CYTOLOGY AND HISTOLOGY

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About the Book

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 أسئلة للتفكير والتقييم الذاتي.

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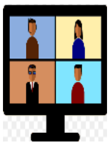
 تواصل عبر مؤتمر الفيديو.

Cytology and Histology

Part 1

The Cell Structure and Function

INTRODUCTION

All organisms are composed of structural and functional units of life called 'cells'. The body of some organisms like bacteria, protozoans and some algae is made up of a single cell whereas the body of higher fungi, plants and animals are composed of many cells. Human body is built of about one trillion cells.

Cells vary in size and structure as they are specialized to perform different functions. But the basic components of the cell are common to all biological cells.

Soon after Anton Van Leeuwenhoek invented the microscope, Robert Hooke in 1665 observed a piece of cork under the microscope and found it to be made of small compartments which he called "cells" (Latin cell = small room). In 1672, Leeuwenhoek observed bacteria, sperms and red blood corpuscles, all of which were cells. Much later, in 1831, Robert Brown, an Englishman observed that all cells had a centrally positioned body which he termed the nucleus.

All living things are made up of cells.

-Cells are the smallest working unit of all living things.

-All cells come from preexisting cells through cells division.

Most cells are between1-100 μm in diameter which can be visualized by light microscope.

Course Objectives

After completing this lesson, you will be able to :

- justify that cell is the basic structural and functional unit of all organisms;
- list the components of the cell and state cell theory;
- differentiate between prokaryotic and eukaryotic cells;
- differentiate between plant and animal cells;
- illustrate the structure of animal cells by drawing labeled diagrams;
- describe the structure and functions of plasma membrane, endoplasmic reticulum (ER), cilia, flagella, nucleus, ribosomes, mitochondria, golgi body, peroxisome, glyoxysome and lysosome;
- describe the general importance of the cell molecules-water, mineral ions, carbohydrates, lipids, amino acids, proteins, nucleotides, nucleic acids, enzymes, vitamins, hormones, steroids and alkaloids;
- justify the need for cell division;
- describe various phases of cell cycle;
- explain the term karyotype and mention the karyotype analysis and its significance.

Organization

Cells are grouped together and work as a whole to perform special functions

Tissue

A group of similar cells to perform a particular function

Animals : epithelial tissue, muscular tissue

Organ

Different tissues group together to carry out specialized functions

Heart : consists of muscles, nervous tissue and blood vessels

System

Several organs and tissues work together to carry out a particular set of functions in a co-ordinated way

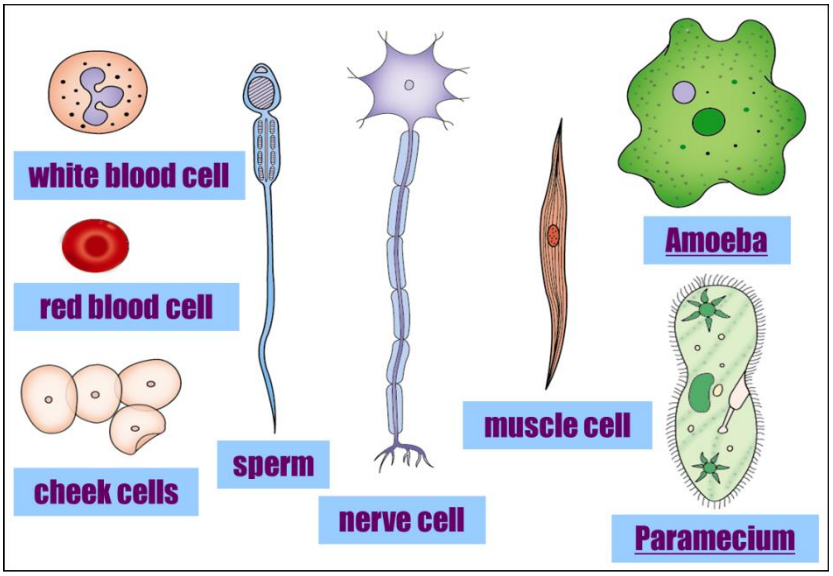
Human : digestive, respiratory, excretory, circulatory and reproductive systems

The cell is the lowest level of structure capable of performing all the activities of life. The first cells were observed and named by Robert Hooke in 1675 from slice of cork.

Cells differ widely in shape.

Most cells are roughly cuboidal or spherical.

Different kinds of animal cells



Nucleus: contains DNA which directs the activity of the cell

Organelle: a cell component that performs specific functions in the cell

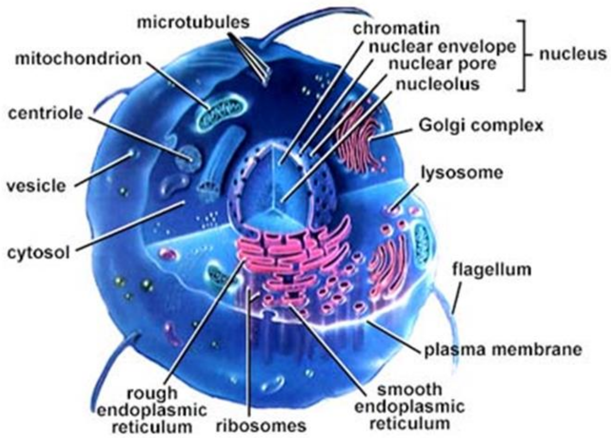
Two basic types of cells

Cytologists recognize two basic types of cells .Organisms which do not possess a well formed nucleus are prokaryotes such as the bacteria. All others possess a well defined nucleus,covered by a nuclear membrane. They are eukaryotes.

Eukaryotes: cells that contain a nucleus and membrane-bound organelles

Prokaryotes: cells that lack nuclei and membrane-bound organelles

Eukaryotes (animals, plants, fungi, protests) and prokaryotes (bacteria) differ greatly in structure



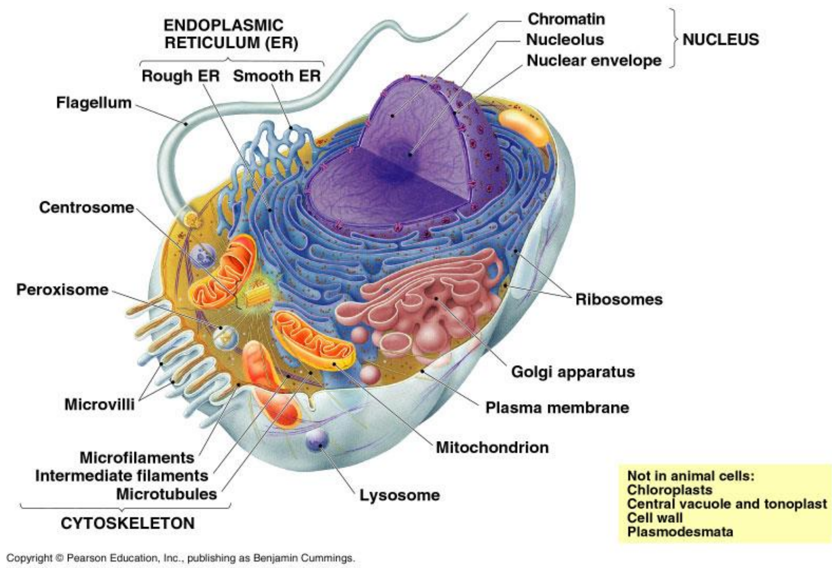
Each living cell carries out the tasks of taking food, transforming food into energy, getting rid of wastes, and reproducing.

Most eukaryotic cells have three main components:

Cell Membrane

Cytoplasm

Nucleus



What Is Cytology?

To discover the definition of cytology, we can break down the word into two parts. The suffix -logy, or -ology, is seen countless times in science and means 'the study of.' To find out what we are studying we look to the prefix cyto, which means 'cell' and is derived from the Greek word kytos meaning 'hollow vessel' or 'container.' Put these two things together, and we have our definition: cytology is the study of cells. More specifically, cytology is a branch of science which studies how cells work, how they grow and what cells are made of.

Early History

The history of cell science is closely linked with the invention and advancement of the microscope. Robert Hooke was the first scientist to use the word 'cell' in 1665 when he looked at slices of cork through a lit compound microscope (a microscope with two or more lenses) and observed very small, irregular boxes that reminded him of tiny rooms, or cells. Hooke wrote about his findings and drew the structures he saw in his book Micrographia, which was published in 1665. We now know that the small 'cells' Hooke observed were actually the walls of plant cells that had died. Anton van Leeuwenhoek used a more powerfully magnifying microscope to look more closely at specimens found in human body fluids in 1683. He noticed tiny specimens that were capable of movement and therefore were alive. Van Leeuwenhoek named these little moving objects 'animalcules' in 1683. With his more advanced microscope, Van Leewenhoek was even able to observe structures within cells, including the nucleus of a red blood cell.

The importance of cells to all forms of life was not fully recognized until the development of the cell theory. The earliest (classical) cell theory was developed in the 1838 by plant scientist Matthias Schleiden and animal scientist Theodor Schwann. They each came to the same conclusion that the living things they studied were composed of cells. The classical cell theory summarized the ideas of the previously mentioned scientists into the following points: (!) All organisms are made up of one or more cells (2) Cells are the fundamental functional and structural units of life And in 1858 Rudolf Virchow added to the classical cell theory with the idea that: Cells only come from other cells.

Who developed the cell theory?

In 1838 M.J. Schleiden and Theodore Schwann formulated the “cell theory.” Which maintains that: concluded that all plants are composed of cells

Theodor Schwann (1839): concluded that all animals are composed of cells

Rudolph Virchow (1855): determined that cells come only from other cells

Modern Cytology

The late 19th century showed further advancement in cell biology, with more and more scientists coming up with ways to grow study and manipulate tissues and cells outside of a living body in a lab. Early 'cell food' mixtures included water, salt, sugar and chemicals to control the levels of acid in the solution. Synthetic 'cell food,' called cell media, was improved by adding amino acids and vitamins to the solutions. New ways to look at cells under the microscope were made possible by the staining of cells. Special dyes were added to cells to make them easier to observe as far back as 1891. Now there are many different kinds of cellular staining, from simple dyes that absorb into different parts of the cell to chemicals that can make cells literally light up under the microscope. Another breakthrough came in 1931 when Ernst Ruska developed the first electron microscope. This type of microscope worked by shooting beams of electrons through a very thin slice of specimen, which would bounce off and create a picture of the specimen on special film that would generate a highly detailed and magnified image. Certain types of electron microscope are now capable of magnifying things by up to two million times their original size!

The Diversity and Unity of Cells

Red blood cells (RBCs) are the most abundant cell type in your body, and they perform a critical job—delivering oxygen throughout your body and picking up carbon dioxide waste from its cells. Along with other types of blood cells, new red blood cells are continually produced from precursor cells, known as stem cells, located in the marrow of your bones. Red blood cells do not resemble a typical animal cell in structure because they are chock full of hemoglobin, the pigment that makes them red and enables them to carry oxygen. Because red blood cells do not have the usual contents of an animal cell, they only live about 120 days before being destroyed by the liver and the spleen. Thus, the body continually faces the daunting task of replacing the 3 million red blood cells it loses every day. If this process of replacing the red blood cells is impaired, as occurs in a condition called aplastic anemia, a person can quickly die. Cells are the fundamental units of all living things. Although the diversity of organisms is incredible, the cells of all organisms share many similarities. In fact, there are only a few structural differences between most types of cells. You will learn about the two main types of cells and how they are similar as well as different. Learning about the structure of cells will later help you understand their complex functions and interactions.

The cell theory

- all organisms are composed of cells.
- cell is the structural and functional unit of life, and cells arise from pre-existing cells.

The cells vary considerably, in shapes and sizes. Nerve cells of animals have long extensions. They can be several centimeter in length. Muscle cells are elongated in shape. Egg of the ostrich is the largest cell (75 mm). Some plant cells have thick walls. There is also wide variation in the number of cells in different organisms.

A cell may be defined as a unit of protoplasm bound by a plasma or cell membrane and possessing a nucleus. Protoplasm is the life giving substance and includes the cytoplasm and the nucleus. The cytoplasm has in it organelles such as ribosomes, mitochondria, golgi bodies, plastids, lysosomes and endoplasmic reticulum. Plant cells have in their cytoplasm, large vacuoles containing non-living inclusions like crystals, and pigments. The bacteria have neither defined cell organelles nor a well formed nucleus.

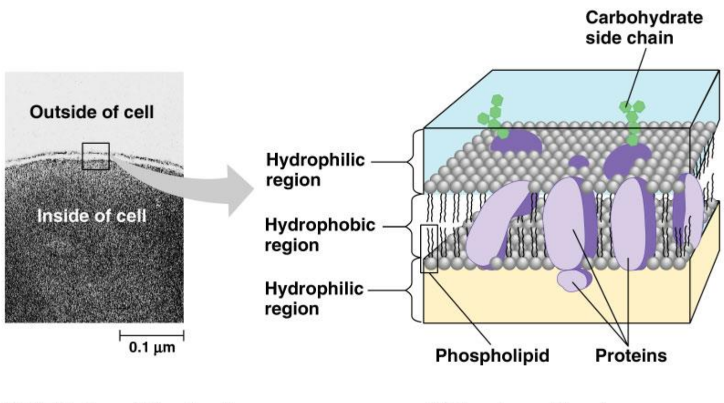
The major components of the cell are (1) cell membrane, (2) cytoplasm, and (3) nucleus.

the Plasma Membrane

Each cell has a limiting boundary, the cell membrane, plasma membrane or plasmalemma. It is a living membrane, outermost in animal cells but internal to cell .The plasma membrane is made of proteins and lipids and several models were of Life proposed regarding the arrangement of proteins and lipids.

-double layer of phospholipids

-various proteins are attached to it -carbohydrate side chains are found only on the outer surface of plasma membrane



(a) TEM of a red blood cell

(b) Structure of the plasma membrane

According to the fluid mosaic model,

(i) The plasma membrane is composed of a lipid bilayer of phospholipid molecules into which a variety of globular proteins are embedded.

