the cycle stages.
- Checkpoints detect external or internal problems and stop the cycle until the problem solved.

Checkpoints of cell cycle

1-The restriction checkpoint

- It occurs in the G_1 phase.
- It detects *the cell size & its interactions with the surrounding environment.*
- Cells that do not receive appropriate growth stimuli do not progress past this point (G_1 phase) and will be die by apoptosis.

It is the most important checkpoint in the cell cycle

2-DNA damage checkpoints

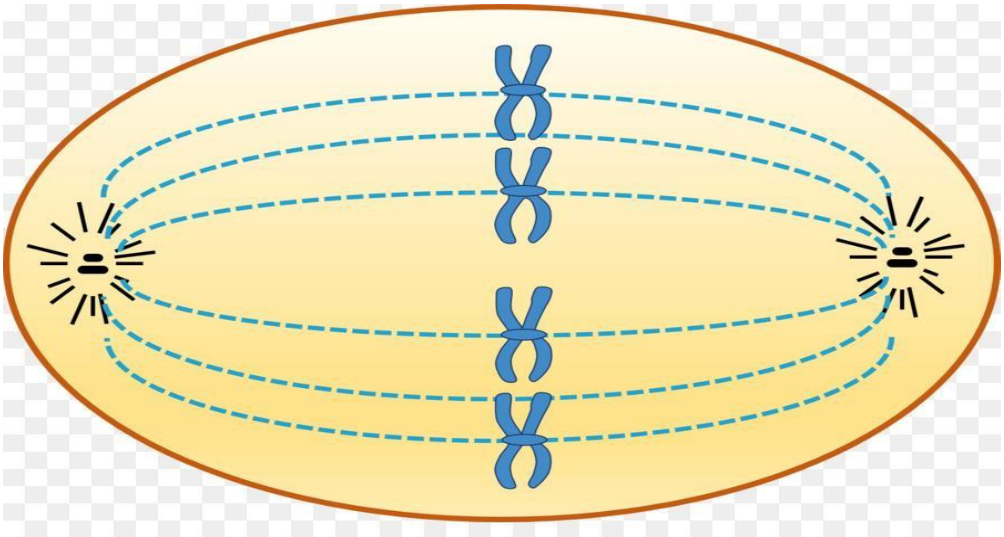
- It occur in G_1, S, and G_2 phases.
- It blocks cell cycle progression until repair of the damaged DNA or cell apoptosis occurs.

3-The unreplicated DNA checkpoint

- It occurs in the G_2 phase.
- It prevents progression of the cycle into the mitosis before complete synthesis of DNA.

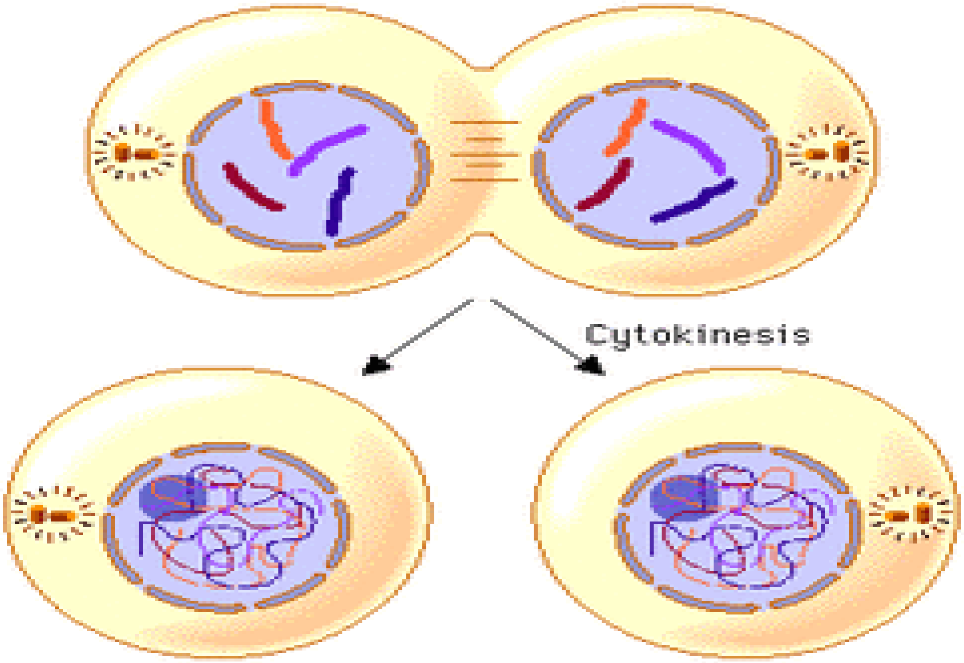
4- The spindle-assembly checkpoint (the metaphase checkpoint)

- It occurs in mitosis.
- It prevents entry into anaphase until all chromosomes have attached properly to the mitotic spindle.



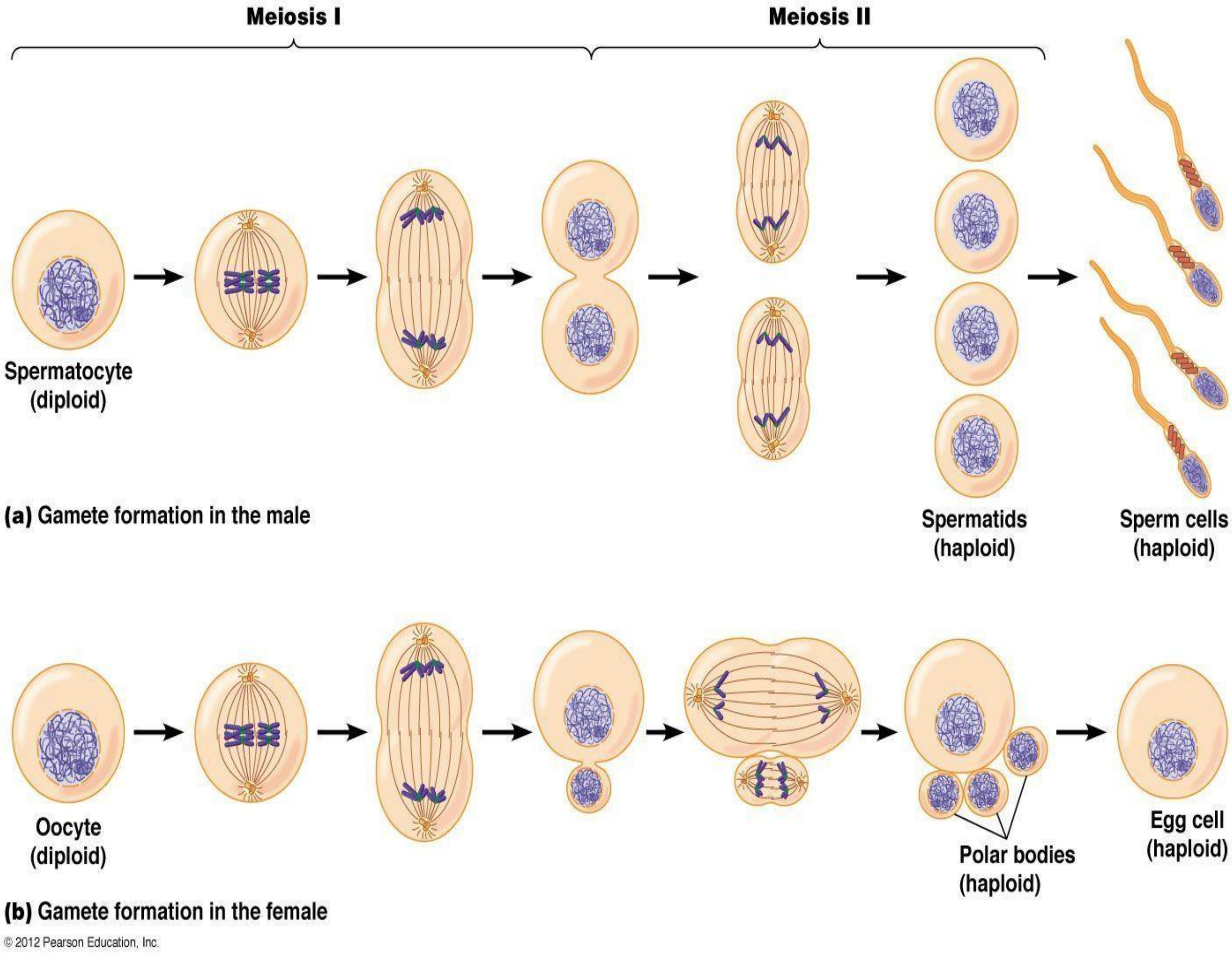
5- The chromosome-segregation checkpoint

- It occurs in telophase.
- It prevents the cytokinesis until all of the chromosomes have been correctly separated.



Meiosis

- It occurs in *germ cells* and results in the formation of gametes.
- It results in formation of *4 daughter cells* (each contains 23 s-chromosomes=haploid number).
- It consists of two successive divisions; *without an intervening S phase.*



I-First meiotic division (reductional division)

is preceded by interphase with an *S phase*, in which the chromosomes are replicated (46 s chromosomes 46 d chromosomes).

<u>1-Prophase I:</u>

A- *Pairing of the homologous chromosomes* occurs forming tetrads(bivalent).

B- Crossing-over occurs between the chromatids of the homologous chromosomes so that each homologous chromosome is no longer solely paternal or maternal but a mixture of both.

3- The nucleolus and the nuclear envelope disappear and the mitotic spindle is formed.

2- Metaphase I:

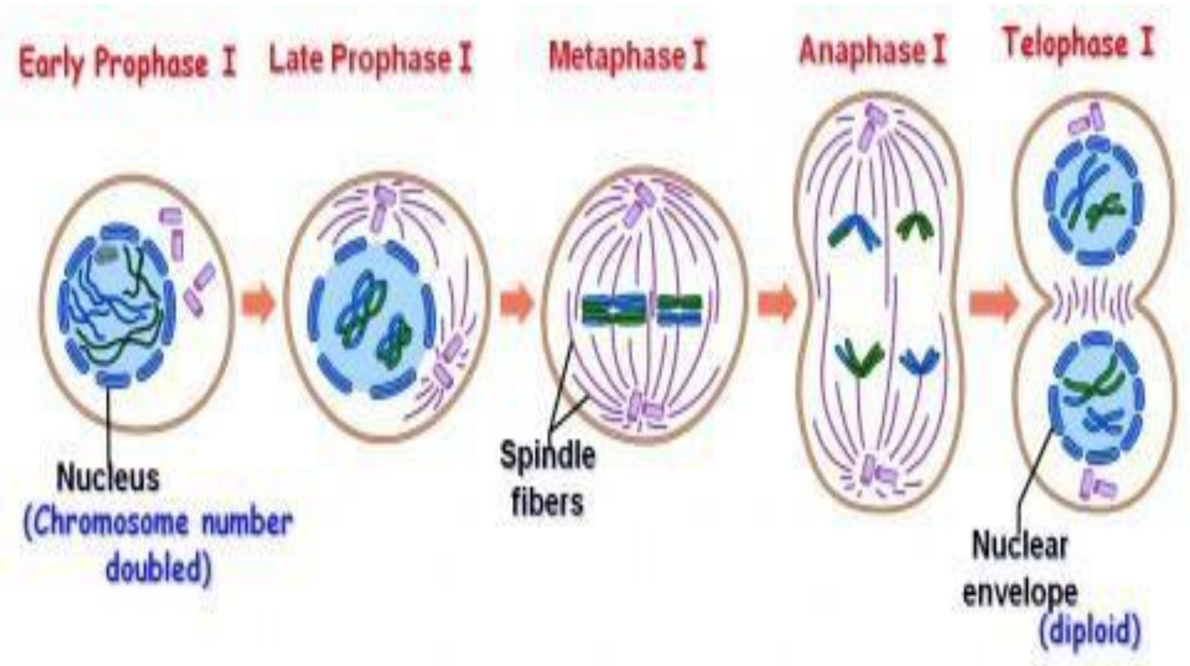
The *paired chromosomes* arrange themselves at the equatorial plate of the cell.

3- Anaphase I:

The centromeres *do not divide*, instead, each chromosome of homologous pairs moves separately towards the opposite poles of the cell.

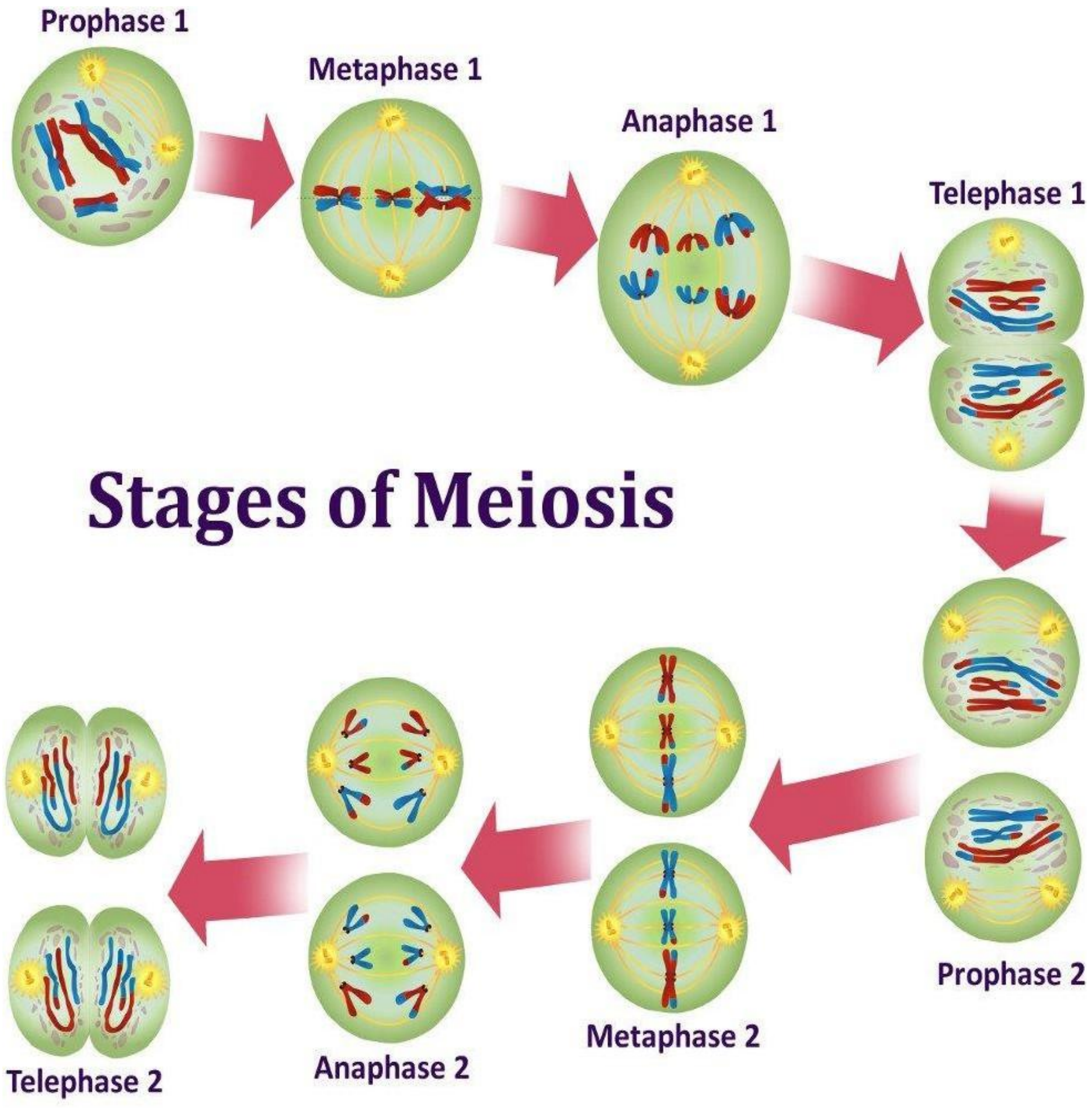
4- Telophase I:

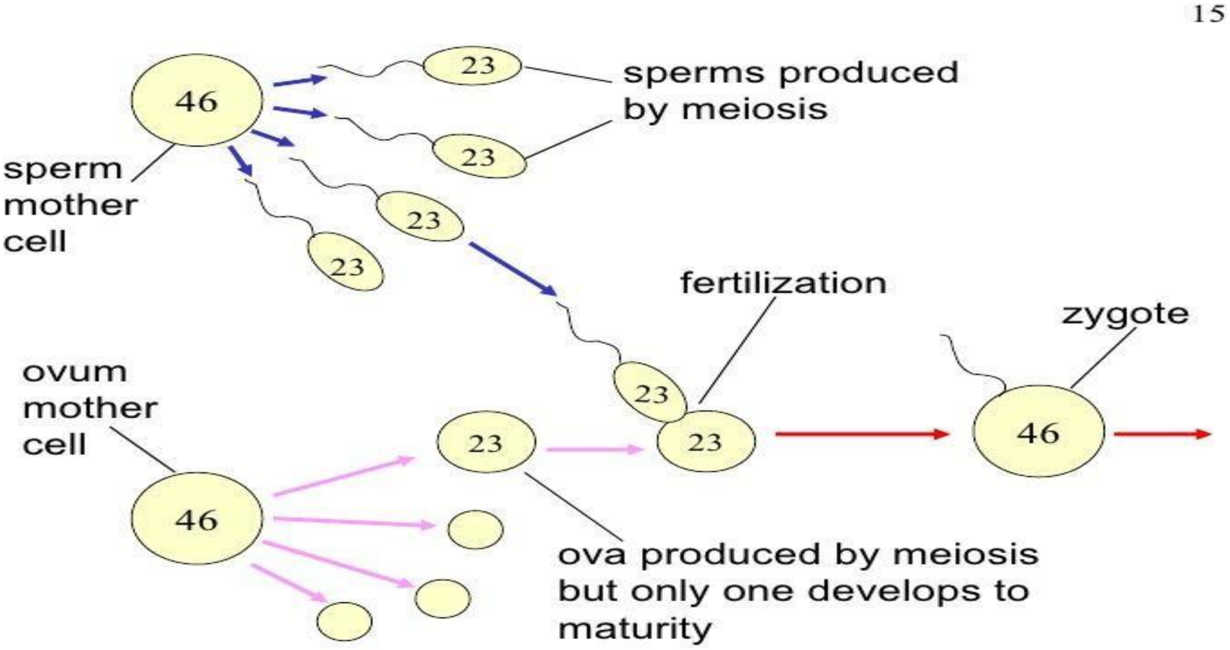
Cytokinesis occurs results in two daughter cells each containing the haploid number (23d-chromosomes).



II- Second meiotic division (equatorial division)

- It is similar to mitosis but, it is *not preceded* by S phase.
- It results information of *4 daughter cells*, each contains 23 s-chromosomes (haploid number).





	Mitosis	Meiosis
1-Types of cells	Somatic cells	Germ cells of testis & ovaries
2- Number of division	Single division	2 successive divisions: Meiosis I & Meiosis II.
3- Interphase	Preceded by interphase with S phase	Meiosis I preceded by interphase with S phase, Meiosis II not preceded by S phase.
3- Prophase	No crossing over	Meiosis I: Crossing over occurs
4-Metaphase	46 d chromosomes arranged individually at the equatorial plane of the cells.	In Meiosis I :23 bivalent arranged at the equatorial plane of the cells.
5- Anaphase	Each chromosome divides at centromere into 2 chromatids	In Meiosis I: each chromosome of a bivalent moves apart.
6- Cells produced 156	Two daughter cells with diploid number of chromosomes (46 S) Daughter cells are genetically identical	Four daughter cells with haploid number of chromosomes (23 S) Daughter cells are genetically variable.

	Meiosis I	Meiosis II
1- Preceded S phase	Present (the cell enter the prophase with 46 d chromosomes).	Absent (the cell enter the prophase with 23 d chromosomes).
2- Prophase	Pairingof homologous chromosomes result in 23 tetrad. Crossing over occurs between each tetrad .	No pairing No crossing over.
3- Metaphase	23 tetrad arranged at the equatorial plane of the cells.	23 d chromosomes arranged individually at the equatorial plane of the cells.
4- Anaphase	No division of the centromere. Each chromosome moves independently to the opposite pole of the cell.	Centromere splits so eachchromatid moves independently to the opposite pole of the cell.
5- Telophase 157	Cytokinesis results in2 daughter cells each with 23 d chromosomes.	Cytokinesis results in4 daughter cells each with 23 S chromosomes.

HISTOLOGY

- **Histology**: is a science concerned with the study of tissues with a microscope, and it is known as the science of microscopic anatomy.

Types of Tissues

- Animal tissues are usually classified into four sections:

- ✓ **Epithelial tissues**: covering the outer surfaces of the body, lining hollow organs, and may adapt to perform other functions.
- ✓ **Connective tissues**: Connect other tissues to each other or to the structure of the body. They are the structures that support the body and aid in animal movement, moreover, formation of blood and lymph.
- ✓ **Muscle Tissues**: form the voluntary and involuntary muscles of the body.
- ✓ **Nervous tissues**: form the animal nervous system.

Epithelial Tissues

- The epithelial tissues cover the outer surface of the body as well as some organs, it also lines some organs from the inside and the internal cavity of the body.
- The epithelial tissue is mainly concerned with covering or protecting various parts of the animal body, but it may adapt to perform other functions such as secretion, sensation, reproduction.

- Epithelial tissues may:
- Cover the outer surface of the body or some organs, and in this case it is called **epithelium**.
- Line some hollow organs, and then it is called **endothelium**.
- Line the internal cavity of the body, and in this case it is called **mesothelium**.

General Characters of epithelial tissues

- The epithelial tissue arises from the three primary germ layers (ectoderm, mesoderm, and endoderm).
- The intercellular substance or matrix between its cells is minimal and almost non-existent.
- Its cells rest on a thin connective tissue membrane known as the basement membrane.
- It has the ability to reproduce to compensate its worn cells.

Types of epithelial tissues

- Epithelial tissues are classified either according to their **structure**, i.e. the shape and arrangement of the constituent cells, or according to their **functions**.

Types of epithelial tissues

- Epithelial tissues are classified according to their structure into two groups:
  - ✓ Simple epithelial tissues.
  - ✓ Stratified epithelial tissues.

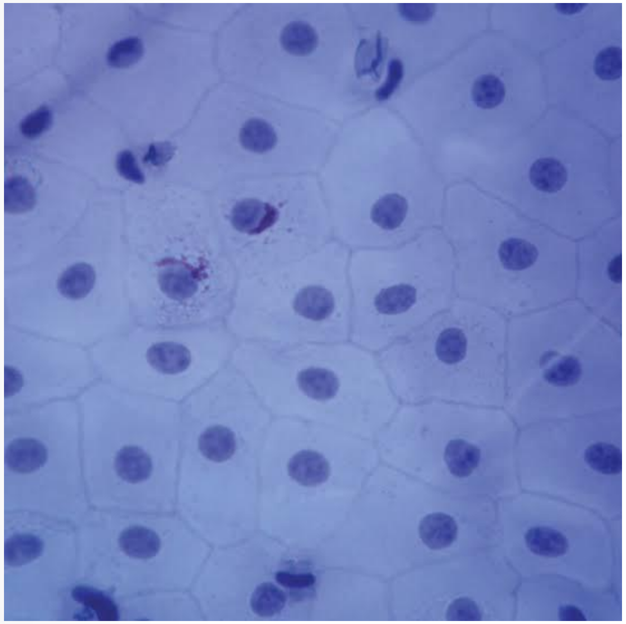
First: Simple epithelial tissues

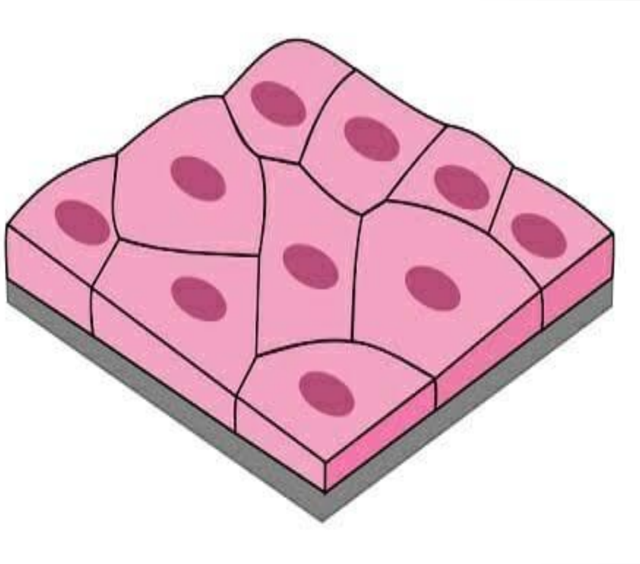
- They are composed of a single layer of cells, resting side by side on a basement membrane, and they are distinguished into several types according to the shape of the cells, as the following:

Squamous epithelium

- Their cells are flattened or disc shaped, with simple or winding edges. The cells appear spindle shaped in the cross section, each containing a nucleus in its wider midsection.
- This type of epithelial tissue is found in the inner lining of the Bowman's capsule in the kidney, and in the blood vessels, also it forms the outermost layer of the digestive tract.

Squamous epithelium

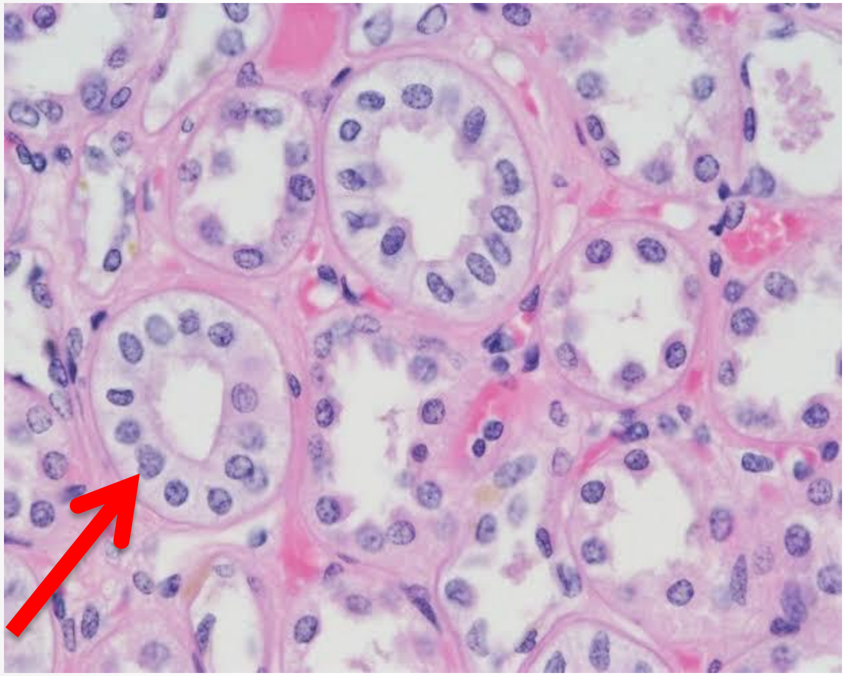


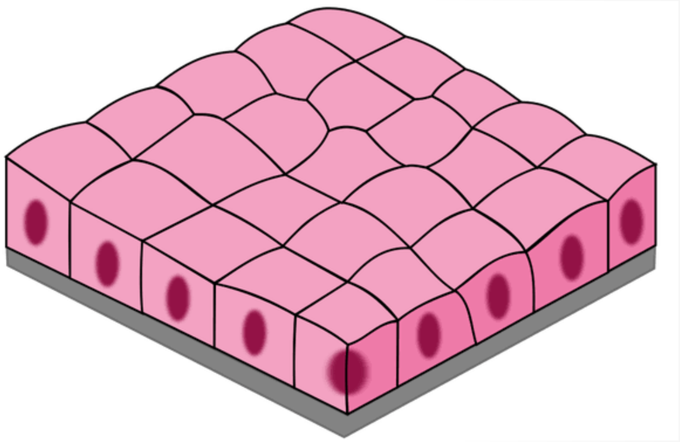


Cuboidal epithelium

- Their cells appear square in cross section, and each contains a central and round nucleus.
- Examples of this type are seen in the kidney tubules and bile ducts.

Cuboidal epithelium

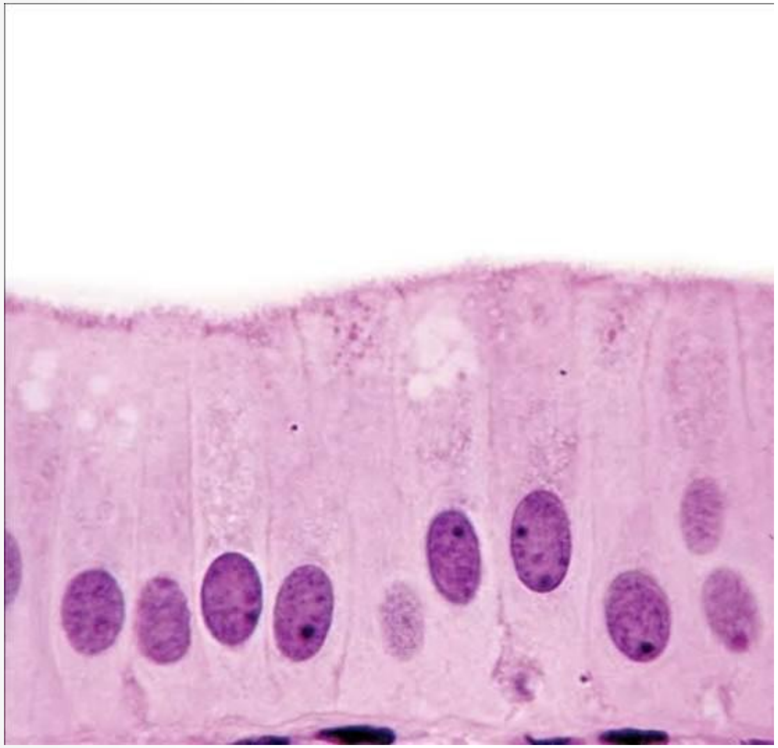


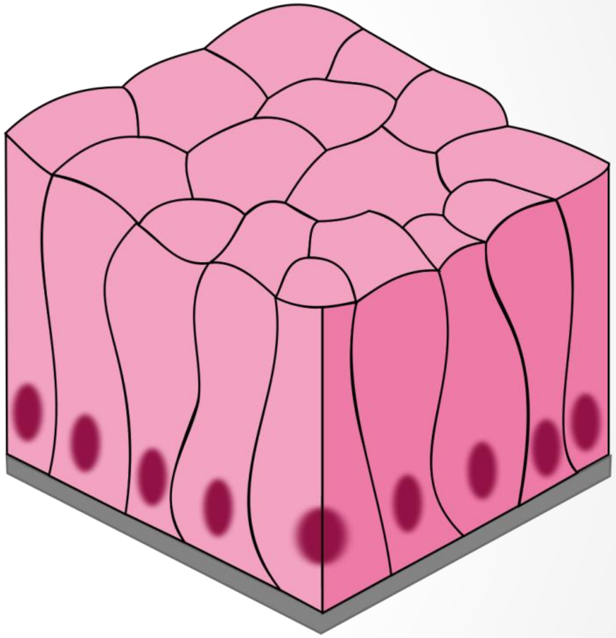


Columnar epithelium

- Formed of long columnar like cells, each contain oval-shaped nucleus runs parallel to the cell's longitudinal axis.
- This epithelial tissue lines the gastrointestinal tract in mammals, from the stomach to the rectum.

Columnar epithelium

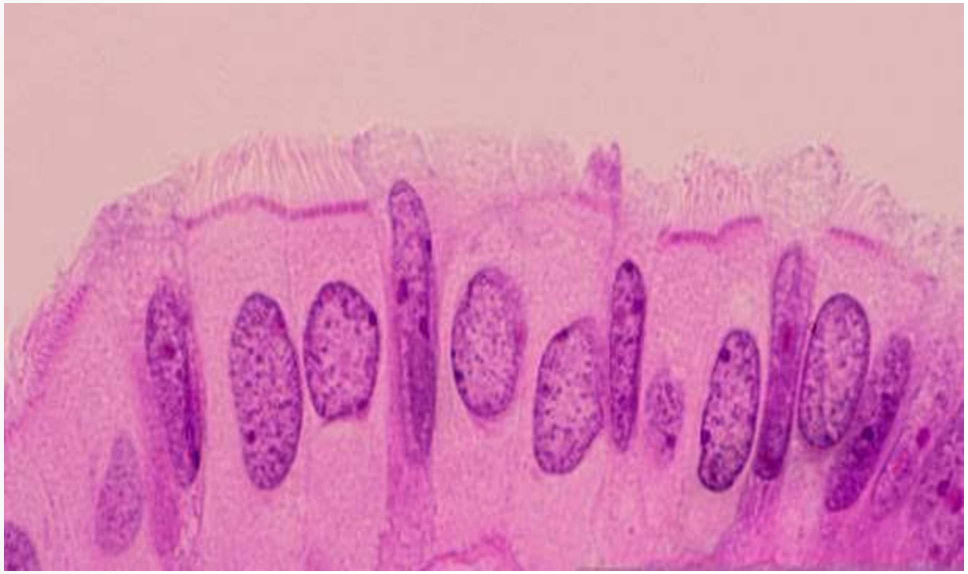


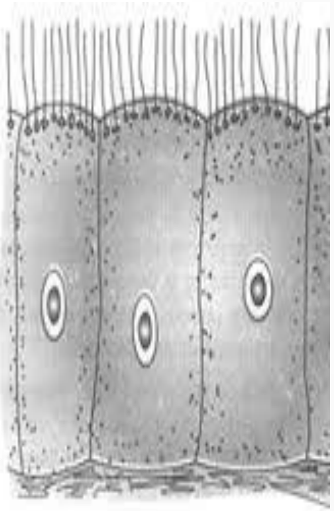


Ciliated columnar epithelium

- It consists of columnar cells whose free edges carry small, mobile protoplasmic growths known as cilia, these cilia strike regularly in one direction, thus creating a continuous stream of air or surrounding fluid, which helps in pushing nutrients into the intestine or in pushing other materials such as eggs through genital tracts.
- Examples of this type are found in the lining of the esophagus, lungs and the oviducts of the frog.

Ciliated columnar epithelium

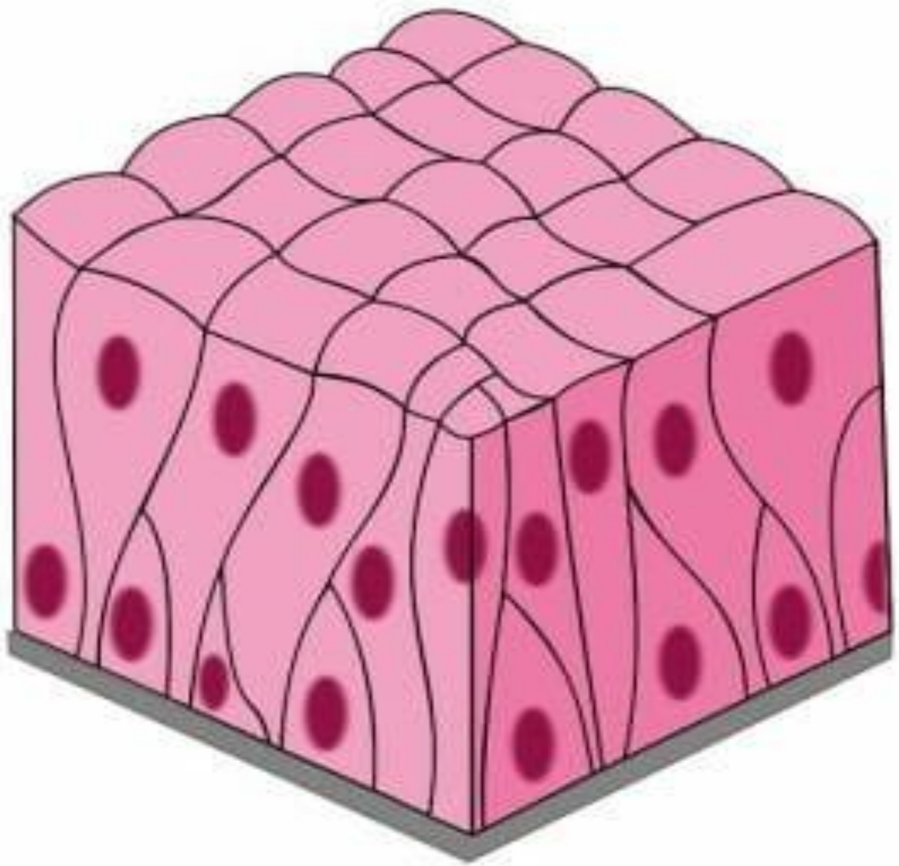




Pseudostratified epithelium

- These are composed of two types of cells, the first type is long cells with narrow inner end that rest on the basement membrane and wide outer end, while the second type has small conical cells that appear confined between the bases of the first type of cells and their outer pointed end does not extend to the surface of the epithelial layer. The nuclei of the first type are located at one level, while the nuclei of the second type are at another level. So the epithelial layer of this type appears to be composed of two layers of cells.
- Such epithelium lines some glands such as parotid gland.

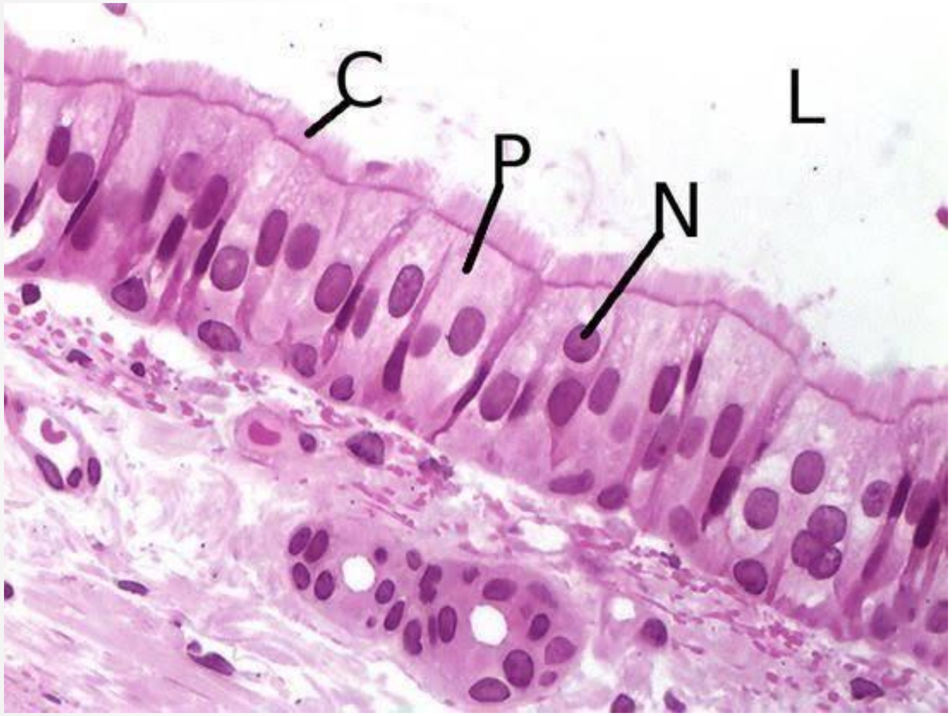
Pseudostratified epithelium

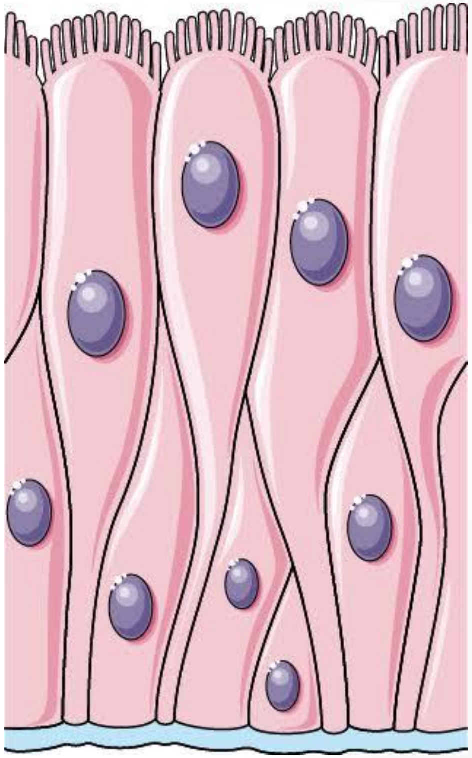


Ciliated pseudostratified epithelium

- Similar to the previous type, except that their long cells bear cilia on their free ends.
- This tissue lines trachea.