(ii) Each phospholipid molecule has two ends, an outer head hydrophilic i.e. water attracting, and the inner tail pointing centrally hydrophobic, i.e. water repelling

(iii) The protein molecules are arranged in two different ways:

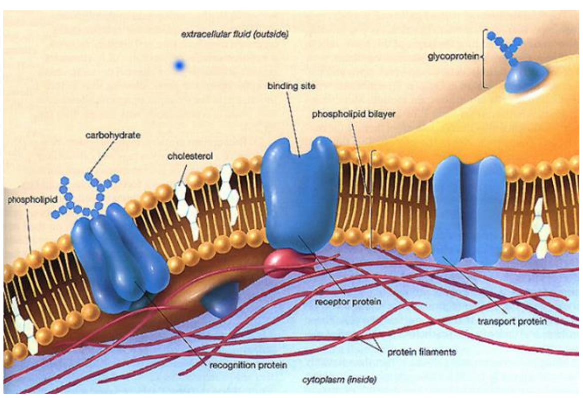
(a) Peripheral proteins or extrinsic proteins: these proteins are present on the outer and inner surfaces of lipid bilayer.

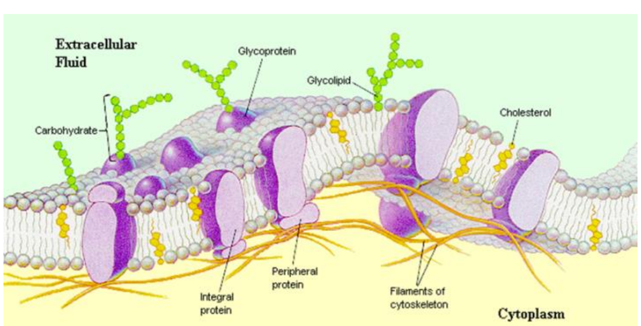
(b) Integral proteins or intrinsic proteins: These proteins penetrate the lipid bilayer partially or wholly.

Structure: phospholipid bilayer with proteins that function as channels, markers, and receptors

-also contains cholesterol which provides rigidity

Structure of the phospholipid molecule

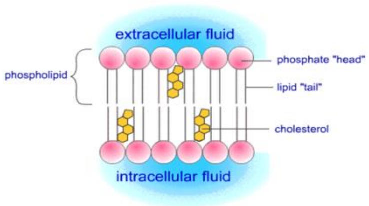




two hydrophobic fatty acid "tails" a hydrophilic "head" consisting of a phosphate group.

Hydrophobic (nonpolar molecules) – Repelled by, not dissolved in or not combining with H_2O.

Hydrophilic (polar molecules) – Easily absorbing in H_2O.



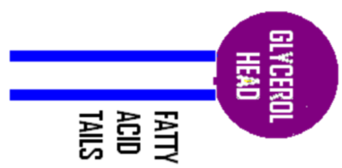
Phospholipids

Heads contain glycerol & phosphate and are hydrophilic (attract water)

Tails are made of fatty acids and are hydrophobic (repel water)

Make up a bilayer where tails point inward toward each other

Can move laterally to allow small molecules (O_2, CO_2, & H_2O to enter



Cell Membrane Proteins

Proteins help move large molecules or aid in cell recognition

Peripheral proteins are attached on the surface (inner or outer)

Integral proteins are embedded completely through the membrane

Cell-cell recognition

Is a cell's ability to distinguish one type of neighboring cell from another

WHAT IS MEANT HYDROPHOBICITY

Hydrophobicity comes also from the greek word Hydro(water) and Phobicity (fear) it refers to the physical property of a material that repels a mass of water.

Some of the common natural Hydrophobic materials are waxes, oil and fats.

The evaluation of hydrophobicity is made through water contact angle measurements. A water droplet would be spherical so the water contact angle will be significantly high Hydrophilicity, also comes from the Greek word Hydro (water) and Philicity (friendship) it refers to a physical property of a material that can transiently bond with water (H2O) through hydrogen bonding. Furthermore it allows the liquid to enter the pores of a material and totally wet it.

Almost all natural materials are hydrophilic in nature.

The evaluation of hydrophilicity is made through water contact angle measurements. A water droplet would occupy as long surface of the hydrophilic material as possible. So the water contact angle will be significantly low.

Function:

(i) The plasma membrane encloses the cell contents. selectively permeable boundary between the cell and the external environment

(ii) It provides cell shape (in animal cells) e.g. the characteristic shape of red blood cells, nerve cells, and bone cells.

(iii) It allows transport of certain substances into and out of the cell but not all substances so much it is termed ‘selectively permeable’.

Transport of small molecules (such as glucose, amino acids, water, mineral ions etc). Small molecules can be transported across the plasma membrane by any one of the following three methods:

(i) Diffusion : molecules of substances move from their region of higher concentration to the regions of lower concentration. This does not require energy. Example : absorption of glucose in a cell.

(ii) Osmosis: movement of water molecules from the region of their higher concentration to the region of their lower concentration through a semipermeable membrane. There is no expenditure of energy in osmosis. This kind of movement is along concentration gradient.

(iii) Active Transport: When the direction of movement of a certain molecule is opposite to that of diffusion i.e. from region of their lower concentration towards the region of their higher concentration, it would require an "active effort" by the cell for which energy is needed. This energy is provided by ATP (adenosine triphosphate). The active transport may also be through a carrier molecule.

Transport of large molecules (bulk transport)

During bulk transport the membrane changes its form and shape. It occurs in two ways:

(i) endocytosis (taking the substance in)

(ii) exocytosis (passing the substance out)

Endocytosis is of two types :

Phagocytosis

1. intake of solid particles
2. membrane folds out going round the particle, forming a cavity and thus engulfing the particle

Pinocytosis

1. intake of fluid droplets
2. membrane folds in and forms a cup-like structure and sucks in the droplets

Cell membrane regulates movement of substance into and out of the cell. If the cell membrane fails to function normally, the cell dies.

THE CYTOPLASM AND THE CELL ORGANELLES

The cytoplasm contains many cell organelles of which we shall learn about :

1. those that trap and release energy e.g. mitochondria ;

2. those that are secretory or involved in synthesis and transport e.g. Golgi, ribosomes and endoplasmic reticulum

3. the organelles for motilily - cilia and flagella

4. the suicidal bags i.e. lysosomes

5. the nucleus which controls all activities of the cell, and carries the hereditary Material

Mitochondria

Mitochondria -1-10 μm long-some cells contain a single large mitochondrion but most cells contain several mitochondria

-Enclosed by two membrane: outer and inner

- The inner membrane is folded inside to form projections called 'cristae' which project into the inner compartment called the 'matrix'.

Function : Oxidises pyruvic acid (breakdown product of glucose) to release energy which gets stored in the from of ATP for ready use. This process is also called cellular respiration. That is why mitochondria are called the 'power house' of a cell.

-cristae = fold inner membrane to increase the surface area -matrix and intermembrane space

matrix contains:-ds circular DNA

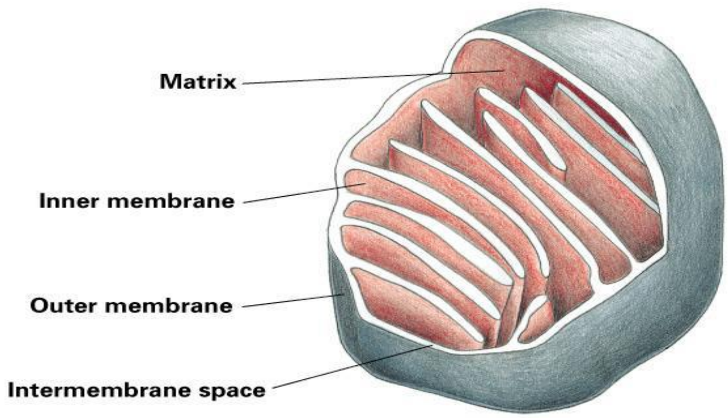
-prokaryote like ribosome (70S) -enzymes in TCA cycle

-enzymes for β-oxidation of fatty acid Glucose and fatty acids are catabolized in the matrix of mitochondria.

-inner membrane of mitochondria contains:

-electron transport chain -ATP synthase

The energy from catabolism in the matrix is converted into ATP.



Mitochondria are dynamic organelles they may exist as individual organelles may become elaborate network

move throughout the cell on cytoskeleton

Changes in the network are mediated by fission and fusion proteins

Mitochondrial energy production

Mitochondria is the power of house of the cell

How are mitochondria organized to be power house.

The food we eat is oxidized to produce high energy electrons that converted to store energy. This energy is stored in high energy phosphat bond in a molecule called Adenosine Triphosphate (ATP).

The food we eat must first be converted to basic chemicals that the cell can use. Some of the best energy supplying foods contain sugar or carbohydrates.

The sugars are broken down by enzymes that split them into simplest form sugar which called glucose . Then glucose enters the cell by special molecules in the membrane called “ Glucose transporter”.

Once inside the cell, glucose is broken down to make ATP in two pathways.

The first pathways requires no oxygen and is called “ anaerobic metabolism” this pathway is called glycolysis and it occur in the cytoplasm, outside of mitochondria During glycolysis, glucose is broken down into pyruvate..

Each reaction is designed to produce some hydrogen ions (electron) that can be used to make energy packet (ATP). However, only 4 ATP molecules can be made by one molecule of glucose run through this pathway. That is why mitochondria and oxygen are so important. We need to continuo the breakdown with the Krebs cycle inside the mitochondria in order to enough ATP to run all the cell function.

Anaerobic and aerobic metabolism

Pyruvat is carried into the mitochondria and it converted into Acetyl Coa which enter the Krebs cycle. This first reaction produce carbon dioxide, because it involves the removal of one carbon from pyruv, atc.

How does the Krebs Cycles work.

The whole idea behind respiration in the mitochondria is to use the Krebs (also called the Citric acid Cycle) to get many electron (in the form of hydrogen ions), are then used to drive pumps that produce ATP. The energy carried by ATP is than used for all kind of cellular function, like movement, transport, entry and exit products, division, etc.

First, you need pyruvate, which is made by glycolysis from glucose. Next you need some carrier molecule for the electrons. There are two types of these : one called Nicotinamide Adenin Dinucleotide (NAD+), and the other is called Flavin Adenin Dinucleotid (FAD+), The third molecule, of course is oxygen.

Pyruvat is a 3 carbon molecule. After inter the mitochondria, it is broken down to a 2 carbon molecule by special enzyme. This release molecule are called acetyl Coa and it enters the Krebs Cycle by joining to 4 carbon molecule called Citric acid (2 carbon + 4 carbon = 6 carbon). That is where the citric acid cycle got it name. (from the first reaction, that make citric acid). Citric acid is then broken down, and modified in a stepwise fashion, and as the happens, hydrogen ions and carbon molecules are released. The carbon molecules are used to make more carbon dioxide and the hydrogen ions are picked up by NAD and FAD.

Eventually the process produces the 4 carbon oxalo acetat again. The reason, the process called cycle, is because its ends up always where it started, with oxalo acetat available to combine with more acetyl Coa.

Mitochondrial energy production

Three major steps in oxidative phosphorylation

1)Production of reducing equivalents (NADH, FADH2) from glycolysis, fatty acid oxidation, and the citric acid cycle

2) Electron transport and generation of proton motive force

3) Phosphorylation - Synthesis of ATP, driven by the proton motive force

Mitochondria produce biosynthetic precursors

OXPHOS also leads to the production of:

· Superoxide: formed when O2 steals electrons from the ETC complexes

· Heat: a by-product of the reactions of OXPHOS

Mitochondria and chloroplast - the energy transformers

Mitochondria (found in plant and animal cells) are the energy releasers and the chloroplasts (found only in green plant cells) are the energy trappers.

Mitochondria (Singular = mitochondrion)

Appear as tiny thread like structures under light microscope. Approximately 0.5 -

1.00 μm (micrometer)

Number usually a few hundred to a few thousand per cell (smallest number is just

one as in an alga, Micromonas.

Mitochondria and Chloroplast

-both are energy transformers of cells mitochondria = cellular respiration

chloroplast = photosynthesis

-both are not part of the endomembrane system

-most of their proteins are synthesized by the free ribosomes in the cytosol

-a few of the proteins are synthesized from their own Ribosomes

both organelles contain small quantity of DNA that direct the synthesis of polypeptides produced by the internal ribosomes

-both organelles grow and reproduce as semiautonomous organelles

Endoplasmic reticulum (ER)

Structure: A network of membranes with thickness between 50 - 60A°. It is of

two types– rough endoplasmic reticulum (RER) i.e. when ribosomes

are attached to it and Smooth endo-plasmic reticulum (SER) when

no ribosomes are present.

Distributed hroughout the cytoplasm and is in contact with the cell

membrane as well as the nuclear membrane

In the year 1945- The lace like membranes of the endoplasmic reticulum were first seen in the cytoplasm of chick embryo cells.

These are membrane bound channels, seen in the form of a network of delicate strands and vesicles in the cytoplasm.

These are single membrane cell organelles.

These form an interconnected network of tubules, vesicles and cisternae with in cells.The cells that are actively synthesizing proteins, such as liver and pancreatic cells and fibroblast, have abundant ER.

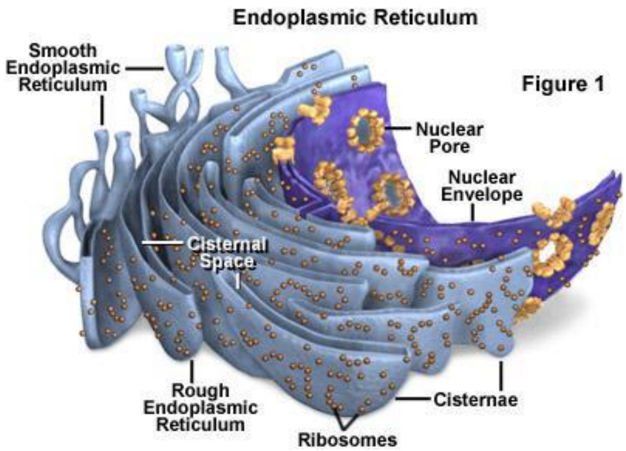
· Endoplasmic reticulum forms 30-60 % of the total membrane in a cell.