Ciliated pseudostratified epithelium





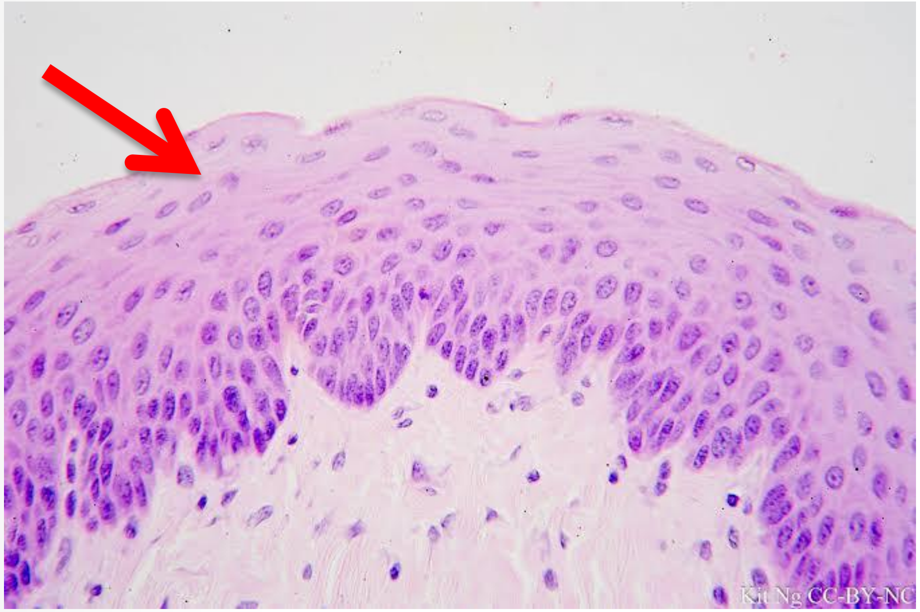
Second: Stratified epithelial tissues

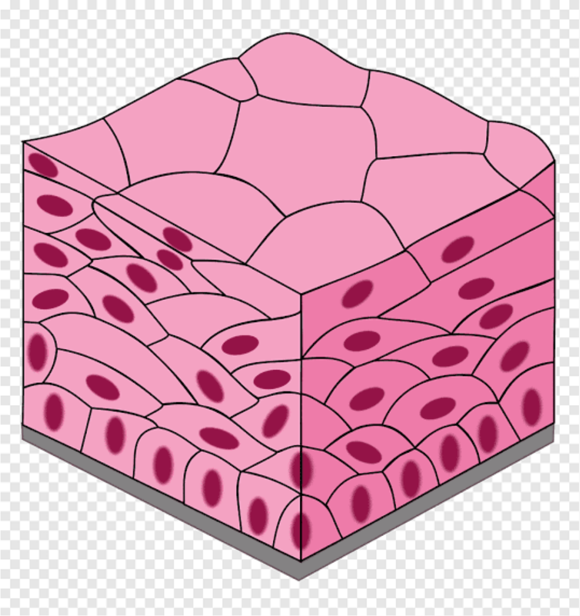
- Stratified epithelium tissue consists of more than one layer of cells, the inner of which rest on the basement membrane, and these tissues are classified into several types according to their shape and the structure of the outer layer of the cells, as the following:

Stratified squamous epithelium

- The lower layer is formed of short columnar or cubic cells and is known as the malpighyan layer.
- The cells of this layer continually divide to form new cells that push them toward the outer surface of the epithelium.
- These cells are initially round or polygonal, but they gradually compress as they move away from the malpighyan layer until they become flattened and due to their transfer away from the food source carried by the blood capillaries spread below the basement membrane, they die and form horny layer.
- It forms the skin epidermis in mammals, furthermore, it is found in the lining of the esophagus in mammals.

Stratified squamous epithelium





Stratified cuboidal epithelium

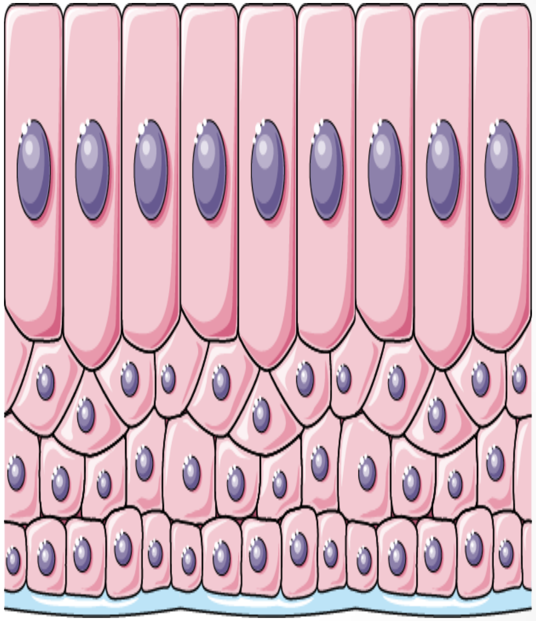
- The inner layer consists of short columnar cells, the upper or outer layer consists of cubic cells, and the layers bound between them are polygonal cells.
- This epithelium is present as lining of the frog's cloaca.
- Also, this type of epithelia lines the large excretory ducts of sweat and salivary glands.

Stratified cuboidal epithelium

Stratified columnar epithelium

- Similar to the previous type except that the outer layer is made up of columnar cells.
- It is found in the conjunctiva of the eye and in parts of the pharynx.

Stratified columnar epithelium



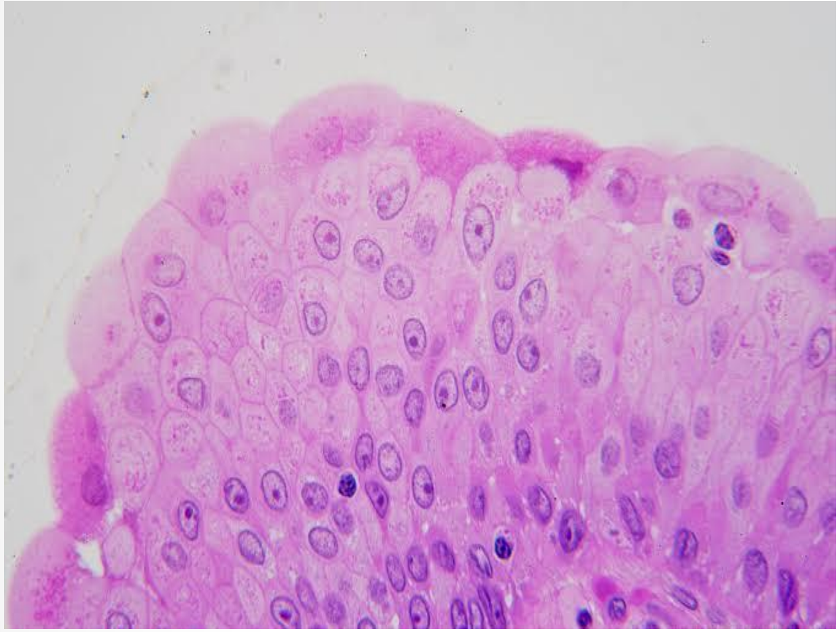
Stratified ciliated columnar epithelium

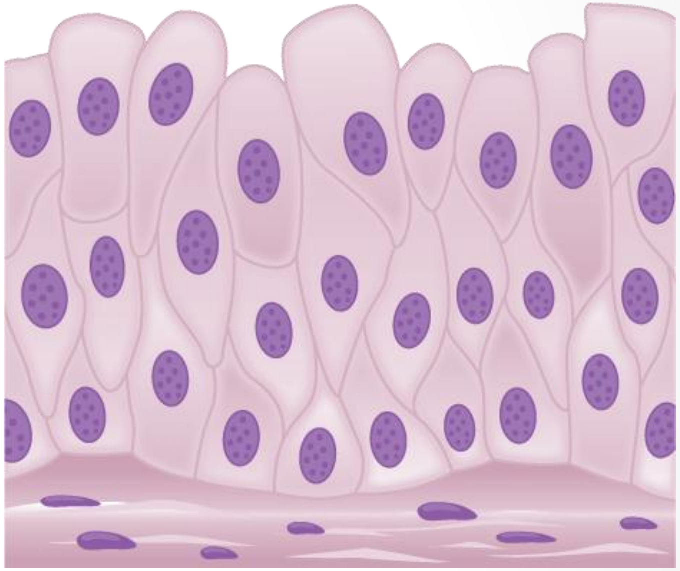
- It differs from the previous type only in the presence of cilia on the free edge of the cells of the outer layer.
- An example is the epithelium lining buccopharyngeal cavity of the toad.

Transitional epithelium

- This type of epithelium lines some organs that have flexible walls that allow them to expand and then return to their normal size.
- As in the urethra and urinary bladder.

Transitional epithelium





End of Lecture

Sixth Lecture

Epithelial Tissues

Classification of epithelial tissues according to their functions

First: Protective or covering epithelial tissue

- Its primary function is to cover and protect the body and its various organs.
- As the epithelium forming skin epidermis and the epithelium lining blood vessels.
- These tissues may secrete a substance known as cuticle, whose function is to protect the tissues that lie beneath them, as in earthworm skin.

Second: Sensory epithelial tissues

- The cells of these tissues receive stimuli and transfer them to nervous tissues.
- This type of epithelium is found in the skin, eyes, ears, and some other parts of the body.

Third: Germinal epithelial tissues

- It is the epithelium of gonads (testes and ovaries) that forms the gametes (sperms and eggs).

Fourth: Glandular or secretory epithelial tissues

- The cells of these tissues adapt to perform a glandular or secretory function.
- Form the glands that are divided into two types:
- ✓ Endocrine glands: They are glands without ducts. Its secretions from cells pass into the blood or lymph directly like adrenal gland and thyroid gland.
- ✓ Exocrine glands: It have ducts that transmit its secretions. These glands are distinguished into many types, which may be unicellular or multicellular.

Seventh Lecture

Connective Tissues

General characteristics of connective tissues

- These tissues arise from the mesoderm.
- Unlike epithelial tissues, it contains a large amount of an intercellular substance called matrix.
- They are never to be found on a surface, and their cells do not rest on a basement membrane

Classification of connective tissues

- Connective tissues are classified according to the nature of its matrix into:
- **First: Connective tissues proper:** the matrix is gelatinous.
- **Second: Skeletal connective tissues:** the matrix is solid or semi-solid.
- **Third: Vascular connective tissues:** the matrix is fluid.

First: Connective tissues proper

- These tissues are characterized by the presence of a large amount of matrix in addition to two types of fibers.
- It is found in almost all parts of the body.
- It includes the following types:

Areolar connective tissue

- This type is characterized by the presence of many gaps between its cells, which makes it have a reticulated appearance.
- This tissue forms the layer between the skin and muscles, and it connects muscles to each other.
- It is also found in the gut and many other parts of the body.

Areolar connective tissue

- This tissue contains different types of cells and two types of fibers as follows:

- **Fibrocytes:** secretory cells that form connective tissue fibers, these cells are elongated with pointed ends and each containing an oval nucleus.
- **Mast cells:** Large, ovoid cells with central round nuclei and many dark granules, these cells secrete the matrix of the connective tissue, it also secretes certain substances such as heparin, that prevent blood clotting inside the blood vessels, histamine, that is released in some types of allergies and causes widening of blood vessels, and serotonin that narrows blood vessels.

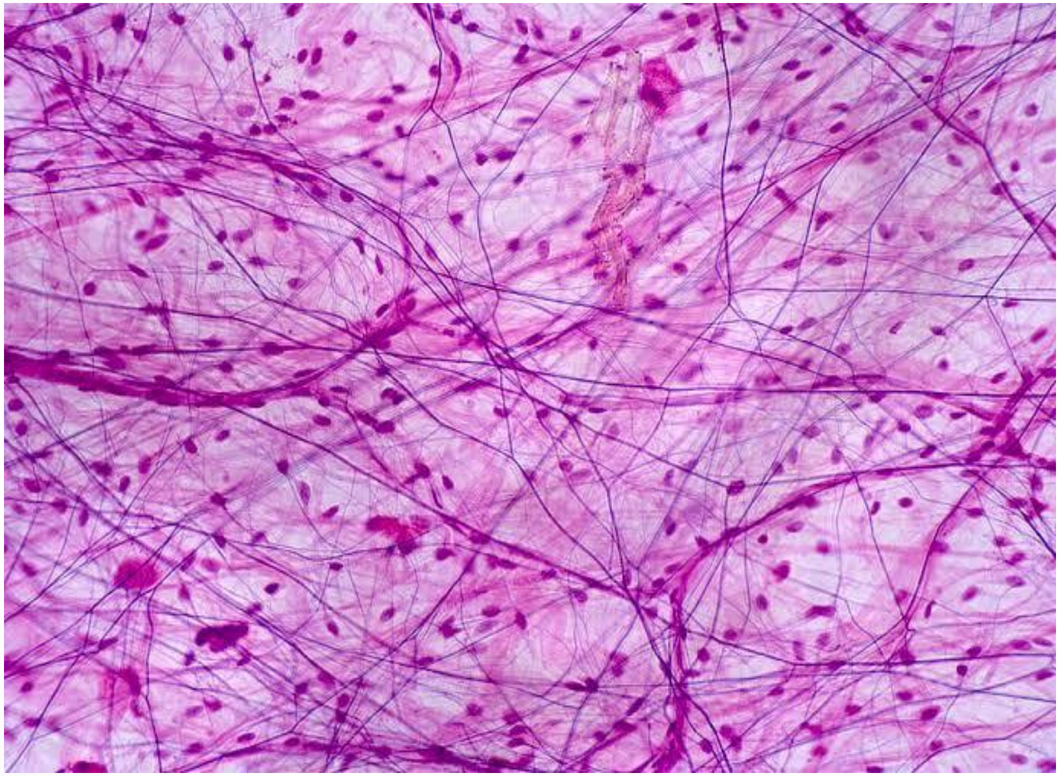
Areolar connective tissue

- **Macrophages:** irregular shaped amoebic cells with round nuclei, it has the ability to move inside the tissue with the help of pseudopodia, these cells protect the body from various diseases by devouring bacteria and other foreign substances.
- **White blood cells:** such as **eosinophils** that contain a nucleus with two small lobes and several cytoplasmic granules, and **lymphocytes** with smaller cells and round nuclei.
- **Plasma cells:** small cells have large eccentric nuclei, and it is believed that they play a role in the production of antibodies as they increase in number in some disease cases.

Areolar connective tissue

- **Fat cells:** fat substances are stored inside their cytoplasm, these substances initially appear as tiny fat droplets that gradually increase in size and then combine with each other into a large fat globule, as a result, the cytoplasm becomes confined in a thin, surrounding layer that lines the cell membrane, and pushes the nucleus to one side of the cell.
- **White collagenous fibres:** it is made up of a special protein known as collagen, they are found in large wavy bundles that branch and intertwine with each other, but the single fibers do not branch.
- **Yellow elastic fibres:** it is made up of another protein known as elastin, and it exists as single, straight fibers that branch and intertwine with each other.

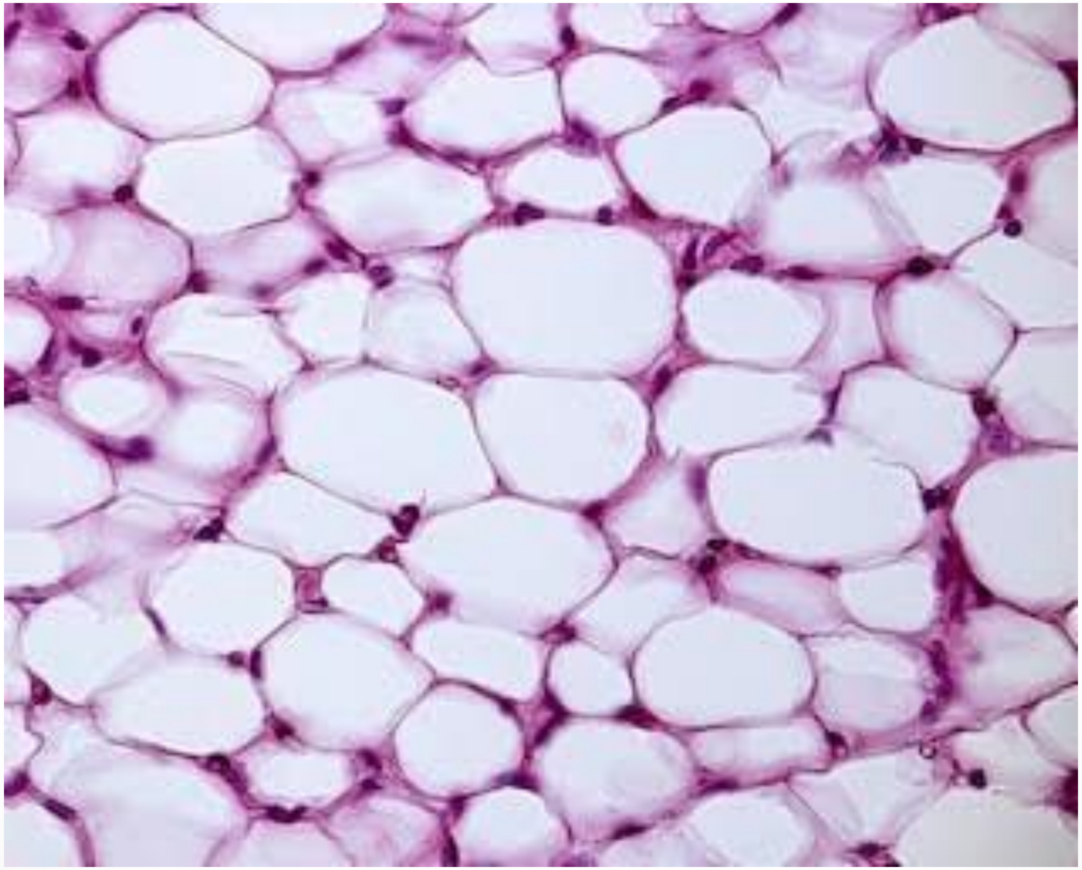
Areolar connective tissue



Adipose connective tissue

- This tissue is dominated by fat cells loaded with fat globules.
- This tissue can be found between bundles of muscle fibers and under the skin (subcutaneous fat).

Adipose connective tissue



End of Lecture

Eighth Lecture

Connective Tissues

Second: Skeletal tissues

- These tissues form the internal structure that is responsible for supporting the body and muscles attachment.
- Skeletal tissue includes bones and cartilages.

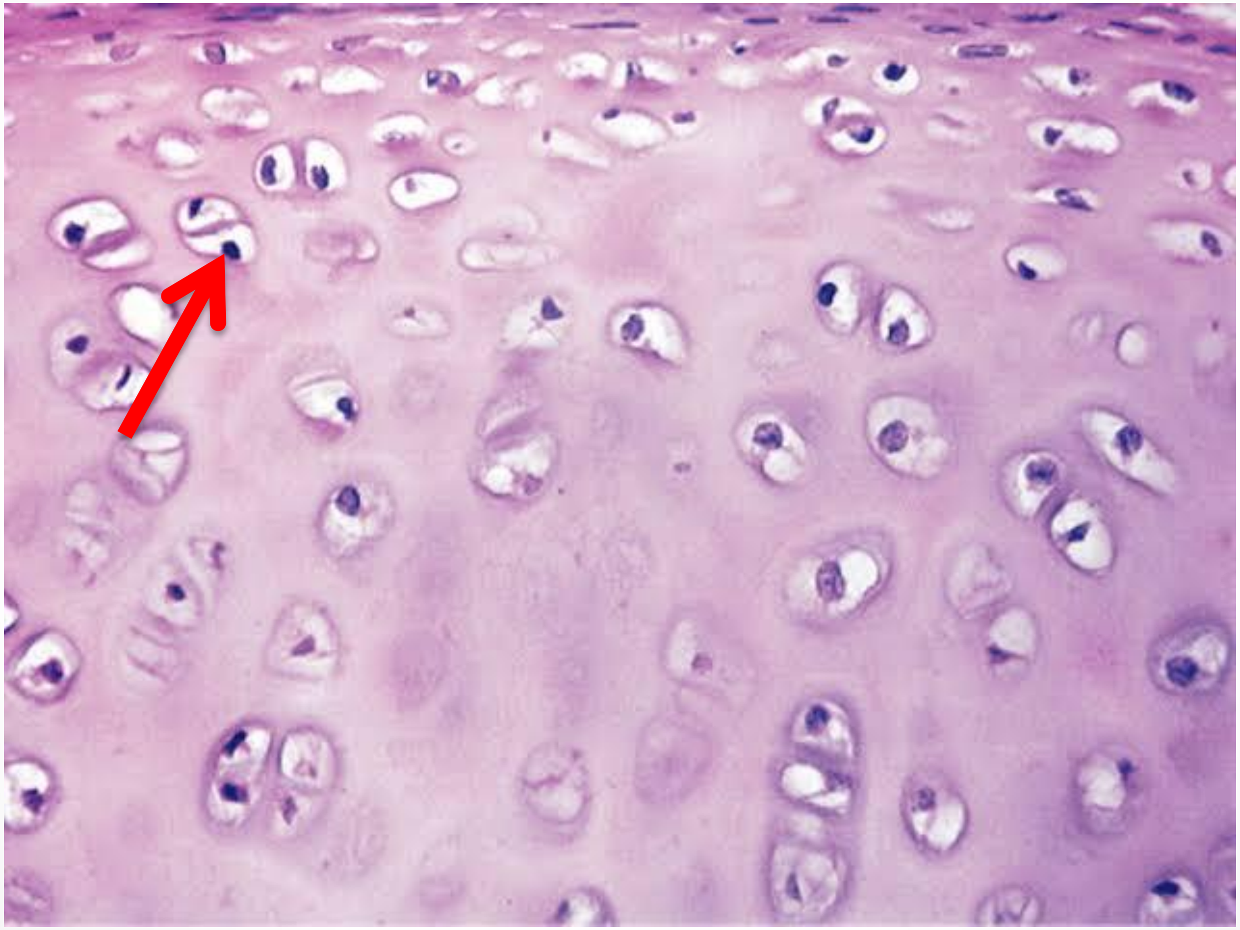
Cartilage

- Cartilage is a semi-solid, translucent connective tissue that is less rigid than bone.
- The cells that form this tissue are known as chondroblasts , which are large cells found within capsules, each capsule contains one, two or four cartilage cells.
- These cells secrete the tissue matrix that is called chondrin.
- The entire cartilage tissue is surrounded externally by a thin membrane of connective tissue known as perichondrium that is rich in capillaries that nourish cartilage cells.
- Several types are known from cartilage tissues, depending on the type of fibers and the nature of matrix:

Hyaline cartilage

- In this cartilage, the matrix is clear and contains no fibers.
- This type of cartilage is found in the trachea and at the ends of long bones, it protects the bones from being eroded by friction, moreover, the skeleton of an embryo is mainly composed of hyaline cartilage.

Hyaline cartilage



Bone

- Bone is one of the hardest tissues in the body. It is made up of bone cells and matrix from both organic and inorganic materials.
- The hardness of the bone is due to the presence of inorganic salts, the most important of which is calcium phosphate, which is deposited within the matrix.
- Two types of bone are known, compact bone and spongy bone.

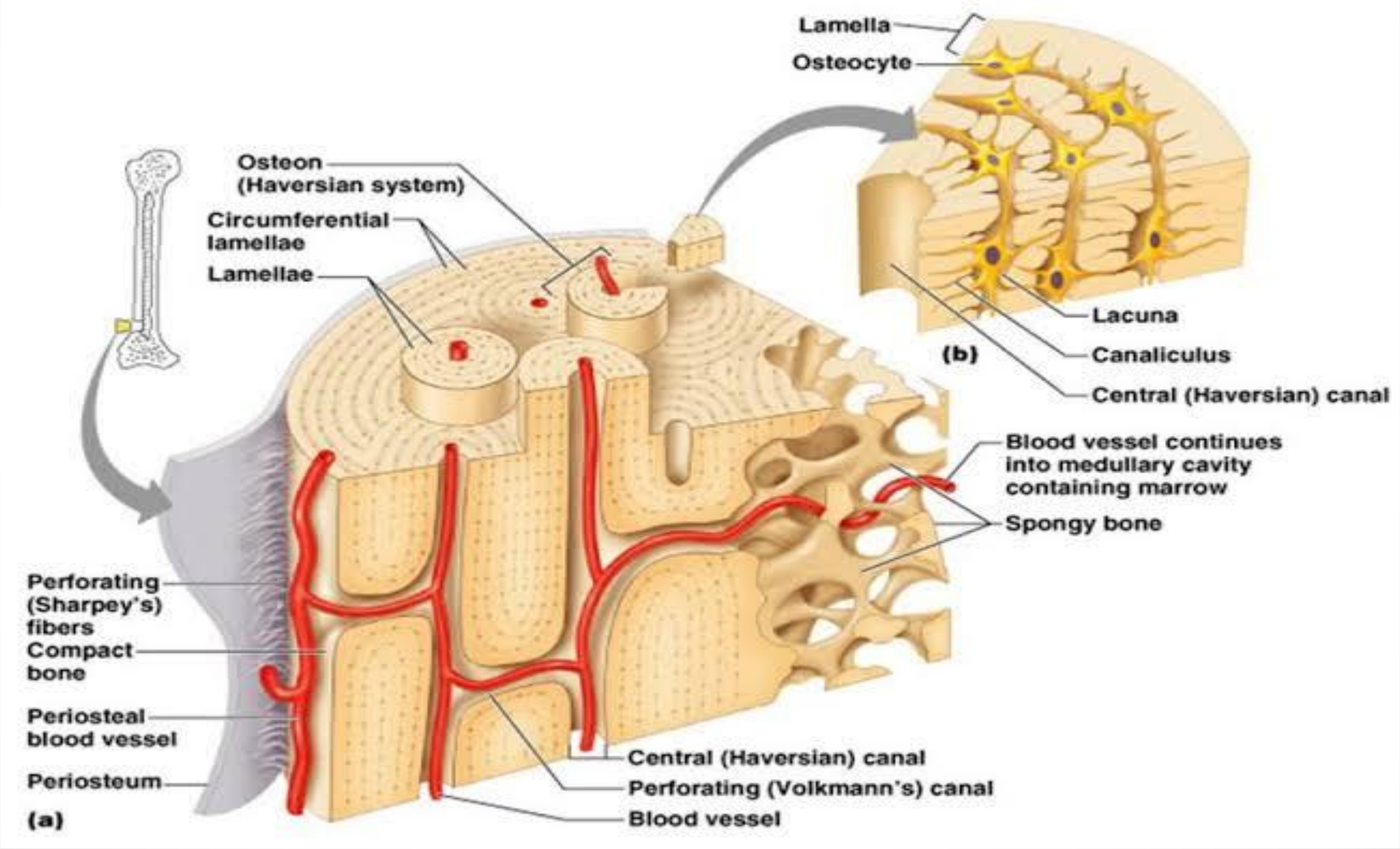
Compact bone

- In its cross section under a microscope, it appears to be made up of circular structures known as Haversian systems.
- Each system consists of a Haversian canal, which is a medial canal surrounded by thin, central sheets of bone material known as bone lamellae.
- The osteocytes that make up bone are arranged between these sheets and within spindle vacuoles known as lacunae.
- Osteocytes are connected to each other by many thin appendages that run into narrow spaces known as canaliculi.

Compact bone

- This system helps in transporting nutrients from Haversian canals, through which capillaries run, to osteocytes.
- Haversian canals are connected to each other by transverse and oblique branches.
- Among adjacent Haversian systems, some bone lamellae and osteocytes appear to be not organized around the Haversian canals forming what are known as non-Haversian systems.

Compact bone



Third: Vascular tissues

- These are the fluid connective tissues that are known as vascular tissues.
- Include blood and lymph.

Blood

- Blood is a form of connective tissue. Its liquid matrix known as plasma that contains blood cells and some tiny fusiform bodies called blood platelets.
- Blood cells are divided into two types, red blood cells and white blood cells.

Red blood cells (Erythrocytes)

- The red color is due to an iron-containing pigment known as hemoglobin.
- Each red blood cell is coated with a thin, flexible membrane that facilitates its passage into narrow capillaries.
- Red blood cells contain nuclei as in fish, reptiles, and birds, whereas in mammals, they have no nuclei that only appear in the early stages, and then gradually dissolve afterwards until they disappear completely in the fully formed cells.

Red blood cells (Erythrocytes)

- Due to the absence of nuclei, they do not survive except for a short time (15-17 weeks), after which they pass to the spleen, where they are destroyed and iron and some pigment materials are left behind. Interestingly, the spleen retains iron, and the pigment is used by the liver to produce bile.
- In mammalian embryos, red blood cells are formed first in the liver and then in the spleen, and in the later stages of pregnancy, the bone marrow begins to participate in this process until it becomes the only place for blood formation where newly formed red blood cells pass into the blood in order to replace the constantly dissolving cells.

Red blood cells (Erythrocytes)

White blood cells (Leukocytes)

- Their numbers are lower than red blood cells.
- They differ from red blood cells in that they have nuclei throughout their lifetime and are free of hemoglobin.
- Some white blood cells are known as macrophages that can devour bacteria and other foreign substances that enter the body.
- White blood cells are classified into two groups according to the presence or absence of granules in the cytoplasm within them.

White blood cells (Leukocytes)

- **First: Agranulocytes:** they are formed in the lymph nodes and do not contain cytoplasmic granules, they include two types:
- ✓ A) **Monocytes:** Relatively large cells, each containing a small horseshoe-shaped nucleus, and around them there is a large space that is filled with cytoplasm.
- ✓ B) **Lymphocytes:** They are small cells, each with a large nucleus surrounded by a narrow space of the cytoplasm.

White blood cells (Leukocytes)

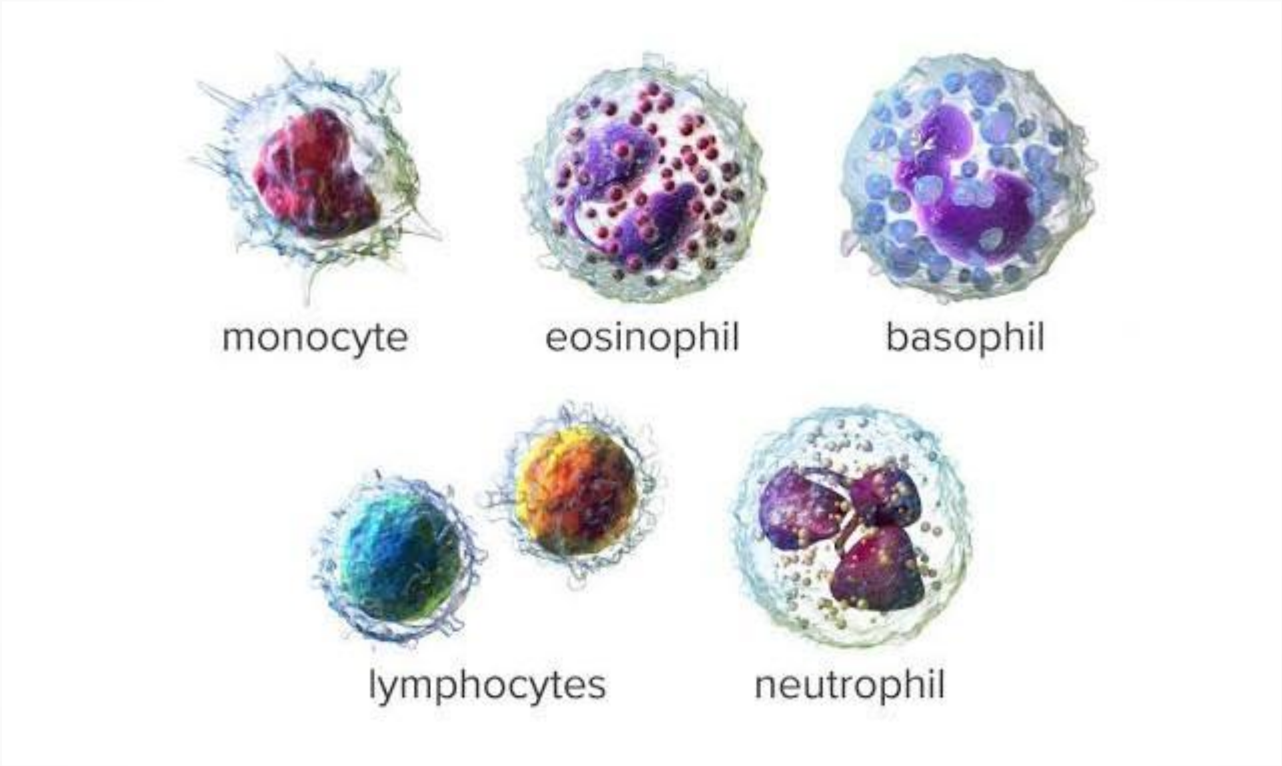
- **Second: Granulocytes:**

✓ A) **Eosinophils:** have acidophilic granules that are stained with acid dyes. The nucleus is divided into 2-3 lobes.

✓ B) **Basophils:** have basophilic granules that are stained with basic dyes. The nucleus is S-shaped.

✓ C) **Neutrophils:** their granules are stained with most dyes (acid and basic dyes). The nucleus consists of several (3-5) lobes. They are known also as polymorphonuclear leukocytes.

White blood cells (Leukocytes)



Blood platelets

- These are tiny, spindle shaped bodies produced by special cells found in the bone marrow known as megakaryocytes.
- When these platelets are exposed to air, they break down and release a substance known as thrombokinase or thromboplastin, which plays an essential role in the process of blood clotting.

Blood plasma

- A pale yellow liquid consisting of 90% water and 10% of the following:
  - ✓ Some inorganic materials such as calcium bicarbonate and potassium bicarbonate.
  - ✓ Some of digestion process metabolites, such as glucose, amino acids, and fatty acids.
  - ✓ Some proteins such as fibrinogen, albumin, and globulin.
  - ✓ Some of hormones and waste products.

Blood functions

- 1- It transports digested nutrients from digestive system to different parts of the body.
- 2- It performs an important respiratory function, as hemoglobin in red blood cells binds with oxygen in the lungs to form an unstable compound known as oxyhemoglobin and this compound is broken down in body tissues where cells obtain oxygen from it, while carbon dioxide exits from cells in the form of carbonic acid, that is dissolved in the blood plasma and expelled outside the body.
- 3- It transfers hormones from endocrine glands to various body organs.

Blood functions

- 4- It transports various salts needed to keep cells in a balanced physiological state.
- 5- It carries excretory wastes from different tissues to the excretory organs, as kidneys, the get rid of these wastes.
- 6- It protects the body from infection and diseases with the help of white blood cells that devour foreign bodies and produce antitoxins.
- 7- It preserves the temperature of humans and warm-blooded animals at a constant level by distributing thermal energy, thus it maintains the occurrence of vital processes in the body at a constant rate all the time regardless of the thermal fluctuations that may occur in the surrounding environment.

End of Lecture

Ninth Lecture

Muscular Tissues

- Muscular tissue is responsible for securing the movement of the organism and the movement of its various parts such as intestine movement, respiratory movements, and blood movement inside the blood vessels, and this is done through the contraction of muscle cells (muscle fibers) that form the tissue.

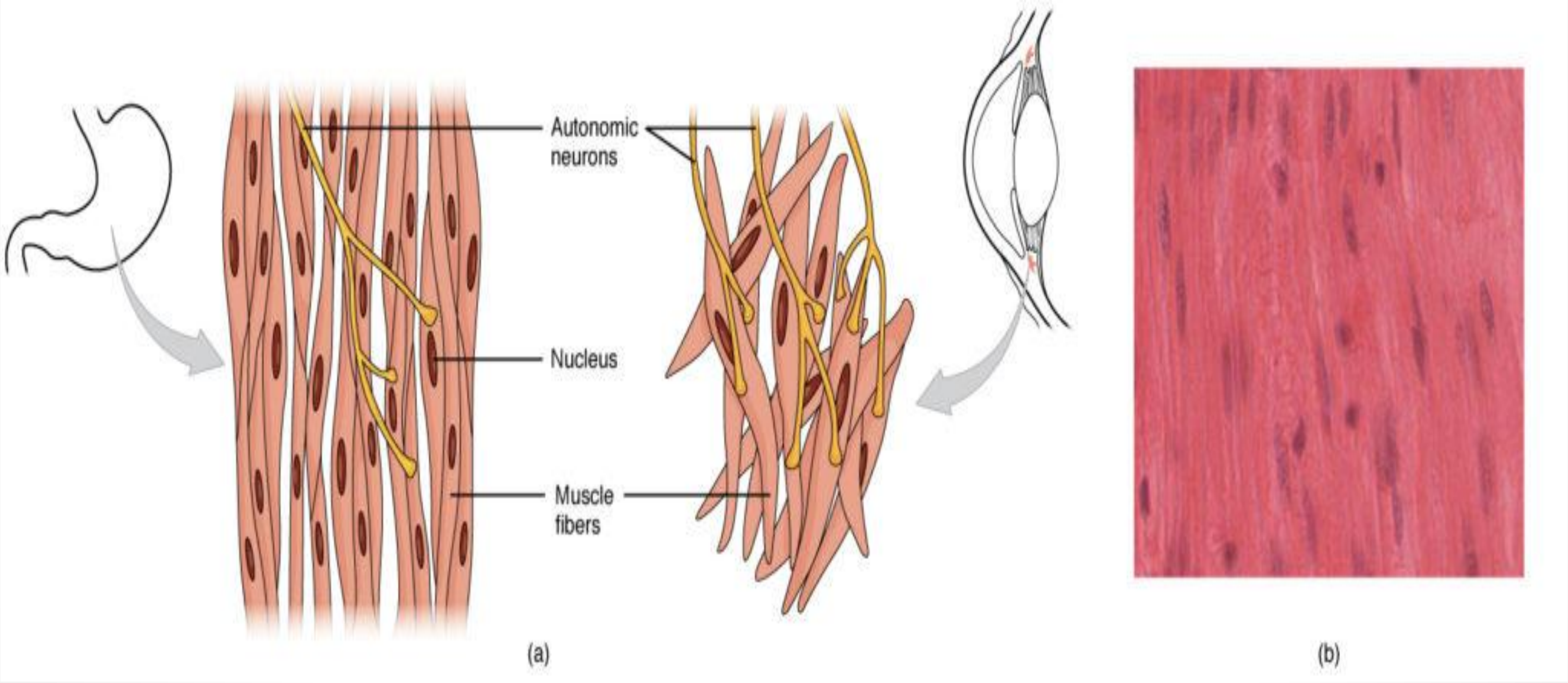
Types of muscles

- According to their physical and functional properties, muscles are divided into two types:
- A) **Smooth muscles**: that are involuntary muscles.
- B) **Striated muscles**: that are functionally divided into two types:
- 1- **Skeletal striated muscles**: voluntary muscles.
- 2- **Cardiac striated muscles**: involuntary muscles.

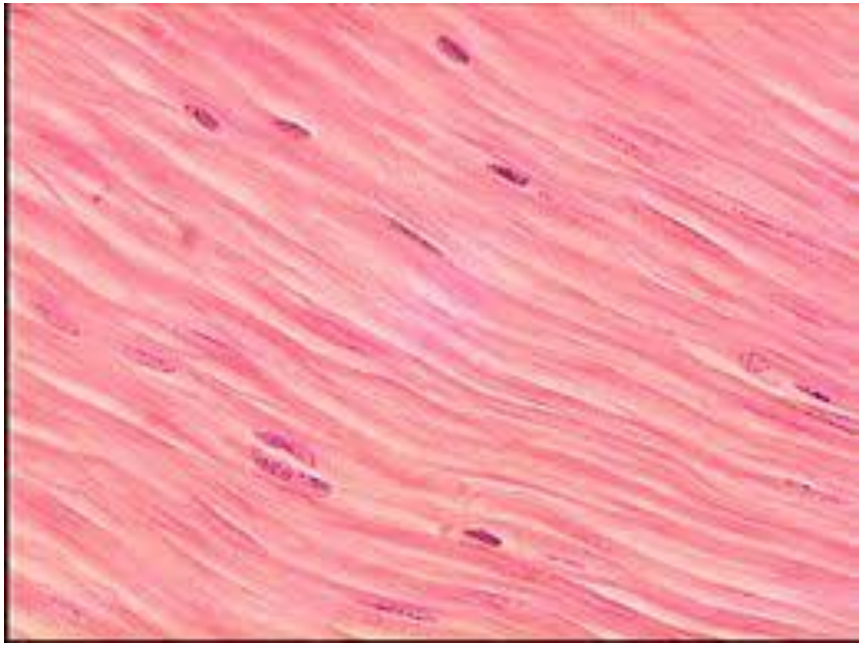
Smooth muscles

- They are called non-striated, visceral, or involuntary muscles.
- Its fibers are characterized by being spindle shaped with a medial nucleus, devoid of transverse striations, and equipped with autonomic nerve fibers.
- Muscle fibers appear in different shapes, longitudinal, circular, or both.
- They are found in the walls of internal or visceral organs such as the stomach, intestine, bladder, and blood vessels.

Smooth muscles



Smooth muscles



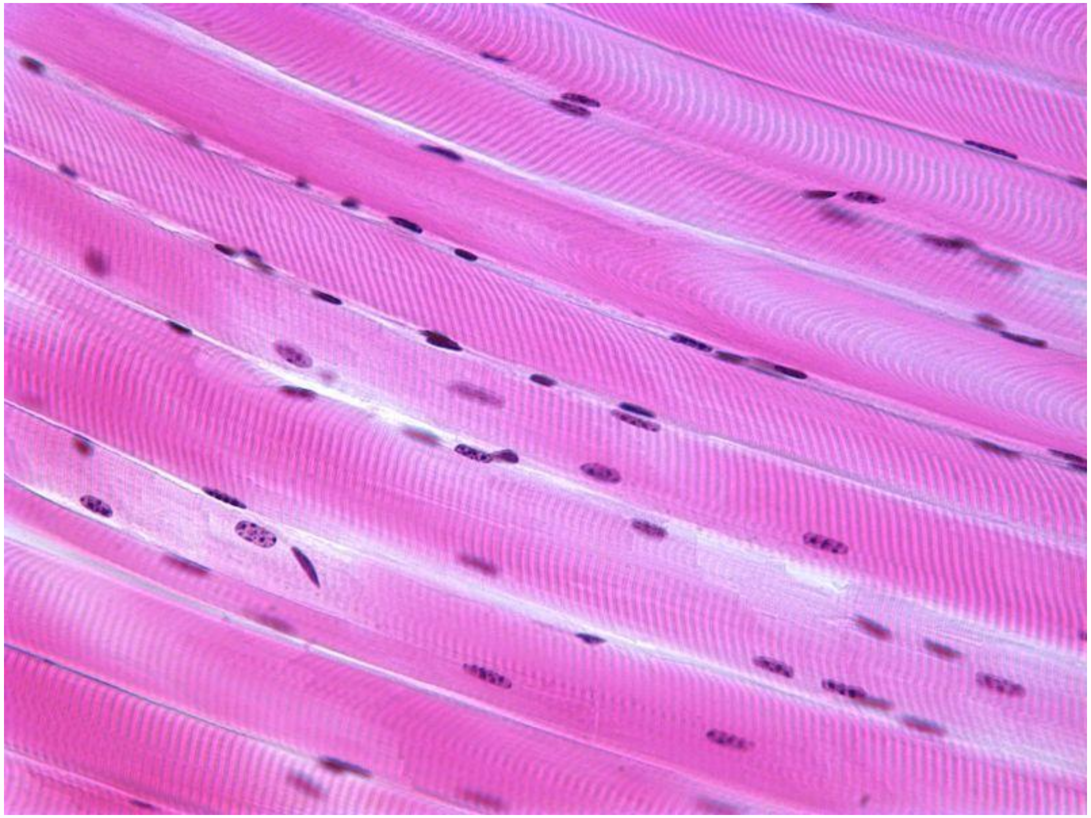
Striated muscles

- The striated muscle tissue is characterized by dark and lighter transverse bands, and is made up of elongated, usually multinucleated fibers, including skeletal muscles and cardiac muscles.

First: Skeletal striated muscles

- They are called skeletal muscles, due to their connection to the skeletal system.
- They are also called red muscles because they are rich in myoglobin, which gives it the red color.
- They are voluntary striated muscles, which undergo the control of the organism.
- Their fibers are cylindrical multinucleated and supplied with somatic nerve fibers.
- They are found in many parts of the body such as muscles of face, mouth, tongue and pharynx.

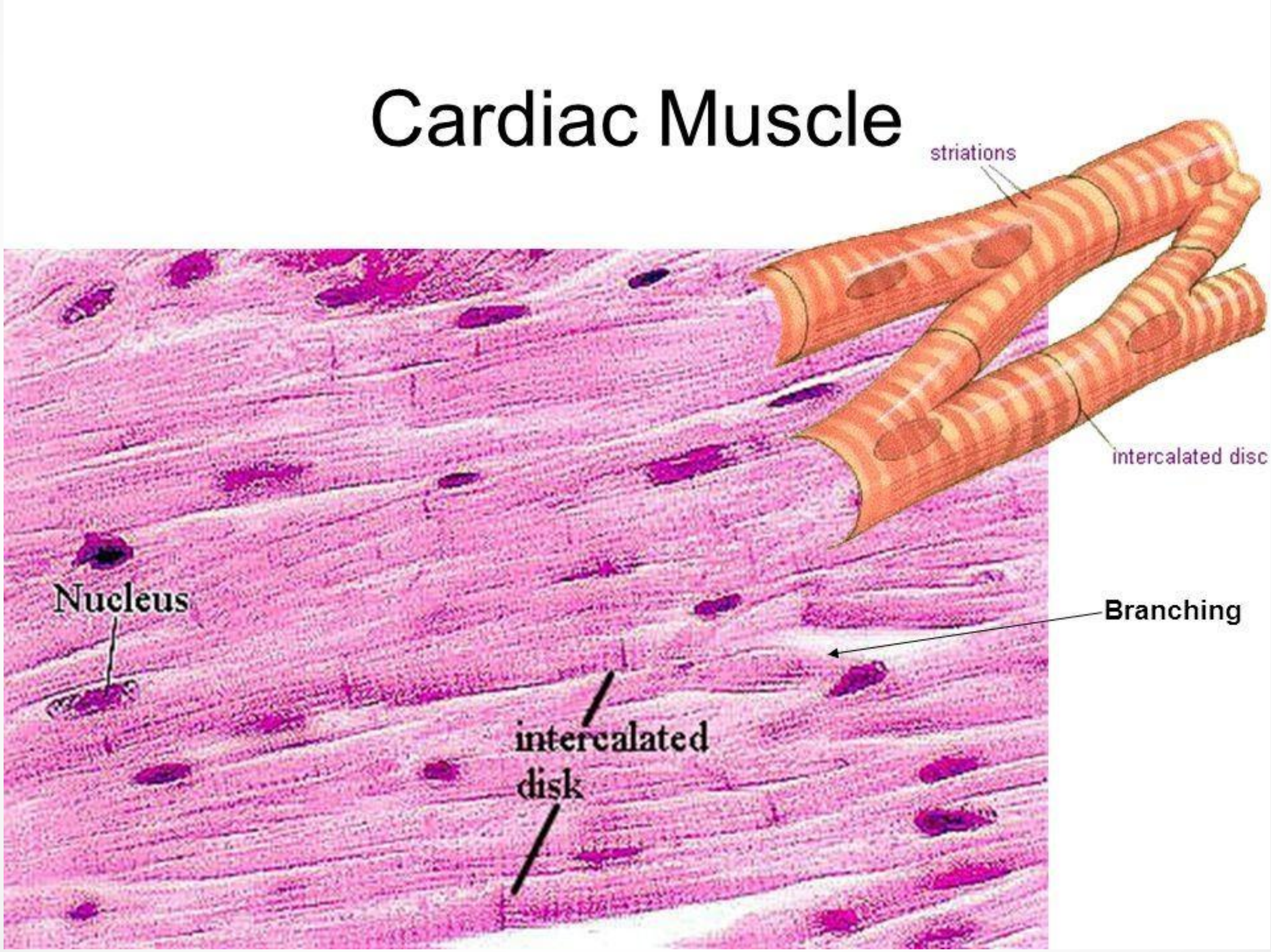
Skeletal striated muscles

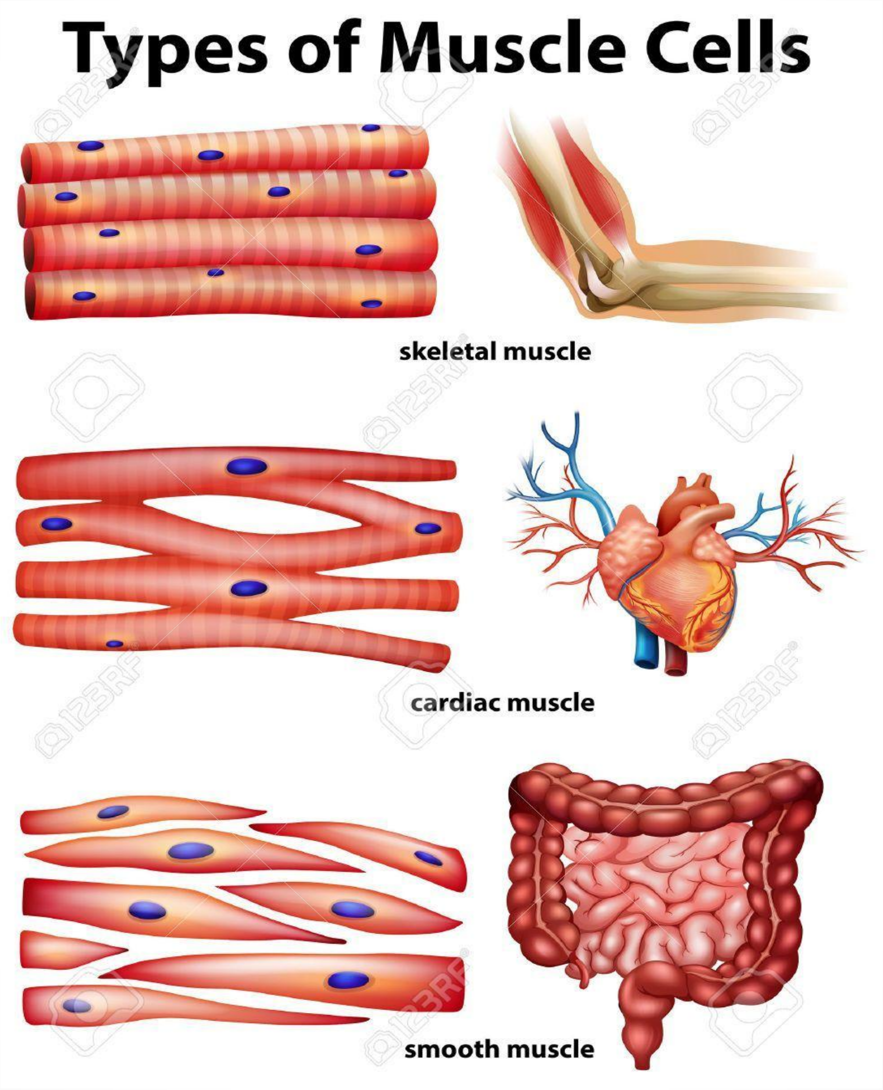


Second: Cardiac striated muscles

- The heart consists of striated muscle fibers that contract both systemically and involuntarily as they are supplied with autonomic nerve fibers.
- The fibers show striations, but it is not as clear as that of skeletal muscle fibers. These fibers branch and intertwine with each other.
- Each muscle cell has one nucleus and sometimes two large oval nuclei, and the nuclei are located at the center in an abundance of sarcoplasm.
- Muscle cells are connected to each other at sites called intercalated discs.
- The spaces between cells are filled with connective tissue that contains many blood and lymphatic vessels.

Cardiac striated muscles





Types of Muscle Cells
skeletal muscle
cardiac muscle
smooth muscle

End of Lecture

Tenth Lecture

Nervous Tissues

- Generally, nervous tissues represent the structural basis of the nervous system.
- Nervous tissues are responsible for receiving internal and external stimuli and sending appropriate responses.

Nerve Cell (Neuron)

- A neuron is the basic anatomical and functional unit of the nervous system that varies in size and shape.
- A ratio of 90% of it is found in the brain and the remained ratio in the rest of the central and peripheral nervous system.
- Neurons do not divide or regenerate, and what is destroyed from them is not replaced, just as a person loses them gradually as he ages.

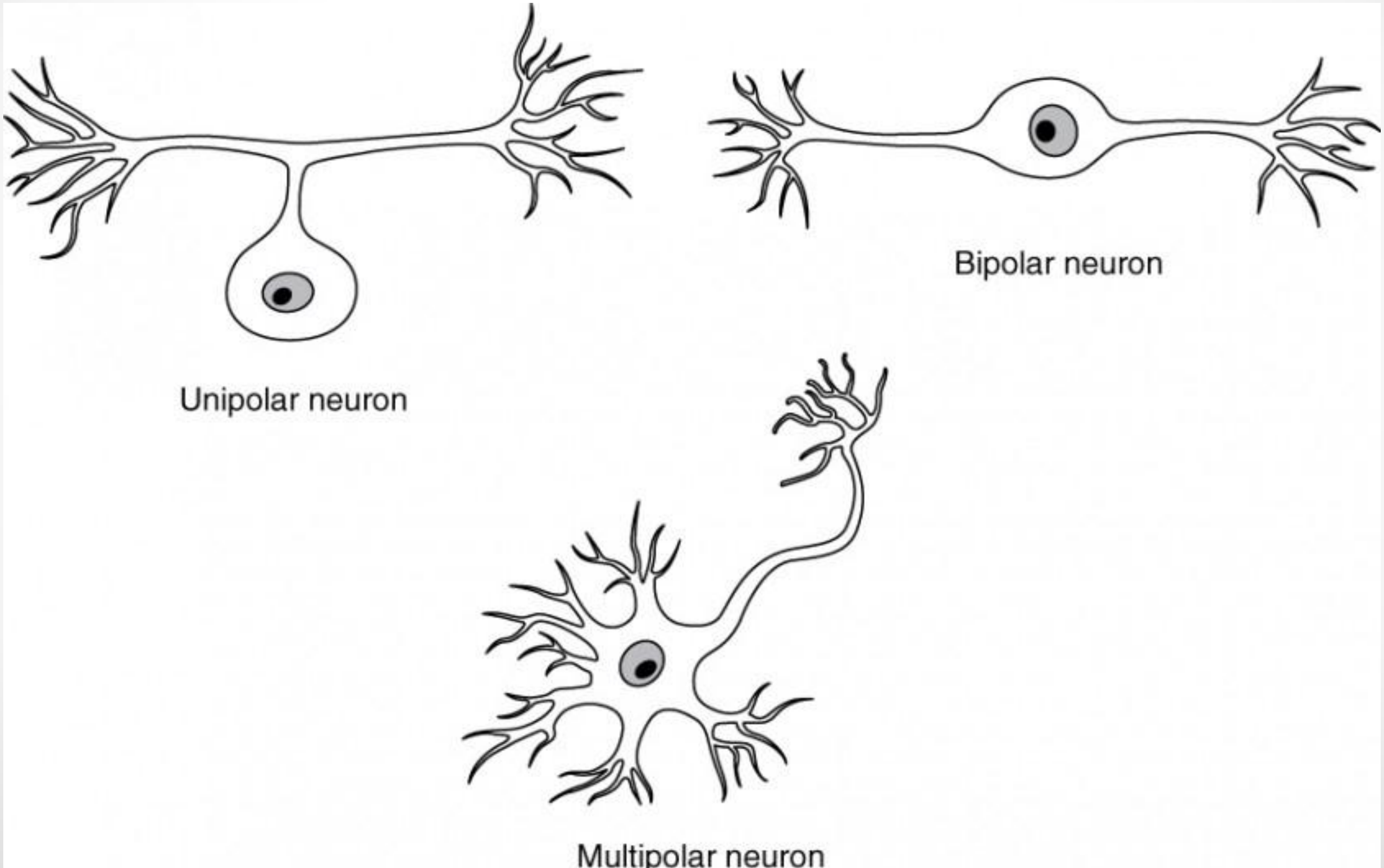
Structure of nervous tissues

- Nervous tissues are distinguished into two types of cells:
- ✓ Neurons: that receive, transmit and send nerve stimuli.
- ✓ Glial cells: that connect neurons to each other, and work to protect, support and provide them with necessary food so as neurons can perform their functions. Glial cells surround neuron and are located either between neurons and each other, between neurons and blood vessels, or between neurons and brain surface.

Types of neurons

- 1- Unipolar: they are cells with a single axon that is branched into two axons, and usually found in the spinal nerve ganglia in the spinal cord.
- 2- Bipolar: each have one cell body from which two appendages emerge, one of which is dendrite and the other is the axon. This type is found in retina.
- 3- Multipolar: where cell body is polygonal and many dendritic appendages emerge from it, as well as the cell axon. They are the most widespread type, especially in the brain and spinal cord.

Types of neurons



Structure of neuron

- ➢ A neuron is composed of two main parts:
- ✓ 1) Cell body.
- ✓ 2) Axon.
- ➢ The cell body is a fusiform, round, or polygonal body that contains a round central nucleus surrounded by the cytoplasm that fills the lumen of the cell body.

Structure of neuron

- Dendrites extend from the cell body towards outside, they receive signals and send them to the cell body, thus, these dendrites are named the receiving part.
- The cell axon is a long extension of the cell body terminating in a group of branches called axon terminals that make synapses with the dendrites of another cell.

Structure of neuron

- The axon is sometimes not covered or covered by a very complex fatty chemical substance called myelin sheath, this coating gives the nerves a white color, and is surrounded externally by a thin membrane called neurilemma.
- This coating performs electrical insulation function to prevent the leakage of nerve emissions that flow through the axon in the form of weak electrical charges, moreover, it also maintains the axon integrity and vitality.

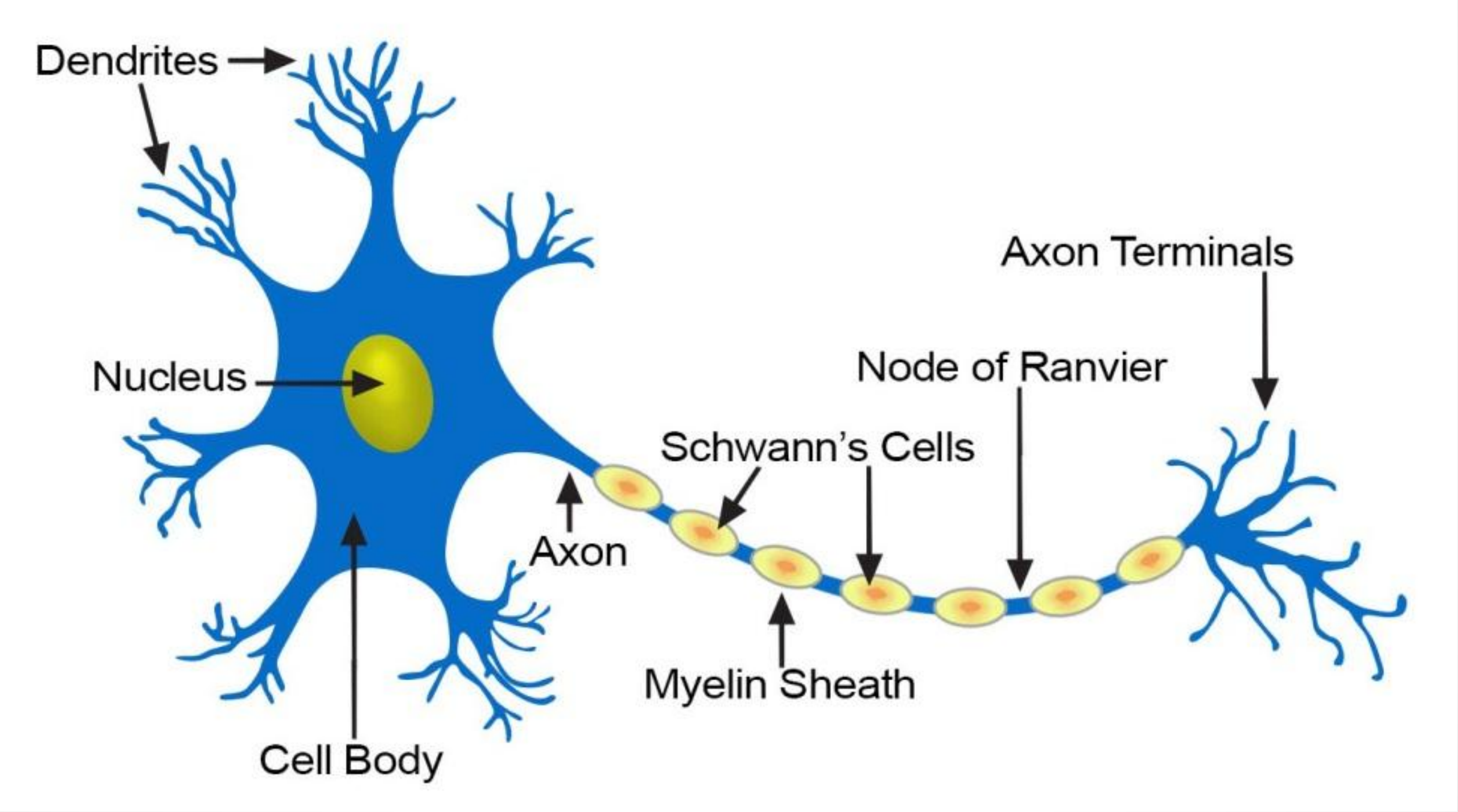
Structure of neuron

- Secreting of myelin sheath is performed by Schwann cells.
- Myelin sheath extends along the axon of the neuron, although in its path there are some constrictions that form the so-called Ranvier nodes relative to its discoverer.

Structure of neuron

- The axon is the part that transmits or conducts nerve signals from the body of the neuron to the outside, as it carries these signals to the receiving part or dendrites of another cell, and this process takes place at the end of the axon when it joins these dendrites at synapses, or when it joins an organ fed by a nerve, as occurs when nerves join muscles in an area called the motor end plate.

Structure of neuron



مقرر علم الاجنـة

Embryology

الفرقة الاولى للعلوم البيولوجية –ساعات معتمده

استاذ المقرر

د/ عبيـــــــده فــــوزى

قسم علم الحيوان – كلية العلوم

العام الجامعى

٢٠٢٣/ ٢٠٢٤

Introduction

- Human development is a continuous process that begins when an oocyte (ovum) from a female is fertilized by a sperm (spermatozoon) from a male.
- Cell division, cell migration, programmed cell death (apoptosis), differentiation, growth, and cell rearrangement transform the fertilized oocyte, a highly specialized, totipotent cell, a zygote, into a multicellular human being.
- Most changes occur during the embryonic and fetal periods; however, important changes also occur during later periods of development.
- The field of study which includes investigations of the molecular, cellular, and structural factors contributing to the formation of an organism is called embryology.
- It is a branch of science that is related to the formation, growth, and development of an embryo.
- It mostly deals with the prenatal stage of development beginning from the formation of gametes, fertilization, the formation of a zygote, development of embryo and fetus to the birth of a new individual.

Definitions of Embryology

- Embryology is a branch of science that is related to the fertilization, formation, growth, and development of embryo. In mammals, it deals with the prenatal stage of development beginning from formation of gametes, fertilization, formation of zygote, development of embryo and fetus to the birth of a new individual.

Embryology is the study of the early development of living organisms till it reaches to adult form.

All animals and insects can reproduce new individuals to ensure the survival of their kind.

A Brief History of Embryology

The theory of preformationism

- ✓ Early embryology was proposed by Marcello Malpighi, and known as **preformationism**, a theory held that the generation of offspring occurs as a result of an unfolding and growth of preformed parts. There were two competing models of preformationism: **the ovism model**, in which the location of these preformed parts prior to gestation was the maternal egg, and the **spermism model**, in which a preformed individual or homunculus was thought to exist in the head of each sperm.
- ✓ Preformationism was the first theory of generation and development that applied to all organisms in the plant and animal kingdoms.
- ✓ The theory of preformation gained much traction before the invention of microscopes and more advanced imaging techniques.
- ✓ The theory also suggested women were simply vessels to carry the growing child, and that girls came from the left testicle, while boys came from the right.

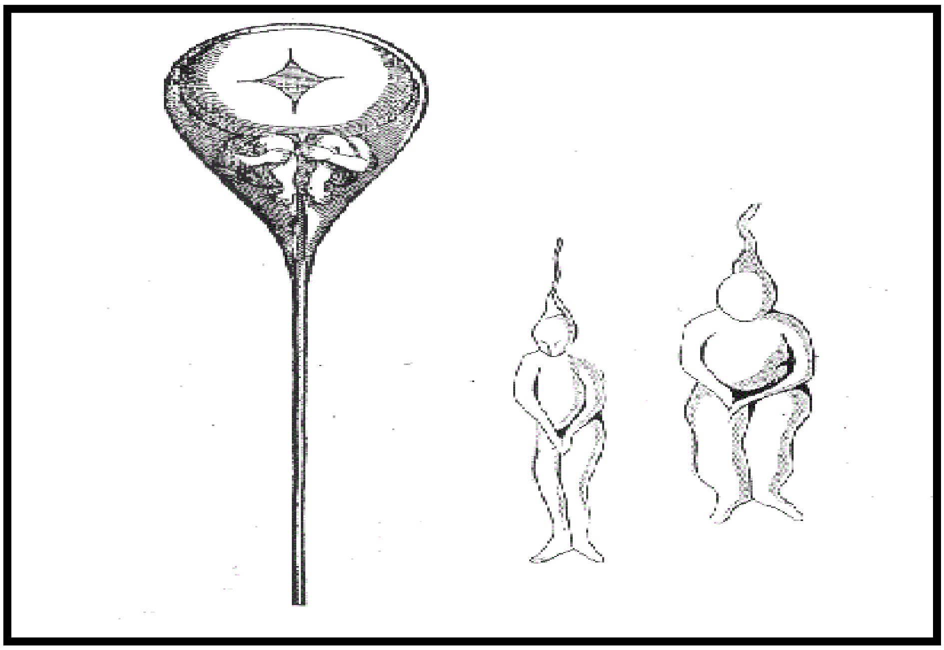
The theory of epigenesis

- ✓ Aristotle first proposed the correct mechanism for the development of an embryo, without having a microscope to observe his theory.

✓ He suggested that animals form through the process of epigenesis, in which a single cell divides and differentiates into the many tissues and organs of an animal.

✓ It wasn't until 1827 that clear evidence was obtained that female mammals also produce a sex cell, the ovum.

✓ The discovery of a female sex cell directly contradicted many aspects of the preformation theory and led to wider acceptance of the epigenesis theory.

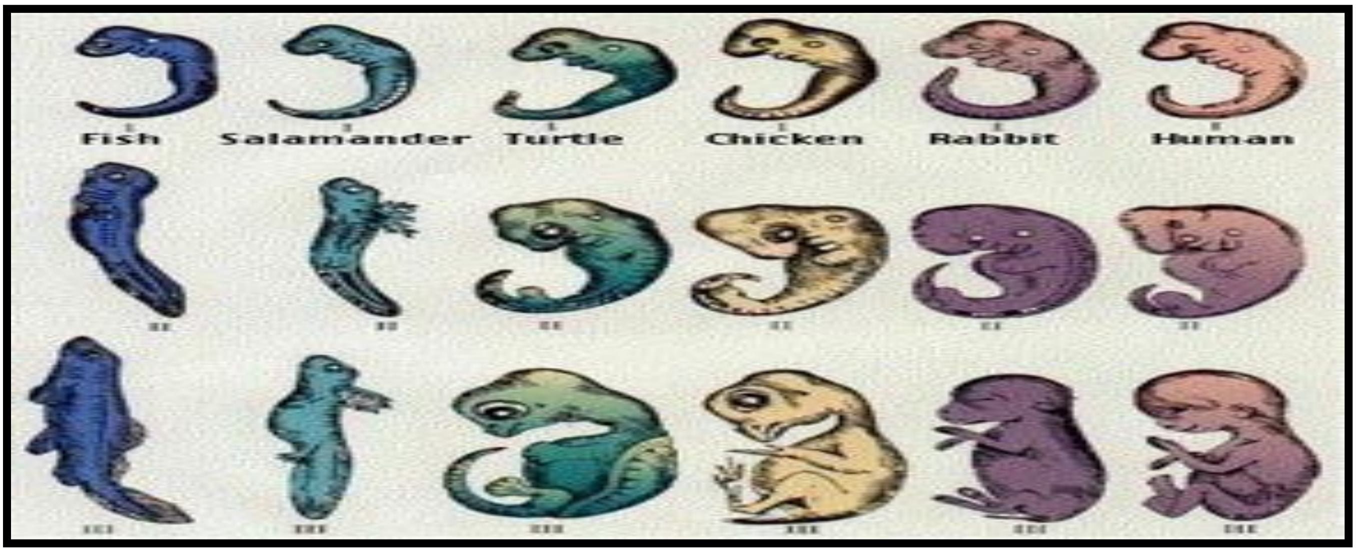


A tiny person (a *homunculus*) inside a sperm, as drawn by Nicolaas Hartsoeker in 1695

The theory of recaptiulation

✓ The embryonic forms of an animal resembled the adult organisms in its evolutionary ancestry.

✓ A historical hypothesis that the development of the embryo of an animal, from fertilization to gestation or hatching (ontogeny), goes through stages resembling or representing successive adult stages in the evolution of the animal's remote ancestors (phylogeny).



https://thebrain.mcgill.ca/flash/capsules/outil_bleu12.html

The Cell Theory

- The cell theory (proposed independently in 1838 and 1839) is a cornerstone of biology.
- All organisms are composed of one or more cells.
- Cells are the smallest living things.
- Cells arise only by division of previously existing cells.
- Ovum was discovered as a single cell and that fertilization is the union of the ovum and spermatozoon to form the zygote.

Importance of embryology

For example:

- Embryology is the basis for understanding the intimate relation between structures in different organ systems, such as the nervous system and muscle, and is primordial for understanding disorders of development that in the human may present as one of the congenital myopathies.

- Provide knowledge essential for creating health care strategies for better reproductive outcomes

- A better understanding of embryology results in new techniques for prenatal diagnoses and treatments, therapeutic procedures to circumvent problems with infertility, and mechanisms to prevent birth defects, the leading cause of infant mortality.

- Supports the research and application of stem cells for the treatment of certain chronic diseases.

Subspecialties (Fields) of embryology

- **Descriptive embryology:** This field of embryology associated with the morphological description of different embryonic stages in the ontogenetic development of individuals of different species.

- **Comparative embryology:** the study of how anatomy changes during the development of different organisms.

- **Evolutionary embryology:** the study of how changes in development may cause evolutionary changes and of how an organism's ancestry may constrain the types of changes that are possible.

- **Experimental embryology:** It involves all those studies that attempt to understand the various fundamental mechanism in the development of different animals, like fertilization, cleavage, gastrulation, embryonic induction, determination, and differentiation.

- **Behavioral embryology:** the study of the early development of the nervous system and behavior with a view toward understanding how the formative periods of neural and behavioral development affect later stages of neurobehavioral ontogeny.

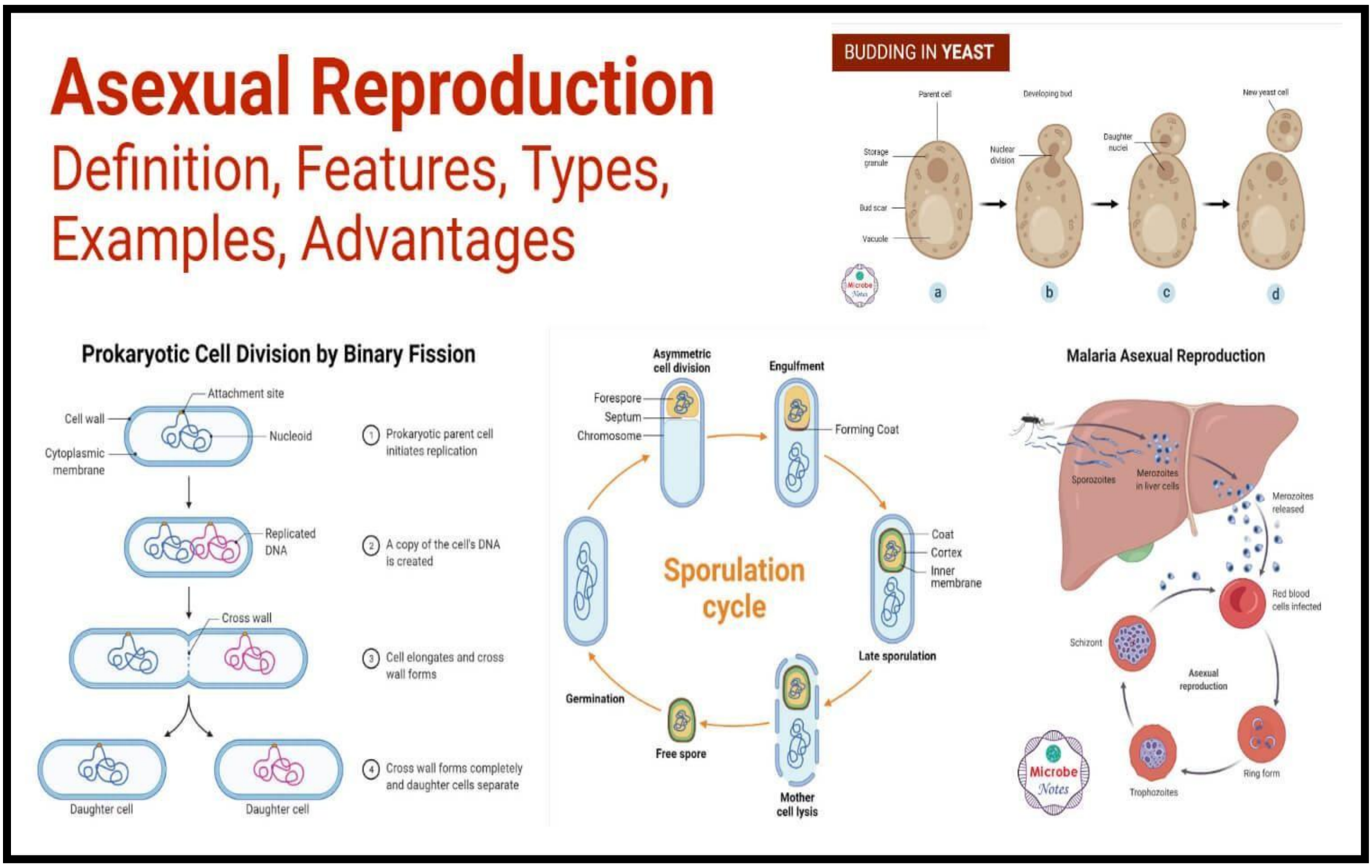
- **Chemical embryology:** The branch of embryology includes all those studies which employ various biochemical, biophysical and physiological techniques for understanding embryological events at a molecular level.

- **Teratology:** Teratology is the division of embryology and pathology that deals with abnormal development (birth defects). This branch of embryology is concerned with various genetic and/or environmental factors that disturb normal development and produce birth defects.

Reproduction

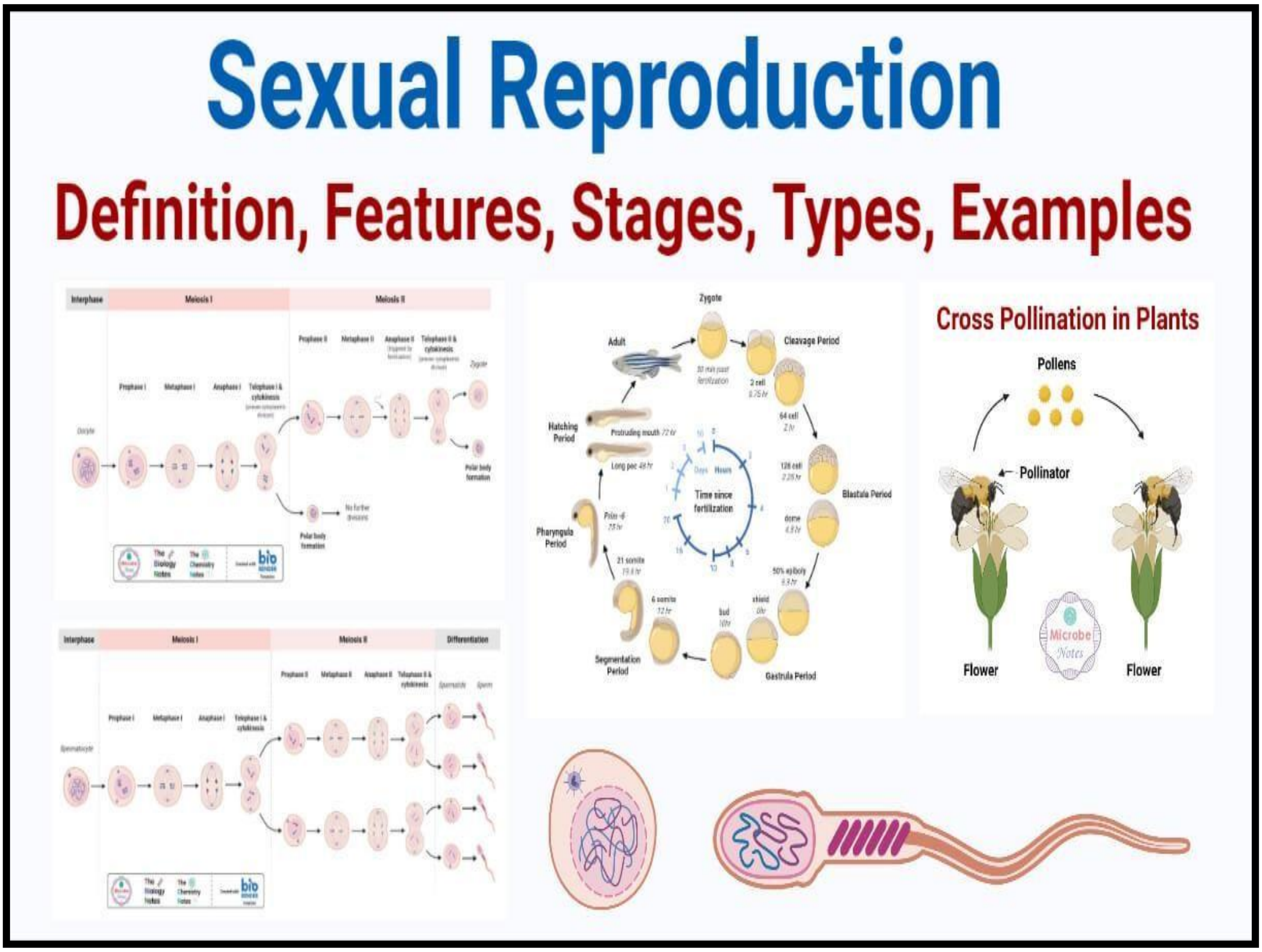
Reproduction may be defined as the biological process by which organisms give rise to their own kind. Reproduction may occur in two ways: **Asexual and Sexual reproduction.**

- Bacterial and protozoan offspring may be produced by single individuals. This is termed asexual reproduction. Lower animals and many plants reproduce asexually. When two individuals are involved in reproduction, it is termed sexual reproduction. Some methods of asexual reproduction are - fission, budding, fragmentation and spore formation.