The ER appears to arise from the outer membrane of the nuclear envelope by out folding , or from the plasma membrane by in folding.

The smooth ER seem to arise from the rough ER by detachment of ribosomes.

There are two basic morphological types of ER namely RER and SER.

The ER membrane is thinner (50 Å) than that of plasma membrane (80-100Å thick)



PHYSICAL STRUCTURE-

The ER is 3-dimensional network of intracellular.

It is formed of three types of element:

1-Cisternae 2-Tubules 3-Vesicles

Cisternae-

These are flattened , unbranched, sac-like element.

They lie in stacks parallel to one another.

They bear ribosomes on the surface that, therefore, appears rough.

It contain glycoproteins named ribophorin-I & ribophorin-II that bind the ribosomes.

Tubules

These are irregular branching element which form a network along with other element.

These are often free of ribosomes

Vesicles

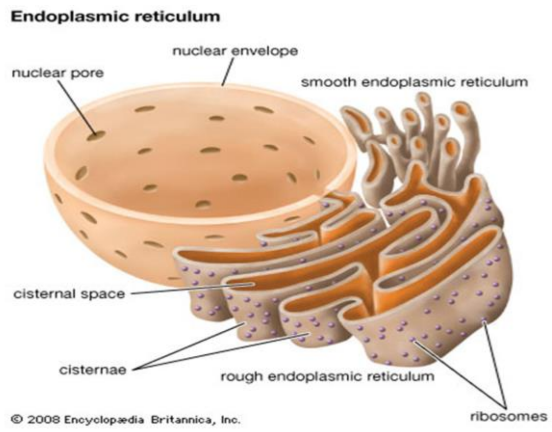
These are oval and rounded ,vacuole like element.

These are also free of ribosomes.

All the element of ER freely communicates with one another, and contain a fluid called endoplasmic matrix, in the ER lumen.

These matrix is different from cytoplasmic matrix outside the ER

The ER may pass from one cell to another through the plasmodesmata in the form of desmotubules.



Molecular structure

The membrane of ER are composed of two layers of phospholipid molecules sandwiched by two layers of proteins molecules like other membrane in the cell wall

Endoplasmic Matrix

The space inside the tubules and vesicles is filled with a watery medium that is different from the fluid in the cytosol outside the ER.

Their walls are constructed of lipid bilayers membranes that contains large amount of proteins , similar to the cell membrane.

SMOOTH ER

Smooth ER is an arrangement of tubules, vesicles and sacs.

The size and structure of the SER varies between the cells.

The SER can change within a cells lifetime to allow the cell to adapt to changes in its function and requirements.

There are no ribosome’s attached to the membrane surface.

The SER is connected to the nuclear envelope

The network of the SER allows there to be enough

The SER is less stable.

The SER is characteristic of cells in which synthesis of non-protein substances takes place.

ROUGH ENDOPLASMIC RETICULIM (RER)

The surface of the RER is studded with ribosome, giving it a rough appearance.

It mainly consists of cisternae

The membrane of the RER forms large double membrane sheets

Which is located near and continuous with the outer layer of the nuclear envelope

RER is very important in the synthesis and packaging of proteins e:g, Russell’s bodies of plasma, nissel’s granules of nerve cell

Binding site of the ribosome on the RER is the translocon

The ribosomes bound to the RER at any one time are not a stable part of this organelles structure

Because ribosomes are constantly being bound and released from the membranes

Ribosomes only binds to the RER once a specific protein-nucleic acid complex forms in the cytosol

This special complex forms when a free ribosome begins translating the mRNA of a protein destined for the secretory pathway

The first 5-30 amino acid polymerized encode a single peptide, a molecular message that is recognized and bound by a single recognition particle (SRP)

The ribosomes that become attached to the endoplasmic reticulum synthesize all trans membrane proteins

Most secreted proteins that are stored in the Golgi apparatus, lysosomes, and endosomes

Translation pauses and the ribosomes complex binds to the RER translocon

Protein Transport

As proteins are formed in the endoplasmic reticulum, they are transported through the tubules toward proteins of the SER that lie nearest to Golgi apparatus

At this point, small transport vesicles composed of small envelopes of smooth ER continually break away and diffuse to the deepest layer of Golgi apparatus

Inside this vesicles are the synthesized proteins and other product from the ER present

<u>Transport vesicles</u>

They are surrounded by coating protein called COP I, COP II.(Coat Protein complex)

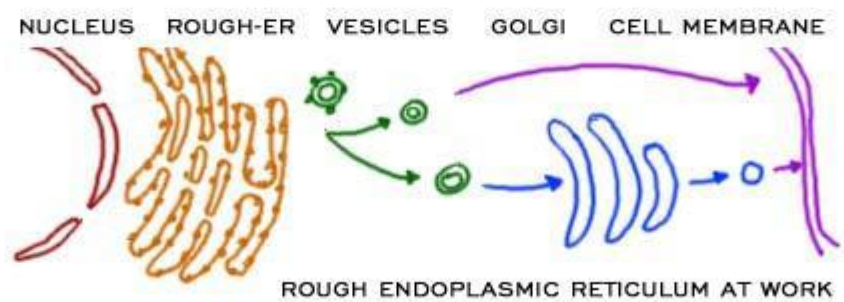
COP II targets vesicles to the Golgi apparatus.

Transparent proteins from the RER to Golgi apparatus

This process is termed as anterograde transport.

COP I transports proteins from the cis end of the Golgi complex back to the RER.

This process is termed as retrograde transport



Second method of transport out of the endoplasmic reticulum involves areas called membrane contact sites.

Where membranes of the endoplasmic reticulum and other organelles are held together , allowing the transfer of lipid and other small molecules

FUNCTIONS OF RER

- Surface for Ribosomes- The RER provides space and ribophorins for the attachment of ribosomes to itself

- Surface for protein synthesis:

- Formation of Glycoprotein- Linking of sugars to for glycoprotein starts in the RER and is completed in Golgi complex

Synthesis of precursors- The RER produce enzyme precursors for the formation of lysosomes by Golgi Complex

- Smooth ER formation- The RER gives rise to the smooth ER by loss of ribosomes

FUNCTIONS OF SER

- The smooth endoplasmic reticulum lacks ribosomes and functions

- Lipid metabolism, carbohydrate metabolism, and detoxification and is especially abundant in mammalian liver and gonad cells

Synthesizes phospholipids

Cells which secrete these products, such as those in the testes, ovaries, and skin oil glands have a great deal of smooth endoplasmic reticulum

Detoxification-The SER brings about detoxification in the liver , i.e., converts harmful materials(drugs, poisons) into harmless ones for excretion by the cell

- Formation of organelles- The SER produces Golgi apparatus , lysosomes and vacuoles

- It also carries out the attachment of receptors on cell membrane proteins and steroid metabolism

Sarcoplasmic Reticulum (SR)

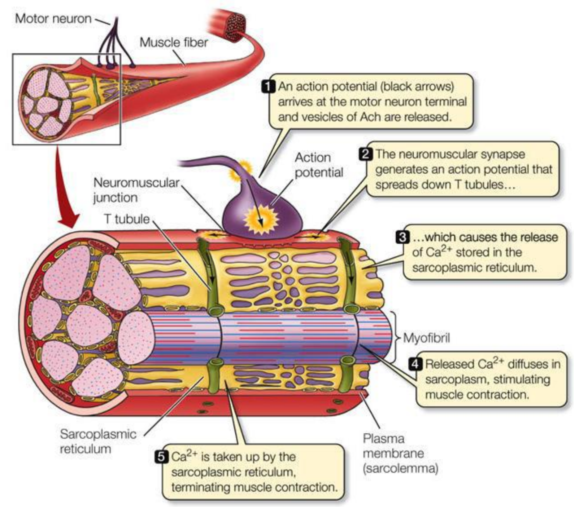
- The sarcoplasmic reticulum (SR) is smooth ER found in smooth and striated muscle

- The only structural difference between this organelle and the smooth endoplasmic reticulum is the medley of proteins they have, both bound to their membranes and drifting within the confines of their lumens. This fundamental difference is indicative of their functions

The endoplasmic reticulum synthesizes molecules, while the sarcoplasmic reticulum stores and pumps calcium ions

The sarcoplasmic reticulum contains large stores of calcium, which it sequesters and then releases when the muscle cell is stimulated

- It plays a major role in excitation-contraction coupling in muscles cells



8e, **Figure 47.5**

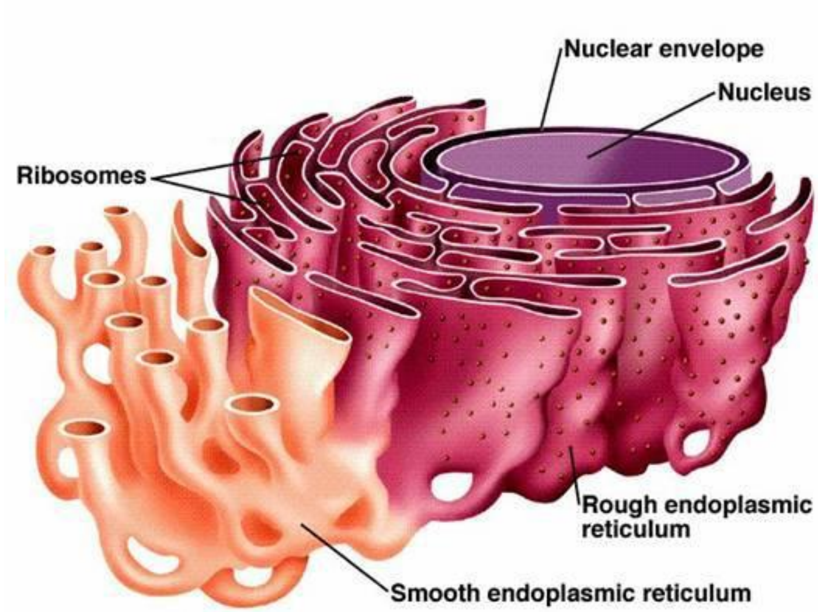
The Endoplasmic reticulum (ER) and Golgi body are single membrane bound structures. The membrane has the same structure (lipid-protein) as the plasma membrane but ribosomes do not have membranes. Ribosomes are involved in synthesis of proteins in the cell, Golgi bodies in secreting and the ER in transportingand storing the products. These three organelles operate together.

-ER consists of a network of membranous tubules and sacs

called cisternae. (cisterna = a reservoir for a liquid)

-the network are interconnected

- The ER membrane is continuous with the nuclear envelope and the cisternal space of the ER is continuous with the space between the two membranes of the nuclear envelope.



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Function

Provides internal framework, compartment and reaction surfaces, transports enzymes and other materials through out the cell. RER is the site for protein synthesis and SER for steroid synthesis, stores carbohydrates.

-Smooth and rough ER (with & without ribosomes)

-Smooth ER: synthesis of lipid (oils, phospholipids, and steroids)

glycogen metabolism in the liver cells detoxification of drugs and poisons

store calcium for muscle contraction

Rough ER: ribosomes are attached to the outside

-is abundant in cells that secrete protein

-synthesis secretory proteins, cell membrane protein

and organelle protein (proteins are targeted to determined location according to the sorting signals. Sorting signals are encoded in a sequences or in the attached oligosaccharides)

-synthesis of phospholipids and ER associated protein proteins are synthesized from the bound ribosomes -threaded into the cisternal space through a pore formed by a protein in the ER

membrane

-protein folds into its native conformation

-an oligosaccharide is attached to the protein = glycosylation -those proteins are wrapped in the transport vesicles that bud from the ER

<u>Golgi Apparatus and its Functions in the cell</u>

The Golgi apparatus is noticeable with both light and electron microscope. It is also called Golgi complex

The Golgi complex was discovered by an Italian physician and Noble Laureate Camillo Golgi in 1898 during an investigation of the nervous system

Its electron microscopic structure was described by Dalton and Felix in 1954

The Golgi apparatus is present in all Eukaryotic cells and absent in Prokaryotes

The Golgi apparatus is specially extensive in the secretory cells

It is absent in few cell types, such as the mammalian RBCs, sperm cells of Bryophytes and Pteridophytes and sieve tubes of plants

A cell may have one large Golgi complex or several very small ones. It occupies different positions in different kind of cells

In secretory and absorptive cells, it usually lies near the nucleus

The invertebrate and plant cells usually have several small Golgi complexes, called Dictyosomes, scattered throughout the cytoplasm

Golgi complex varies in size and form in different cell types but usually has similar organization for any one kind of cells

Electron microscope shows it as a central stack (pile) of parallel, flattened, intercommunicating sacs or cisternae and many peripheral tubules and vesicle surface area for the action or storage of key enzymes or the products of the enzymes.

Cisternae 1

The cisternae vary in number from 3-7 in most animal cells and from 10-20 in plant cells-

Usually equally spaced in the stack, separated from each other by thin layers of inter cisternal cytoplasm

Cisternae may be flat but are often curved

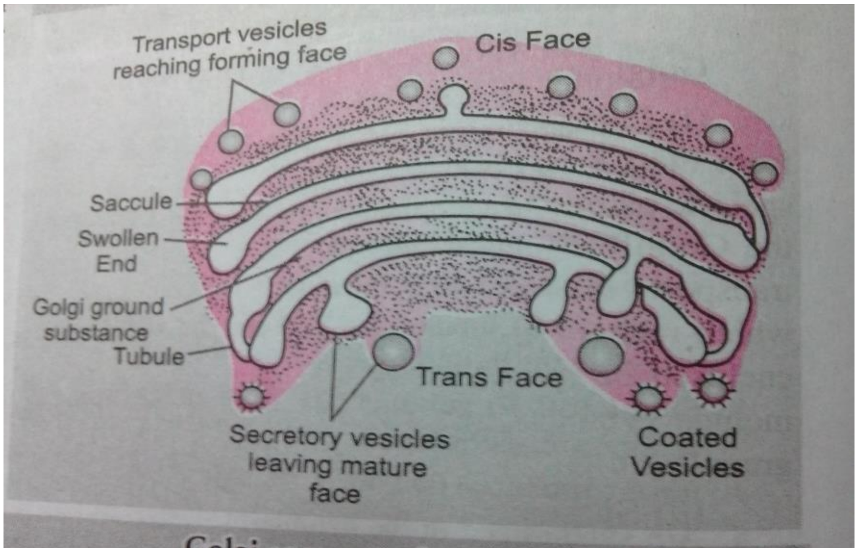
Golgi complex has a distinct polarity, the two poles are called cis face and trans face, which act respectively as the receiving and shipping departments

Convex side of stack -> forming (cis) face

Concave side of stack -> maturing (trans) facetrans

Secretory materials reach the Golgi complex from Smooth Endoplasmic Reticulum (SER) by way of transport vesicles which bud off from SER and fuse with golgi cisternae on the cis face

From the trans face Secretory vesicles arises that carry the processed material to their destination



Golgi apparatus in section

Functions of Golgi Complex

Secretion Synthesis Sulfation Apoptosis

Phosphorylation Cell-specific functions

SECRETION

Although the golgi apparatus is involved in many different cellular processes ,its principle role in many cells is in secretion

Golgi plays an important role in the synthesis of proteoglycans, which are molecules present in the extracellular matrix of animals

SYNTHESIS

It is also a major site of carbohydrate synthesis

This includes the production of glycosaminoglycans (GAGs), long unbranched polysaccharides which the Golgi then attaches to a protein synthesised in the endoplasmic reticulum to form proteoglycans ‘

Enzymes in the Golgi polymerize several of these GAGs via a xylose link onto the core protein.

The Golgi apparatus is involved in cell secretions; secretory vesicles are also shown, which break off the membranes and transport materials to the cell (plasma) membrane.

Is a stack of membranous sacs of the same thickness as ER.

Exhibit great diversity in size and shape. In animal cells present around

the nucleus, 3 to 7 in number.

In plant cells, many in number of and present scattered

throughout the cell called dictyosomes.

Synthesis and secretion as enzymes, participates in transformation of membranes to give rise to other membrane structure such as lysosome, acrosome, and dictyosomes,synthesize wall element like pectin, mucilage.

The Golgi apparatus:

-Major sites for carbohydrate symthesis

-sorting and dispatching station for the products of the ER

-consists of flatten membranous sacs, cisternae

-unlike ER cisternae, the Golgi cisternae are not physically connected. -a Golgi stacks has polarity: cis face (the receiving side) and trans face (the shipping side)

-transport vesicle from ER fuses to the cis face to transfer the material to the Golgi

-proteins and lipids are altered; glycosylation and phosphorylation (tagging the sorting signal)

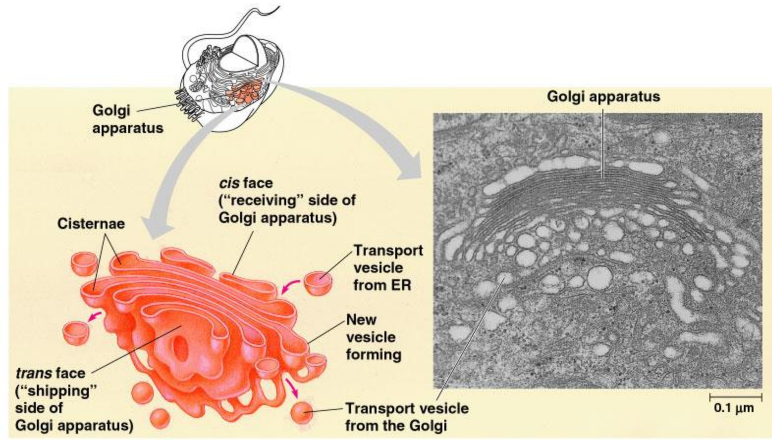
-oligosaccharides portion of the glycoproteins are modified: Golgi removes some sugar monomers and substitutes others

-some polysaccharides are synthesized in the Golgi e.g pectin and cellulose of the plant cell wall and most of the glycosaminoglycans of animal extracellular matrix

-Golgi products (that will be secreted) depart from the trans face of the Golgi by transport vesicle for the correct docking.

Relationships among Organelles of the Endomembrane System

-secretory proteins, lysosomes, vacuoles and membrane are synthesized by the rough ER, then transported through the Golgi as a vesicle. -during this process, their molecular compositions and metabolic functions are modified.

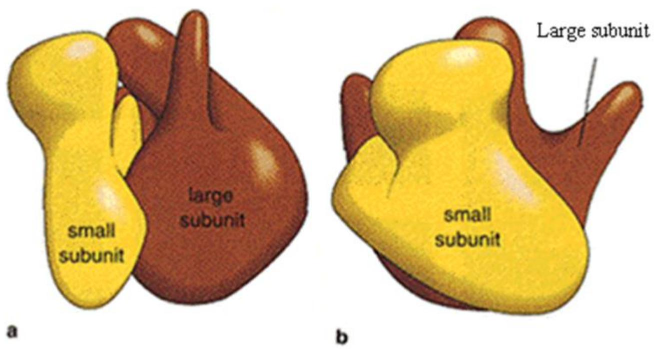


Ribosomes

Spherical about 150 - 250Å in diameter, made up of large molecules of RNA and proteins (ribonucleo proteins) Present either as free particles in cytoplasm or attached to ER. Also found stored in nucleolus inside the nucleus. 80S types found in eukaryotes and 70S in prokaryotes (Ssvedberg unit of measuring ribosomes).

Site for protein synthesis The microbodies (tiny but important)

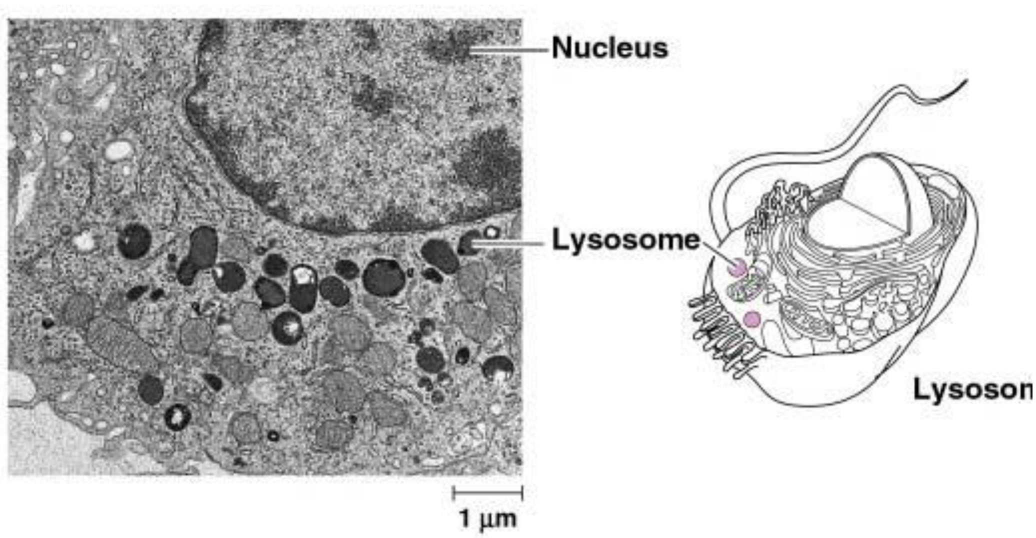
Function: location of protein synthesis



These are small sac-like structures bounded by the single membranes. These are of different kinds of which we will take up three, viz. lysosomes, peroxisomes and glyoxysomes.

Ribosomes are found in both prokaryotes and eukaryotes. In both types of cells, ribosomes are composed of two subunits, one large (60s) and one small (40s), in prokaryotes the large unit is 50s and the small unit is 30s. Each subunit has its own mix of proteins and rRNA. As mentioned, ribosomes are sites of protein synthesis. They receive mRNA from the nucleus, which carries a coded message from DNA. Each mRNA codes for the correct sequence of amino acids in a polypeptide and, as mentioned, a protein contains one or more polypeptides. In eukaryotic cells, some ribosomes occur freely within the cytoplasm, either singly or in groups called polyribosomes. Proteins synthesized by polyribosomes are used in the cytoplasm. Many ribosomes are attached to the endoplasmic reticulum (ER), an organelle composed of many saccules and channels. After the ribosome binds to a receptor at the ER, the polypeptide being synthesized

enters the lumen of the ER, where it may be further modified. A protein takes its final shape inside the lumen of the ER then go out to perform its function.



(a) Lysosomes in a white blood cell

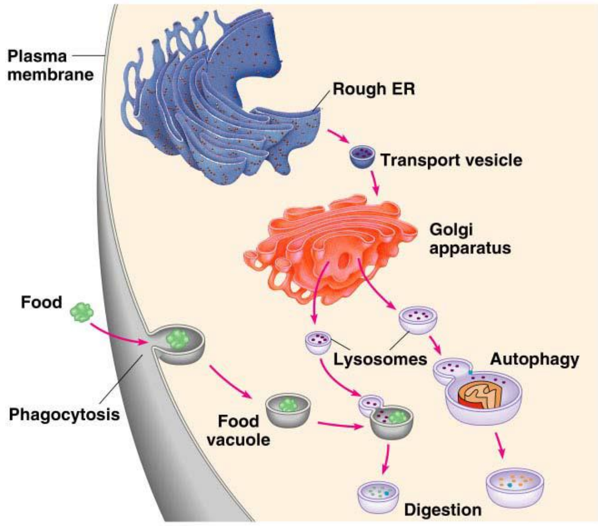
Lysosomes: principal sites of intracellular digestion

-contain hydrolytic enzymes (required acidic pH) to digest proteins, polysaccharides, fats and nucleic acids(if those hydrolases leak out of the lysosmes, they are not likely to do damage unless the cells become acidic) lysosomal enzymes and membranes are made by rough

ER and transferred to the Golgi for processing

-lysosomal membranes are highly glycosylated to protect

them from lysosomal proteases



Food particles engulfed as a food vacuole (phagocytosis) or an endosome (product of receptor-mediated endocytosis) is fused with the lysosome.

-The digestion products are passed to cytosol and become nutrient for the cell.

autophagy = process which cells recycle its own

organic material

-the organelles are fused with a lysosome

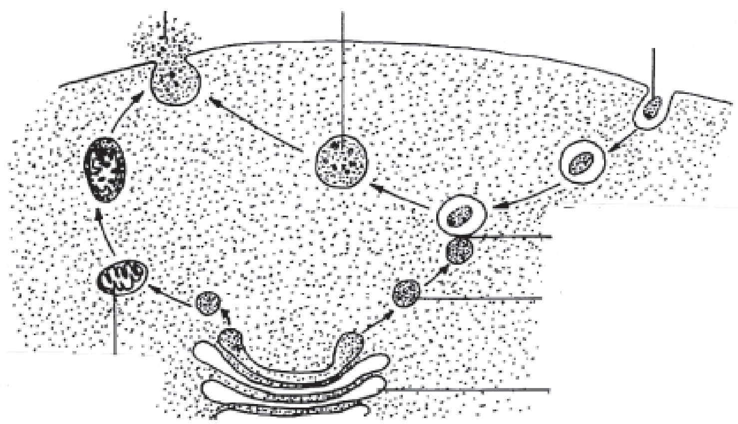
-after digestion, the organic monomers are

returned to the cytosol for reuse

1. Lysosomes (lysis = breaking down; soma = body)

Lysosomes are present in almost all animal cells and some non-green plant cells

They perform intracellular digestion.



The main features of lysosomes are as follows : of Life

(i) Membranous sacs budded off from Golgi body.

(ii) May be in hundreds in a single cell.

(iii) Contain several enzymes (about 40 in number)

(iv) Materials to be acted upon by enzymes enter the lysosomes.

(v) Lysosomes are called “suicidal bags” as enzymes contained in them can digest the cell’s own material when damaged or dead.

Importance of intracellular digestion by the lysosomes

(i) help in nutrition of the cell by digesting food, as they are rich in various hydrolysing enzymes which enable them to digest almost all major chemical constituents of the living cell.

(ii) Help in defense by digesting germs, as in white blood cells.

(iii) Help in cleaning up the cell by digesting damaged material of the cell.

(iv) Provide energy during cell starvation by digestion of the own parts of the cells (autophagic, auto : self; phagos: eat up).

(v) Help sperm cells in entering the egg by breaking through (digesting) the egg membrane.

(vi) In plant cells, mature xylem cells lose all cellular contents by lysosome activity.

(vii) When cells are old, diseased or injured, lysosomes attack their cell organelles and digest them. In other words lysosomes are autophagic, i.e. self-devouring.

2. Peroxisomes

Found both in plant and animal cells. Found in the green leaves of higher plants. They participate in oxidation of substrates resulting in the formation of hydrogen peroxide.

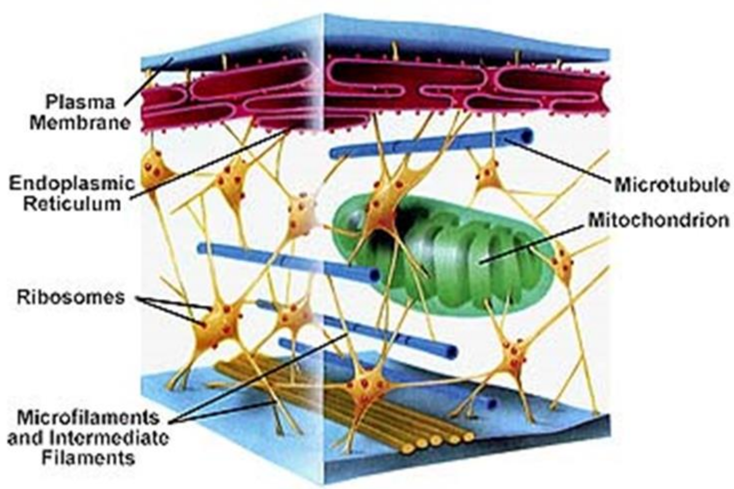
- They often contain a central core of crystalline material called nucleoid composed of urate oxidase crystals.
- These bodies are mostly spherical or ovoid and about the size of mitochondria and lysosomes.
- They are usually closely associated with ER.
- They are involved in photorespiration in plant cells.
- They bring about fat metabolism in cells.