Asexual Reproduction. Created with biorender.com

- In sexual reproduction, is a type of reproduction that involves a complex life cycle in which a gamete (such as a sperm or egg cell) with a single set of chromosomes (haploid) combines with another to produce a zygote that develops into an organism composed of cells with two sets of chromosomes (diploid). Sexual reproduction is the most common life cycle in multicellular eukaryotes, such as animals, fungi and plants. This is a more common mode of reproduction in plants and animals.



https://thebiologynotes.com/sexual-reproduction/

Basic Concepts of embryonic development include:

1. Gametogenesis
2. Fertilization
3. Cleavage
4. Blastulation
5. Gastrulation
6. Organization (Organogenesis)

Gametogenesis

Gametogenesis is the process by which male and female sex cells or gametes, i.e., sperms and ova are formed respectively in the male and female gonads (testes and ovaries). The gametes differ from all other cells (= somatic cells) of the body in that their nuclei contain only half the number of chromosomes found in the nuclei of somatic cells. Meiosis forms the most significant part of process of gametogenesis.

Gametogenesis for the formation of sperms is termed **spermatogenesis**, while that of ova is called **oogenesis**.

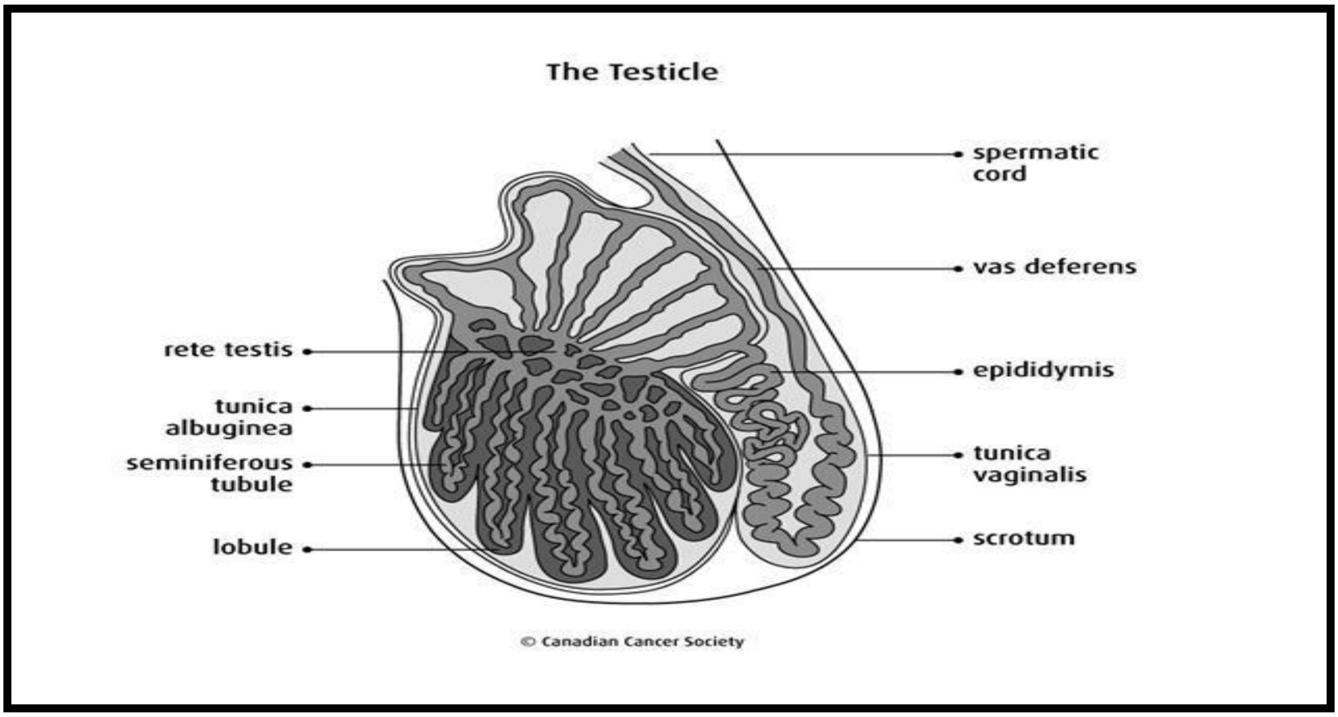
- ❖ Both spermatogenesis and oogenesis comprise similar phases of sequential changes as: **multiplication phase, growth, and maturation phases**.

Spermatogenesis:

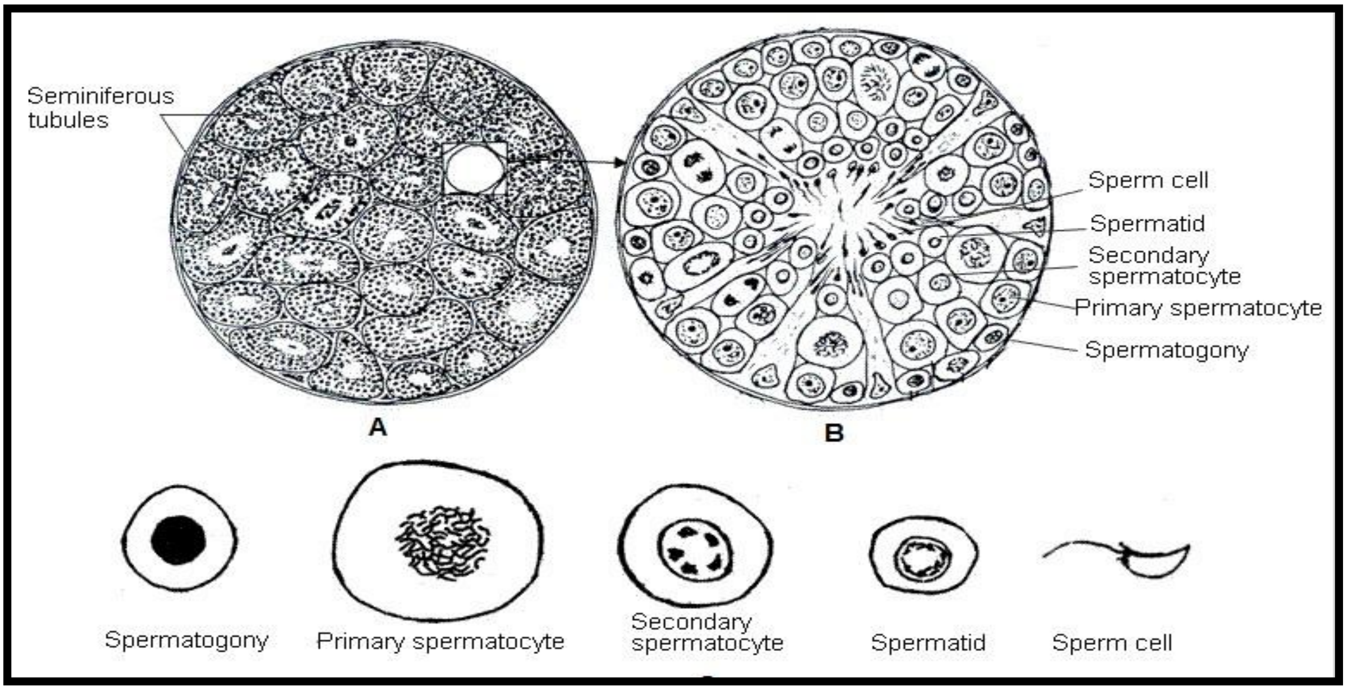
The process of formation of sperms is called spermatogenesis. It occurs in the seminiferous tubules of the testes. The seminiferous tubules are lined by germinal epithelium. The germinal epithelium consists largely of cuboidal primary or primordial germ cells (PGCs) and contains certain tall somatic cells called Sertoli cells (= nurse cells). Spermatogenesis includes formation of spermatids and formation of spermatozoa.

The testes structure

The testicles (testes) are part of a man’s reproductive system. A man has 2 testicles. Each testicle is egg-shaped and about 5 cm long. The testicles are covered by a sac of skin called the scrotum. The scrotum hangs below the penis, between the legs. The testicles make sperm. They also make testosterone, which is a male sex hormone.



T.s. of rat testis



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✓ Each testicle is covered by tough, fibrous layers of tissue called the tunica. The outer layer is called the tunica vaginalis and the inner layer is called the tunica albuginea.

- ✓ The testicle is divided into parts called lobules. Each lobule contains tiny U-shaped tubes called seminiferous tubules. There are about 800 seminiferous tubules tightly coiled within each testicle.
- ✓ The seminiferous tubules open into a series of uncoiled, interconnected channels called the rete testis. Ducts, or tubes, connect the rete testis to a tightly coiled tube called the epididymis. The epididymis joins to a long, large duct called the vas deferens.
- ✓ Each testicle is held in the scrotum by a spermatic cord. Each spermatic cord is made of tough connective tissue and muscle. It contains the vas deferens, blood vessels, lymph vessels and nerves.
- ✓ Lymph fluid
- ✓ travels through vessels in the spermatic cord and drains from the testicles into several groups of lymph nodes at the back of the abdomen. These lymph nodes are called the retroperitoneal lymph nodes.
- ✓ Sertoli cells are the cells that are randomly scattered throughout the seminiferous tubules and provide nutrients to the developing spermatogonia.

Spermatogenesis: includes the following phases:

Multiplication Phase:

At sexual maturity, the undifferentiated primordial germ cells divide several times by mitosis to produce a large number of spermatogonia (Gr. sperma = seeds, gonos- generation). Spermatogonia (2N) are of two types: type A spermatogonia and type B spermatogonia. Type A spermatogonia serve as the stem cells which divide to form additional spermatogonia. Type B spermatogonia are the precursors of sperms.

Maturation Phase:

Each primary spermatocyte undergoes two successive divisions, called maturation divisions. The first maturation division is reductional or meiotic.

Hence, the primary spermatocyte divides into two haploid daughter cells called secondary spermatocytes. Both secondary spermatocytes now undergo second maturation division which is an ordinary mitotic division to form, four haploid spermatids, by each primary spermatocyte.

Growth Phase:

Each type B spermatogonium actively grows to a larger primary spermatocyte by obtaining nourishment from the nursing cells.

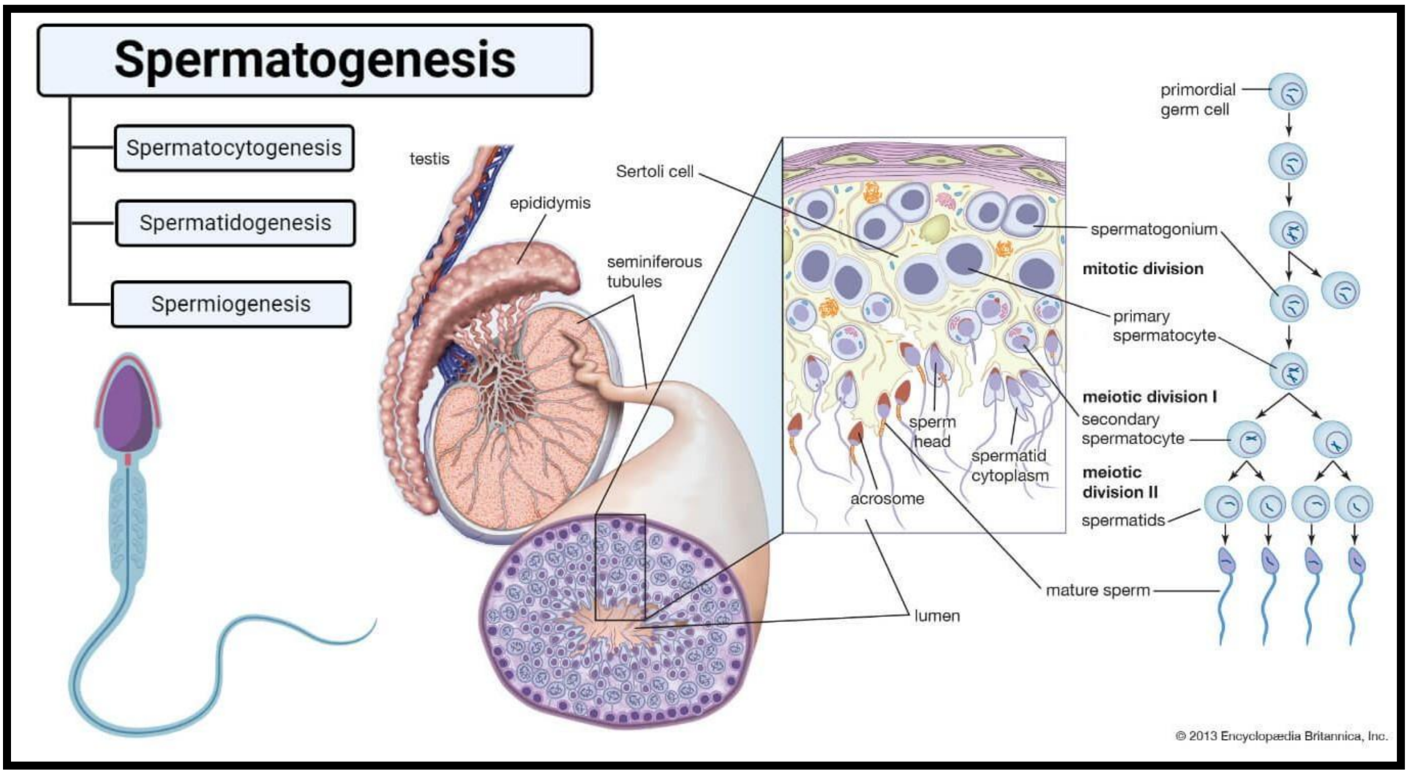
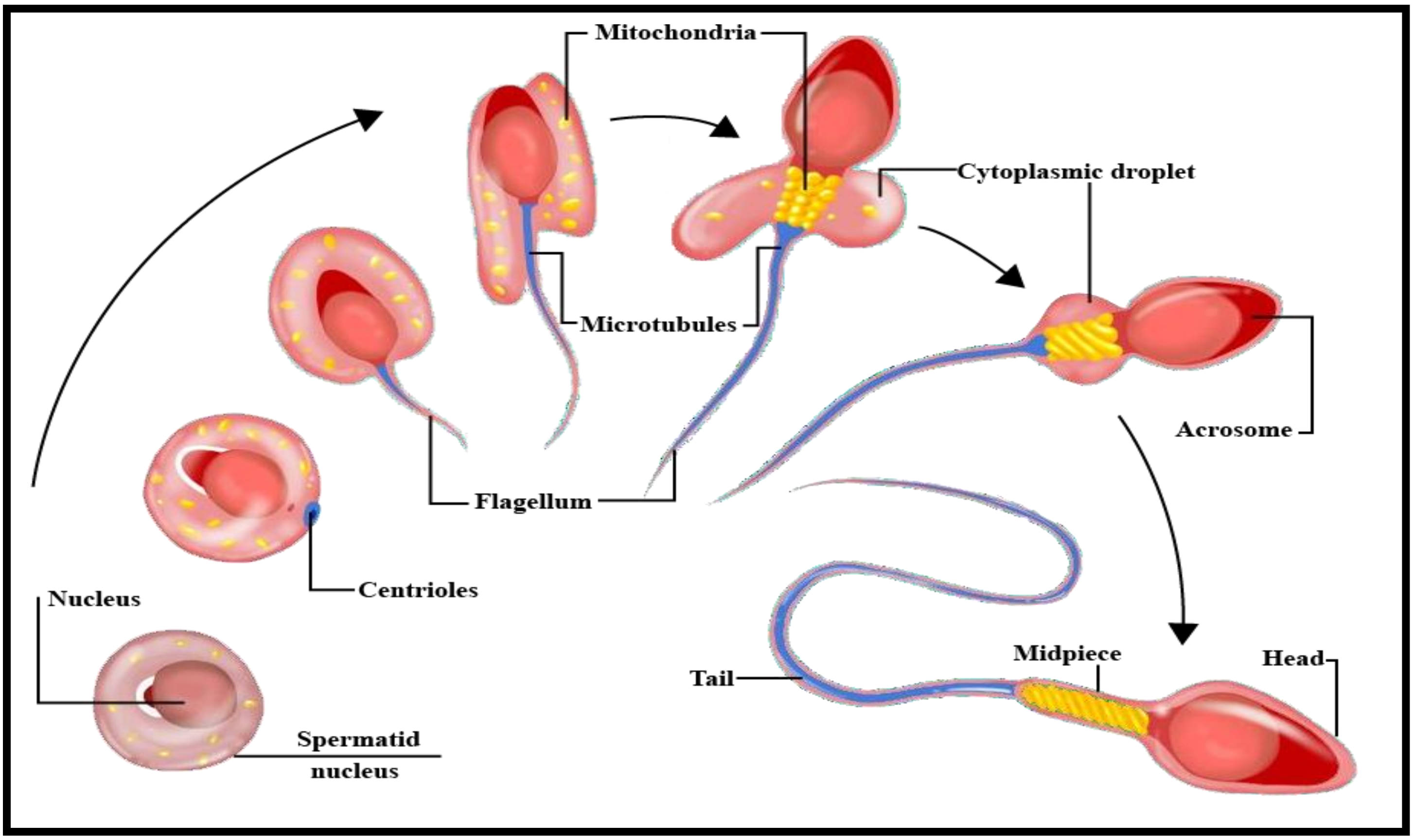


Image Source: Britannica, Created with BioRender.com.

Formation of Sperms from Spermatids (Spermiogenesis):

The transformation of spermatids into spermatozoa is called spermiogenesis. The spermatozoa are later on known as sperms. Thus four sperms are formed from one spermatogonium. After spermiogenesis sperm heads become embedded in the Sertoli cells and are finally released from the seminiferous tubules by the process called spermiation.



https://byjus.com/question-answer/spermiogenesis-spermateleosis-is-formation-of-spermatozoa-from/

Spermatozoon (Sperm):

The sperms are microscopic and motile cells. Sperms remain alive and retain their ability to fertilize an ovum (egg) from 24 to 48 hours after having been released in the female genital tract. A typical mammalian sperm consists of a head, neck, middle piece and tail.

Head:

It contains anterior small acrosome and posterior large nucleus. Acrosome is formed from Golgi body of the spermatid. Acrosome contains hyaluronidase proteolytic enzymes which are popularly known as sperm lysins that are used to contact and penetrate the egg (ovum) at the time of fertilization.

Neck:

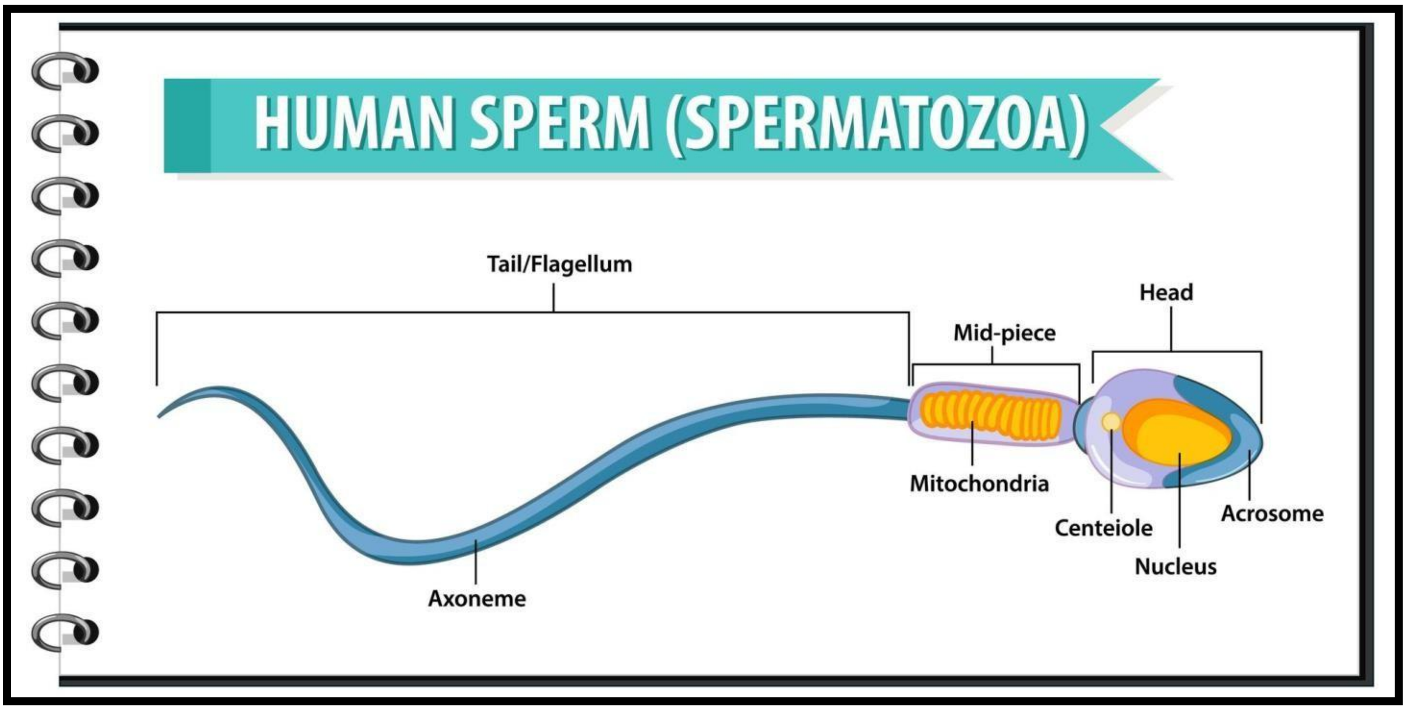
It is very short and is present between the head and middle piece. It contains the proximal centriole towards the nucleus which plays a role in the first cleavage of the zygote and the distal centriole which gives rise to the axial filament of the sperm.

Middle piece:

The middle piece of human sperm contains the mitochondria coiled around the axial filament called mitochondrial spiral. They provide energy for the movement of the sperm. So, it is the "power house of the sperm". At the end of the middle piece there is a ring centriole (annulus) with unknown function. Posterior half of nucleus, neck and middle piece of sperm are covered by a sheath called manchette.

Tail:

The tail is several times longer than the head. In its most part called main piece, the axial filament is surrounded by a thin layer of cytoplasm. The part behind the main piece is called end piece which consists of naked filament alone. The sperm swims about by its tail in a fluid medium.



https://www.vecteezy.com/vector-art/1434164-human-sperm-or-spermatozoa-cell-structure

Different shape and size of sperm

Observe sperm of different animal species and compare the shape of sperm head, the size of acrosome (structure on the top of head containing enzymes important for penetrating the egg) and size and number of sperm tails.

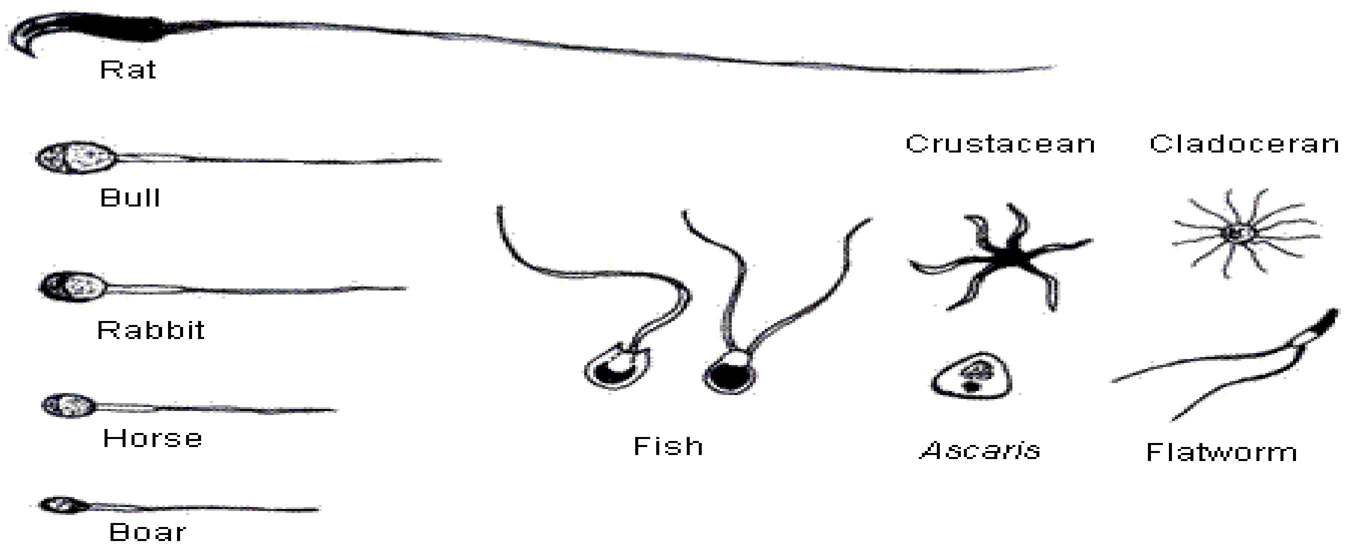


Fig.: Sperm of different animal species.

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Purpose of Spermatogenesis

The process of Spermatogenesis occurs to create mature male gametes, which then fertilize female gametes to create a zygote, a single-celled organism. This results in cell division and multiplication to create a fetus. For a healthy offspring, the number of chromosomes must be maintained properly across the body as failure can lead to some abnormalities.

Oogenesis

The process of formation of a mature female gamete (ovum) is called oogenesis. It occurs in the ovaries (female gonads).

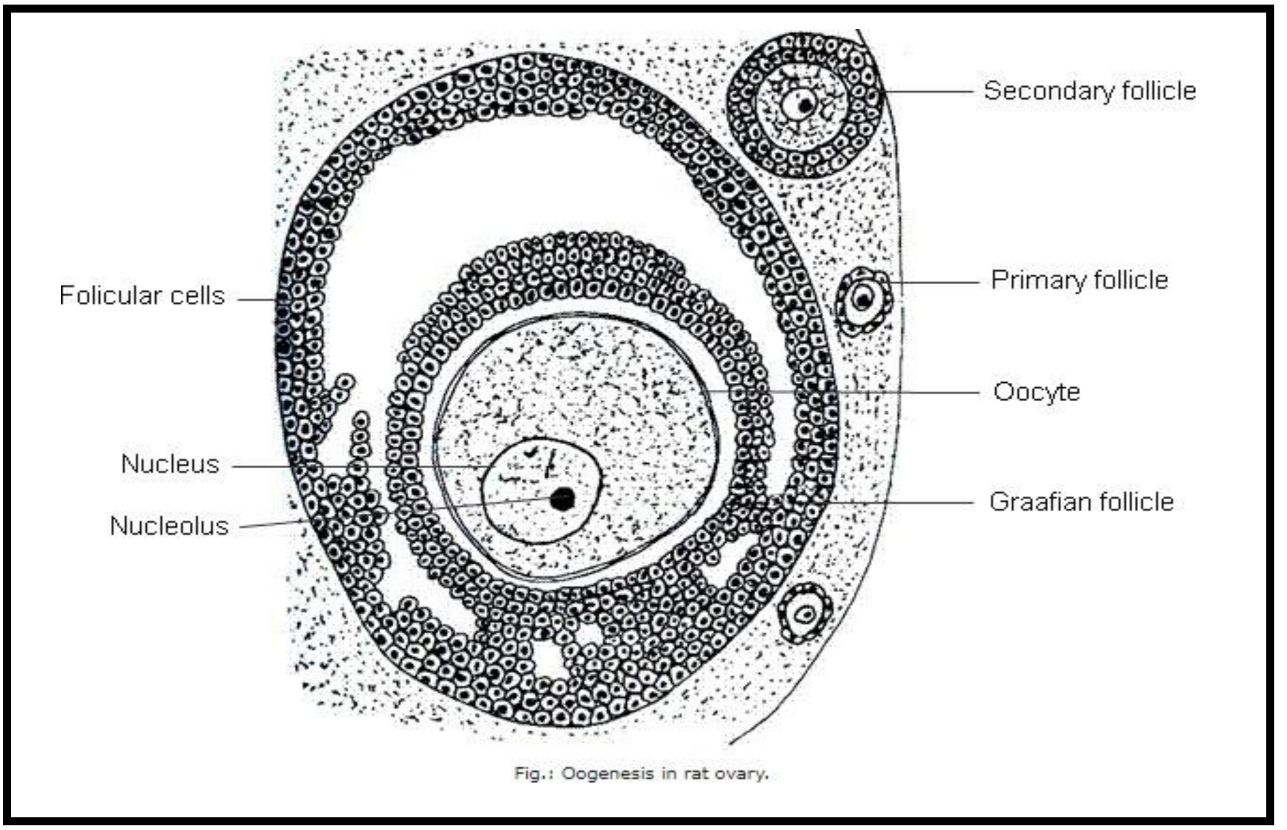
Ovum structure:

The ovum is one of the largest cells that measures approximately 120 µm in diameter. The ovum has a large, centrally located nucleus which is covered by cytoplasm. This oocyte nucleus and nucleolus are termed **germinal vesicle** and **germinal disc** respectively. Likewise, the cytoplasm (yolk) of an ovum is termed **ooplasm**. It has less amount of yolk (in humans) and hence it is alecithal. This ooplasm is enclosed by a peripheral layer called the cortex which has many microvilli. These microvilli are tubular projections of the plasmalemma that aids in the transportation of substances in and out of the cytoplasm.

The human ovum is typically covered by 3 layers:

1. Inner thin vitelline membrane
2. Middle zona pellucida
3. Outer corona radiata

- ✓ The narrow space present between the vitelline membrane and zona pellucida is called the perivitelline space. The zona pellucida is often seen as a thick girdle that is surrounded by the corona radiata.
- ✓ For fertilization to occur, the hyaluronidase in the acrosome of the sperm has to scatter the outer corona radiata from the middle zona pellucida of an ovulated oocyte. This invariably allows contact between the oocyte’s core and the sperm.



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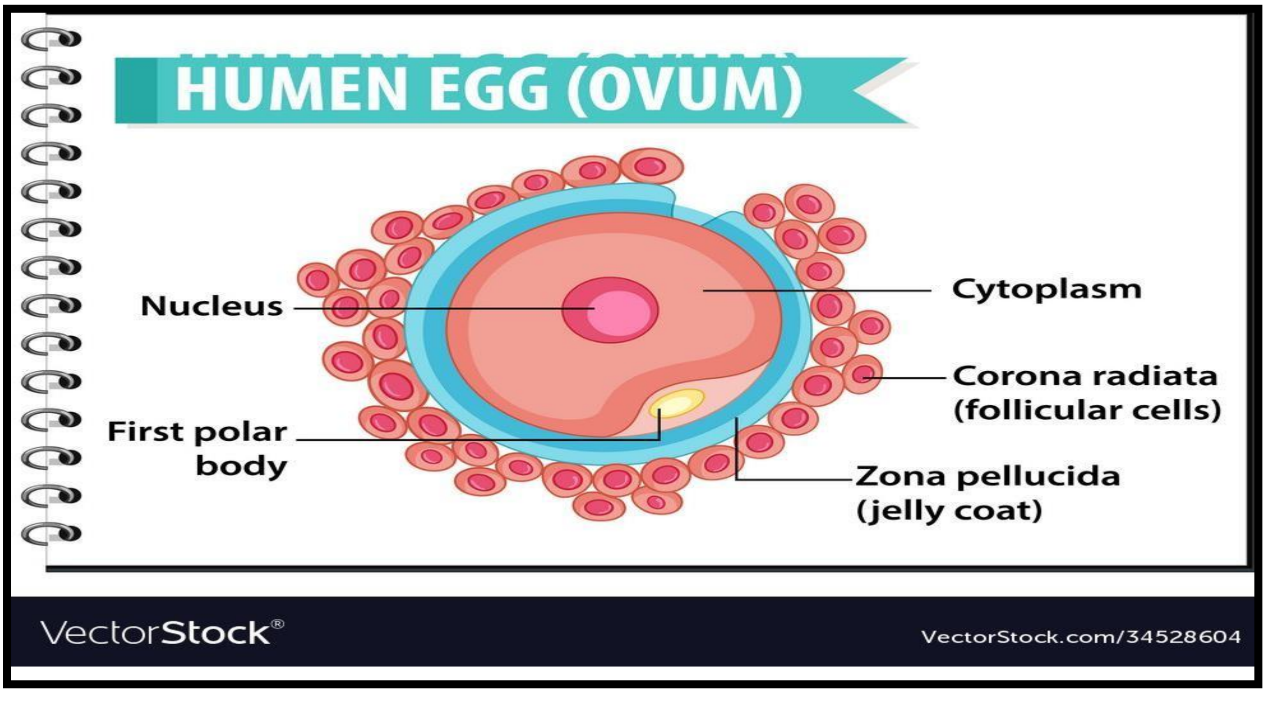


Types of Egg:

<u>According to the proportion of the yolk to the cytoplasm</u> of the ovum there are three types of egg:

[I] Microlecithal egg:

In microlecithal eggs the amount of yolk is much less than the amount of cytoplasm. These eggs are very small in size. Some embryologists described microlecithal eggs as alecithal eggs or oligolecithal eggs or miolecithal (i.e. little yolk) eggs.

- ❖ The eggs of Amphioxus and mammals are of this type.
- ❖ The mammalian eggs contain so little yolk that they are sometimes called alecithal (without yolk) eggs.

[II] Mesolecithal eggs:

Here yolk is moderate in amount and such eggs are called mesolecithal or medialecithal (i.e. median yolk). The distribution of yolk is distinctly unequal.

- ❖ The eggs of sharks, fishes and many amphibians are of this type.

[III] Macrolecithal or polylecithal eggs:

Enormous amount of yolk is present in macrolecithal eggs and here yolk is several times greater than cytoplasm. These eggs may be small or big.

- ❖ The eggs of teleost fishes, reptiles, birds and monotremates (egg laying mammals) are of this type.

<u>According to distribution of yolk granules or platelets</u> in the cytoplasm of the ova or egg, the eggs are classified as follows:

1. Homolecithal/Isolecithal:

The yolk in these eggs is uniformly distributed through the cytoplasm.

- ❖ Examples are of Amphioxus, many invertebrates and mammals including man.

2. Centrolecithal:

Yolk is concentrated in the interior of the egg and the cytoplasm is distributed as a thin layer on the outside of the yolk.

- ❖ As in insects and many other arthropodes.

3. Teleolecithal:

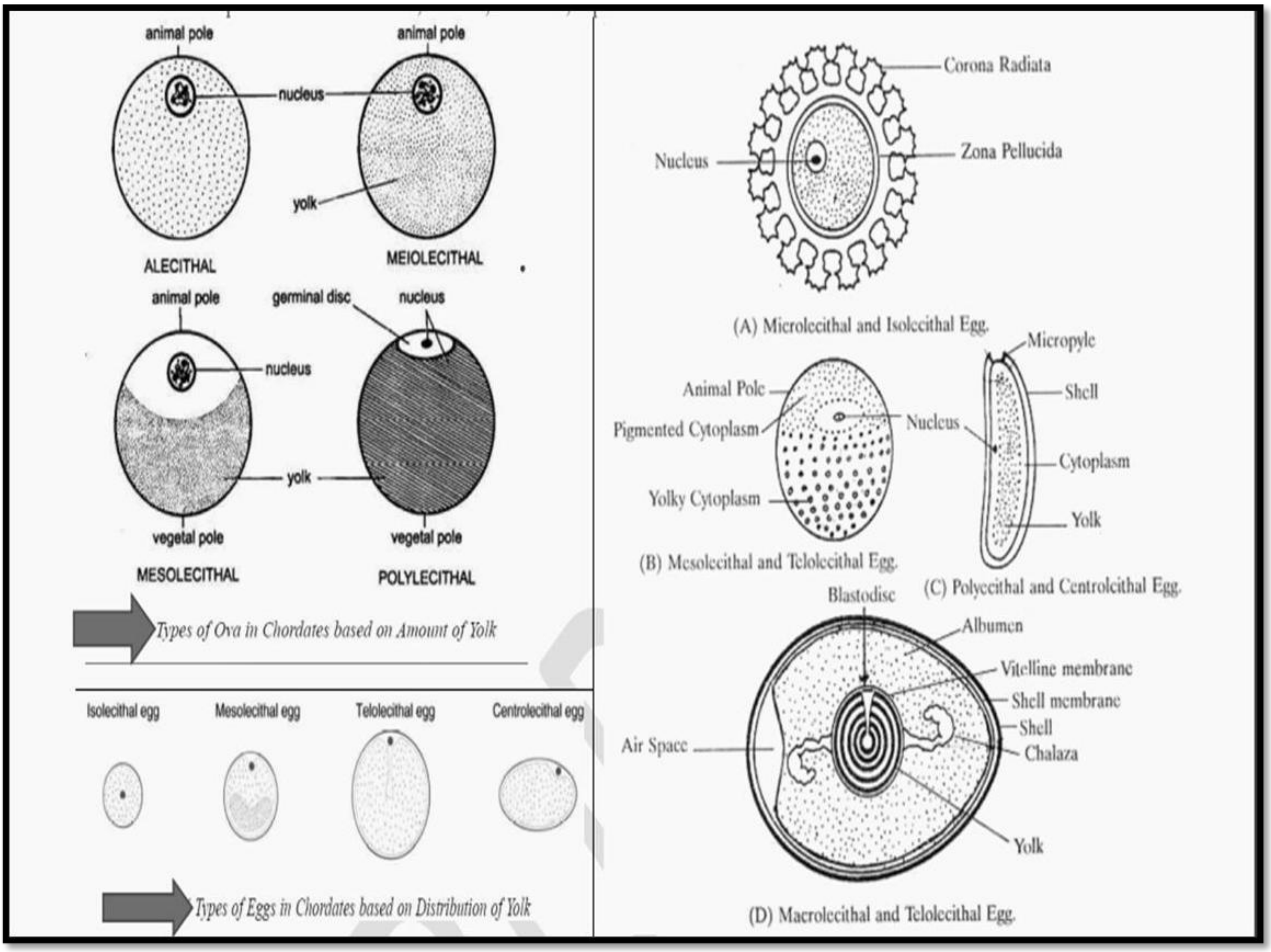
Yolk becomes more abundant and tends to concentrate in one hemisphere of the egg. Because of the uneven distribution of yolk, such an egg is said to have a vegetal pole, where the concentration of yolk is greatest and an animal pole, where the concentration of yolk is smallest.

In fact, in macrolecithal eggs, the amount of yolk is so massive that it occupies almost all the vegetal pole, and the active cytoplasm and germinal vesicles (nucleus) remain confined to a small cap at the animal pole.

- Examples are of fishes, amphibians, and reptiles, birds and monotremes eggs.

Functions of Yolk:

Although yolk of egg is used for two purposes—supply of energy and synthesis of the products required for elaboration of the embryonic body. The yolk also has important influence on—(i) the size of the ovum, (ii) differentiation of ooplasm, (iii) patterns of cleavage, (iv) morphogenetic movements of blastomeres during gastrulation, and (v) the type of development whether direct or indirect.



https://www.bajkulcollegeonlinestudy.in

Oogenesis: consists of three phases: multiplication, growth and maturation.