3. Glyoxysomes

- The microbodies present in plant cells and morphologically similar to peroxisomes.
- Found in the cell of yeast and certain fungi and oil rich seeds in plants.
- Functionally they contain enzymes of fatty acid metabolism involved in the conversion of lipids to carbohydrates during germination.

The Cytoskeleton

Structure: a network of thin, fibrous elements made up of microtubules (hollow tubes) and microfilaments (threads made out of actin)



Function: -acts as a support system for organelles-maintains cell shape

-a network of fibers extending throughout the cytoplasm

-function: provide mechanical strength to the cell

establish cell shape

locomotion (several types of cell motility)

intracellular transport of organelles

-3 main types of fiber:

1.microtubules: determine the positions of membraneenclosed

organelles and intracellular transport

2.microfilament: determine the shape of the cell and

necessary for the whole cell locomotion

3.intermediate filament: provide mechanical strength and resistance to shear stress

Cytoskeleton functions

Cell shape

Organization of cellular structures

Cell movement

Caused by assembly, disassembly and sliding of the filaments

Organelle movement Ex: Endocytosis

Movement of membrane from ER to Golgi apparatus, etc…

Cell division

Cytoskeleton and Cell Motility

Cell motility requires interaction of

cytoskeleton with proteins called motor molecules

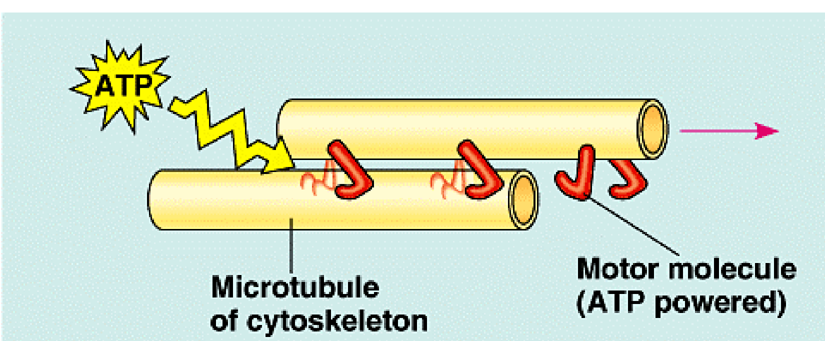
in ATP dependent manner.

Sliding of neighboring

microtubules moves

cilia and flagella.

In muscle contraction, motor molecules slide microfimaments.



(a)

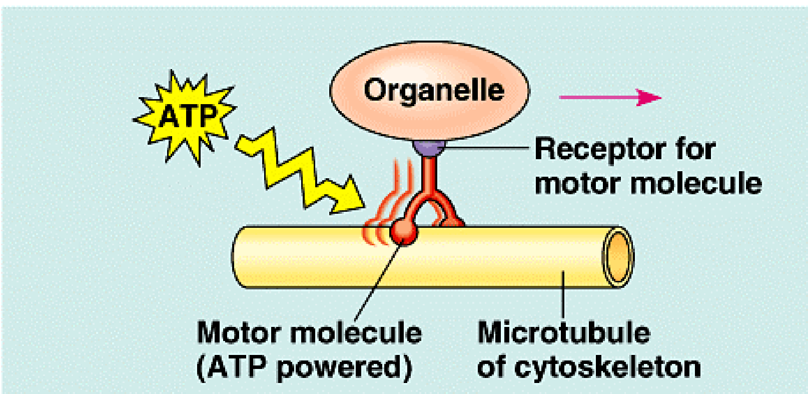
Walking of organelles along microtubules

Motor molecule attached to receptor on

organelles can "walk" the organelles along

microtubules or microfilaments.

e.g. migration of neurotransmitters containing vesicles to the tips of nerve cell axon.



(b)

<u>Microtubules</u>

-are straight, hollow Cylinders -have a diameter of about 25 nm

-are variable in length but can grow 1000 times as long as they are thick

-are built by the assembly of dimers of alpha

tubulin and beta tubulin. -are found in both animal and plant cells

-grow at each end by the

polymerization of tubulin

dimers (powered by the

hydrolysis of GTP)

-shrink at each end by the release of tubulin dimers (depolymerization)

-participate in a wide variety of cell activities. Most

involve motion. The motion is provided by protein "motors"

that use the energy of ATP to move along the microtubule.

Microtubule motors

There are two major groups of microtubule motors:

kinesins (most of these move toward the plus end

of the microtubules) and

dyneins (which move toward the minus end).

Examples: The rapid transport of organelles, like vesicles and

mitochondria, along the axons of neurons takes place

along microtubules with their plus ends pointed toward

the end of the axon. The motors are kinesins.

The migration of chromosomes in mitosis and meiosis takes place on microtubules that make up the

spindle fibers. Both kinesins and dyneins are used as motors

function of microtubules:

*shape and support the cell

*resist compression

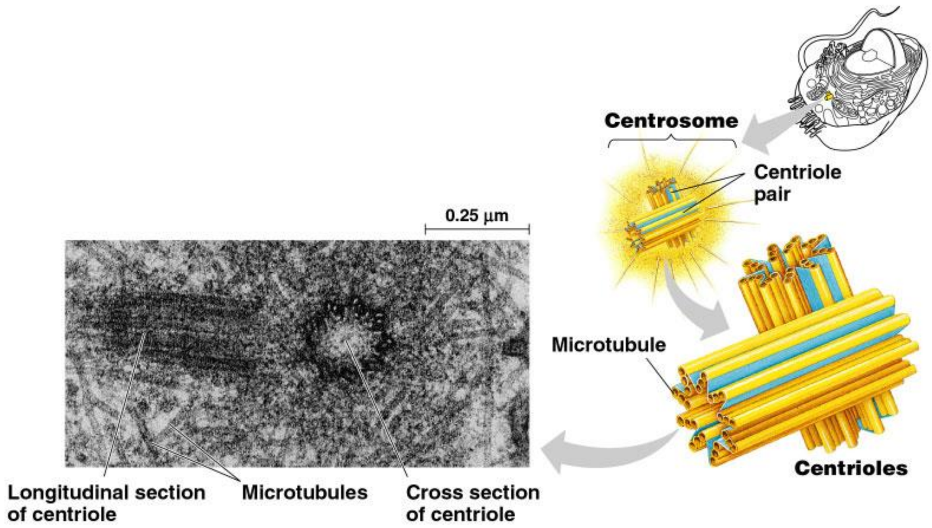
*serve as track along which organelle can move via motor molecule

*responsible for separation of chromosome during cell division

*component of centrosome, centrioles, cilia and flagella

Centrosomes and Centrioles

Centrosomes (microtubule-organizing center) = a region near the nucleus from which microtubules



Vacuoles

Vacuoles, like vesicles, are membranous sacs, but vacuoles are larger than vesicles. The vacuoles of some protists are quite specialized; they include contractile vacuoles for ridding the cell of excess water, and digestive vacuoles for breaking down nutrients. Vacuoles usually store substances, such as nutrients or ions. Plant vacuoles contain not only water, sugars, and salts, but also pigments and toxic molecules. The pigments are responsible for many of the red, blue, or purple colors of flowers and some leaves. The toxic substances help protect a plant from herbivorous animals. Few animal cells contain vacuoles, but fat cells, or adipocytes, contain a very large lipid-engorged vacuole that takes up nearly two-thirds of the volume of the cell.

-diverse functions in cell maintenance food vacuoles formed by phagocytosis and

digested by lysosomes contractile vacuoles (in protists) pump excess

water out of the cells central vacuole (a versatile compartment in plants) stores protein and metabolic by-products, reservoir of inorganic ions, pigments

Centrioles

-each centrosomes contain a pair of centrioles

-found in animal cells

-composed of 9 sets of triplet microtubules arranged in a ring

-centrioles replicate before cell division

-may help organize microtubule assembly but centrioles are not essential for this function

centrosomes of most plants lack centrioles.

Centriole It is present in all the animal cells (but not in Amoeba), located just outside the nucleus. It is cylindrical, 0.5 μm in length and without a membrane. It has 9 sets of peripheral triplet tubules but none in the centre (9 + 0). Each set has three tubules arranged at definite angles (Fig. 4.10). It has its own DNA and RNA and therefore it is self duplicating.

Function : Centrioles are involved in cell division. They give orientation to the

'mitotic spindle' which forms during cell division

Cilia and Flagella

-both cilia and flagella are constructed from

microtubules

-both provide either locomotion for the cell or move

fluid pass the cell

-found in prokaryotes and eukaryotes

-cilia and flagella differ in their beating pattern

cilia sweep mucus carrying trapped debris from the lungs.

A flagellum has an undulating motion that

generates force in the same direction as the

flagellum's axis.

Cilia works like oars. The alternating power and

recovery strokes generating force in a direction

perpendicular to the cilium's axis.

-Celia and flagella have the same ultrastructure =

microtubules core sheathed in an extension of

plasma membrane

-"9+2" arrangement of microtubules (9 doublets +2 single)

-both are anchored in the cell by a basal body,

whose structure is identical to a centriole

-each microtubule connects to the next by a motor molecule dynein

-dynein is responsible for the bending of cilia and flagella

-addition of phosphate group from ATP to dynein causes conformational change in this protein which result in grabing, moving and releasing of the outer

microtubule

Microfilament or Actin Filament

-a twisted double chain of actin subunits of 7 nm diameter

-bear tension (pulling force)

-found in all eukaryotic cells

-combine with other protein to form a three dimensional

network beneath the plasma membrane

Bundles of microfilament make up core of microvilli (to

increase cell surface area) of the animal cells specialized in

transport materials across plasma membrane.

-this network make the semisolid consistency of the cortex = gel state in the outer cytoplasmic layer

-the interior cytoplasm is the more fluid state

(sol)

-cytoplasm can be converted between gel-sol due

to the reversible assembly of microfilaments into

the networks

Intermediate filament

cytoplasmic ropelike fibers with average 10 nm in diameter

(and thus are "intermediate" in size between actin filaments

(8 nm) and microtubules (25 nm)

-There are several types of intermediate filament, each

constructed from one or more proteins characteristic of it.

keratins are found in epithelial cells and also form hair

and nails (over 20 different kinds of keratins have been found)

nuclear lamins form a meshwork that stabilizes the

inner membrane of the nuclear envelope

neurofilaments strengthen the long axons of neurons;

vimentins provide mechanical strength to muscle (and other) cells.

Despite their chemical diversity, intermediate filament play similar

roles in the cells: providing a supporting framework within the cells

Protein biosynthesis

RNA is transcribed in the nucleus; once completely processed, it is transported to the cytoplasm and translated by the ribosome and tRNA.Protein biosynthesis is the process whereby biological cells generate new proteins; it is balanced by the loss of cellular proteins via degradation or export. Translation, the assembly of amino acids by ribosomes, is an essential part of the biosynthetic pathway, along with generation of messenger RNA (mRNA), aminoacylation of transfer RNA (tRNA), co-translational transport, and post-translational modification. Protein biosynthesis is strictly regulated at multiple steps. They are principally during transcription (phenomena of RNA synthesis from DNA template) and translation (phenomena of amino acid assembly from RNA).

DNA is transcribed into a variety of RNA intermediates. The last version is used as a template in synthesis of a polypeptide chain. Protein will often be synthesized directly from genes by translating mRNA. When a protein must be available on short notice or in large quantities, a protein precursor is produced. A pro-protein is an inactive protein containing one or more inhibitory peptides that can be activated when the inhibitory sequence is removed by proteolysis during posttranslational modification. A pro-protein is a form that contains a signal sequence (an N-terminal signal peptide) that specifies its insertion into or through membranes, i.e., targets them for secretion. The signal peptide is cleaved off in the endoplasmic reticulum. Pro-proteins have both sequences (inhibitory and signal) still present.

Protein biosynthesis, although very similar, is different for prokaryotes and eukaryotes Transcription

Diagram showing the process of transcription

In transcription an mRNA chain is generated, with one strand of the DNA double helix in the genome as a template. This strand is called the template strand. Transcription can be divided into 3 stages: initiation, elongation, and termination, each regulated by a large number of proteins such as transcription factors and coactivators that ensure that the correct gene is transcribed. Transcription occurs in the cell nucleus, where the DNA is held. The DNA structure of the cell is made up of two helixes made up of sugar and phosphate held together by hydrogen bonds between the bases of opposite strands. The sugar and the phosphate in each strand are joined together by stronger phosphodiester covalent bonds. The DNA is fnzipped" (disruption of hydrogen bonds between different single strands) by the enzyme helicase, leaving the single nucleotide chain open to be copied. RNA polymerase reads the DNA strand from the 3-prime (3') end to the 5-prime (5') end, while it synthesizes a single strand of messenger RNA in the 5'-to-3' direction. The general RNA structure is very similar to the DNA structure, but in RNA the nucleotide uracil takes the place that thymine occupies in DNA. The single strand of mRNA leaves the nucleus through nuclear pores, and migrates into the cytoplasm.

The first product of transcription differs in prokaryotic cells from that of eukaryotic cells, as in prokaryotic cells the product is mRNA, which needs no post-transcriptional modification, whereas, in eukaryotic cells, the first product is called primary transcript, that needs post-transcriptional modification (capping with 7-methyl-guanosine, tailing with a poly A tail) to give hnRNA (heterophil nuclear RNA). hnRNA then undergoes splicing of introns (noncoding parts of the gene) via spliceosomes to produce the final mRNA.