Multiplication phase:

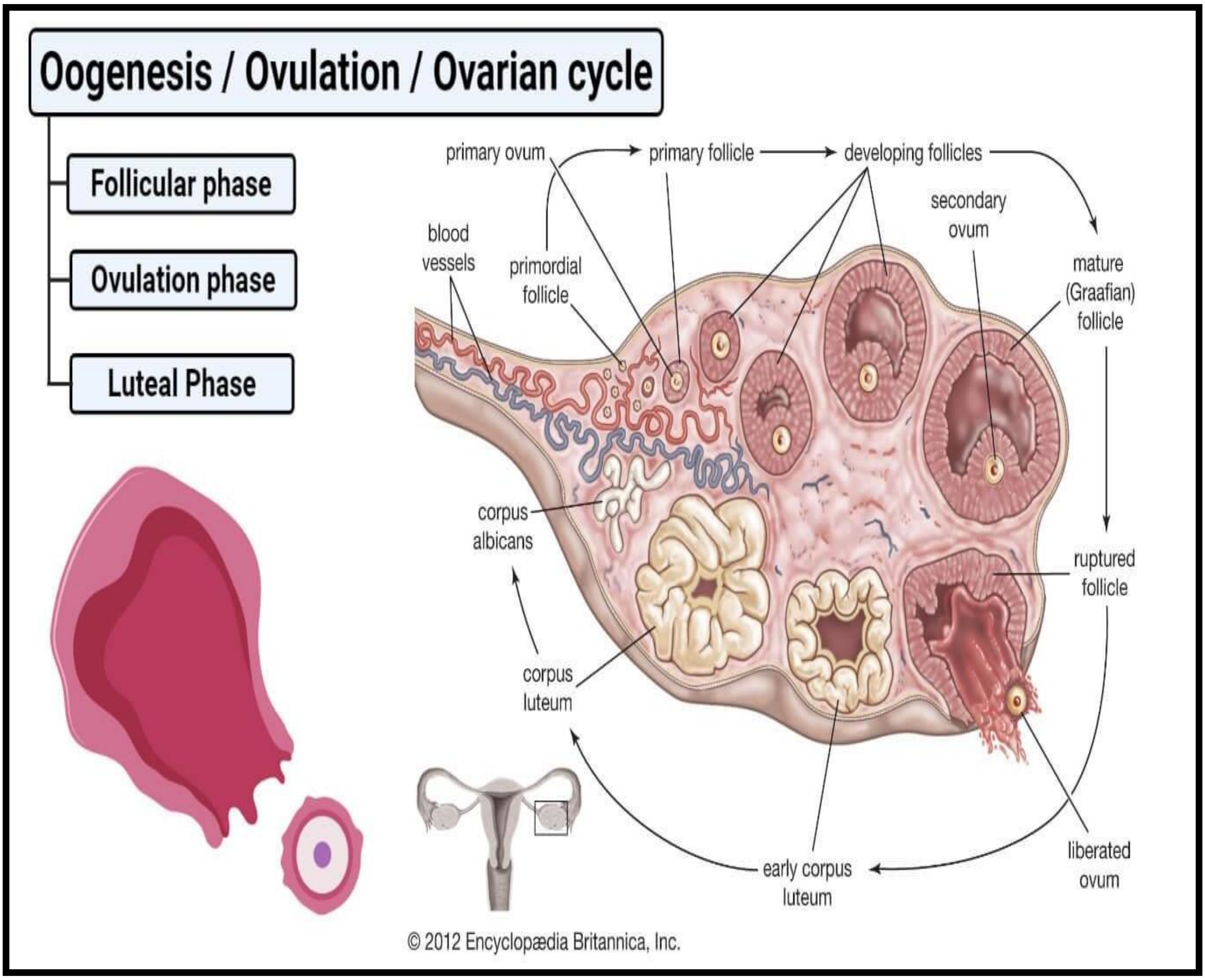
In the foetal development, certain cells in the germinal epithelium of the ovary of the foetus are larger than others. These cells divide by mitosis, producing a couple of million egg mother cells or oogonia in each ovary of the foetus. No more oogonia are formed or added after birth. The oogonia multiply by mitotic divisions forming the primary oocytes.

Growth phase:

This phase of the primary oocyte is very long. It may extend over many years. The oogonium grows into a large primary oocyte. Each primary oocyte then gets surrounded by a layer of granulosa cells to form primary follicle. A large number of these follicles degenerate during the period from birth to puberty. So at puberty only 60,000- 80,000 primary follicles are left in each ovary.

Maturation phase:

Like a primary spermatocyte, each primary oocyte undergoes two maturation divisions, first meiotic and the second meiotic. The results of maturation divisions in oogenesis are, however, very different from those in spermatogenesis. In the first, meiotic division, the primary oocyte divides into two very unequal haploid daughter cells— a large secondary oocyte and a very small first polar body or polocyte. In the second maturation division, the first polar body may divide to form two second polar bodies. The secondary oocyte again divides into unequal daughter cells, a large ootid and a very small second polar body. The ootid grows into a functional haploid ovum. Thus, from one oogonium, one ovum and three polar bodies are formed. The ovum is the actual female gamete. The polar bodies take no part in reproduction and, hence, soon degenerate.



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The ovarian cycle

Of the roughly 500'000 follicles that are present in the two ovaries at the beginning of sexual maturity, only around 480 reach the graafian follicle stage and are thus able to release oocytes (ovulation). This number is simply derived by multiplying the number of cycles per year and the number of years in which a woman is fertile.

Ovulation represents an exceptional fate of a follicle.

- It is a series of cyclic changes occurring in the reproductive tract of female with the periodicity of 28 days
- It is also known as menstrual cycle,
- also known as endometrial cycle

- It occur From puberty to menopause
- It is characterized by loss of vaginal blood (breaking of endometrium wall of uterus)
- The cycle is under Influenced of hormones secreted by pituitary gland (FSH and LH), and ovary (progesterone and oesterogen).
- Menstrual phase
- Proliferative phase or follicular or ovulatory phase
- Luteal or secretory phase

Menstrual phase

- This phase is characterized by discharge of blood, connective tissues and mucus due to cast off of epithelial lining of endometrium wall
- It Lasts for **3-5 days**
- Ovum remain unfertilized,
- At this time level of oestrogen and progesterone is very low in blood resulting in Breaking of endometrium wall of uterus
- About 50-100 ml blood with mucus are discharges as menstrual flow.

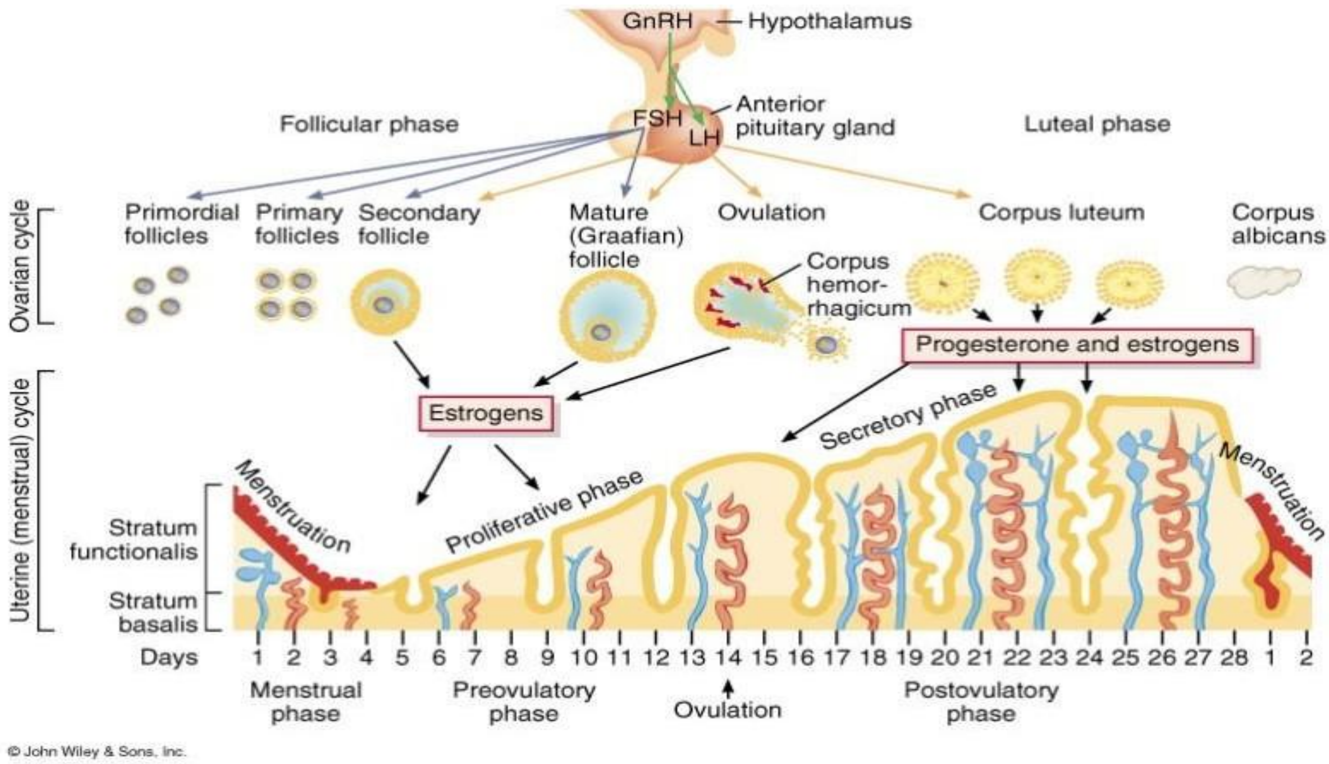
Proliferative phase

- This phase is characterized by rapid proliferation and repair of damaged endometrium wall
- It Lasts for **9-10 days** (5th – 14thdays)
- Anterior pituitary gland releases **Follicular stimulating Hormone (FSH)** which stimulates development and maturation of grafian follicle. So, it is also known as Follicular Phase.
- Mature grafian follicle secrete **oestrogen.** Its level gradually increases and maximize at 12thday
- Oestrogen stimulates endometrium repair and proliferation. It also stimulates Ovulation

- Endometrium become 2-3 mm thick and highly vascular

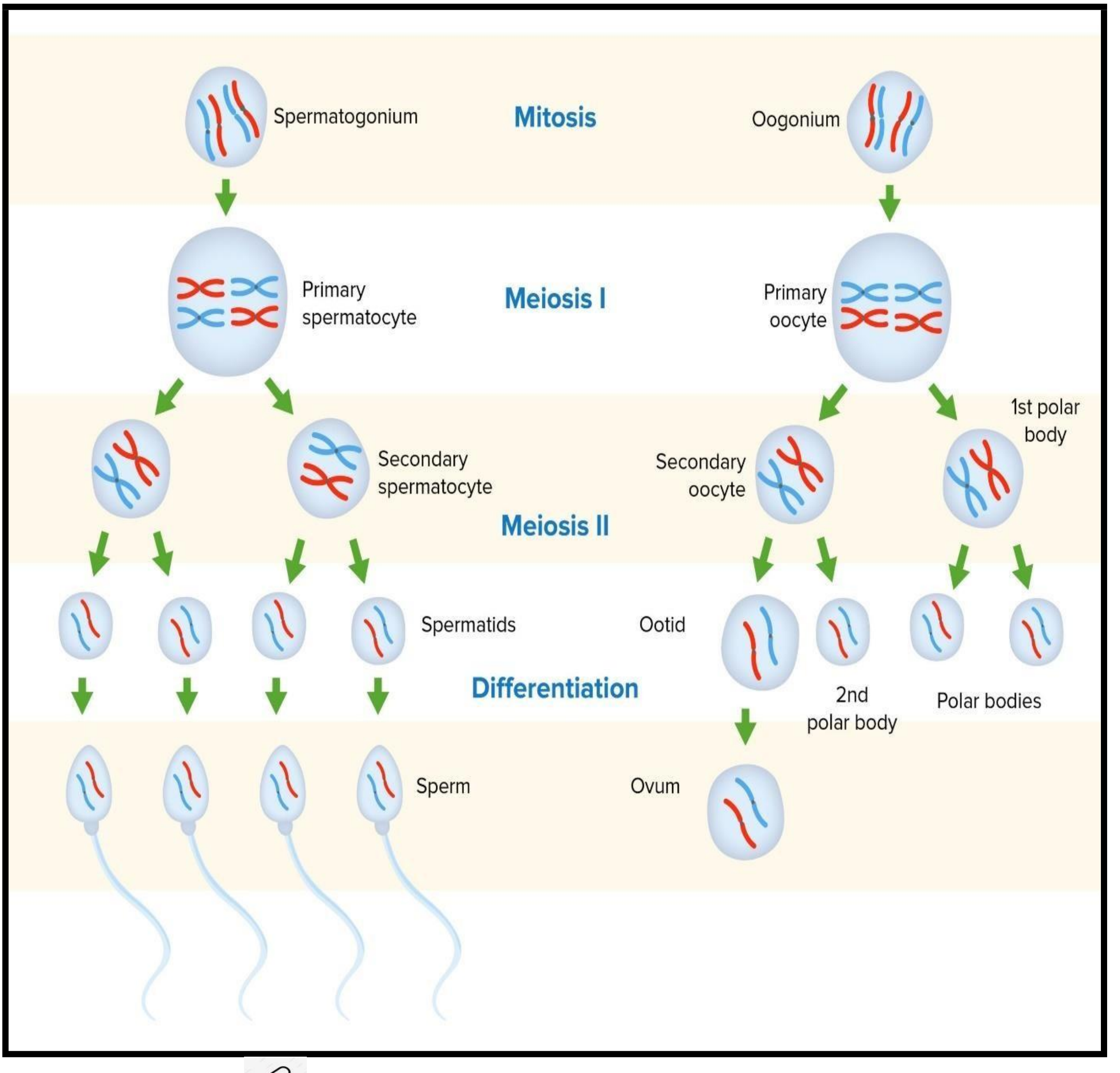
Luteal phase

- This phase is characterized by release of Ovum from mature graffian follicle which is stimulated by the secretion of **luteinizing hormone** (LH) by pituitary gland.
- It Lasts for **12-14 days** (14th-28th day)
- LH along with FSH stimulate ovulation.
- Mature graffian follicle release ovum and the rapture follicular cell form **corpus luteum**
- Corpus luteum secrete progesterone, high level of progesterone inhibits maturation of any other follicles
- Progesterone also stimulates thickening of endometrium wall
- When ovum remain unfertilized, corpus luteum degenerate; level of both hormone (progesterone and oestrogen) decreases, causing breaking of endometrium wall continuing the menstrual phase.



Purpose of Oogenesis

The goal of oogenesis is to produce one egg with massive amounts of cytoplasm.



https://cdn.lecturio.com/assets/Gametogenesis-1200x956.jpg

	Spermatogenesis	Oogenesis
Process		
Location	Occurs *entirely* in testes	Occurs *mostly* in ovaries
Meiotic divisions	Equal division of cells	Unequal division of cytoplasm
Germ line epithelium	Is involved in gamete production	Is not involved in gamete production
Gametes		
Number produced	Four	One (plus 2 – 3 polar bodies)
Size of gametes	Sperm smaller than spermatocytes	Ova larger than oocytes
Timing		
Duration	Uninterrupted process	In arrested stages
Onset	Begins at puberty	Begins in foetus (pre-natal)
Release	Continuous	Monthly from puberty (menstrual cycle)
End	Lifelong (but reduces with age)	Terminates with menopause

http://ib.bioninja.com.au/higher-level/topic-11-animal-physiology/114-sexual- reproduction/gametogenesis.html

The timing of meiosis differs in females and males

In males

1- The spermatogonia enter meiosis and produce sperm from puberty until death.

2-The process of sperm production takes only a few weeks.

3- Four sperms result from spermatogenesis.

In females

1-This process is more complex. The first meiotic division starts before birth but fails to proceed. It is eventually completed about one month before ovulation, the second meiotic division occurs just before the actual process of fertilization occurs. Thus, in females, the completion of meiosis can be delayed for over 50 years.

2- All meiosis is ended in females at menopause.

The result is the egg cell and three polar bodies.

3- Only I egg produced A polar body consists of the chromosomes and nucleus resulting from meiotic division but it receives almost no cytoplasm. All the cytoplasm is found in the secondary oocyte.

The cytoplasm will provide energy to the developing embryo until it implants.

In the mammalian ovary, the oocytes are closely associated with somatic cells called granulosa cells which aid oocyte maturation and ovulation.

Fertilization

Fertilization, the process by which male and female gametes nuclei fuses together to produce diploid zygote.

Types of Fertilization:

1. External:

Eggs are librated in water.

- Occurs outside the female genital system.
- Female laid a large number of eggs, them the male pour its sperms in the same region in water
- e.g. in fish and amphibian.

2. Internal:

- land-dwellers
- specialized structures for housing gametes.
- embryo more protected during development.
- Occurs in animals that have a well developed reproductive system, animals may be:

a) **Oviparous:** zygote develops in a shell e.g. birds.

b) **Viviparous:** zygote develops inside uterus e.g. mammals.

The intrauterine life is about 21 days in the rat, 70 days in the in the Guinea pig while its about 280 days in human.

c) **Ovoviviparous: -** e.g. dog fish

It has 4 major steps:

1. Contact and recognition between sperm and egg. (Same species)
2. Regulation of sperm entry into the egg. (Only one and inhibiting the others)
3. Fusion of the genetic material of sperm and egg.
4. Activation of egg metabolism to start development.

Egg Maturation at Sperm Entry

Most eggs are not fully mature at the time of fertilization. Sperm entry activates metabolism and relieves meiotic arrest.

Polar body formation results in egg maturation to be ready for actual fertilization (Pronucleus formation).

Cleavage and Blastula Formation

Meaning of Cleavage:

- Is the process of repeated rapid mitotic cell divisions of the zygote (unicellular structure) to form the Blastula (multicellular structure).
- The produced cells named Blastomeres.
- During this stage the size of the embryo does not change, the blastomeres become smaller with each division.
- The type & pattern of cleavage differ from species to species.
- continues divisions to form a ball of 32 cells called the morula.
- The morula continues divisions to form the hollow blastula with up to several hundred cells.
- The cavity of the blastula is the blastocoel.

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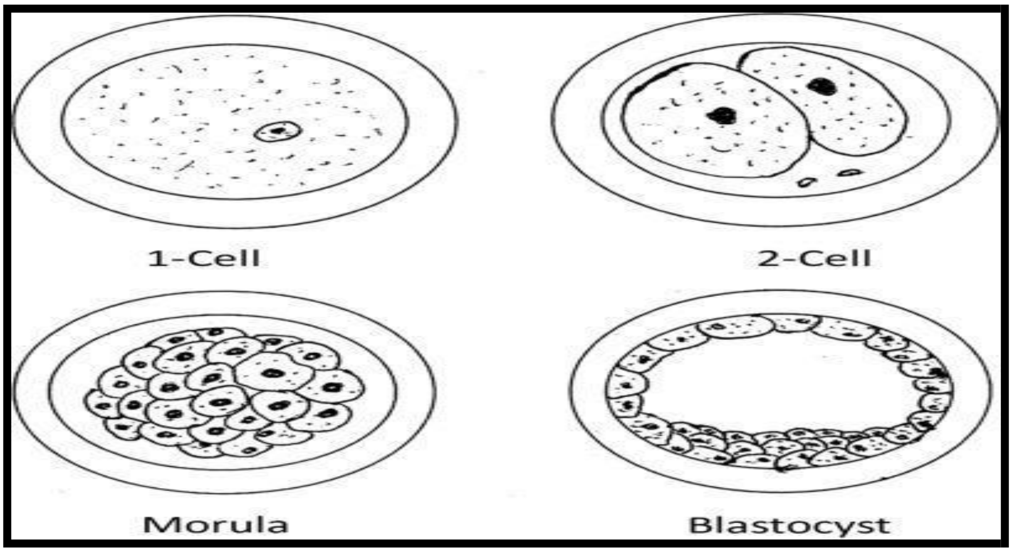


https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/ova

Planes of Cleavage:

Considerable amount of reorganization occurs during the period of cleavage and the types of cleavage depend largely upon the cytoplasmic contents.

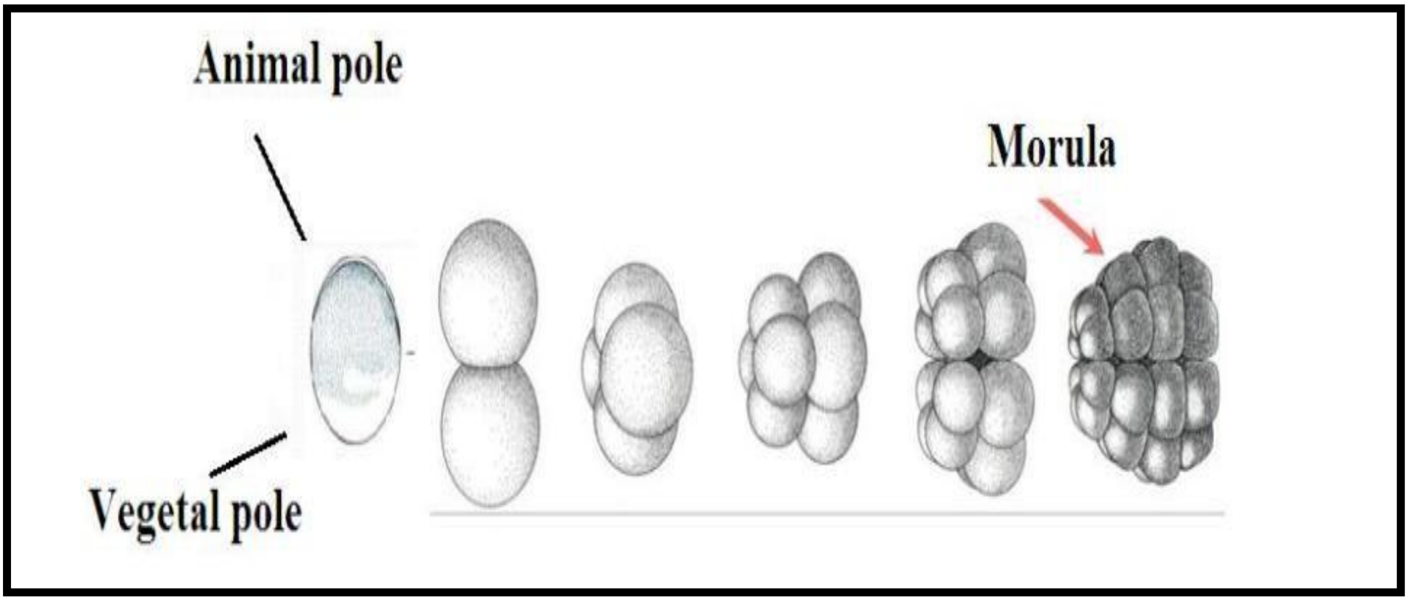
A: Holoblastic or total cleavage:

When the cleavage furrows divide the entire egg.

It may be:

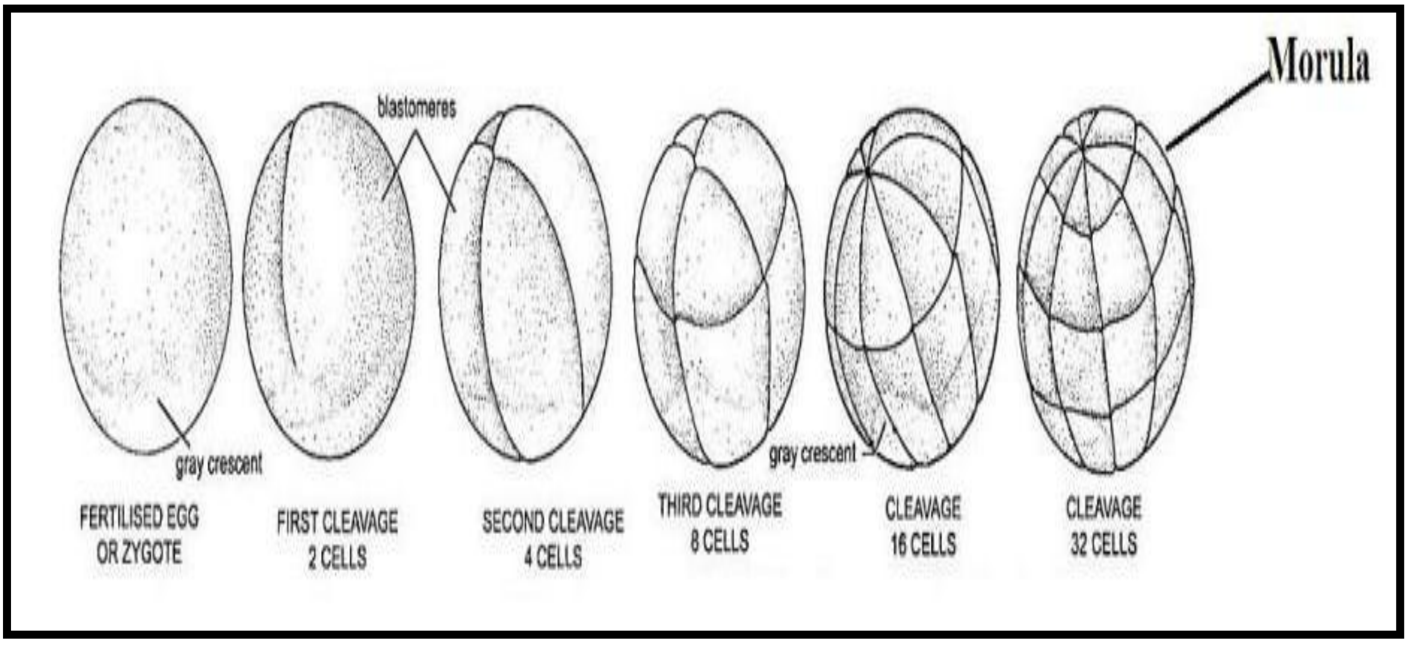
Equal:

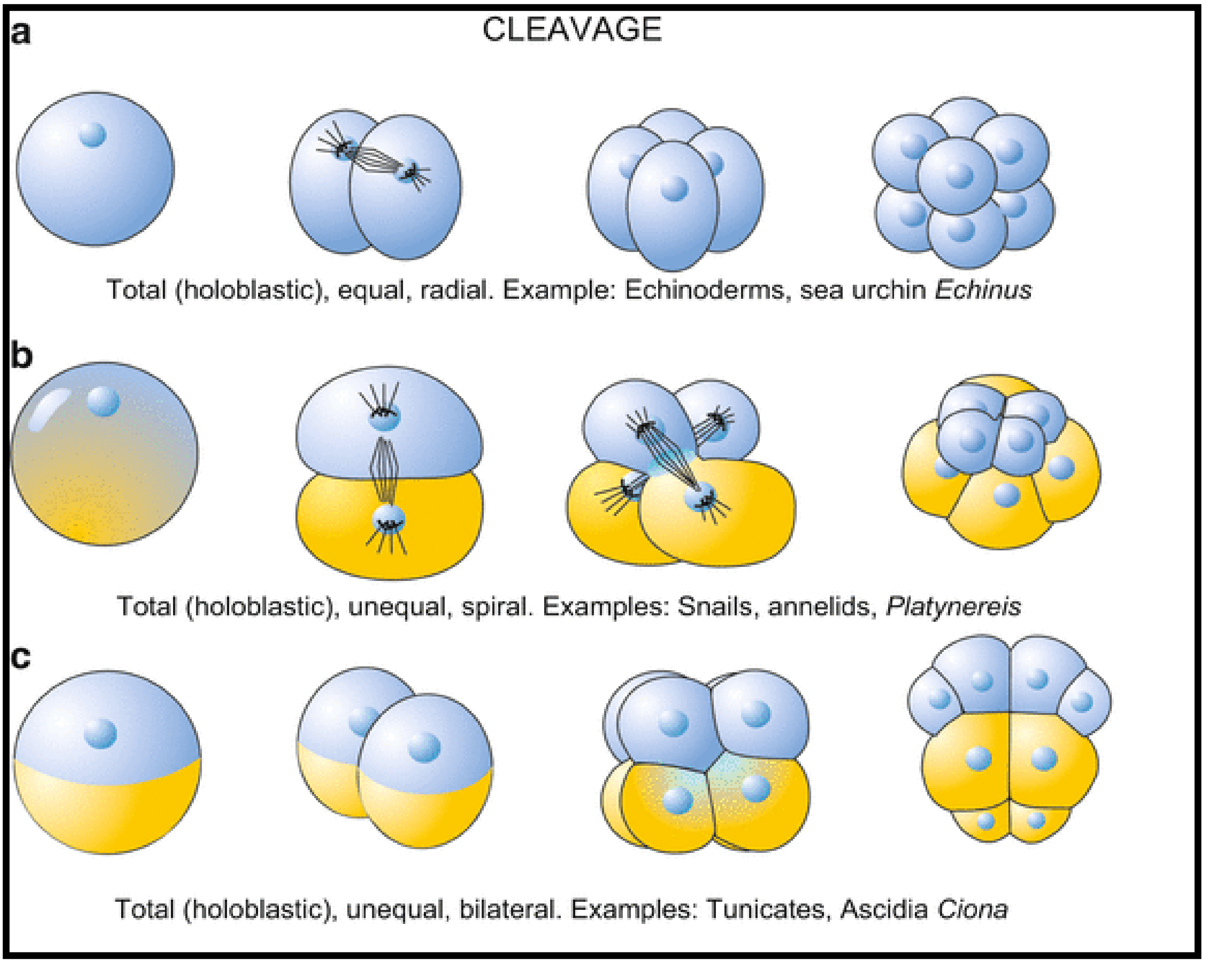
When the cleavage furrow cuts the egg into two equal cells. It may be radially symmetrical, bilaterally symmetrical, spirally symmetrical or irregular.



Unequal:

When the resultant blastomeres become unequal in size.





https://veteriankey.com/stages-and-principles-of-animal-development-terms-of-developmental-biology/

B. Meroblastic cleavage:

When segmentation takes place only in a small portion of the egg resulting in the formation of blastoderm, it is called meroblastic cleavage. Usually the blastoderm is present in the animal pole and the vegetal pole becomes laden with yolk which remains in an uncleaved state, i.e., the plane of division does not reach the periphery of blastoderm or blastodisc.

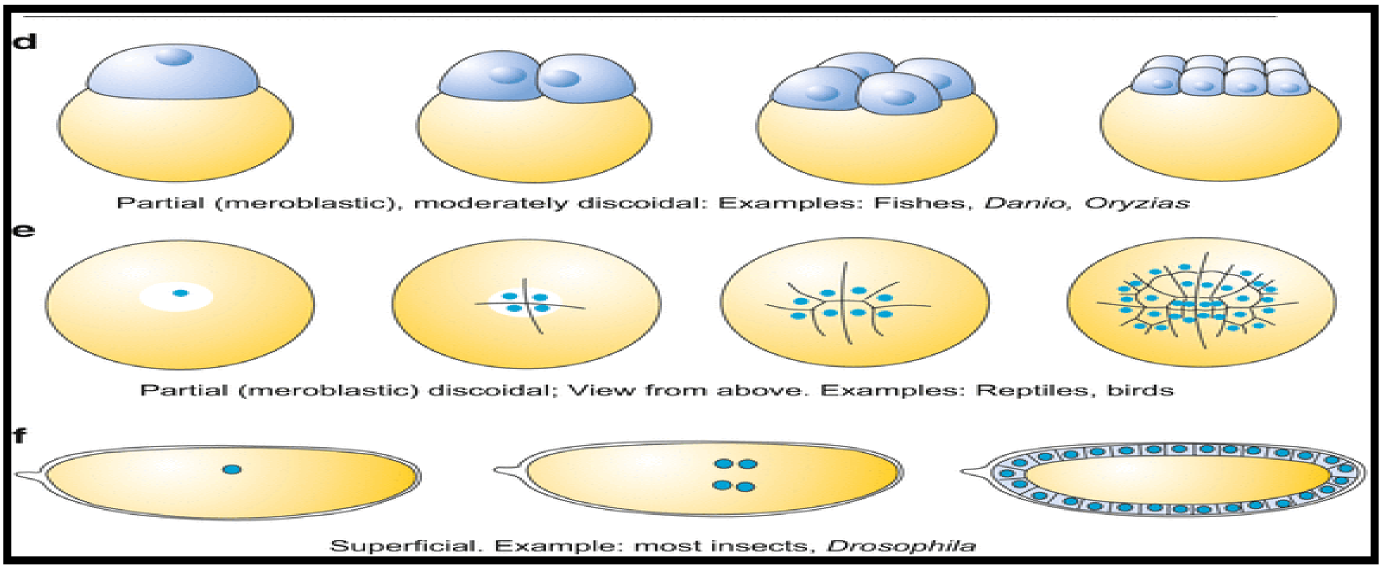
Two major types of meroblastic cleavage are discoidal and superficial:

1- Discoidal

In discoidal cleavage, the cleavage furrows do not penetrate the yolk. The embryo forms a disc of cells, called a blastodisc, on top of the yolk. Discoidal cleavage is commonly found in monotremes, birds, reptiles, and fish that have telolecithal egg cells (egg cells with the yolk concentrated at one end).

2- Superficial

In superficial cleavage, mitosis occurs but not cytokonesis, resulting in a polynuclear cell. With the yolk positioned in the center of the egg cell, the nuclei migrate to the periphery of the egg, and the plasma membrane grows inward, partitioning the cytoplasm into individual cells. Superficial cleavage occurs in arthropods that have centrolecithal eggs.



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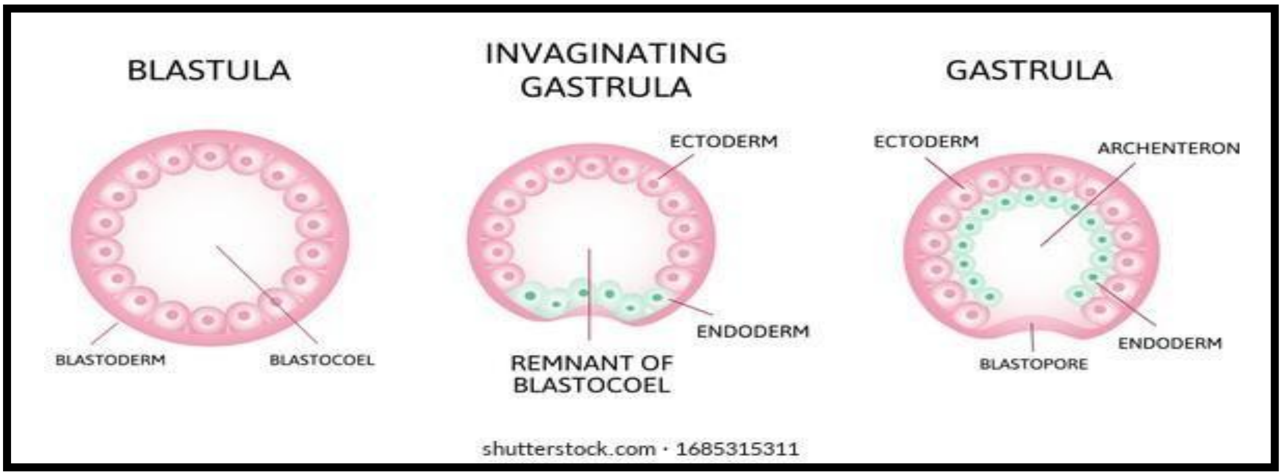
Gastrulation

The morphogenetic process called gastrulation rearranges the cells of a blastula into a three-layered (triploblastic) embryo, called a gastrula, that has a primitive gut. It means rearrangement of blastula cells that transforms the blastula into a gastrula. The blastula develops a hole in one end and cells start to migrate into the hole; this forms the gastrula which characterized by cell movement. Blastocoel is gradually disappeared and a new cavity is formed archenteron.



Germ Layer Patterns

Diploblastic gastrula = 2 germ layers

Endoderm (inner)

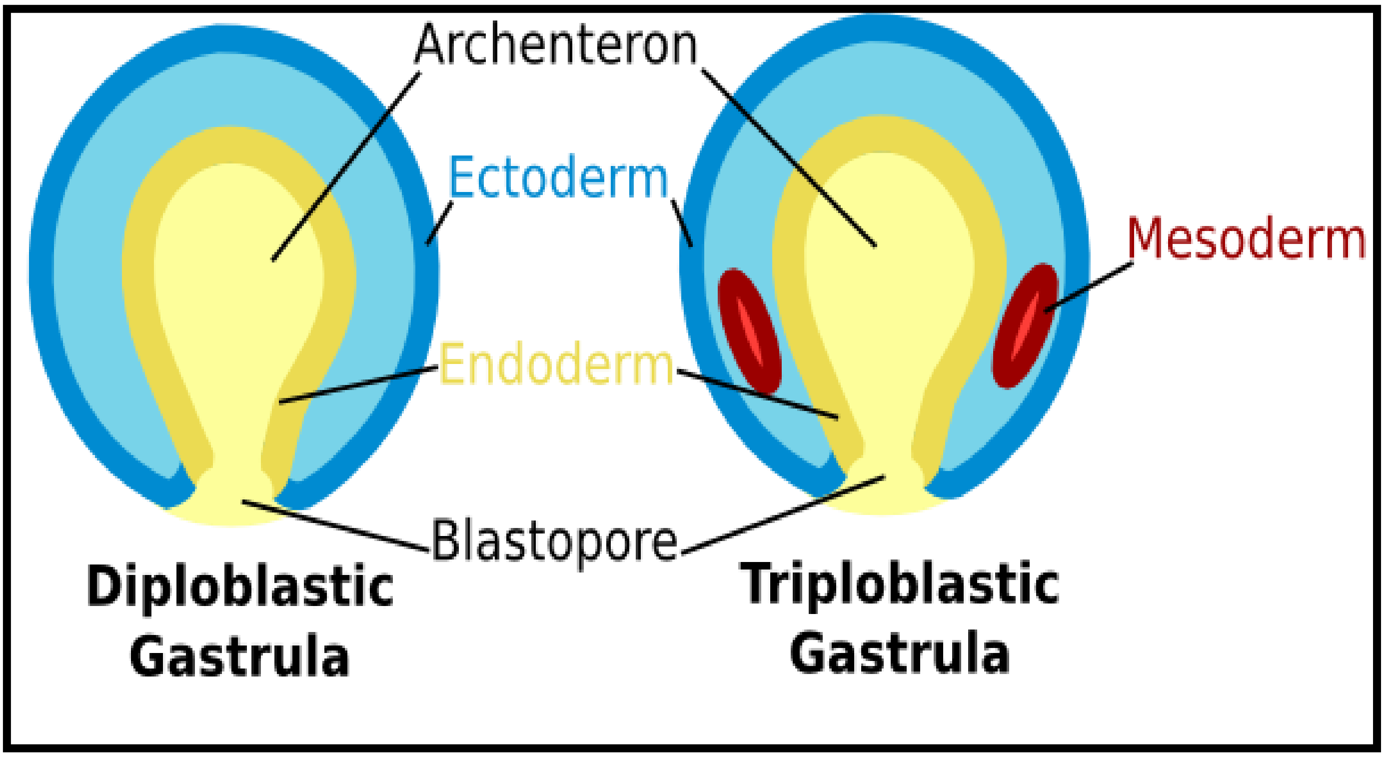
Ectoderm (outer)

Triploblastic = 3 germ layers

Endoderm (inner)

Mesoderm (middle)

Ectoderm (outer)

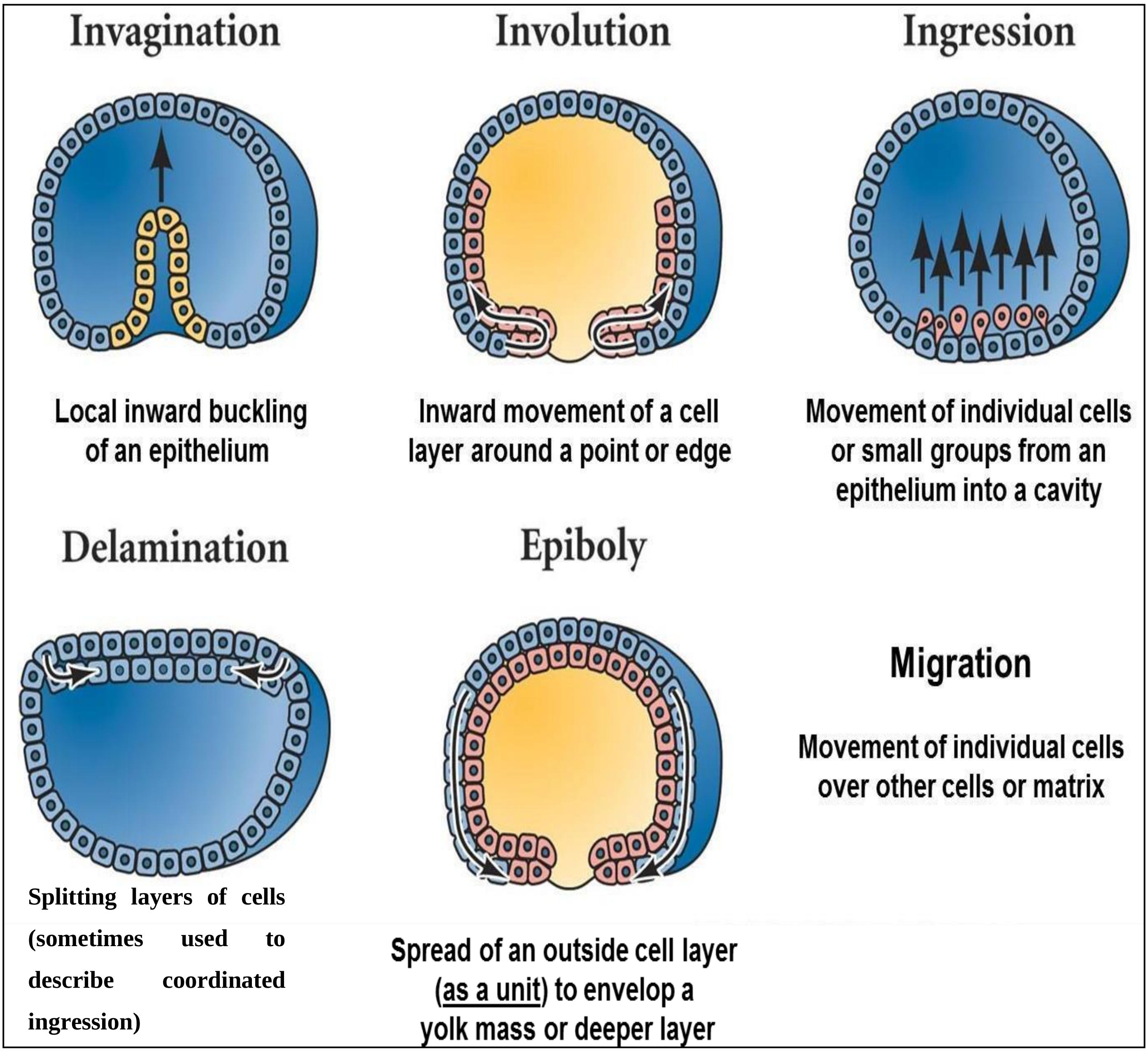


The pattern of gastrulation is affected by the amount of yolk. The cells at the vegetal pole invaginate, initiating gastrulation.

Gastrulation patterns

gastrulation patterns exhibit enormous variation throughout the animal kingdom, they are unified by the five basic types of cellmovements that occur during gastrulation:

- Invagination.
- Involution.
- Ingression.
- Delamination.
- Epiboly


Invagination
Local inward buckling of an epithelium
Involution
Inward movement of a cell layer around a point or edge
Ingression
Movement of individual cells or small groups from an epithelium into a cavity
Delamination
Splitting layers of cells (sometimes used to describe coordinated ingression)
Epiboly
Spread of an outside cell layer (as a unit) to envelop a yolk mass or deeper layer
Migration
Movement of individual cells over other cells or matrix

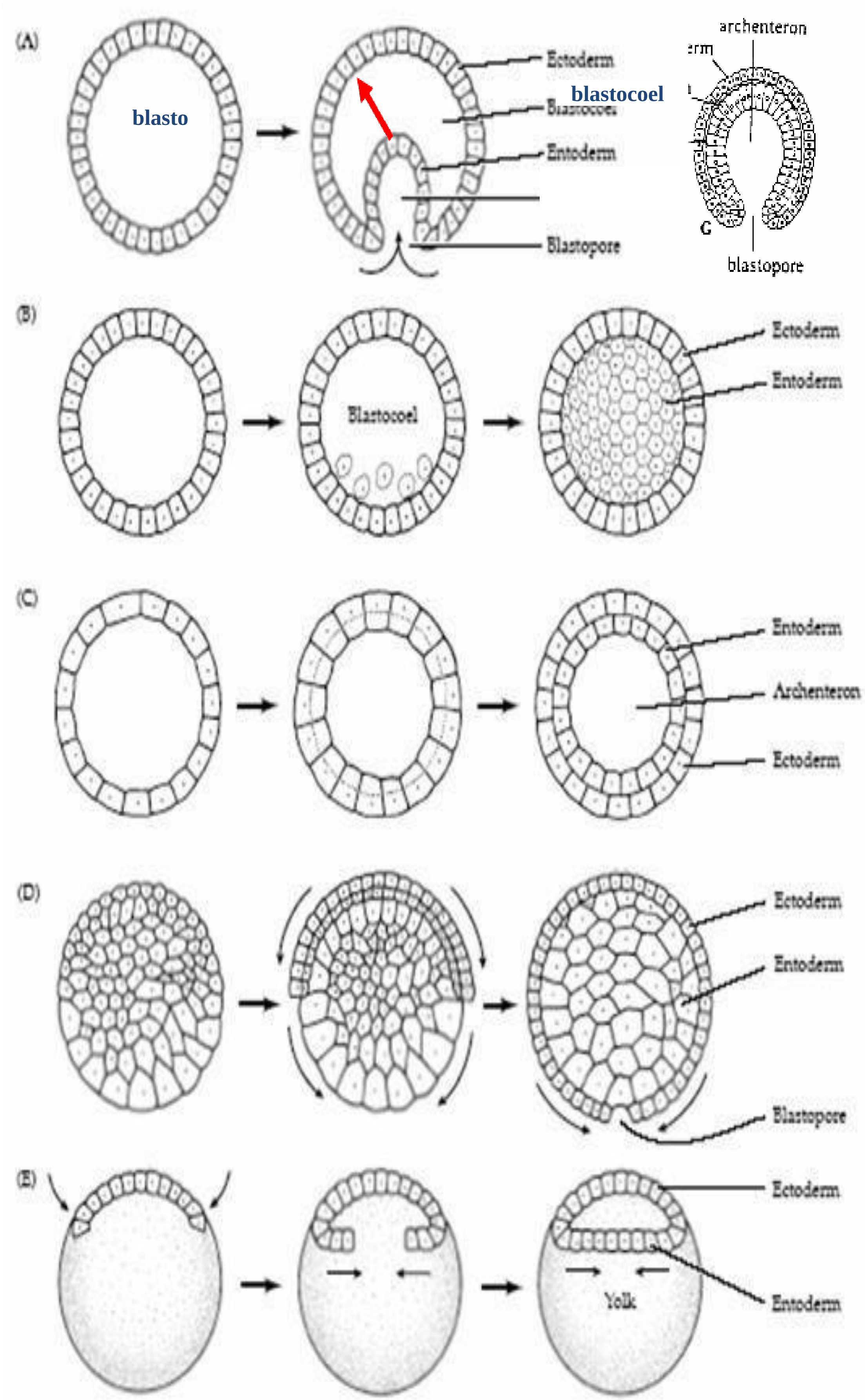
Invagination

Delamination

Ingression

Epiboly

Involution



Blastopore

Blastopore means a mouth-like opening of the archenteron on the surface of the embryo during the invagination of the archenteron. In many animals, the Blastopore becomes the anus.

The Blastopore is responsible for organizing and defining the germ layers. Through this layer, there is communication which takes place between the embryo and the outside environment in the womb. There is also a transfer of the necessary fluids until the gastrulation period lasts.

- ✓ In Coelenterate it becomes the mouth.
- ✓ In Protostomia (including Annelida, Mollusca, Arthropoda oups), it becomes subdivided into two opening, one of which becomes the mouth and other the anus.
- ✓ In Deuterostomia (including Echinodermata and Chordata), only the anus is formed.

Organogenesis

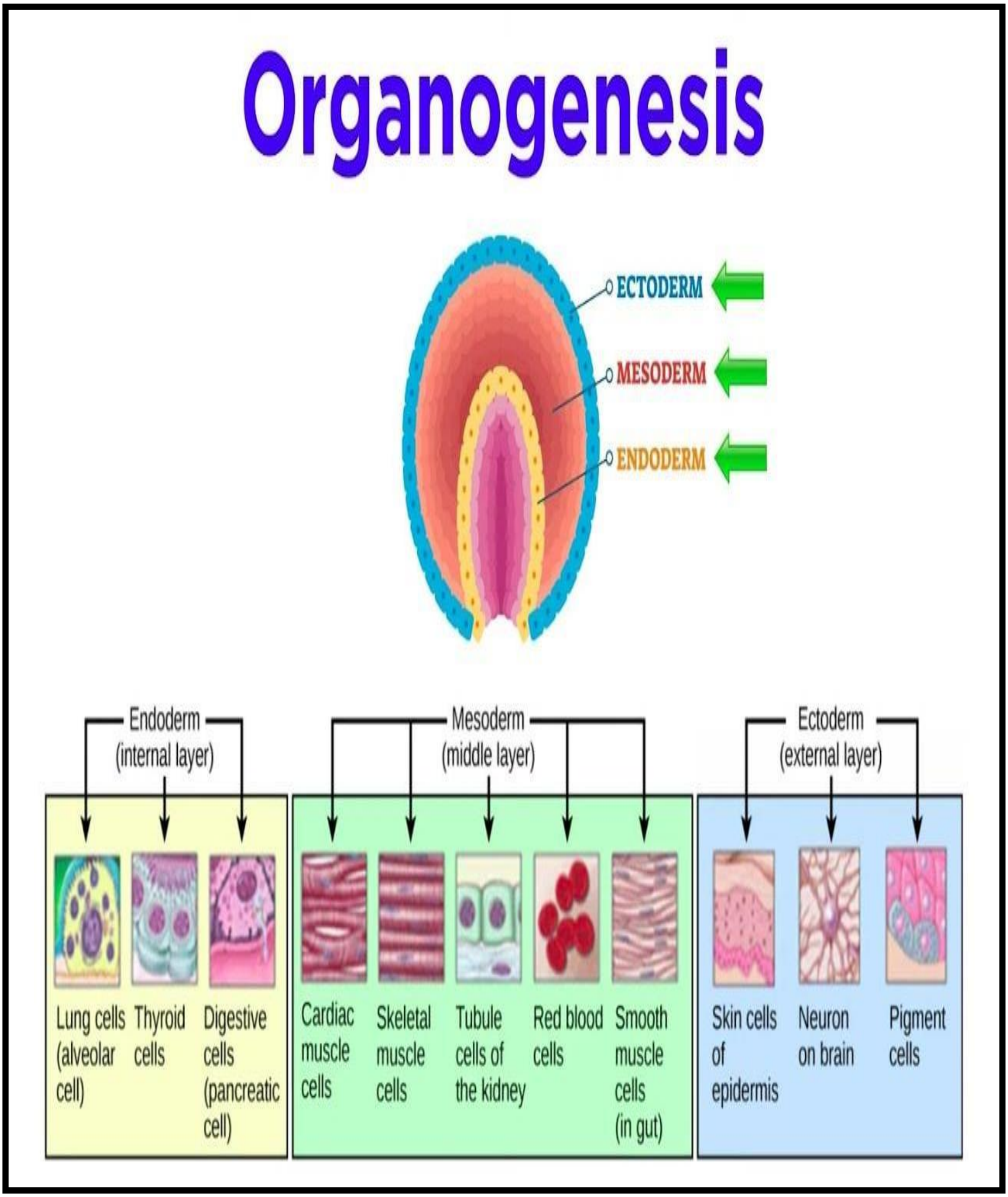
✓ Organ formation it is basically cell differentiation. The embryois called "fetus"

✓ During the fifth phase of development, the *organogenesis* (organs formation), the continuous masses of cells of the three germinal layers split up into smaller groups of cells, called the *primary organ rudiments*, each of which is destined to produce a certain organ or part of the adult animal body.

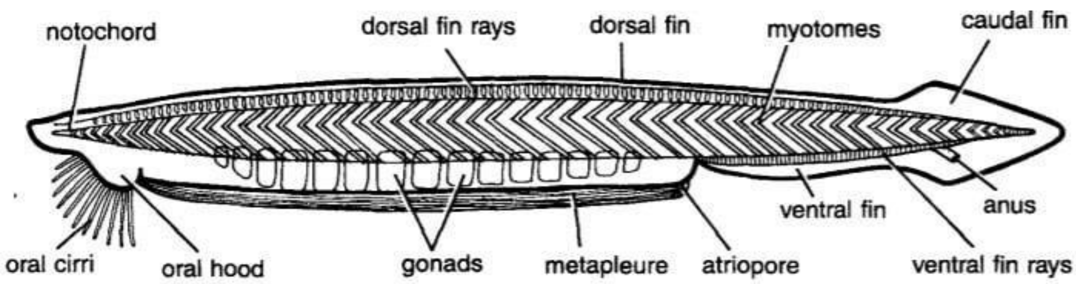
Germ layers

Embryonic Germ Layer	Vertebrate Adult Structures
Ectoderm (outer layer)	Epidermis of skin; epithelial lining of oral cavity and rectum; nervous system
Mesoderm (middle layer)	Skeleton; muscular system; dermis of skin; cardiovascular system; excretory system; reproductive system—including most epithelial linings; outer layers of respiratory and digestive systems
Endoderm (inner layer)	Epithelial lining of digestive tract and respiratory tract; associated glands of these systems; epithelial lining of urinary bladder

Differentiation of the Three Germ Layers



Early embryonic development of Amphioxus



Egg:

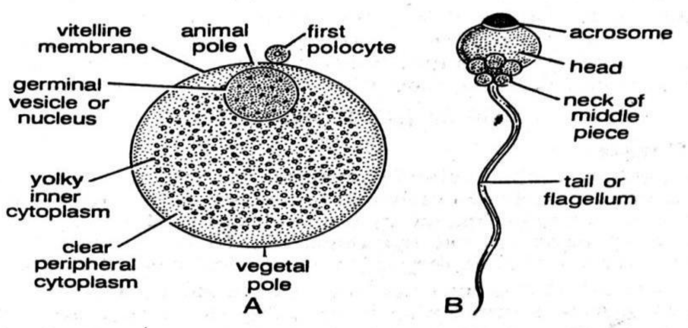
1 : The egg of Amphioxus is microlecithal and isolecithal type.

2 : The nucleus is almost centric because the yolk content is very less and does not affect the nucleus of the egg considerably.

3 : It can be differentiated into upper animal hemisphere and lower vegetal hemisphere containing animal pole and vegetable pole respectively.

Sperm:

1. The sperm of Amphioxus is extremely minute about 4μ in length and consist of a beak or acrosome, a head with a large compact nucleus, a neck or middle piece and a very long vibratile tail.



Amphioxus: A. Unfertilized egg. B. Sperm

FERTILIZATION:

Only one sperm can fuse with the egg. It is not yet known whether the entire sperm enters the egg or only the head enters. After the entry of sperm, the membrane becomes fibrous and is called fertilization membrane. A fluid filled space then appears between the fertilization membrane and the cell membrane. The fertilization membrane prevents the entry of more sperm. The chromosome of the egg and sperm come very close, develop a nuclear membrane around them and form a single nucleus- zygote nucleus. The egg is now called the zygote.

CLEAVAGE:

It is complete i.e., holoblastic which divides the egg completely into blastomeres.

1. First cleavage plane is meridional that is passing through the animal pole to vegetal pole axis forming two equal blastomeres.

2. Second plane of cleavage is also meridional but at right angle to the first one forming four equals sized blastomeres.

3. Third plane of cleavage is latitudinal which is slightly above the equatorial plane, The product is the 8-cell stage of which four upper are smaller cells called micro mere and four lower larger are called megameres.

4. Fourth set of cleavage is meridional forming 16 cell stage.

5. Fifth set of cleavage is latitudinal forming 32 cells in four tiers.

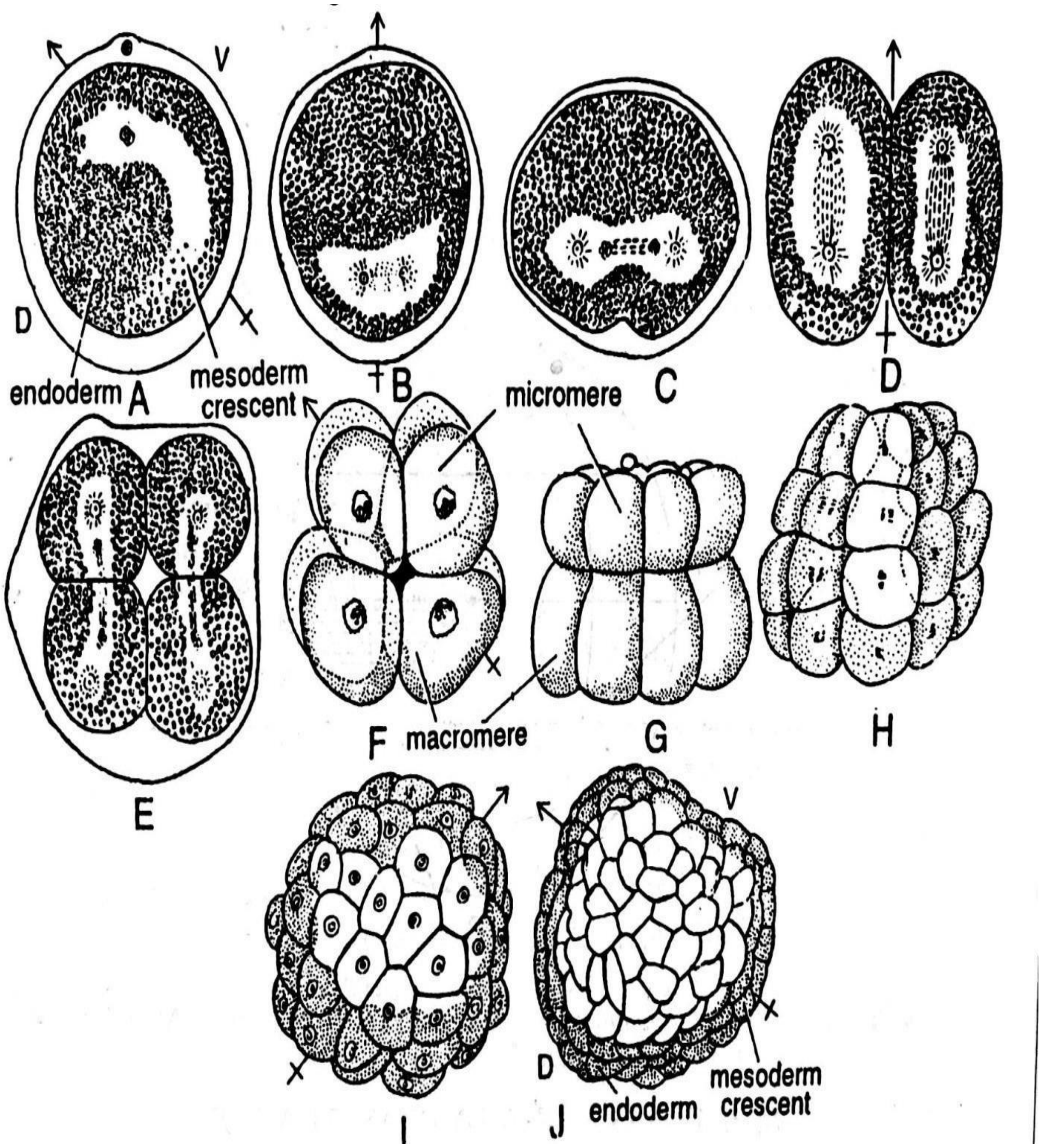
6. Sixth set of cleavage is meridional forming 64 cell stage.

7. The cleavage till now is synchronous i.e., all cells at a particular cleavage divide at a time.

8. The cleavage plane on seventh cleavage onwards is asynchronous i.e., all cells at particular cleavage do not divide at a time.

9. As the division advances, the embryo is converted into a solid ball of cell called as morula.

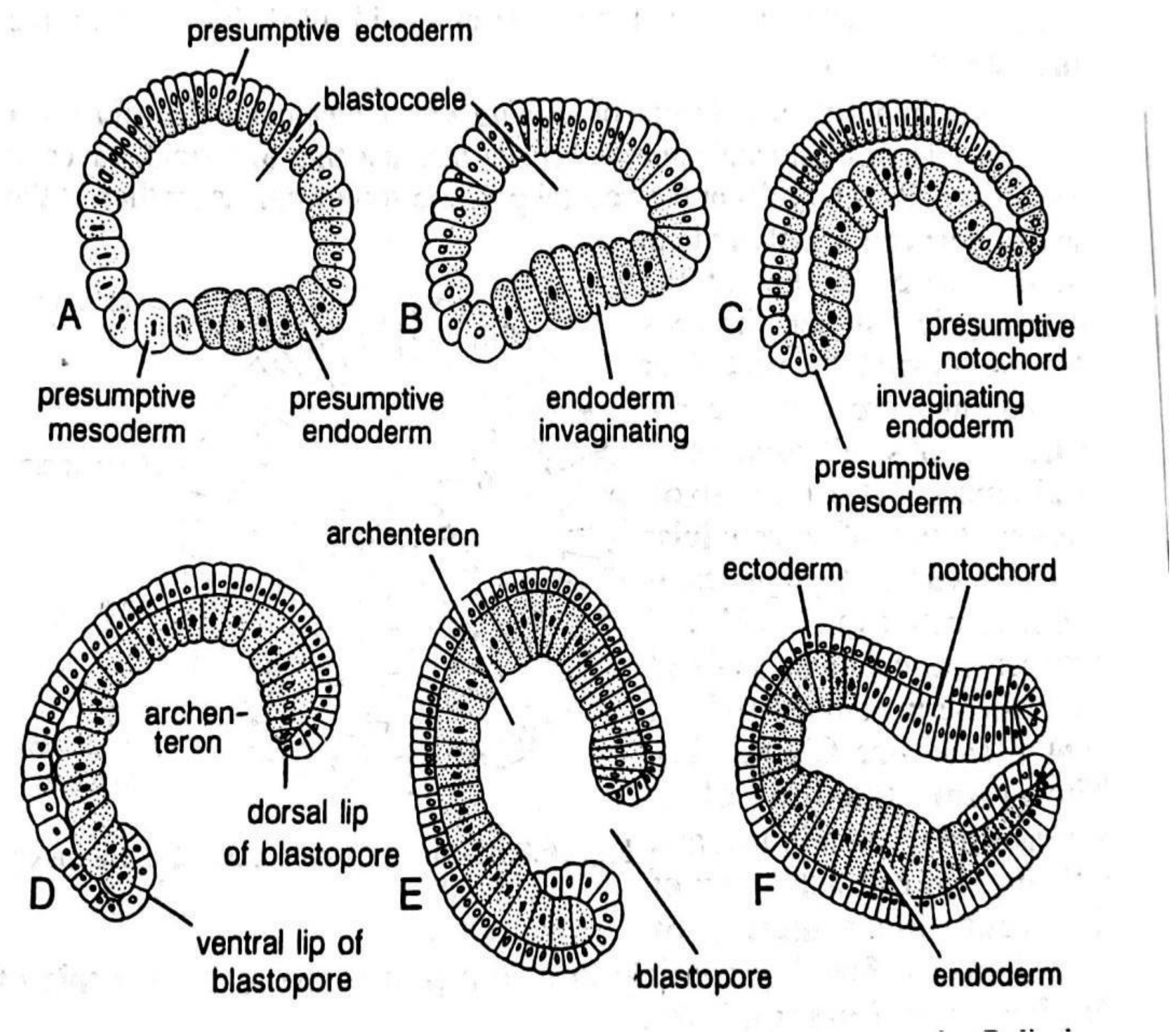
10. Soon a small cavity appears in the interior of the embryo. it became fluid filled and expense gradually pushing the cells on periphery and as a result a hollow ball of cells is formed having a spacious fluid filled cavity called blastocoel surrounded by a single layer of cells. This is called Blastula.



Cleavage and blastulation in Amphioxus- A-Fertilized egg, B.Mitosis of 1st cleavage .C- nuclear division. D-Two cell stage.E-Four cell stage.F-Eight cell stage. G-sixteen cell stage. H-Thirty cell stage. I-Morula stage J-Blastula stage

GASTRULATION:

Gastrulation is a process by which the monoblastic blastula is converted into a structure containing well-defined three germinal layer from which different organs can be formed.



Gastrulation of Amphioxus: A series of consecutive stages.

Summary

- ✓ Phylum: Chordata – Class: Cephalochordata
- ✓ Sexes are separate
- ✓ The gonads which are in the form of hollow sacs enclosed in coelomic pouches- twenty six in number on each side
    - genital ducts are lacking
- ✓ On maturity of gonads the sperms and ova are liberated into the atrium and from where they are discharged outside through the atriopore in breeding season
- ✓ The spermatozoa contain spherical head, very short mid-piece and tail
- ✓ The ovum of is 0.10 mm to 0.12 mm in diameter
- ✓ Type of Egg: According to amount of yolk oligolecithal or microlecithal

According to distribution of yolk isolecithal

- ✓ Fertilization: External
- ✓ **Type of cleavage:** holoblastic cleavage

The first is holoblastic and meridional passes through the egg axis from pole to pole. Result in two identical blastomeres.

The second in a vertical plane, at right angles to the first plane, forming four cells.

The third is horizontal (latitudinal) nearer the animal pole. Each of the four blastomeres dividing into a smaller micromere at the animal pole and a larger macromere at the vegetal pole. Eight blastomeres are produced.

The Fourth cleavage is double plane each one oriented from animal to vegetal pole. Results in eight animal micromeres and eight vegetal macromeres.

The Fifth is latitudinal and double parallel to plane three – one occurring in the animal, the other in the vegetal hemisphere. They result in 32-cells, arranged in four tiers.

The sixth cleavage are approximately meridional, producing 64-blastomeres

The cleavages pattern beyond this is irregular and difficult to follow.

The blastomeres remain loosely packed and form the embryonic stage, called morula.

Early embryonic development of Frog

Xenopus laevis

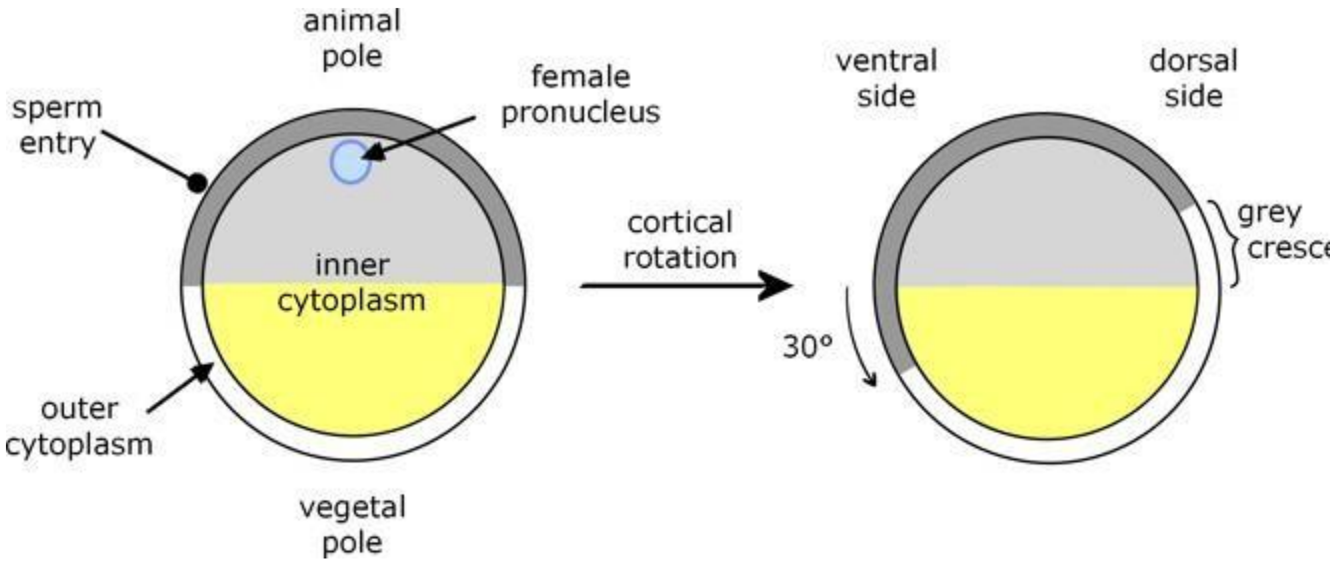
There are three groups of present-day amphibians:

- urodeles (having a tail) e.g. salamanders;
- anurans (without a tail) e.g. frogs and toads; and
- caecilians (without limbs) so resemble worms or snakes.

Most embryological studies have been on frogs because their development can be observed easily, especially the African clawed frog (Xenopus laevis) because it is easy to stimulate egg laying, and the following description is based mainly on this species.

Egg and fertilisation

Amphibian eggs are generally large, with a substantial quantity of yolk. In Xenopus the cytoplasm is in two distinct parts, inner and outer (or cortical). The inner cytoplasm of the animal hemisphere is darker than that of the vegetal hemisphere; and, corresponding with this, the animal cortical cytoplasm is pigmented, whereas the vegetal cortical cytoplasm is not. In the haploid egg meiosis is halted at metaphase II, and on fertilisation meiosis completes to yield the diploid zygote.

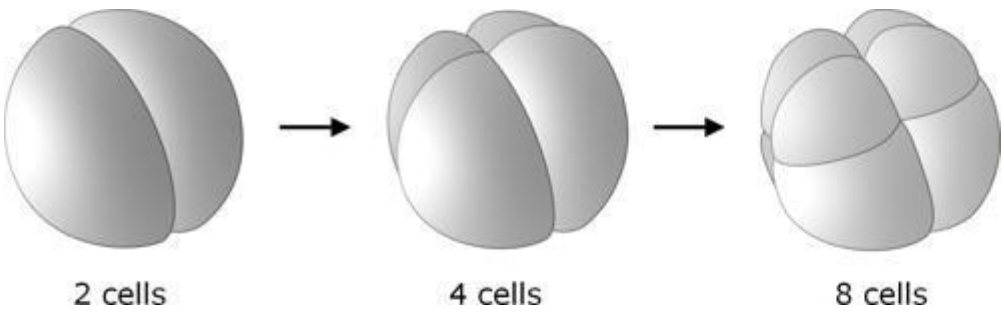


Xenopus fertilisation

Sperm entry and completion of meiosis prompts the cortical cytoplasm to rotate by about 30° relative to the deep cytoplasm, such that part of the underlying animal hemisphere becomes visible as a ‘grey crescent’. Due to this rotation, sperm entry (which always occurs in the animal hemisphere) specifies the dorsal-ventral (back-front) axis of the embryo, because gastrulation begins opposite sperm entry, on the same side as the grey crescent.

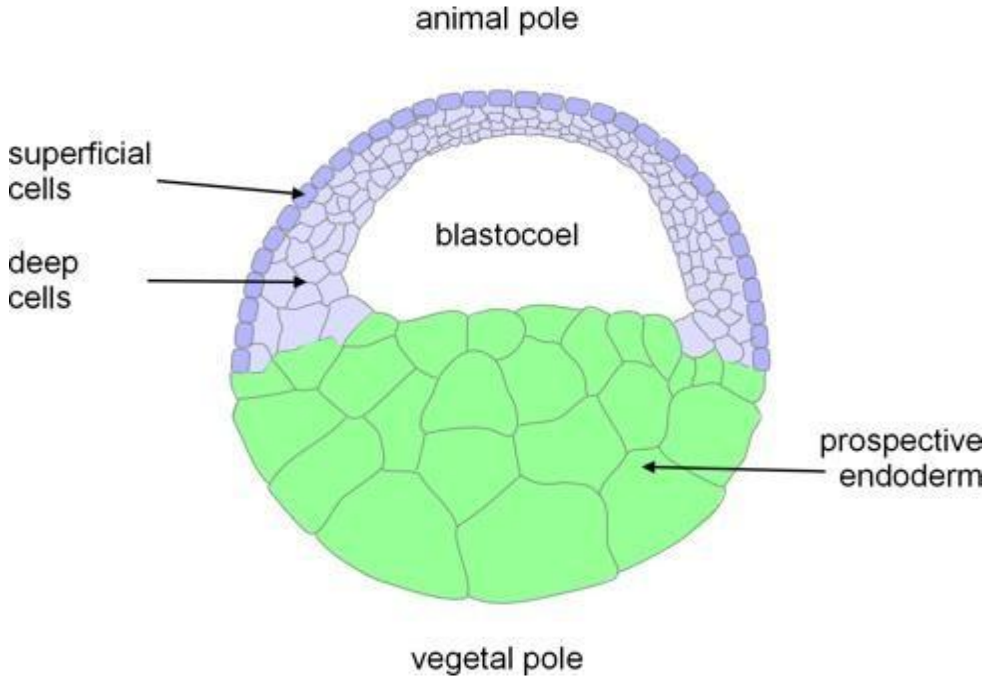
Cleavage and Blastula

Cleavage is holoblastic: the first divisions extend right through the zygote. The first cell division goes through the poles of the zygote (meridional), as does the second but at right angles to the first, to produce four approximately symmetrical cells. The third division is at right angles to the first two (latitudinal), and approximately equatorial except that it is somewhat towards the animal pole. This occurs because, although cleavage is holoblastic, division is slower through the yolky vegetal hemisphere; and this pattern continues with subsequent divisions being more frequent in the animal hemisphere, which leads to cells there being smaller than in the vegetal hemisphere.



Xenopus cleavage: the first 3 cell divisions.

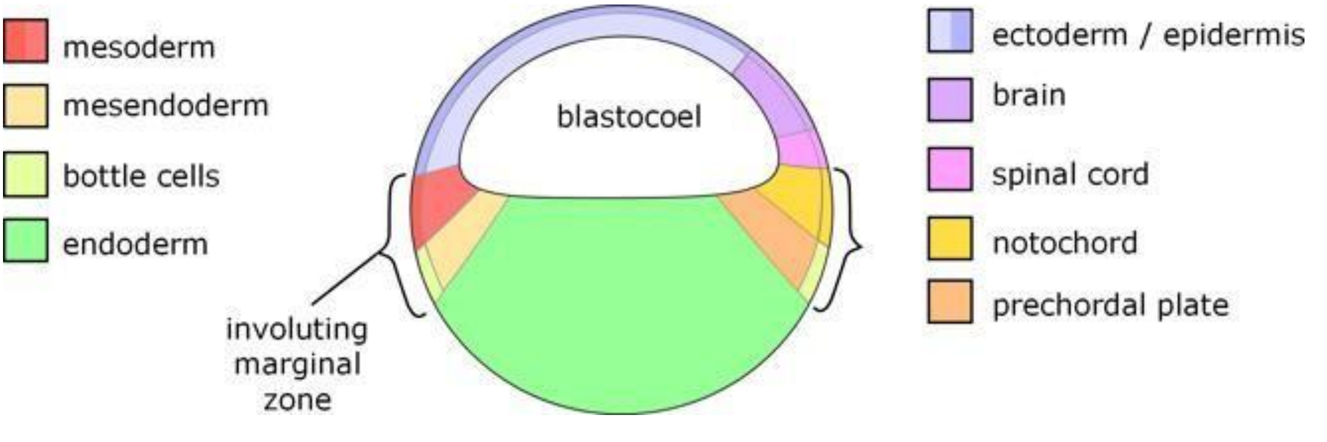
A blastocoel begins to develop from the first cell division and is evident from the 8-cell stage. Eventually it occupies a large part of the animal half of the blastula. Its dome-like roof is formed by numerous small, pigmented micromeres, whilst the vegetal half is composed of large yolk-laden, pale macromeres. Also, the cells of the animal hemisphere and upper part of the vegetal hemisphere form an outer epithelial layer and an inner or deep layer whose cells are more mesenchymal in nature.



Section through *Xenopus* blastula.

Gastrulation

Before describing the cell movements that occur during gastrulation it's probably helpful to summarise the fates of different parts of the blastula.



Section through *Xenopus* blastula section, showing prospective fates following gastrulation.

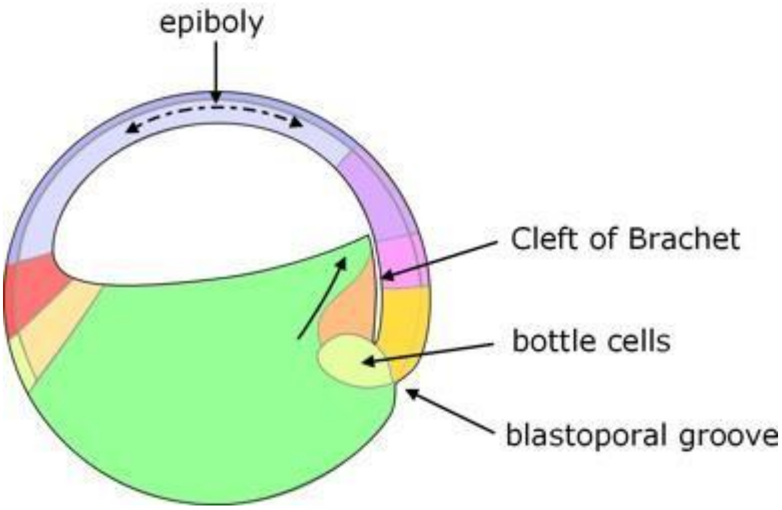
The cells of the animal hemisphere spread (epiboly) to cover the whole of the embryo, to form the ectoderm. Cells along the dorsal centreline form the neural plate, which produces the neural tube and then reforms the epidermis above the neural tube.

- A band of cells (the involuting marginal zone, IMZ) around the equator of the blastula moves inwards and then upwards. Mainly, these form mesoderm, the most dorsal part of which is the notochord.
- Most of the cells of the vegetal hemisphere are enveloped by the expanding ectoderm, are incorporated within the body of the embryo, and develop into endoderm.

The first external sign of gastrulation is when cells just below the equator, called bottle cells, on the dorsal side invaginate to form a crescent-shaped groove, which is the beginning of the blastopore.

However, before this, some deep cells (presumptive prechordal plate) of the dorsal side of the vegetal hemisphere begin to move toward the animal pole. They move close to the inside of the animal dome, but separated from it by a small gap known as the Cleft of Brachet.

Bottle cells. Bottle cells occur on the outer surface of the embryo where invagination occurs. Their outer surface constricts, and this constriction creates a local depression which develops into the invagination through which cells involute. They are called 'bottle cells' because the constriction makes them somewhat bottle-shaped.

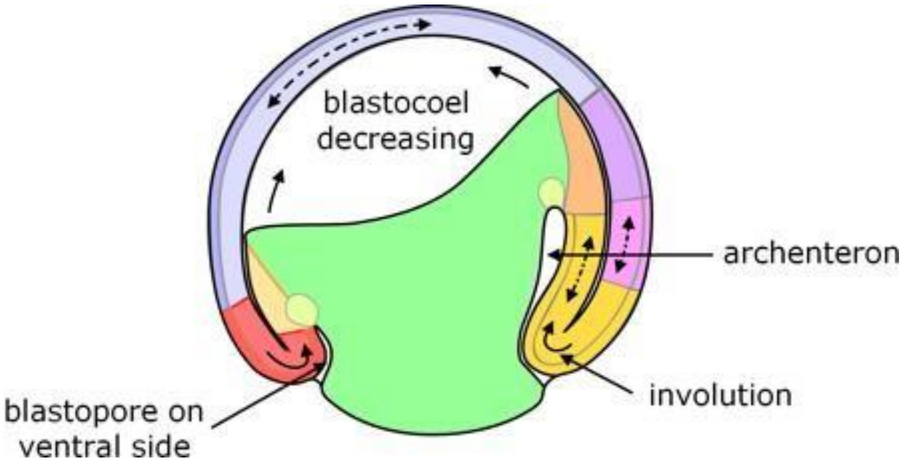


Start of gastrulation

At the same time, the animal hemisphere begins epiboly (partly by flattening of its cells, and partly by intercalation of cells from different layers) and, as it does so, its cells along the upper edge (dorsal lip) of the blastopore start to roll over the lip (involute) into the blastopore. These cells, which are predominantly presumptive notochord, move towards the animal pole, close to the overlying outer layer of cells, behind the presumptive prechordal plate.