Translation

Diagram showing the process of translation

Diagram showing the translation of mRNA and the synthesis of proteins by a ribosome

The synthesis of proteins from RNA is known as translation. In eukaryotes, translation occurs in the cytoplasm, where the ribosomes are located. Ribosomes are made of a small and large subunit that surrounds the mRNA. In translation, messenger RNA (mRNA) is decoded to produce a specific polypeptide according to the rules specified by the trinucleotide genetic code. This uses an mRNA sequence as a template to guide the synthesis of a chain of amino acids that form a protein. Translation proceeds in four phases: activation, initiation, elongation, and termination (all describing the growth of the amino acid chain, or polypeptide that is the product of translation).

In activation, the correct amino acid (AA) is joined to the correct transfer RNA (tRNA). The AA is joined by its carboxyl group to the 3' OH of the tRNA by an ester bond. When the tRNA has an amino acid linked to it, it is termed "charged". Initiation involves the small subunit of the ribosome binding to 5' end of mRNA with the help of initiation factors (IF), other proteins that assist the process. Elongation occurs when the next aminoacyl-tRNA (charged tRNA) in line binds to the ribosome along with GTP and an elongation factor. Termination of the polypeptide happens when the A site of the ribosome faces a stop codon (UAA, UAG, or UGA). When this happens, no tRNA can recognize it, but releasing factor can recognize nonsense codons and causes the release of the polypeptide chain. The capacity of disabling or inhibiting translation in protein biosynthesis is used by some antibiotics such as anisomycin, cycloheximide, chloramphenicol, tetracycline, streptomycin, erythromycin, puromycin, etc.

NUCLEUS

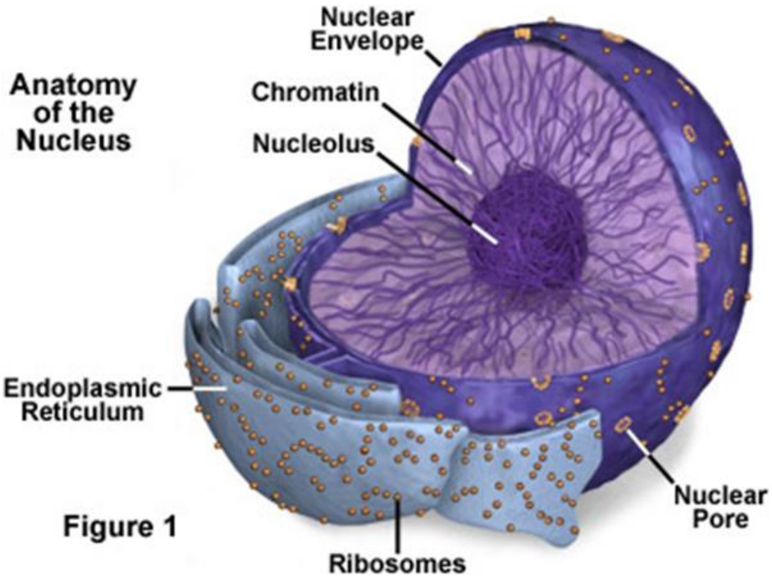


Figure 1

General structure of the nucleus :

(i) It is the largest organelle seen clearly when the cell is not dividing.

(ii) It stains deeply, is mostly spherical, WBC have lobed nuclei.

(iii) It is mostly one in each cell (uninucleate, some cells have many nuclei;

(multinucleate).

(v) Double layered nuclear membrane having fine nuclear pores encloses nucleoplasm which contains chromatin network and a nucleolus.

The nucleus is enclosed by a nuclear envelope which is a double

membrane of 20 -40 nm apart.

-Where the double membranes are fused, a nuclear pore complex allows

Large macromolecules and particles to pass through.

Functions

- Maintains the cell in a working order.
- Co-ordinates the activities of other cell organelles.
- Takes care of repair work.
- Participates directly in cell division to produce genetically identical daughter cells. This division is called mitotic cell division.
- Participates in production of meio-gametes and meiospores through another type of cell division called meiotic cell divisioin.The parts of a nucleus are given here :

Nuclear membrane

- Double layered membrane is interrupted by large number of nuclear pores.
- Membrane is made up of lipids and proteins (like plasma membrane) and has ribosomes attached on the outer membrane which make the outer membrane rough.
- The pores allow the transport of large molecules in and out of nucleus, and the membranes keep the hereditary material in contact with the rest of the cell.

Because of its large size, the nucleus is a noticeable structure in the eukaryotic cell

Chromatin

The nucleus contains chromatin within a semi fluid nucleoplasm. Chromatin looks grainy, but actually it is a network of strands. Just before the cell divides, the chromatin condenses and coils into rod like structures called chromosomes. All the cells of an organism contain the same number of chromosomes except for the egg and sperm, which have half this number. Chromatin (and therefore chromosomes) is composed of DNA, protein, and some RNA. The DNA is organized into genes, each of which has a specific sequence of bases that code for a polypeptide. The coded information is relayed to the ribosomes by a type of RNA called messenger RNA (mRNA).This mRNA has a sequence of bases that mirrors the sequence of bases in a gene. This sequence specifies the order of amino acids that are to occur in a particular polypeptide. A protein contains one or more polypeptides. Because the proteins of a cell determine its structure and functions, the nucleus may be thought of as the command center of the cell. The nucleolus is a dark structure within the nucleus where another type of RNA, called ribosomal RNA (rRNA), is produced. Proteins join with rRNA to form the subunits of ribosomes. The assembled

ribosomal subunits are then sent out of the nucleus into the cytoplasm, where they join and assume their role in protein synthesis. The nucleus is separated from the cytoplasm by a double membrane known as the nuclear

envelope. Even so, the nucleus communicates with the cytoplasm. The nuclear envelope has nuclear pores of sufficient size (100 nm) to permit the passage of ribosomal subunits and mRNA out of the nucleus into the cytoplasm, and the passage of proteins from the cytoplasm into the nucleus

- Within the nuclear membrane there is jelly like substance (karyolymph or nucleoplasm) rich in proteins.
- In the karyolymph, fibrillar structures form a network called chromatin fibrils, which gets condensed to form distinct bodies called chromosomes during cell division. On staining the chromosomes, two regions can be identified in the chromatin material heterochromatin, dark and euchromaticn (light).

Heterochromatin has highly coiled DNA and genetically less active than euchromatin which has highly uncoiled DNA and genetically more active.

The number of chromosomes is fixed in an organism. During mitotic cell division chromosomes divide in a manner that the daughter cells receive identical amounts of hereditary matter.

Nucleolus

- Membraneless, spheroidal bodies present in all eukaryotic cells except in sperms and in some algae.
- Their number varies from one to few, they stain uniformly and deeply.
- It has DNA, RNA and proteins.

 Store house for RNA and proteins; it disappears during early phase of cell cycle and reappears after telophase in the newly formed daughter nuclei.

 Regulates the synthetic activity of the nucleus.

 Thus nucleus and cytoplasm are interdependent, and this process is equal to nucleo–cytopalsmic interaction.

MOLECULES OF THE CELL

The cell and its organelles are made of organic chemicals such as proteins, carbohydrates, nucleic acid and fats. These are aptly termed biomolecules.
Inorganic molecules such as water and minerals are also present in a cell.

A. Water

 Water with unique physical and chemical properties has made life possible on earth.

 It is a major constituent of protoplasm.

 It is a medium in which all the metabolic reactions occur.

 It is a universal solvent in which most substances remain dissolved sparingly or completely.

 It is responsible for turgidity of cells.

Vitamins, Minerals & Water

VITAMIN	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
★ A (Fat Soluble)	-**Vision** -Nerves -Growth	-Milk is fortified with it -Liver -Cantaloupe -Sweet Potatoes -Yellow fruits and vegetables	**-Blindness** -Stunted Growth -Impaired immune system	-Loss of appetite -Blurred vision -Abdominal pain -Hair loss -Joint pain

VITAMIN	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
★ D (Fat Soluble)	-Helps body absorb calcium and phosphorus -Helps strengthen bones	-Milk is fortified with it -Milk Products **-(Sunlight!)**	-Rickets (bowed legs) -Bones become too weak to support body weight	-Most toxic of all vitamins! -Appetite loss -Nausea & vomiting -Kidney damage

VITAMIN	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
E (Fat Soluble)	-Maintains cell membranes	-Fruits and Veggies -Vegetable oils -Fortified grains and cereals -Nuts & seeds	-Nerve deterioration -Can cause anemia in pre-mature babies	-Brain hemorrhages -Stroke -Headaches -Muscle weakness -Nausea

VITAMIN	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
★ K (Fat Soluble)	**-Helps blood clot normally**	-Dark green leafy vegetables -Liver	-Hemorrhaging	-Breakage of red blood cells which causes skin to turn yellow- (called ***jaundice*** in infants-can lead to brain damage)

VITAMIN	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
C *Ascorbic Acid* (Water Soluble)	-Maintains connective tissues -Protects body against infection	-Citrus fruits -Orange juice -Strawberries	-Scurvy (spots on the skin and bleeding gums) -Breakdown of collagen	-Kidney stones -Interferes with actions of Vitamin E
VITAMIN	**FUNCTION**	**FOOD SOURCES**	**DEFICIENCIES**	**TOXICITIES**
B1 *Thiamine* (Water Soluble)	-COENZYME! -Used for energy metabolism -Nerve function -Helps digestive system	-Milk -Bran -Whole grains -Poultry -Fish -Dried Beans	-Beriberi (Swelling in legs, sore muscles, stiffness and weakness)	-None

VITAMIN	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
B2 *Riboflavin* (Water Soluble)	-COENZYME! -Promotes growth -Used for energy metabolism	-Milk -Yogurt -Cheese -Green leafy vegetables	-Premature aging -Cracks in the corner of mouth -Inflammation of tongue and mouth	-None
VITAMIN	**FUNCTION**	**FOOD SOURCES**	**DEFICIENCIES**	**TOXICITIES**
B3 *Niacin* (Water Soluble)	-COENZYME! -Maintains nervous system -Used for energy metabolism	-Milk -Eggs -Meat, fish, poultry -Whole grains -Enriched grains	**-Pellagra** (Skin disorder) -Dermatitis	-Diarrhea -Heartburn -Nausea -Ulcers

VITAMIN	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
★ Folate *Folic Acid or Folicin* (Water Soluble)	-Makes new cells	-Leafy green vegetables -Legumes -Seeds	-Can lead to neural tube defects like **spina bifida** in infants -Anemia -Heartburn -Diarrhea	-Masks B12 deficiency
VITAMIN	**FUNCTION**	**FOOD SOURCES**	**DEFICIENCIES**	**TOXICITIES**
B6 *Pyriodoxine* (Water Soluble)	-Helps make red blood cells -Good for overall health	-Green leafy vegetables -Animal protein	-Anemia -Abnormal brain wave pattern -Irritability	-Depression -Fatigue -Impaired memory

VITAMIN	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
B12 *Cobalamin* (Water Soluble)	-Helps make new cells -Maintains nerves and cells	-Whole grains -Animal foods	-Insomnia -Fatigue -Poor nerve funcion	-Water retention

Vitamins are organic compounds required by the body in small amounts for metabolism, for protection, for maintenance of health and proper growth

They cannot be synthesized by the body. Must be obtained by outside sources like diet, rumen of bacteria & sun.

Vitamins also assist in the formation of hormones, blood vessels, nervous system chemicals and genetic materials

They generally act as catalysts, combining with proteins to create metabolically active enzymes that are essential for life reactions

Without enzymes, many of the reactions essential to life would slow down or cease

MINERALS

Essential inorganic nutrients, required in small amounts, needed for the functioning of the body

They make up about 4%of body weight of adults, they cannot be changed or broken down

As many as 20 minerals may be required!

Required for growth, maintenance, reproduction and lactation. □Some which are needed in high quantities are referred to as macro-elements, examples include Na, K, Mg, Cl etc.

□Others are needed in smaller quantities and are termed microelements, they include Fe, Cu, F, I etc.

MINERAL	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
Calcium (Macro)	-Maintains strength of bones and teeth	-Milk -Milk & dairy products -Dark green leafy vegetables	-Osteoporosis	-Kidney stones
MINERAL	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
Phosphorus (Macro)	-Helps build body cells -Works with calcium	-Dairy products -Grain products -Meat	-Osteoporosis	-Can prevent calcium from working

MINERAL	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
Magnesium (Macro)	-Helps build bones -Helps nerves and muscles work normally -Regulates body temperature	-Dark green leafy vegetables -Whole grain products	-Heart disease -Heart spasms	-Diarrhea -Lack of Coordination -Confusion -Coma
MINERAL	**FUNCTION**	**FOOD SOURCES**	**DEFICIENCIES**	**TOXICITIES**
Iron (Trace)	-Helps carry oxygen to the blood -Helps cells use oxygen	-Red meat -Dark green leafy vegetables	**-Anemia** -Paleness -Weakness	-Heart disease -Elevated LDLs

MINERAL	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
Zinc (Trace)	-Helps body make proteins -Heal wounds -Affects sense of taste and smell	-Meat -Liver -Fish -Dairy products	-Stunted growth -Rash -Hair Loss	-Low copper absorption
MINERAL	**FUNCTION**	**FOOD SOURCES**	**DEFICIENCIES**	**TOXICITIES**
Fluorine (Trace)	-Helps strengthen teeth and prevent cavities	-Fluoridated water -Toothpaste	-Tooth decay	-Staining of teeth during development

MINERAL	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
Copper (Trace)	-Helps iron make red blood cells	-Whole grain products	-Weak bones -Weak blood vessels	-Vomiting -Nervous system disorders
MINERAL	**FUNCTION**	**FOOD SOURCES**	**DEFICIENCIES**	**TOXICITIES**
Iodine (Trace)	-Helps body use energy	-Iodized salt -Saltwater fish -Some dairy products	-Goiter (Swelling of the thyroid gland in the neck)	-Thyroid gland stops working

MINERAL	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
Sodium (Electrolyte)	-Maintains fluid balance in the body	-Salt -Packaged foods	-Muscle cramps	-High blood pressure

MINERAL	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
Chloride (Electrolyte)	-Maintains fluid balance in the body	-Salt	-Can cause convulsions in infants	-High blood pressure

MINERAL	FUNCTION	FOOD SOURCES	DEFICIENCIES	TOXICITIES
Potassium (Electrolyte)	-Maintains fluid balance in the body	-Fruits, especially bananas and oranges -Meat, poultry and fish -Dry beans -Dairy products	-Irregular heart beat -Loss of appetite -Muscle cramps	-Slowing of the heart beat

The Biological Molecules of Cells

Despite their great diversity, organic molecules in cells, called biological molecules, are grouped into only four categories: carbohydrates, lipids, proteins, and nucleic acids. You are very familiar with these molecules because certain foods are known to be rich in carbohydrates, lipids, and proteins. When you digest these foods, they break down into subunit molecules. Your body then takes these subunits and builds from them the large macromolecules that make up your cells. Many different foods also contain nucleic acids, the type of molecule that forms your genes. Certain biological molecules in cells are composed of a large number of the same type of subunits, called monomers. When monomers join the result is a polymer. A protein can contain hundreds of amino acid monomers, and a nucleic acid can contain hundreds of nucleotide monomers. How can polymers get so large? Just as a train increases in length when boxcars are hitched together one by one, so a polymer gets longer as monomers bond to one another. A cell uses the same type of reaction to synthesize any type of biological molecule. It is called a dehydration reaction because the equivalent of a water molecule—that is, an JOH (hydroxyl group) and an JH (hydrogen atom), is removed as the reaction occurs. To break down a biological molecule, a cell and also the digestive tract uses an opposite type of reaction: During a hydrolysis reaction, JOH group from water attaches to one monomer, and an JH from water attaches to the other monomer. In other words, water is used to break the bond holding monomers together. attaches to one monomer, and an JH from water attaches to the other monomer. In other words, water is used to break the bond holding monomers together.

Carbohydrates

Carbohydrates are almost universally used as an immediate energy source in living things, but they also play structural roles in a variety of organisms. Carbohydrates are polymers of individual monomers called saccharides, or sugars. Typically, the sugar glucose is a monomer of carbohydrate polymers. The term carbohydrate may refer to either a single sugar molecule (monosaccharide), two sugar molecules (disaccharide), or many sugar molecules bonded together (polysaccharide).

Monosaccharide (Ready Energy):

Because monosaccharide has only a single sugar molecule they are called simple sugars. A simple sugar can have a carbon backbone of three to seven carbons. The word carbohydrate might make you think that every carbon atom is bonded to an H and an JOH. This is not strictly correct, as you can see by examining the structural formula for glucose. Still, sugars do have many polar JOH groups, which make them soluble in water. Glucose, with six carbon atoms, has a molecular formula of $C6H12O6$. Glucose has two important isomers, called fructose and galactose, but even so, we usually think of glucose when we see the formula $C6H12O6$.

That's because glucose has a special place in the chemistry of organisms. Glucose is transported in the blood of animals, and it is also the molecule that is broken down in nearly all types of organisms as an immediate source of energy. In other words, cells use glucose as the energy source of choice. Ribose and deoxy-ribose, with five carbon atoms, are significant because they are found in the nucleic acids RNA and DNA, respectively

Disaccharides: Varied Uses

A disaccharide (di, two; saccharide, sugar) contains two monosaccharaides

bonded together. The brewing of beer relies on maltose, a disaccharide usually derived from barley. During the production of beer, yeast breaks down maltose to two units of glucose and then uses glucose as an energy source. As the yeast use glucose for energy, they use a process called fermentation, which produces ethyl alcohol. Sucrose, a disaccharide acquired from sugar beets and sugarcane, is of special interest because we use it at the table and in baking as a sweetener. Our body digests sucrose to its components, glucose and fructose. (Later, the fructose is changed to glucose, our usual energy source.) If the body doesn't need more energy at the moment, the glucose is metabolized to fat! While glucose is the energy source of choice for animal cells, fat is the body's primary energy storage form. That's why eating lots of sugary desserts can make you gain weight. When you make lemonade at home, you add sucrose. But drinks made commercially often contain high-fructose corn syrup (HFCS). In the 1980s, a commercial method was developed for converting the glucose in corn syrup to the much sweeter-tasting fructose. Nutritionists are not in favor of eating highly processed foods that are rich in sucrose, HFCS, and white starches. They say these foods provide "empty" calories, meaning that although they supply energy, they don't supply any of the vitamins, minerals, and fiber needed in the diet. In contrast, minimally processed foods provide glucose, starch, and many other types of nutritious molecules.

Polysaccharides as Energy Storage Molecules

Polysaccharides are polymers of monosaccharide. Some types of polysaccharides function as short-term energy storage molecules because they are much larger than a sugar and are relatively insoluble. Polysaccharides cannot easily pass through the plasma membrane and are kept (stored) within the cell. Plants store glucose as starch. The cells of a potato contain granules where starch resides during winter until energy is needed for growth in the spring. Starch exists in two forms—one is non- branched and the other is branched. Animals store glucose as glycogen, which is more highly branched. Branching subjects a polysaccharide to more attacks by hydrolytic enzymes; therefore, branching makes a polysaccharide easier to break down. Spiraling makes these polysaccharides more compact. The storage and release of glucose from liver cells is controlled by hormones. After we eat, the pancreas releases the hormone insulin, which promotes the storage of glucose as glycogen.

Lipids

Although molecules classified as lipids are quite varied, they have one characteristic in common: They are all insoluble in water due to their long nonpolar hydrocarbon chains and their relative lack of hydrophylic functional groups. It is said that oil and water do not mix. For example, salad dressings are rich in vegetable oils. Even after shaking, the vegetable oil will separate out from the water. Lipids are very diverse and they have varied structures and functions. Fats (such as bacon fat, lard, and butter), and oils (such as corn oil, olive oil, and coconut oil) are some well-known lipids. In animals, fats are used for both insulation and long-term energy storage. Fat below the skin of marine mammals is called blubber; around the waist of humans, it is often referred to as a “spare tire.” Instead of fat, plants use oils for long-term energy storage. In animals, the secretions of oil glands help waterproof skin, hair, and feathers.

Fats and Oils: Long-Term Energy Storage

Fats and oils contain two types of subunit molecules: glycerol and fatty acids. Glycerol is a compound with three JOH groups. The JOH groups are polar; therefore, glycerol is soluble in water. A fatty acid has a long chain of carbon atoms bonded only to hydrogen, with a carboxyl group at one end. A fat or oil forms when the carboxyl portions of three fatty acids react with the JOH groups of glycerol. This is a dehydration reaction because in addition to a fat molecule, three molecules of water result. Fats and oils are degraded during a hydrolysis reaction, in which water is added to the molecule. Because three long fatty acids are attached to each glycerol molecule, fats and oils are called triglycerides and pack a lot of energy in one molecule. Thus it is logical that fats and oils are the body’s primary long-term energy storage molecules. Fatty acids are the primary components of fats and oils. Most of the fatty acids in cells contain 16 or 18 carbon atoms per molecule, although smaller or larger ones are also found. Fatty acids are either saturated or unsaturated (). Unsaturated fatty acids have double bonds in the carbon chain wherever the number of hydrogens is less than two per carbon atom. Saturated fatty acids have no double bonds between the carbon atoms. The carbon chain is saturated, so to speak, with all the hydrogens it can hold. Saturation or unsaturation of a fatty acid determines its chemical and physical properties. In general, oils are liquids at room temperature because they contain unsaturated fatty acids. The double bond creates a bend in the fatty acid chain. Such kinks prevent close packing between the hydrocarbon chains and account for the fluidity of oils. On the other hand, butter, which contains mostly saturated fatty acids, is a solid at room temperature. The saturated fatty acid chains can pack together more tightly because they have no kinks Trans fats contain fatty acids that have been partially hydrogenated to make them more saturated, and thus more solid. Trans fats are often found in processed foods—margarine, baked goods, and fried foods in particular. Saturated fats and trans fats have been linked to a cardiovascular disease called atherosclerosis, in which lipid material, called plaque, accumulates inside blood vessels. Plaque contributes to high blood pressure and heart attacks. Unsaturated oils, particularly monounsaturated (one double bond) oils but also polyunsaturated (many double bonds) oils, have been found to be protective against atherosclerosis. These healthy oils are found in abundance in olive oil, canola oil, and certain fish.

Phospholipids: Membrane Components

Phospholipids, as implied by their name, contain a phosphate group. Essentially, a phospholipid is constructed like a triglyceride, except that in place of the third fatty acid attached to glycerol, there is a charged phosphate group. The phosphate group is usually bonded to another polar functional group, . Thus, one end of the molecule is water-soluble. This portion of the molecule is the polar head. The hydrocarbon chains of the fatty acids, or the nonpolar tails, are not water-soluble. Because phospholipids have both hydrophilic (polar) heads and hydrophobic (nonpolar) tails, they tend to arrange themselves so that only the polar heads interact with the watery environment outside and the nonpolar tails crowd inward away from the water. Between two compartments of water, such as the outside and inside of a cell, phospholipids become a bilayer in which the polar heads project outward and the nonpolar tails project inward. The bulk of the plasma membrane that surrounds cells consists of a fairly fluid phospholipid bilayer, as do all the other membranes in the cell. A plasma membrane is absolutely essential to the structure and function of a cell, and thus phospholipids are vitally important to humans and other organisms.

Steroids: Four Fused Rings Steroids are lipids that possess a unique carbon skeleton made of four fused rings, shown in Figure 7. Unlike other lipids, steroids do not contain fatty acids, but they are similar to other lipids because they are insoluble in water. Steroids are also very diverse. Each type of steroid differs primarily in the types of functional groups attached to the carbon skeleton.

Cholesterol () is a component of an animal cell's plasma membrane, and it is the precursor of other steroids, such as the sex hormones testosterone and estrogen. The male sex hormone, testosterone, is formed primarily in the testes, and the female sex hormone, estrogen, is formed primarily in the ovaries. Testosterone and estrogen differ only by the functional groups attached to the same carbon skeleton, and yet they have a profound effect on the body and the sexuality of humans and other animals. Most likely you are aware that some people take anabolic steroids, such as synthetic testosterone, to increase muscle mass. The result is usually unfortunate. The presence of the steroid in the body upsets the normal hormonal balance: The testes atrophy, and males may develop breasts; females tend to grow facial hair and lose hair on their heads. Because steroid use gives athletes an unfair advantage and destroys their health—heart, kidney, liver, and psychological disorders are Common—they are banned by professional athletic associations.

Proteins

Proteins are of primary importance in the structure and function of cells. Here are some of their many functions: Support Some proteins are structural proteins. Examples include the protein in spider webs; keratin, the protein that makes up hair and fingernails; and collagen, the protein that lends support to skin, ligaments, and tendons. Metabolism Many proteins are enzymes. They bring reactants together and thereby speed chemical reactions in cells. They are specific for one particular type of reaction and can function at body temperature. Transport Channel and carrier proteins in the plasma membrane allow substances to enter and exit cells. Other proteins transport molecules in the blood of animals—for example, hemoglobin is a complex protein that transports oxygen. Defense: Some proteins, called antibodies, combine with disease-causing agents to prevent them from destroying cells and upsetting homeostasis the relative constancy of the internal environment. Regulation Hormones are regulatory proteins. They serve as intercellular messengers that influence the metabolism of cells. For example, the hormone insulin regulates the content of glucose in the blood and in cells, while growth hormone determines the height of an individual. Motion: The contractile proteins actin and myosin allow parts of cells to move and cause muscles to contract. Muscle contraction enables animals to move from place to plac

The structures and functions of cells differ according to the type of protein they contain. Muscle cells contain actin and myosin; red blood cells contain hemoglobin; support cells produce the collagen they secrete.

Mitosis and Meiosis

Mitosis: -division of somatic (body) cells

Meiosis-division of gametes (sex cells

Mitosis

What is the purpose of mitosis?

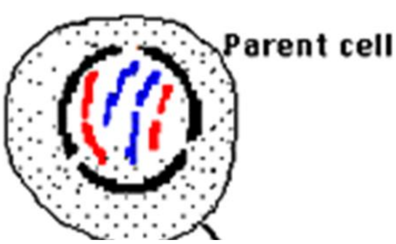
Cell division

Products genetically identical

Growth of organism

Prophase ,Metaphase,Anaphase,Telophase,Interphase

Cell preparing to divide



Prophase

Genetic material doubles

Chromosome pair up!

Chromosomes thicken and shorten

-become visible

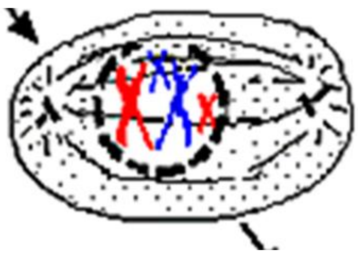
chromatids joined by a centromere

Centrioles move to the opposite sides of the nucleus

Nucleolus disappears

Nuclear membrane disintegrate

Prophase



<u>Metaphase</u>

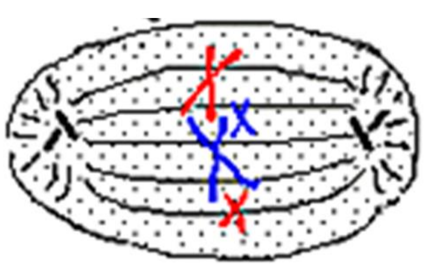
Chromosomes meet in the middle!