The dorsal part of the blastopore deepens to form a pouch known as the archenteron which gets progressively larger, gradually displacing the blastocoel which in due course almost disappears.

The blastoporal groove progressively extends laterally on both sides until the two ends of the groove meet on the ventral side of the blastula, and the resulting blastoporal groove completely encircles the vegetal pole of the blastula. At the ventral side of the blastopore, cells of the expanding animal hemisphere involute and move towards the animal pole. What were part of the outer layer of cells becomes endoderm, and the deep cells become predominantly mesoderm.



Mid-gastrulation: the archenteron has formed, the blastopore encircles the vegetal pole, and involution is taking place all around the lip of the blastopore.

It will be apparent from the foregoing that involution begins at the dorsal side before the ventral side. Consistent with this, the involuted cells on the dorsal side move further than those on the ventral side, and there is an overall rotation of the inner cells with respect to the outer cell layers.

Summary

- ✓Phylum: Chordata – Class: Amphibia
- ✓Fertilization: External.
- ✓Type of Egg: According to amount of yolk mesolecithal. According to distribution of yolk telolecithal.

Spawning:

The mesolecithal eggs of frog enclosed in a protective gelatinous albumen are laid in water. The cluster or masses of eggs which remain stick together is called spawn. A spawn of *Rana tigrina* may have 3000 to 4000 ova. The spawn is laid during pseudocopulation or amplexus.

- ✓Type of cleavage: Unequal holoblastic cleavage.
- ✓Adult toads live on land most of the time and rely on water for hydration, breeding, and temperature regulation, Mating.
- ✓Cleavage and blastulation the period of cleavage and blastula formation completed within 24 hours.
- ✓The cleavage furrow elongates at a rate of about 1mm/minute in the animal hemisphere but slows to 0.03mm/minute in the vegtal pole.

The first is meridional. It cuts the egg through its median animals-vegetal polar axis and result in two equals sized blastomeres.

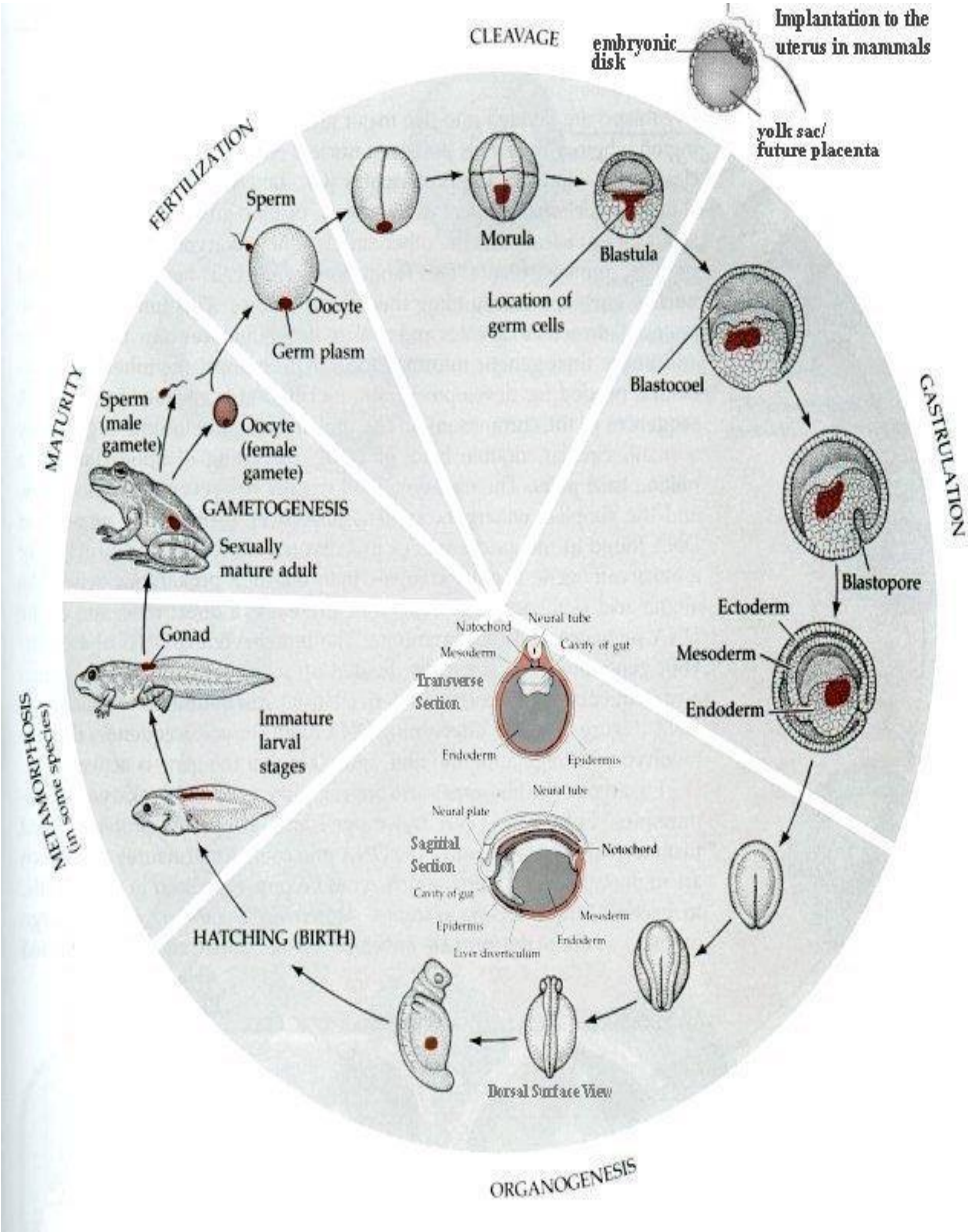
The second at the right angles to the first plane.

The third orient parallel to the polar axis and displaced near the animal pole. The eight blastomeres stage consists of four large-sized, yolk rich, vegtal cells (macromeres)and four small-sized, yolk poor, animal cells (micromeres).

The fourth cleavage is double plane each one oriented from animal to vegtal pole result in 16-cell stage.

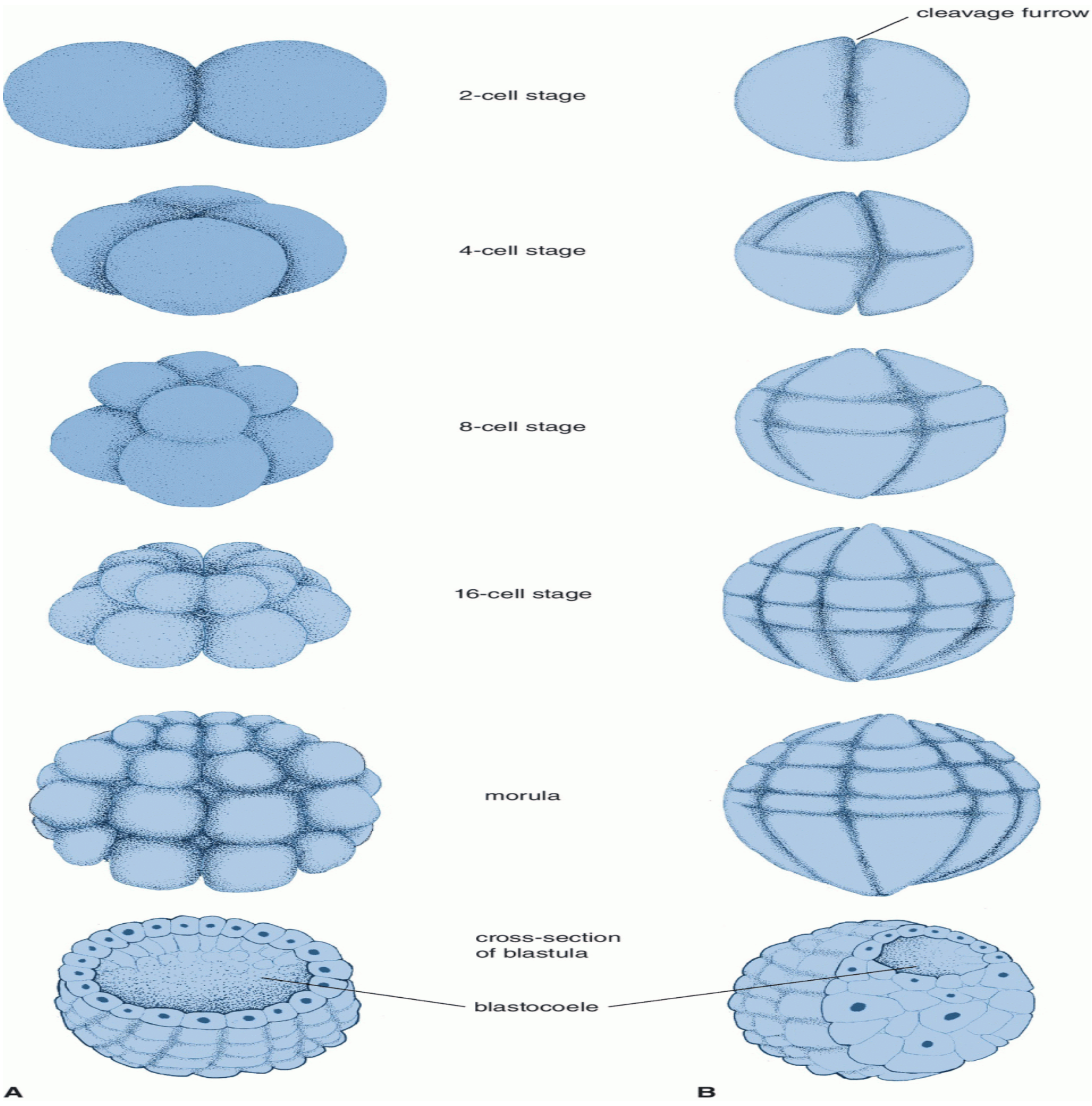
In amphibians, an embryo between the 16-and 64-cell stages is commonly called a morula. A cavity (blastocoel) appears in the animal's hemisphere above the mass of yolk. The blastula Blastula is a hollow spherical embryonic stage. The blastoderm remains two-cell thick towards the animal pole of the egg, the sides and floor of the blastoceol are multilayered blastoderm of large yolky blastomeres. -The blastoderm encloses ecenteric (peripheral) blastocoel.

-The blastocoel becomes infiltered by water and albuminous fluid secreted by the surrounding blastomeres.


CLEAVAGE
embryonic disk
Implantation to the uterus in mammals
yolk sac/ future placenta
FERTILIZATION
Sperm
Oocyte
Germ plasm
Morula
Blastula
Location of germ cells
Blastocoel
GASTRULATION
Blastopore
Ectoderm
Mesoderm
Endoderm
MATURITY
Sperm (male gamete)
Oocyte (female gamete)
GAMETOGENESIS
Sexually mature adult
Gonad
Immature larval stages
METAMORPHOSIS (in some species)
HATCHING (BIRTH)
Notochord
Neural tube
Mesoderm
Cavity of gut
Transverse Section
Endoderm
Epidermis
Neural tube
Neural plate
Sagittal Section
Notochord
Cavity of gut
Mesoderm
Epidermis
Endoderm
Liver diverticulum
Dorsal Surface View
ORGANOGENESIS

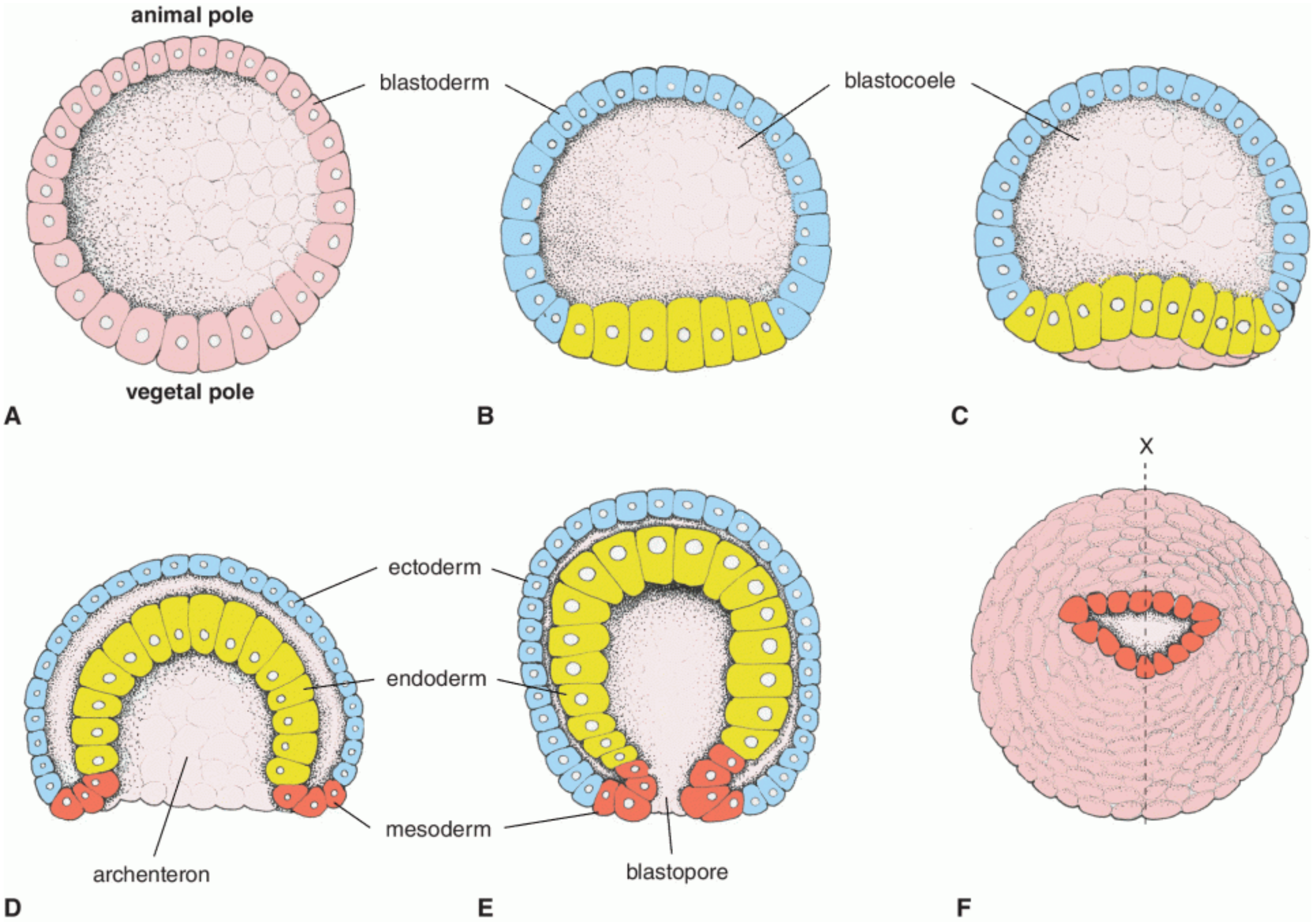
Quick comparative review between Amphioxus and Frog early development

1- *Stages of cleavage from the 2-cell stage to the early blastula stage in Amphioxus, A, and amphibians, B.*



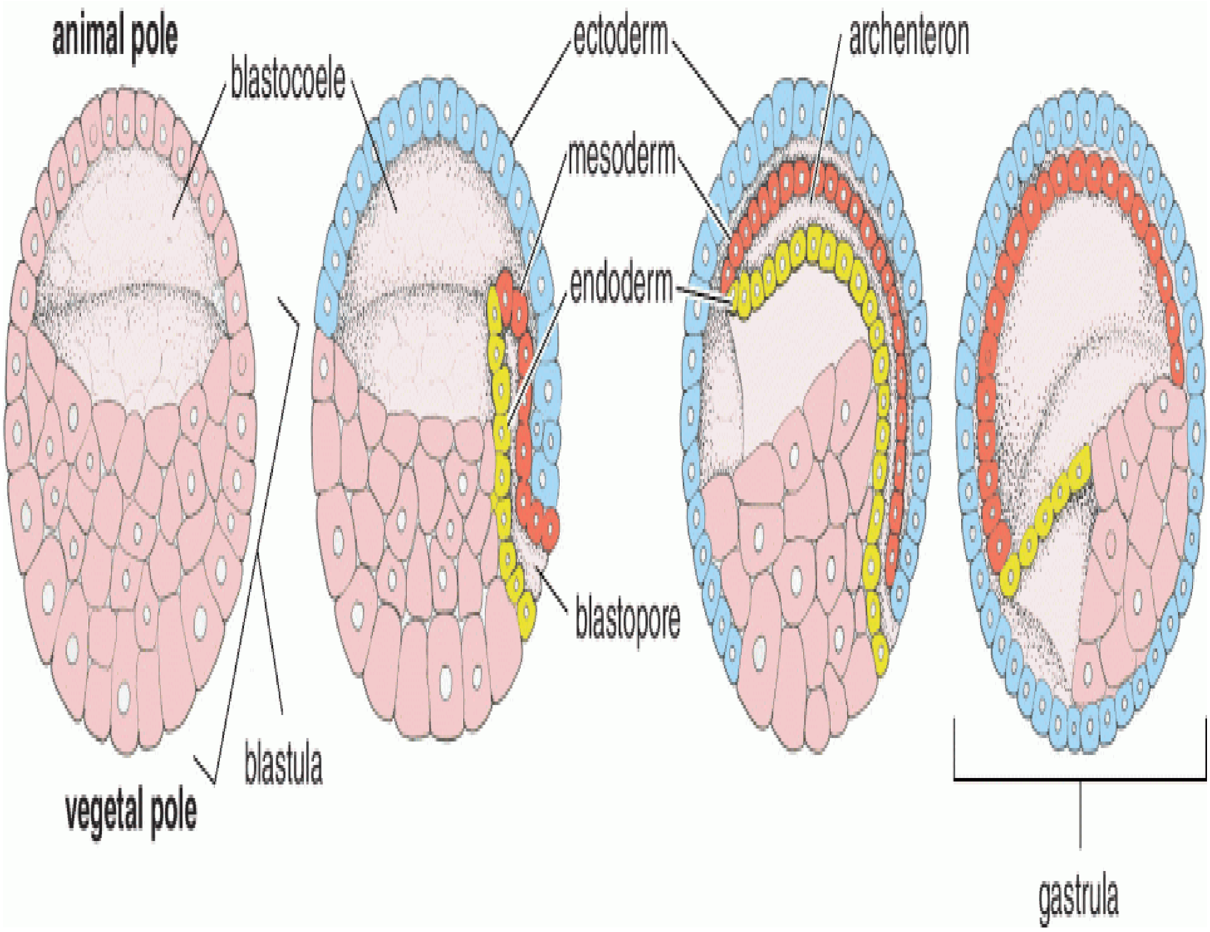
2- *Sections showing sequential stages of gastrulation in Amphioxus from the blastula stage A to the gastrula stage E. The section shown in E is at the level indicated in the embryo at the gastrula stage in F.*

The pattern of gastrulation in Amphioxus represents a comparatively simple model for illustrating the major cellular events in germ layer formation observed in more evolutionarily advanced species. Gastrulation in Amphioxus begins when the blastoderm at the vegetal pole flattens and invaginates. The embryo then undergoes a series of morphological changes. As cells at the vegetal pole invaginate, the spherical shape of the embryo changes with the sequential formation of a cavity referred to as the archenteron or primitive gut. The opening of the archenteron to the exterior is known as the blastopore. The outer layer of cells form the ectoderm, and the inner layer the endoderm. Cells responsible for the formation of the notochord and other mesodermal structures originally occupy a position at the edge of the blastopore. Later, these cells migrate to a position between the ectoderm and endoderm. Thus, the endodermal and mesodermal structures relocate from the surface of the embryo to its interior, forming a trilaminar embryo referred to as a gastrula.



3- Sequential stages of gastrulation in amphibians from the blastula stage to the gastrula stage.

Because of the presence of yolk filled cells in the vegetal hemisphere of the amphibian blastula, invagination, as observed in Amphioxus, cannot occur. At the junction of the animal and vegetal hemispheres, cells from the surface move to the interior forming a cleft, the forerunner of the primitive gut. Following an influx of endodermal cells from below the cleft and mesodermal cells from above, the cleft deepens. With the constant movement of cells from the surface to the interior, a circular blastopore is formed. The blastocoele becomes obliterated and the yolk-laden cells at the vegetal pole move to the interior. Finally, a trilaminar embryo, similar to that observed in Amphioxus, is formed.



Early embryonic development of Birds

Egg and fertilization

Testes

The male bird or rooster, possess a pair of testes, each testis is an oval body, cream white in colour and. From its inner border, a vas deferens emerges to run backwards, lateral to the ureter to open into the cloaca. Just before its opening, it dilates forming a small vesicular seminalis.

Ovaries

In the adult of most flying birds only one ovary of the left side, the right one degenerates.

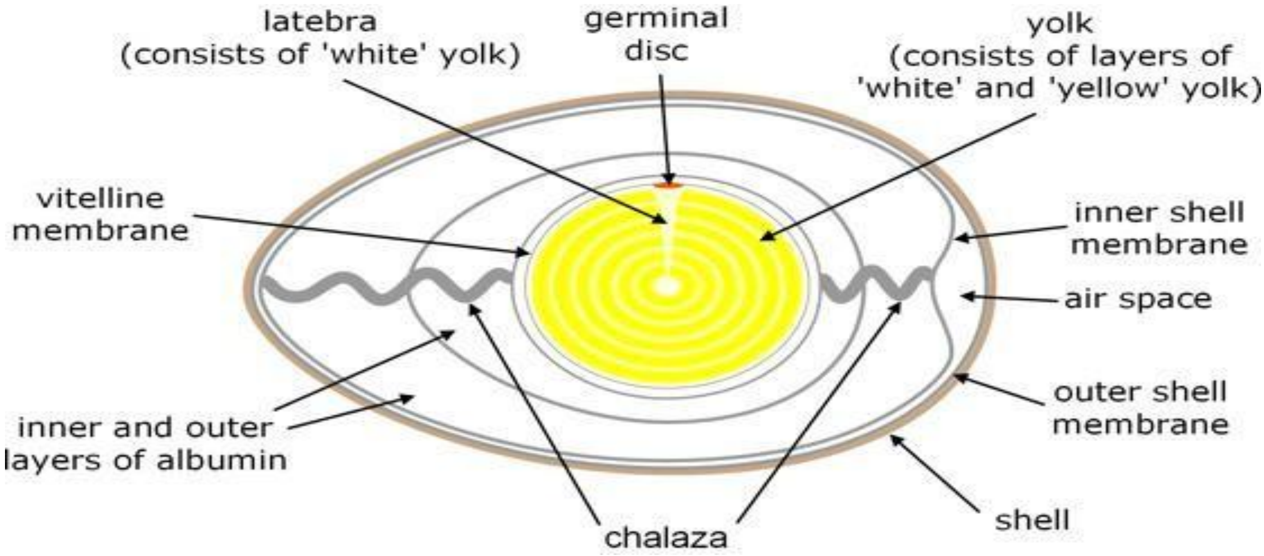
The structure of ovum:

The oocyte grows due to the accumulation of yolk in it, the cytoplasm localized at the animal pole in which the nucleus embedded.

The mature oocyte migrates towards the periphery and finally buldged out from the ovary, connected with the ovary only by means of stalk. The fully formed egg contains a large amount of yolk. The cytoplasm is very little and is in the form of a small disc (the blastodisc or germinal disc).

After fertilization the ovum is surround by various envelopes added to the delicate vitelline membrane.

The cleavage starts immediately in the germinal disc. The fully formed and laid egg is surrounded on the outer side by a calcareous shell. The shell consisting chiefly of calcium carbonate.



Section through domestic hen's egg.

Fertilisation of the egg occurs in the oviduct, before the albumen and shell are added to it. The egg is laid about 24 hours after fertilisation, by which time the development has reached the blastula stage.

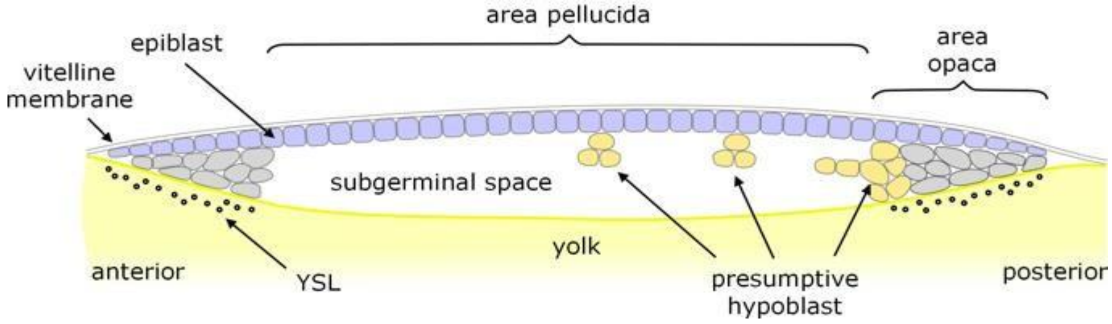
Cleavage and blastula

Consistent with having a large yolk, cleavage is meroblastic and is restricted to the germinal disc, and cell divisions do not extend into the yolk at all. The first division passes near the centre of the germinal disc and the next few divisions are at right angles to the preceding one, but then divisions become more irregular and asymmetric.

View from above of the germinal disc after the first few cleavages.

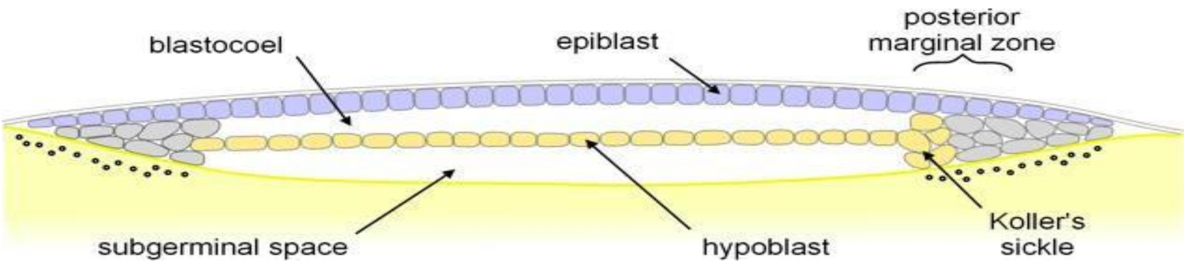
Hence, the early divisions give rise to a disc of cells (blastoderm), several layers thick, sitting on top of the yolk, with a subgerminal cavity in-between. Cells on the periphery of the disc are open to the cytoplasm of the germinal disc, i.e. they form a yolk syncytial layer (YSL).

Across most of the disc, the cells thin to a substantially single layer (but see below) of epithelial cells called the epiblast. This thinning appears to be mainly through cells of the deeper layers being shed, and possibly through some of the lower layer cells being intercalated with the uppermost layer. The central area is relatively translucent and is called the area pellucida, and beneath this is a substantially cell-free subgerminal space. Around the margins of the germinal disc, the cells remain several layers thick, and this relatively opaque peripheral ring is called the area opaca.



Longitudinal section through the blastoderm.

The hypoblast (sometimes called the primary hypoblast) then forms. Some of its cells arise as separate ‘islands’ beneath the epiblast; it is not known to what extent these are left-overs from the preceding thinning process or arise by delamination (ingression) from the overlying epiblast. Most of the hypoblast cells arise from the posterior marginal zone (especially the area known as Koller’s sickle, named because it is crescent shaped when viewed from above) by some of its underlying cells spreading anteriorly and incorporating the ‘islands’. The space between the epiblast and hypoblast is the blastocoel.

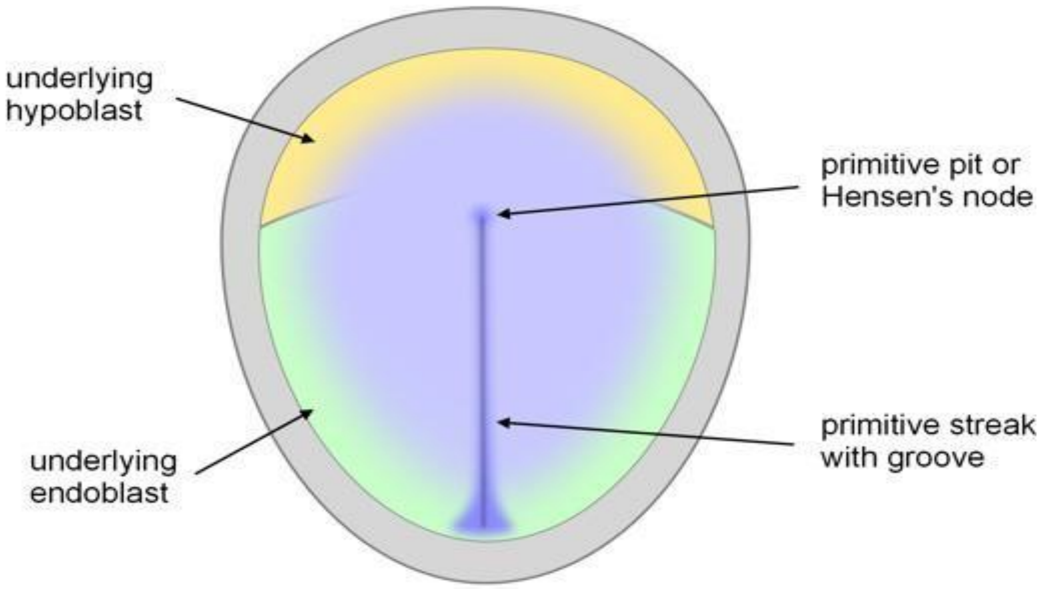


Longitudinal section through the blastula.

Gastrulation

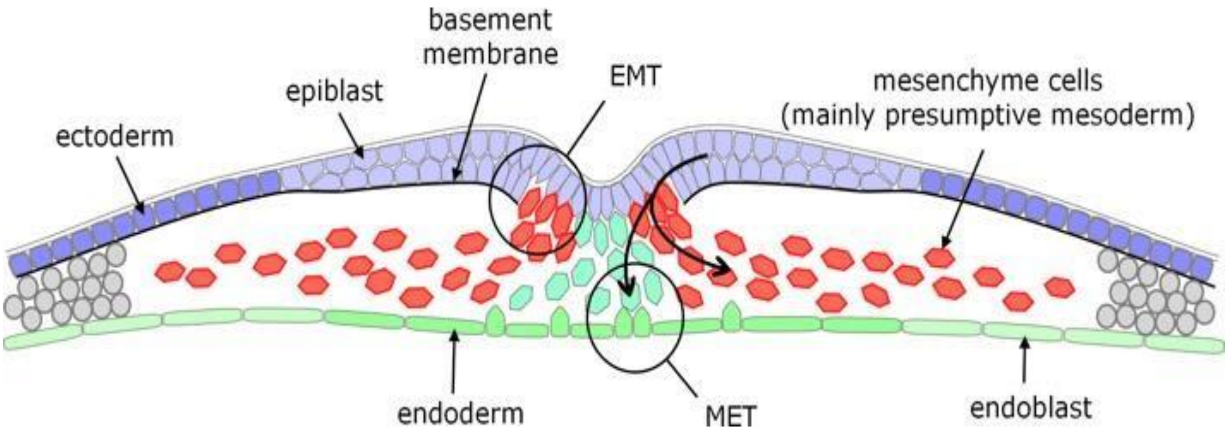
The key feature of gastrulation in birds is the primitive streak.

Initially this is a thickening of the epiblast along its midline, originating close to its posterior end (just forward of Koller's sickle) and then extending anteriorly until it reaches a maximum extent of about 2/3 across the area pellucida. As these thickening progresses along the epiblast, in tandem with it, a lower layer of cells spreads from the posterior margin. This endoblast (or secondary hypoblast) displaces the (primary) hypoblast anteriorly (figure 5). When the primitive streak reaches its maximum length, a groove develops on its dorsal (upper) surface along its length, culminating in a funnel-shaped depression at its anterior end, known as the primitive pit or Hensen's node.



Early primitive streak, at it's maximum extent, viewed from above, with the epiblast faded at the margin to view the underlying hypoblast and endoblast.

The epiblast spreads (epiboly); and it is through the primitive groove and pit that epiblast cells now ingress between the epiblast and endoblast. This translocation involves a change from an epithelial nature of the epiblast cells to a mesenchymal nature (epithelial-to-mesenchymal transition, EMT) such that the cells can migrate.



Transverse section through the primitive streak.

Some cells entering the primitive groove move across the intervening space and enter the endoblast to become endoderm (progressively displacing the endoblast to the sides of the embryo). Because the endoderm is an epithelial tissue, these migrating cells must revert to an epithelial nature i.e. undergo a mesenchymal-to-endothelial transition (MET).

Other cells spread out to form mesoderm between the overlying epiblast (ectoderm) and underlying endoderm.

In general, early cells entering the primitive streak become endoderm and later ones become mesoderm; but at any particular time some cells entering the streak are presumptive endoderm and some presumptive mesoderm.

Epiblast cells that do not enter the primitive streak remain as the ectoderm.

Early cells entering the primitive pit (Hensen’s node) move anteriorly, enter the endoblast and become the endoderm of the presumptive foregut. Cells following these become head mesenchyme, prechordal plate mesoderm, and then chordamesoderm which becomes the most anterior part of the notochord, i.e. starting at the most anterior, progressively more posterior parts of the mesoderm are laid down. When the posterior-ward growth of the chordamesoderm reaches the primitive pit, the pit itself starts to retreat posteriorly; and, as it moves progressively further posteriorly, cells entering the node become progressively more posterior parts of the chordamesoderm (and subsequently notochord).

While gastrulation is proceeding, the cells of the marginal zone start to spread outwards, beginning the extraembryonic membranes.

Embryonic development of mammals (humans)

Humans are classified within the group of mammals called eutherians which (with a few exceptions) use a placenta to nourish the developing embryo within the mother.

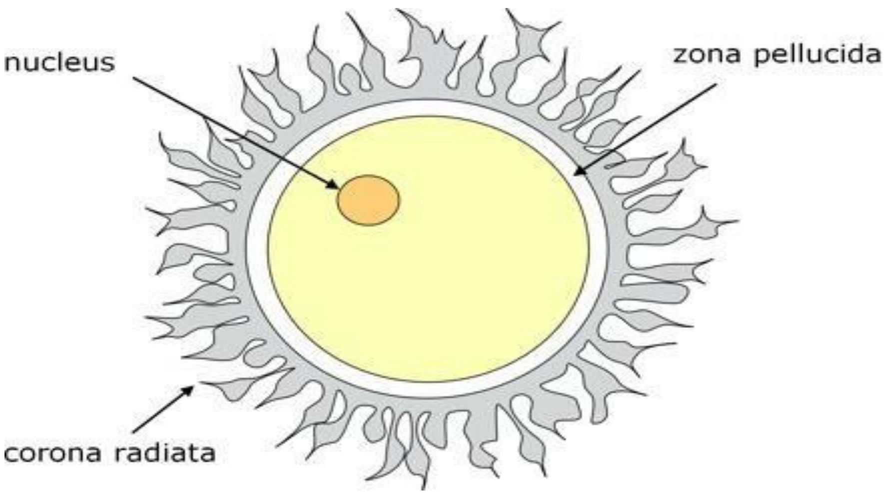
The other main groups of present-day mammals are:

marsupials (pouched), and

monotremes (egg-laying).

Egg and fertilisation

The human ovum comprises a single cell, about 0.1 mm in size, containing the haploid nucleus. It is enveloped by a clear jelly-like coat called the zona pellucida; and the whole is surrounded by a population of follicular cells (originating from the ovary) which form the corona radiata.

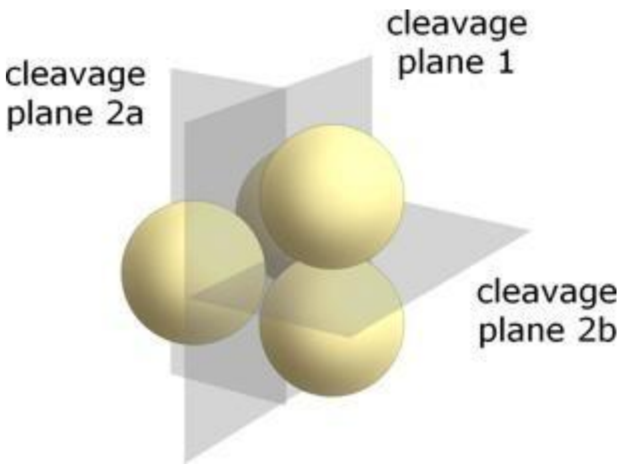


Section through human ovum.

Fertilisation takes place in the upper region of the oviduct (Fallopian tube) and the early stages of development unfold as the embryo travels along the oviduct. During its passage along the oviduct, the embryo loses some of the cells of the corona radiata, but the zona pelludica remains intact. Implantation in the uterus occurs when development has reached the blastocyst (blastula) stage.

Cleavage to blastocyst

Consistent with the absence of a significant yolk, cleavage in mammals is holoblastic, meaning that the first division extends right through the egg cell. The first division is typical of other organisms having holoblastic cleavage, with the division being meridional – extending from one pole to the other. However, in mammals the second cleavage is unusual: one cell divides meridionally, but the other divides equatorially; which is called rotational cleavage.



Rotational cleavage: cleavage 2a is meridonal, 2b is equatorial.

In most other organisms (having holoblastic cleavage) both of the second divisions are meridional, and the third or subsequent divisions are equatorial.

Also, whereas in other vertebrates the early cell divisions tend to be synchronous, this is often not the case with mammals, such that there is an odd number of cells instead of the usual geometric increase 2, 4, 8 … .

Early cell divisions also tend to be slower than for other animals.

The cell divisions up to just before implantation take place within the zona pellucida, so there is no overall increase in size of the embryo, but its cells become smaller as they proliferate.

Compaction and morula

Up to 8 – 16 cells, they form a loose association within the zona pellucida, but then they compact, with tight junctions forming between the outer cells. This is called the morula stage.

It is about now that the embryonic genome is activated, and this is followed by the first clear differentiation of cells, with further cell divisions resulting in inner cells being distinct from the peripheral ones, and the beginning of a fluid-filled cavity, the blastocoel.

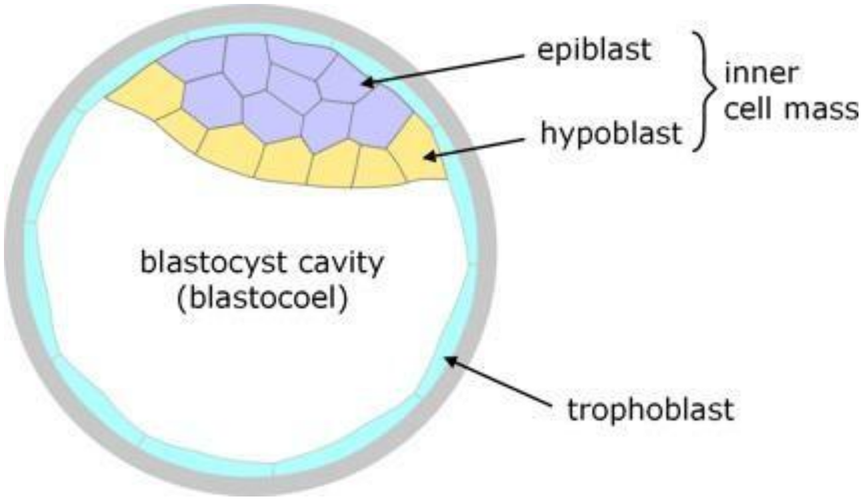
Blastocyst

The blastocyst is the mammalian equivalent of the blastula in other vertebrates. It comprises three populations of cells:

an outer cell layer (trophoblast) which develops into the placenta; and

an inner cell mass:

most of which is the epiblast, which is the source of embryonic tissues, and the amnion, although the layer of cells in contact with the blastocoel is the hypoblast, most of which forms extraembryonic tissues.



Human blastocyst.

Implantation and embryonic disc

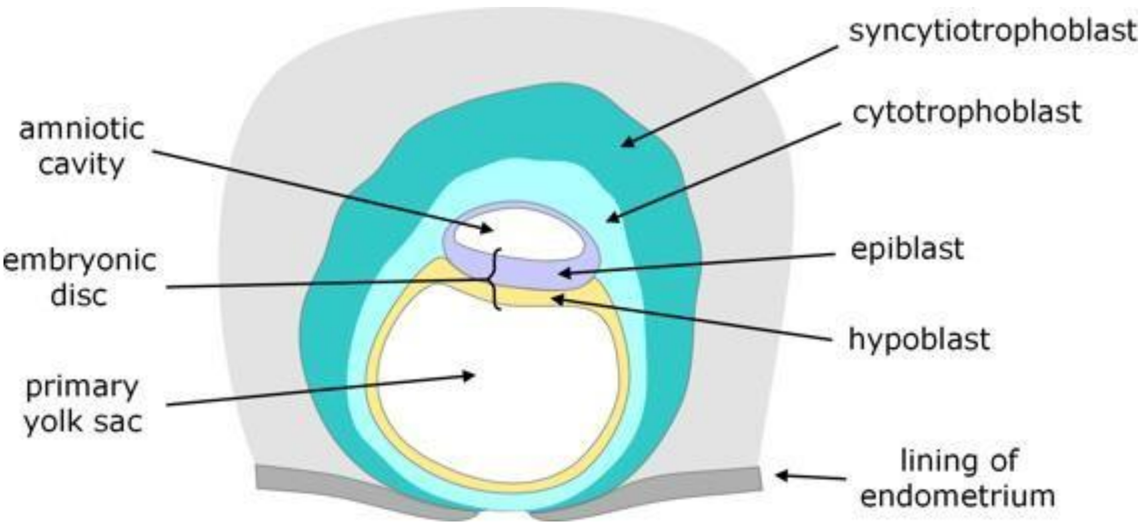
About 7 days after fertilisation the embryo loses the zona pellucida, and implants into the lining of the uterus, by which time it comprises about 200 cells.

Around the time of implantation:

- the amniotic cavity arises within the epiblast,
- the blastocyst cavity becomes the primary yolk sac, which is lined by cells that spread from the hypoblast.

In addition, cells from the epiblast and hypoblast organise into a two-layered structure known as the embryonic disc, positioned between the primary yolk sac and amniotic cavity. Previously these two layers had been thought to correspond with the first two germ layers, the ectoderm and endoderm, but see below.

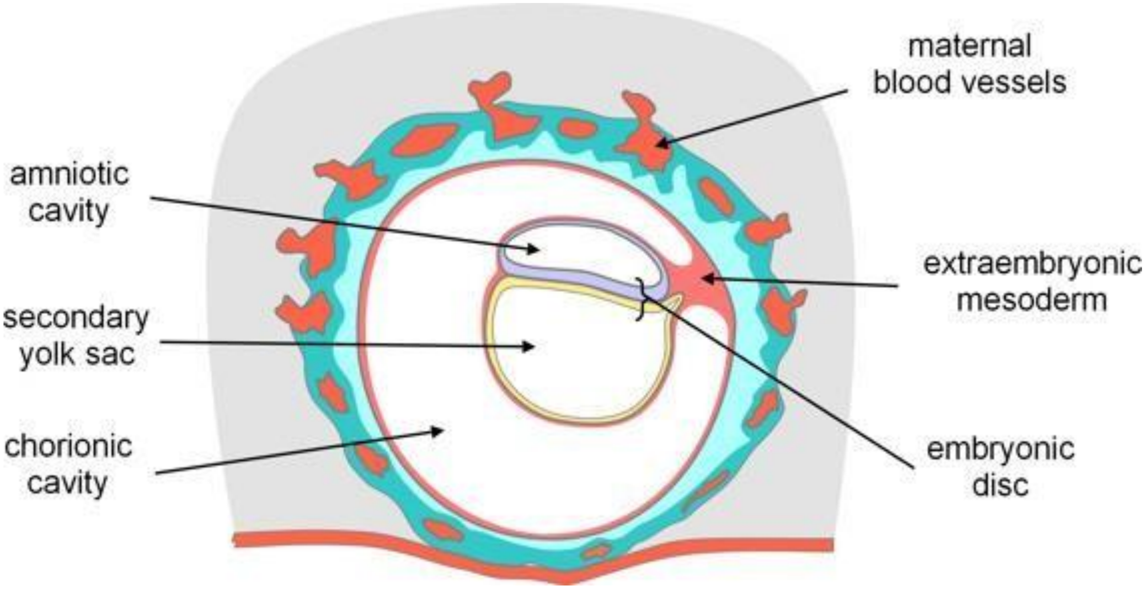
The trophoblast penetrates the uterine wall and begins to form the placenta; at an early stage it differentiates into two distinct layers, known as the cytotrophoblast and the syncytio trophoblast.



Embryo shortly after implantation, with embryonic disc.

Extraembryonic mesoderm

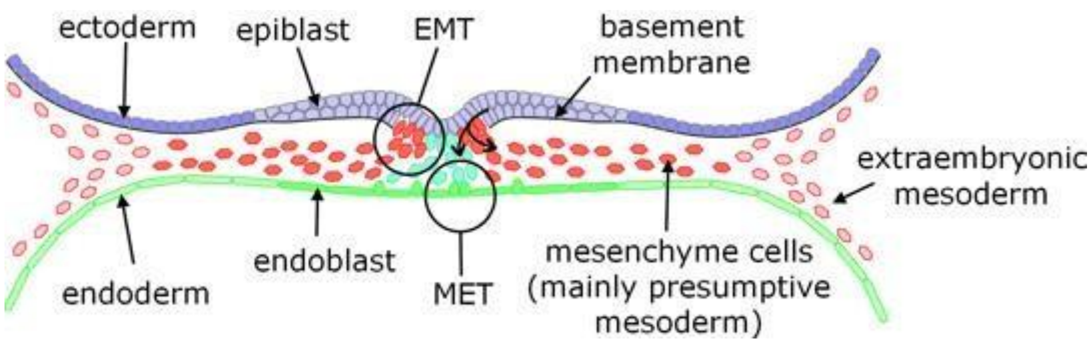
Extraembryonic mesoderm is a layer of tissue that arises between the lining of the primary yolk sac and the cytotrophoblast, and spreads to cover the amniotic cavity as well. As this tissue thickens, cavities form within it, and coalesce to form the chorionic cavity which is lined with extraembryonic mesoderm (figure 5). (Note that this is different from the germ-layer mesoderm which forms later, see below.) In this process some of the primary yolk sac is lost, and what remains is called the secondary yolk sac. The embryo remains attached to the internal lining of the chorion by a connecting stalk of extraembryonic mesoderm which becomes the umbilical cord.



Longitudinal section pre-gastrulation (approx. day 14).

Gastrulation

From about day 14 after fertilisation, a groove appears near the caudal end of the epiblast, it extends about two-thirds of the way along the midline towards the cranial end, terminating in a widening with a depression at its centre. This primitive groove and primitive pit are where gastrulation occurs. As gastrulation proceeds, the primitive node recedes caudally, with a corresponding shortening of the primitive streak.



Transverse section (perpendicular to figure 5) through the embryonic disc, showing gastrulation.

In the course of gastrulation, cells of the epiblast proliferate and move towards the groove where they transition from epithelial to mesenchymal in character, and ingress below the surface. In the early phase, these ingressing cells enter the hypoblast, reverting to epithelial cells (mesenchymal to epithelial transition) to become the definitive endoderm; at the same time displacing the hypoblast cells from the embryonic disc to line the yolk sac. As this stage proceeds, further cells ingressing from the epiblast move into the space between the epiblast and endoderm to form a middle layer of cells called mesoderm. (At the edges of the embryonic disc this embryonic mesoderm merges with the previously formed extraembryonic mesoderm.) Once the mesoderm is formed, the remaining epiblast is called ectoderm, and the three germ layers are complete.

Four extraembryonic membranes (or embryonic membranes or foetal membranes):

Formed in amniotes (reptiles, birds and mammals) outside the body of embryo by the cells of presumptive ectoderm, mesoderm and endoderm. These are:

- Chorion
- Amnion
- Allantois
- Yolk sac

1- Chorion (serosa): The outermost covering, formed by ectoderm and mesoderm as a protective layer head fold and tail fold of ectoderm and mesoderm emerge from respective parts of embryo, start growing and folding upon the dorsal side where both fuse (= sero-amniotic connection) to form outer chorion and inner amnion.

- ✓ The site of exchange between the embryo and the environment around it.
- ✓ **In reptiles and birds**, the principal function of the chorion is the respiratory exchange of gases.
- ✓ In mammals, the chorion serves a much more all-embracing function which includes not only respiration but also nutrition, excertion, filtration, and synthesis-with hormone production begin an important example of the last function.

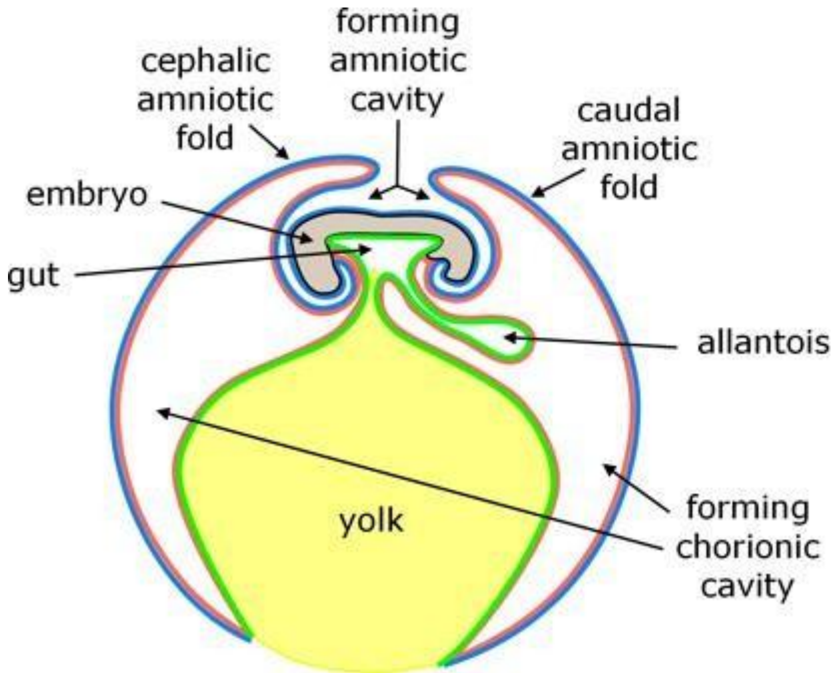
2- Amnion: It forms private (closest) chamber of embryo filled with amniotic fluid, isotonic to the body fluid. The aquatic medium for embryo to float and grow, denotes the aquatic origin of life. This fluid having cells of embryo is used (amniocentesis) to test its sex and genetic disorders.

- ✓ A thin ectodermally derived membrane which eventually encloses the entire embryo in a fluid-filled sac. The amniotic membrane is functionally specialized for the secretion and absorption of the amniotic fluid that bathes the embryo. So characteristic is this structure that the reptiles, birds, and mammals as a group are often called amniotes. The fishes and amphibians, lacking an amnion, are collectively called an amniotes.

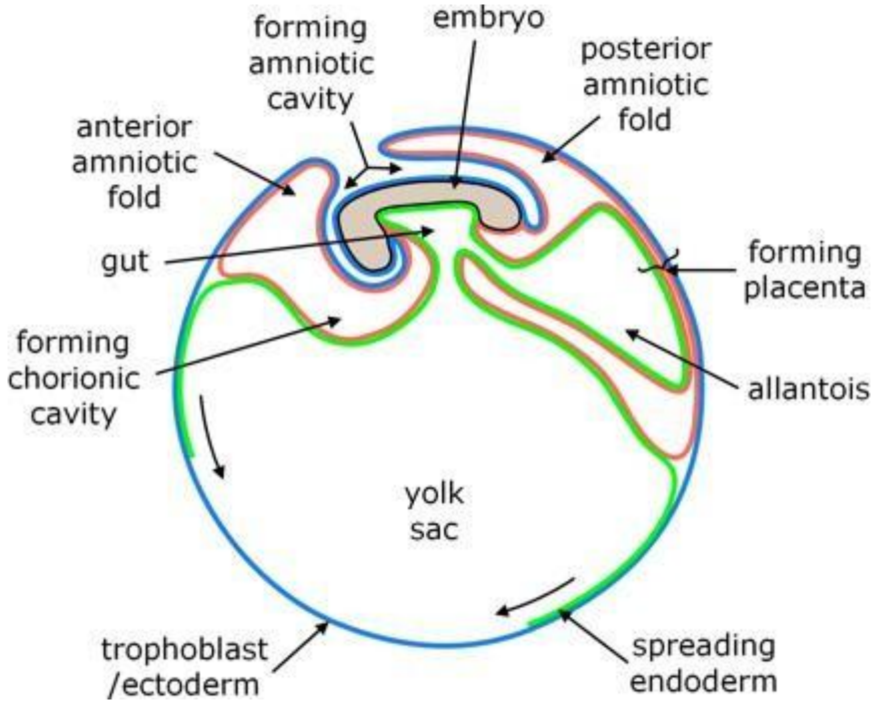
3- Allantois: It develops from the inner endoderm and outer mesoderm. Its principal functions are to act as a reservoir for storing or removing urinary wastes and to mediate gas exchange between the embryo and its surroundings.

- ✓ **In reptiles and birds,** the allantois is a large sac, and because the egg is a closed system with respect to urinary wastes, the allantois must sequester nitrogenous by-product so that they do not subject the embryo to osmotic stress or toxic effects.
- ✓ **In mammals** the role and prominence of the allantois vary with the efficiency of the interchange that takes place at the fetal-maternal interface. The allantois of the pig embryo rivals that of the bird in both size and functional importance, whereas the human allantois has been reduced to a mere vestige that contributes only a well-developed vascular network to the highly efficient placenta.

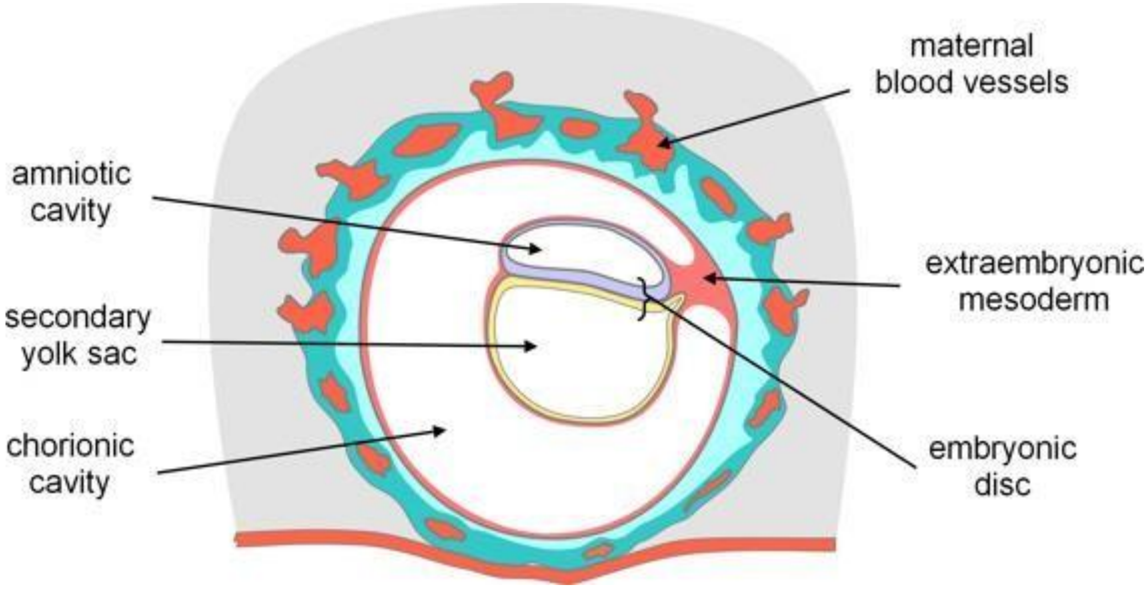
4- The yolk sac: The endodermal yolk sac is intimately involved with nutrition of the embryo in large-yolked forms such as reptiles and birds. Despite the lack of stored in mammalian eggs, the yolk sac has been preserved, possibly because other important secondary functions are associated with it. For example, the yolk sac endoderm induces the surrounding extraembryonic mesoderm to form the first blood cells and blood vessels.



Chick extraembryonic membranes



Rabbit extraembryonic membranes

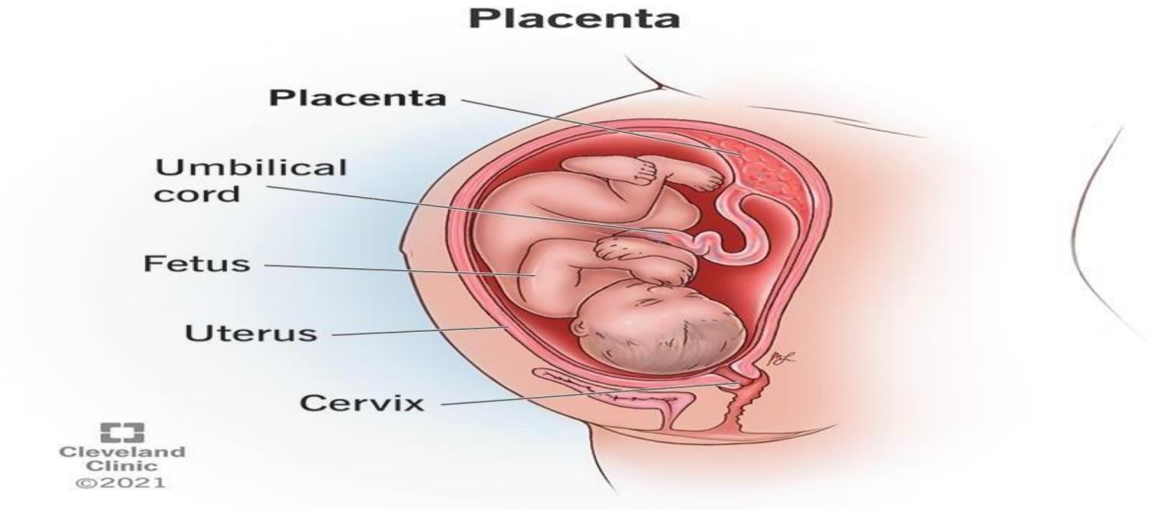


Human extraembryonic membranes

Placenta

What is the placenta?

The placenta is a temporary organ that forms in your uterus during pregnancy. It attaches to your uterine wall and provides nutrients and oxygen to your baby through the umbilical cord. Certain conditions of the placenta can cause pregnancy complications.



The placenta is a temporary organ that connects your baby to your uterus during pregnancy. The placenta develops shortly after conception and attaches to the wall of your uterus. Your baby is connected to the placenta by the umbilical cord. Together, the placenta and umbilical cord act as your baby's lifeline while in the uterus. Functions of the placenta include:

- Provides your baby with oxygen and nutrients.
- Removes harmful waste and carbon dioxide from your baby.
- Produces hormones that help your baby grow.
- Passes immunity from you to your baby.
- Helps protect your baby.

When does the placenta form?

- The placenta begins to form after a fertilized egg implants in your uterus around seven to 10 days after conception. It continues to grow throughout your pregnancy to support your baby. The placenta starts as a few cells and grows to be several inches long.

When does the placenta take over?

- The placenta takes over hormone production by the end of the first trimester (12 weeks of pregnancy). Up until this time, the corpus luteum handles most of the hormone production. Many people's first-trimester symptoms of nausea and fatigue go away once the placenta takes over in the second trimester.

What does the placenta do?

- The placenta helps to keep your baby alive and healthy during pregnancy. Your blood passes through the placenta and provides oxygen, glucose and nutrients to your baby through the umbilical cord. The placenta can also filter out harmful waste and carbon dioxide from your baby's blood. The placenta enables the exchange of oxygen and nutrients between the bloodstreams of you and your baby without ever mixing them. It acts as your baby's lungs, kidneys and liver until birth.
- As you get closer to delivery, the placenta passes antibodies to your baby to jumpstart its immunity. This immunity sticks with your baby for the first several months of life.
- The placenta produces several important hormones like lactogen, estrogen and progesterone during pregnancy. These pregnancy hormones are beneficial to both you and your baby. For example, the placenta produces a hormone that suppresses milk production during pregnancy.

Does the placenta move?

- The placenta appears to move only because the uterus expands as the pregnancy and fetus grow. Your healthcare provider will look at the location of your placenta during your 20-week anatomy ultrasound and determine if its position may cause complications. Most placentas move to the top or side of the uterus by 32 weeks of pregnancy.

Where does the placenta form?

The placenta can form anywhere in your uterus. It develops wherever the fertilized egg implants into your uterine wall. Some of the positions of the placenta are:

- Posterior placenta: The placenta grows on the back wall of your uterus.
- Anterior placenta: The placenta grows on the front wall of your uterus closest to your abdomen.
- Fundal placenta: The placenta grows at the top of your uterus.
- Lateral placenta: The placenta grows on the right or left wall of your uterus.

The placenta can move up until about 32 weeks of pregnancy. It's common to have a placenta that moves upwards and away from your cervix as your baby gets bigger.

What does the placenta look like?

The placenta looks like a disc of bumpy tissue rich in blood vessels, making it appear dark red at term. Most of the mature placental tissue is made up of blood vessels. They connect with the baby through the umbilical cord and branch throughout the placenta disc like the limbs of a tree.

What color is the placenta?

The placenta has two sides: the side attached to your uterus and the side closest to your baby. The side attached to your uterine wall is a deep reddish blue color, while the side facing your baby is gray.

How big is a normal placenta?

The placenta is about 10 inches long and 1 inch thick at its center. It weighs around 16 ounces (1 pound) by the time your baby is born.

What is the placenta made of?

The placenta begins to develop when the fertilized egg implants into your uterine wall. The placenta contains mostly blood vessels contained within structures called "villi." The blood vessels connect with the baby's bloodstream through the umbilical cord. The rest of the placental tissues mainly connect the villi to the umbilical cord and allow your blood to bathe the villi, supplying the baby with oxygen and nutrients.

What types of substances are bad for the placenta?

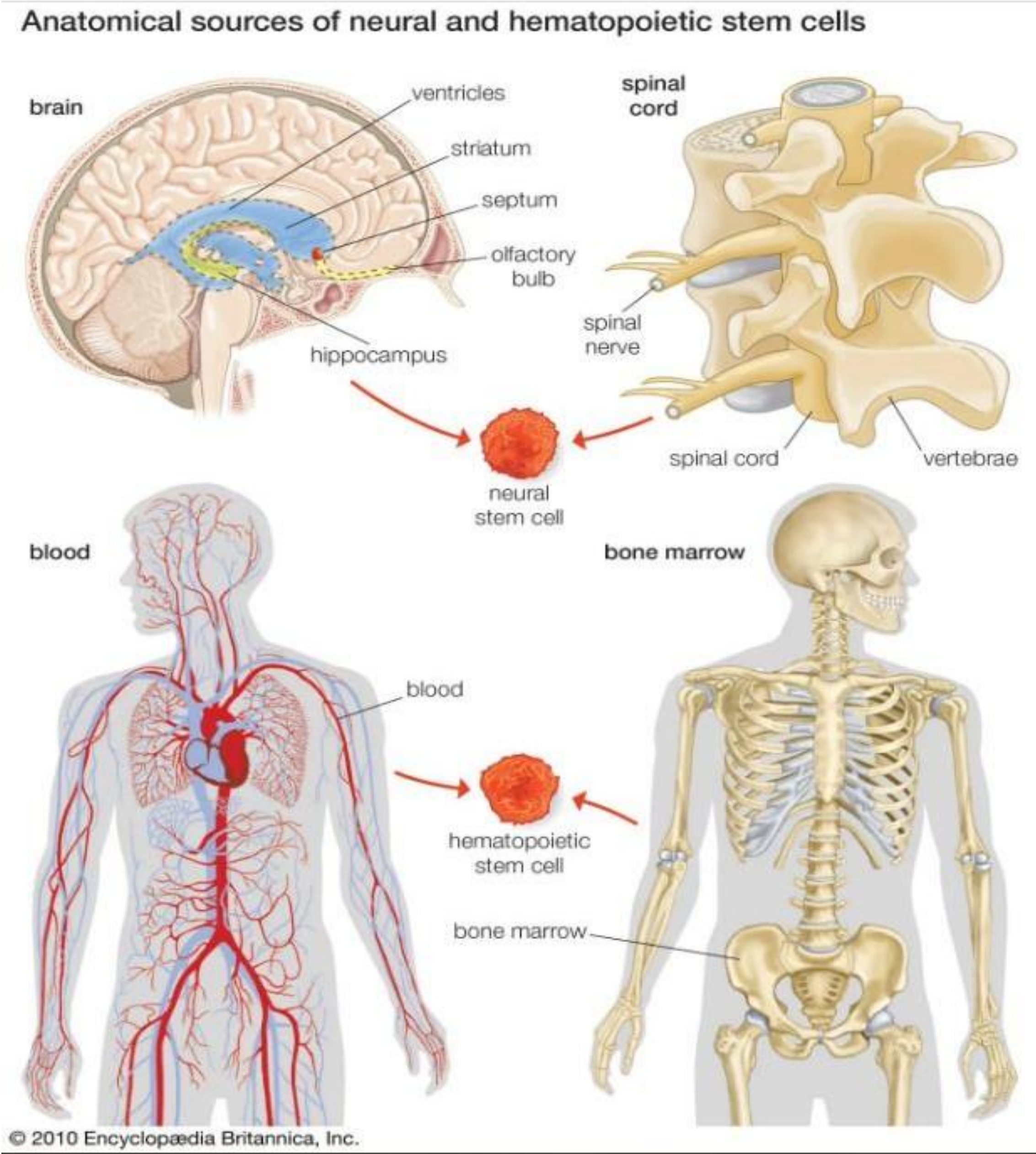
Medicine, drugs, alcohol, and nicotine can all transfer from your bloodstream to your baby through the placenta. Talk to your healthcare provider before taking any prescription or over-the-counter medications (including vitamins and supplements) during pregnancy. Drinking alcohol or smoking cigarettes is not recommended during pregnancy.

How is the placenta delivered?

The placenta is delivered shortly after your baby is born (usually between five and 30 minutes after). This is called the afterbirth or the third stage of labor. If you've delivered your baby vaginally, your uterus will continue to contract to expel the placenta. Your healthcare provider may push on your belly or ask you for one final push. If your baby was born via C-section, your healthcare provider removes the placenta through the incision used to deliver your baby. In rare cases, parts of the placenta stay in your uterus after delivery. This can cause bleeding, pain and infection.

Stem cells

Stem cell, an undifferentiated cell that can divide to produce some offspring cells that continue as stem cells and some cells that are destined to differentiate (become specialized). Stem cells are an ongoing source of the differentiated cells that make up the tissues and organs of animals and plants. There is great interest in stem cells because they have potential in the development of therapies for replacing defective or damaged cells resulting from a variety of disorders and injuries, such as Parkinson disease, heart disease, and diabetes. There are two major types of stem cells: embryonic stem cells and adult stem cells, which are also called tissue stem cells.



Types of stem cells

There are several types of stem cells that can be used for different purposes.

Embryonic stem cells

Embryonic stem cells come from human embryos that are three to five days old. They are harvested during a process called in-vitro fertilization. This involves fertilizing an embryo in a laboratory instead of inside the female body. Embryonic stem cells are known as pluripotent stem cells. These cells can give rise to virtually any other type of cell in the body.

Non-embryonic (adult) stem cells

Adult stem cells have a misleading name, because they are also found in infants and children. These stem cells come from developed organs and tissues in the body. They’re used by the body to repair and replace damaged tissue in the same area in which they are found.

For example, hematopoietic stem cells are a type of adult stem cell found in bone marrow. They make new red blood cells, white blood cells, and other types of blood cells. Doctors have been performing stem cell transplants, also known as bone marrow transplants, for decades using hematopoietic stem cells in order to treat certain types of cancer.

Adult stem cells can’t differentiate into as many other types of cells as embryonic stem cells can.

Induced pluripotent stem cells (iPSCs)

Scientists have recently discovered how to turn adult stem cells into pluripotent stem cells. These new types of cells are called induced pluripotent stem cells (iPSCs). They can differentiate into all types of specialized cells in the body. This means they can potentially produce new cells for any organ or tissue. To create iPSCs, scientists genetically reprogram the adult stem cells, so they behave like embryonic stem cells.

The breakthrough has created a way to “de-differentiate” the stem cells. This may make them more useful in understanding how diseases develop. Scientists are hoping that the cells can be made from someone’s own skin to treat a disease. This will help prevent the immune system from rejecting an organ transplant. Research is underway to find ways to produce iPSCs safely.

Cord blood stem cells and amniotic fluid stem cells

Cord blood stem cells are harvested from the umbilical cord after childbirth. They can be frozen in cell banks for use in the future. These cells have been successfully used to treat children with blood cancers, such as leukemia, and certain genetic blood disorders.

Stem cells have also been found in amniotic fluid. This is the fluid that surrounds a developing baby inside the mother’s womb. However, more research is needed to help understand the potential uses of amniotic fluid stem cells.

In vitro fertilization (IVF)

In vitro fertilization (IVF) is a complex series of procedures used to help with fertility or prevent genetic problems and assist with the conception of a child.

During IVF, mature eggs are collected (retrieved) from ovaries and fertilized by sperm in a lab. Then the fertilized egg (embryo) or eggs (embryos) are transferred to a uterus. One full cycle of IVF takes about three weeks. Sometimes these steps are split into different parts and the process can take longer.

IVF is the most effective form of assisted reproductive technology. The procedure can be done using a couple's own eggs and sperm. Or IVF may involve eggs, sperm or embryos from a known or anonymous donor. In some cases, a gestational carrier — someone who has an embryo implanted in the uterus — might be used.

Your chances of having a healthy baby using IVF depend on many factors, such as your age and the cause of infertility. In addition, IVF can be time-consuming, expensive and invasive. If more than one embryo is transferred to the uterus, IVF can result in a pregnancy with more than one fetus (multiple pregnancy).

Why it's done

In vitro fertilization (IVF) is a treatment for infertility or genetic problems. If IVF is performed to treat infertility, you and your partner might be able to try less-invasive treatment options before attempting IVF, including fertility drugs to increase production of eggs or intrauterine insemination — a procedure in which sperm are placed directly in the uterus near the time of ovulation.

Sometimes, IVF is offered as a primary treatment for infertility in women over age 40. IVF can also be done if you have certain health conditions. For example, IVF may be an option if you or your partner has:

- **Fallopian tube damage or blockage.** Fallopian tube damage or blockage makes it difficult for an egg to be fertilized or for an embryo to travel to the uterus.
- **Ovulation disorders.** If ovulation is infrequent or absent, fewer eggs are available for fertilization.
- **Endometriosis.** Endometriosis occurs when tissue similar to the lining of the uterus implants and grows outside of the uterus — often affecting the function of the ovaries, uterus and fallopian tubes.
- **Uterine fibroids.** Fibroids are benign tumors in the uterus. They are common in women in their 30s and 40s. Fibroids can interfere with implantation of the fertilized egg.
- **Previous tubal sterilization or removal.** Tubal ligation is a type of sterilization in which the fallopian tubes are cut or blocked to

permanently prevent pregnancy. If you wish to conceive after tubal ligation, IVF may be an alternative to tubal ligation reversal surgery.

- **Impaired sperm production or function.** Below-average sperm concentration, weak movement of sperm (poor mobility), or abnormalities in sperm size and shape can make it difficult for sperm to fertilize an egg. If semen abnormalities are found, a visit to an infertility specialist might be needed to see if there are correctable problems or underlying health concerns.

- **Unexplained infertility.** Unexplained infertility means no cause of infertility has been found despite evaluation for common causes.

- **A genetic disorder.** If you or your partner is at risk of passing on a genetic disorder to your child, you may be candidates for preimplantation genetic testing — a procedure that involves IVF. After the eggs are harvested and fertilized, they're screened for certain genetic problems, although not all genetic problems can be found. Embryos that don't contain identified problems can be transferred to the uterus.

- **Fertility preservation for cancer or other health conditions.** If you're about to start cancer treatment — such as radiation or chemotherapy — that could harm your fertility, IVF for fertility preservation may be an option. Women can have eggs harvested from their ovaries and frozen in an unfertilized state for later use. Or the eggs can be fertilized and frozen as embryos for future use.

Women who don't have a functional uterus or for whom pregnancy poses a serious health risk might choose IVF using another person to carry the pregnancy (gestational carrier). In this case, the woman's eggs are fertilized with sperm, but the resulting embryos are placed in the gestational carrier's uterus.

Risks of IVF include:

- **Multiple births.**
- **Premature delivery and low birth weight.**
- **Ovarian hyperstimulation syndrome.**
- **Miscarriage.**
- **Egg-retrieval procedure complications**
- **Ectopic pregnancy.**
- **Birth defects.**
- **Cancer.**
- **Stress.**

The End

Glossary of embryological terms

Gametes

gamete

Reproductive cell: e.g. ovum or sperm.

meiosis

The process where a single cell divides twice to give four cells containing half of the original genetic material; typically produces sperm or ovum.

haploid

Sperm and egg cells result from meiosis and are haploid: they have only half of the number of chromosomes of somatic (body) cells, e.g. in humans, haploid cells have 23 chromosomes, whereas somatic cells have 46 chromosomes.

polar body

Production of an ovum involves 2 rounds of cell division, giving rise to 4 (sometimes only 3) nuclei, only one of which is incorporated within an ovum. The resulting 3 (or 2) nuclei are small polar bodies which eventually degrade. One polar body may remain associated with the ovum for a while. [check]

animal pole and **vegetal pole**

In most ova, the nucleus is not in the centre but displaced to one end - this is called the animal pole, and the opposite end is the vegetal pole. In general there is more yolk towards the vegetal pole.

germinal disc

The embryo-forming part of the egg, e.g. excluding the body of the yolk.

zona pellucida

A clear layer surrounding the cell of the mammalian ovum (c.f. area pellucida of bird and reptile blastula).

corona radiata

The outermost layer of the mammalian ovum.

Zygote

zygote

Fertilised egg.

pronucleus

A pronucleus is the male or female polar body or ‘nucleus’ within the zygote, at the start of fertilisation.

Cleavage

cleavage

The first few cell divisions of the zygote, during which there is an increase in number of cells, but not in overall size or mass, so the cells get smaller.

holoblastic cleavage

The cell divisions pass right through the zygote.

meroblastic cleavage

The cell divisions do not extend right through the zygote (generally there is a large amount of yolk)

discoidal cleavage

A form of meroblastic cleavage where the cell divisions are restricted to the germinal disc.

rotational cleavage

A form of holoblastic cleavage where the two second cell divisions are in different planes, one meridional and one equatorial.

morula

An early stage of embryonic development, especially in mammals, when the cells are in the form of a loose clump.

compaction

A stage of embryonic development when the loose clump of cells becomes more compact, usually involving the formation of tight junctions between peripheral cells and the formation of a central blastocoel.

blastomere

One of the cells resulting from cleavage; or one of the cells of the blastoderm.

blastodisc

The germinal disc during and after cleavage, up to the stage of the blastula.

Blastula

blastula

The early embryo, after cleavage and the first differentiation of cells, just before gastrulation.

blastocyst

The name for the blastula in mammals.

blastoderm

A surface layer of cells of the blastula.

blastocoel

A space within the body of cells of the blastula, generally arising during cleavage.

subgerminal space / cavity

A space between the cells of the blastula and the underlying yolk.

yolk syncytial layer (YSL)

A layer at the surface of the yolk containing nuclei, but the cytoplasm of the cells is continuous with the yolk, i.e. the cell membranes are incomplete.

mid blastula transition (MBT)

Generally refers to the stage of the blastula when the embryonic genome becomes active and/or the cells begin to differentiate.

epiblast

In amniotes: the upper, epithelial layer of the blastula, i.e. before gastrulation, which in most cases is the source of all of the germ layers.

In anamniotes: sometimes used to refer to the upper, epithelial layer of the gastrula, i.e. after gastrulation, which usually becomes the ectoderm.

hypoblast

In amniotes: a layer of cells below the epiblast, which is substantially displaced in the course of gastrulation and does not become part of the embryo.

In anamniotes: sometimes used to refer to a lower layer of cells that have involuted in the course of gastrulation, and usually becomes mesoderm and endoderm (except amphibians).

trophoblast

The outer layer of cells of the mammalian blastocyst.

inner cell mass

Generally refers to mammals where the blastocyst comprises an outer layer of cells (the trophoblast), an inner cell mass (generally containing epiblast and hypoblast) and a blastocoel.

area pellucida

Central part of the reptile or bird blastula, that is over the blastocoel and is relatively translucent (c.f. zona pellucida of the mammalian ovum).

area opaca

Area of the reptile or bird blastula, that is around the area pellucida and above the marginal cells, and is relatively opaque.

enveloping layer (EVL)

A thin outer layer of cells of the teleost blastula, which persists through early embryonic development, but is shed at hatching.

Gastrulation

gastrulation

The overall term for the various processes through which the blastula develops into the gastrula in which all three germ layers - ectoderm, mesoderm and endoderm - are formed.

presumptive and **definitive**

Presumptive refers to cells which are still undifferentiated, or partly differentiated, but destined to become the final or definitive tissue.

epithelial

Surface cells are generally epithelal in nature, and move as a sheet of cells.

mesenchymal

Mesenchymal cells are usually below the surface, and migrate individually through tissues.

EMT and **MET**

When cells transition between epithelial and mesenchymal in nature by 'epithelail-to-mesenchymal transition' or 'mesenchymal-to-epithelial transition'.

epiboly

Spreading of a layer of cells in the course of gastrulation. This can be achieved by thinning of individual cells, and/or intercalation of cells from within the same or adjacent cell layer.

invagination

The process whereby a layer of cells indents and forms a cavity or pouch.

involution

Movement of cells from the outside to the inside, the cells remaining epithelial in nature and moving as a layer of cells.

ingression

Movement of cells, typically from the outside to the inside, the cells being (or transitioning to) mesenchymal in nature, and moving individually.

blastopore

A sac-like cavity in the outer surface of the blastula through which cells are internalised, usually by involution.

primitive streak

A depression in the epiblast of birds and mammals through which cells are internalised by ingression.

ectoderm

The outer germ layer; generally produces the outer layer of the embryo, and central nervous system via the neural tube.

mesoderm

The middle germ layer; from it forms the notochord, somites, some of the skeleton and musculature.

endoderm

The inner germ layer; it forms most of the digestive tract and associated organs.

extraembryonic membranes

These are membranes that develop along with the embryo but do not form part of the final embryo.
Usually these are the amniote amnion, chorion, and membranes of the yolk sac and allantois.

The yolk sac of teleosts is part of the embryo, and the yolk sac of chondrichthyans is reabsorbed, so these are not strictly extraembryonic.

Although the teleost enveloping layer (EVL) does not become part of the embryo, it is not usually regarded as an extraembryonic membrane.

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