Chromosomes arrange at equator of cell

Become attached to spindle fibres by centromeres

Homologous chromosomes do not associate

Metaphase

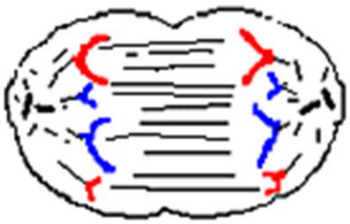


Anaphase:

Chromosomes get pulled apart

Spindle fibres contract pulling chromatids to the opposite poles of the cell

Anaphase



Telophase

Chromosomes uncoil

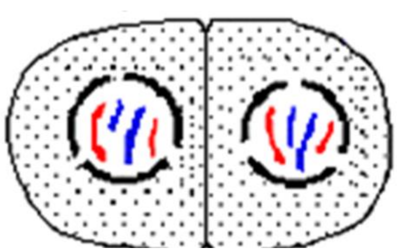
Spindle fibres disintegrate

Centrioles replicate

Nucleur membrane forms

Cell divides

Telophase

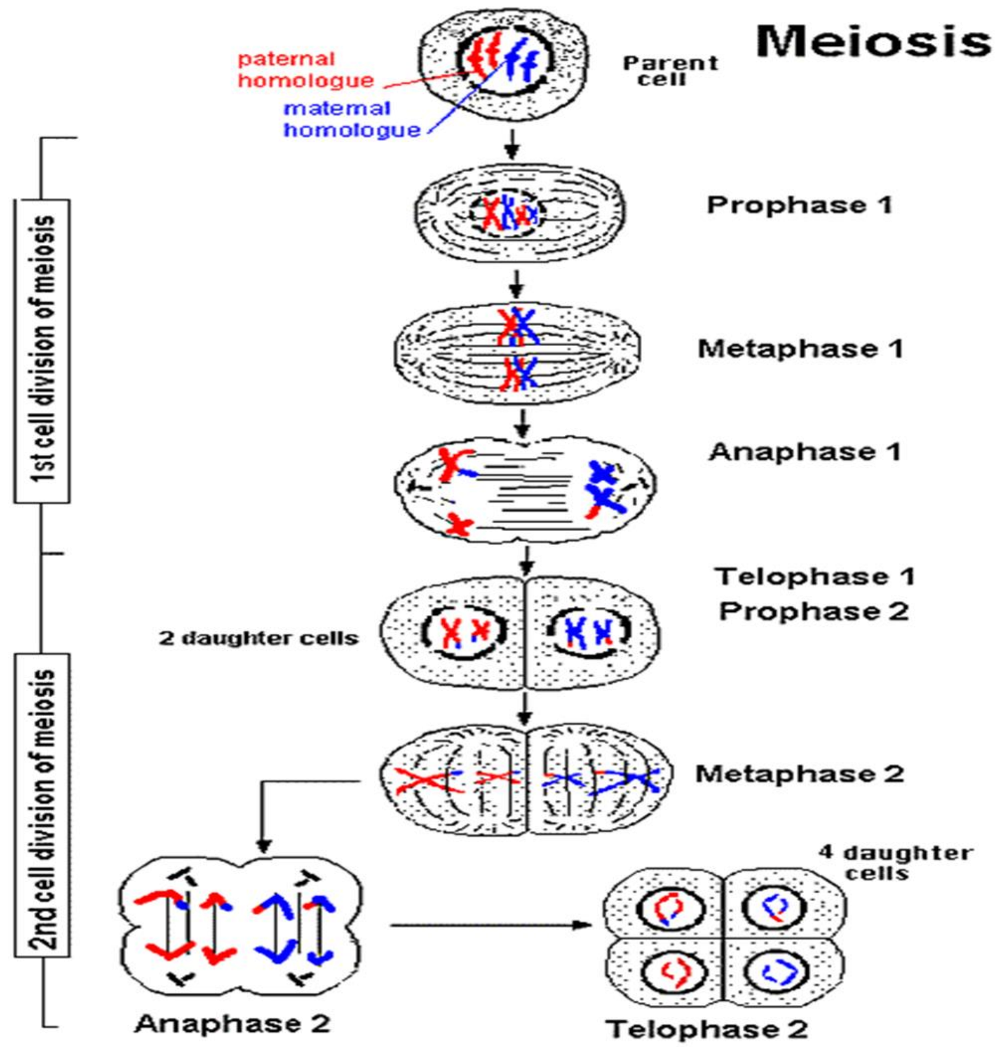


Meiosis

4 daughter cells produced

Each daughter cell has half the chromosomes of the parent

2sets of cell division involved



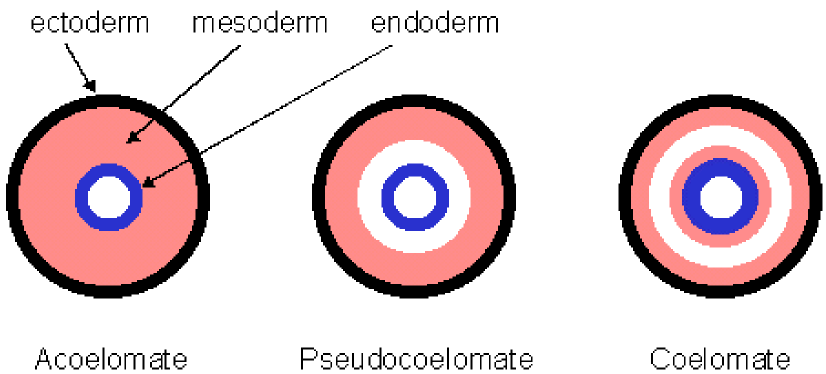
Part 2 Histology

Tissues

Tissues: a group of closely associated cells that perform related functions and are similar in structure .Between cells: nonliving extracellular material

Embryonic Tissues

Ectoderm, mesoderm, and endoderm are embryonic tissues that give rise to all of the tissues, organs, and organ systems in the body.



Ectoderm forms the outer layer of skin and nervous system.

Mesoderm forms the muscles, connective tissues, skeleton, kidneys, and circulatory and reproductive organs.

Endoderm forms the lining of the gut, respiratory tract, and urinary bladder. It also forms the glands associated with the gut and respiratory tract.

Junctions

Cells are joined to each other by proteins. The point of connection between two cells is called a junction.

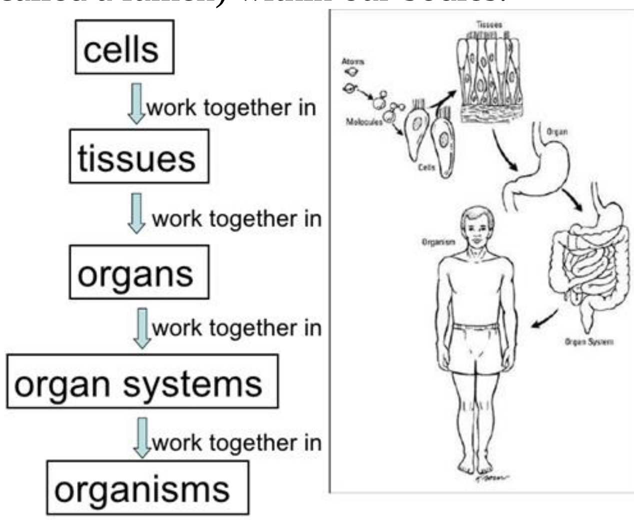
Junctions bind cells together. Some kinds of junctions prevent the passage of molecules between cells. Other kinds of junctions allow molecules to pass from one cell to another.

Different types of tissues have different structures and functions.

A tissue may be held by a sticky extracellular matrix that bind the cells together in a fabric of fibers (Tissue= cells + extracellular matrix).

Four basic types of tissue function
Epithelium lining and …covering
Connective tissue…support
Muscle tissue…movement
Nervous tissue…control

All of these tissues are found in our bodies, but epithelial tissue has a special function-it must cover all the surfaces of the body. Therefore, it is found in our skin, and it is also found covering all the surfaces of the openings (each one is called a lumen) within our bodies.



Terms
Simple = one layer
stratified" – more than one layer of cells (which are named according to the shape of the cells in the apical layer)
"squamous" – wider than tall
"cuboidal" – as tall as wide(cube)
"columnar" - taller than wide -rectangular (column)
Transitional = ability to change shape
Pseudostratified = false layered (appears to be more than one layer, but only one);
ciliated = with cilia

The Basal Lamina
Non cellular supporting sheet between the epithelium and the connective tissue deep to it consists of proteins secreted by the epithelial cells

Functions:
Acts as a selective filter, determining which molecules from capillaries enter the epithelium
Acts as scaffolding along which regenerating epithelial cells can migrate

Basal lamina and reticular layers of the underlying connective tissue deep to it form the basement membrane.

Cell Junctions

The cells within this tissue are firmly attached to each other. As a border-tissue, if the cells weren't adherent to one another, it would be a leaky border. This would be no good-- liquids from inside of us would drip out! Yuck! So the cells all make the type of junctions with each other called tight junctions.

Desmosome: binding spots between cells with proteins called adherins

Tight junctions: impermeable

E.g. gut tube, doesn't let enzymes from gut into blood stream

Gap junctions: tubes that let small molecules pass between cells

Endothelium

A simple squamous epithelium that lines the interior of the circulatory vessels and heart

Mesothelium

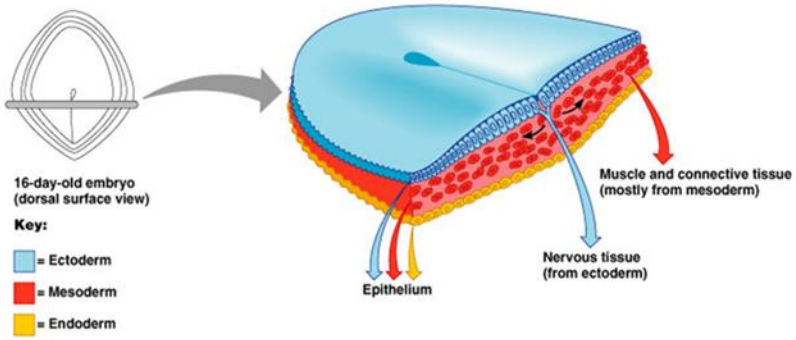
Simple squamous epithelium that lines the peritoneal, pleural and pericardial cavities and covers the viscera

Epithelium lines both the outside (skin) and the inside cavities and lumen of bodies. The outermost layer of our skin is composed of dead stratified squamous, keratinized epithelial cells.

Epithelial tissues

Tissues that line the inside of the mouth, the esophagus and part of the rectum are composed of non-keratinized stratified squamous epithelium. Other surfaces that separate body cavities from the outside environment are lined by simple squamous, columnar, or pseudo stratified epithelial cells. Other epithelial cells line the insides of the lungs, the gastrointestinal tract, the reproductive and urinary tracts, and make up the exocrine and endocrine glands. The outer surface of the cornea is covered with fast-growing, easily regenerated epithelial cells. Endothelium (the inner lining of blood vessels, the heart, and lymphatic vessels) is a specialized form of epithelium. Another type, mesothelium, forms the walls of the pericardium, pleurae, and peritoneum.

In general, there are epithelial tissues deriving from all of the embryological germ layers.
from ectoderm (e.g., the epidermis);
from endoderm (e.g., the lining of the gastrointestinal tract);
from mesoderm (e.g., the inner linings of body cavities).



General characters of epithelial tissue
It may develop from ectoderm , mesoderm , endoderm.
The epithelial cells rest on a basement membrane which may be clear or not clear.
No blood vessels can enter in between epithelial cells but nerves can , so epithelial tissue is avascular tissue.
Epithelial tissue receives nutrition by diffusion from the underlying connective tissue.
covers the whole surface of the body. It is made up of cells closely packed and ranged in one or more layers. This tissue is specialized to form the covering or lining of all internal and external body surfaces. Epithelial tissue that occurs on surfaces on the interior of the body is known as endothelium. Epithelial cells are packed tightly together, with almost no intercellular spaces and only a small amount of intercellular substance. Epithelial tissue, regardless of the type, is usually separated from the underlying tissue by a thin sheet of connective tissue; basement membrane. The basement membrane provides structural support for the epithelium and also binds it to neighboring structures

Functions of Epithelial tissue
Protection
Epithelial cells from the skin protect underlying tissue from mechanical injury, harmful chemicals, invading bacteria and from excessive loss of water.
Skin protects from sunlight & bacteria & physical damage. to protect the tissues that lie beneath it from radiation, desiccation, toxins, invasion by pathogens, and physical trauma

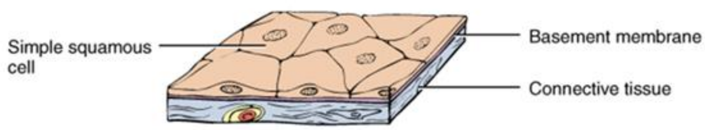
Sensation
Sensory stimuli penetrate specialized epithelial cells. Specialized epithelial tissue containing sensory nerve endings is found in the skin, eyes, ears, nose and on the tongue.
Secretion
In glands, epithelial tissue is specialized to secrete specific chemical substances such as enzymes, hormones and lubricating fluids. the secretion of hormones into the blood vascular system, and/or the secretion of sweat, mucus, enzymes, and other products that are delivered by ducts glandular epithelium.
Different glands produce perspiration, oil, digestive enzymes and mucus
Absorption
Certain epithelial cells lining the small intestine absorb nutrients from the digestion of food. Lining of small intestine, absorbing nutrients into blood
Excretion
Epithelial tissues in the kidney excrete waste products from the body and reabsorb needed materials from the urine. Sweat is also excreted from the body by epithelial cells in the sweat glands.
Diffusion
Simple epithelium promotes the diffusion of gases, liquids and nutrients. Because they form such a thin lining, they are ideal for the diffusion of gases (eg. walls of capillaries and lungs). the regulation and exchange of chemicals between the underlying tissues and a body cavity;
Cleaning
Ciliated epithelium assists in removing dust particles and foreign bodies which have entered the air passages.
Reduces friction
The smooth, tightly-interlocking, epithelial cells that line the entire circulatory system reduce friction between the blood and the walls of the blood vessels.
Filtration
Lining of Kidney tubules filtering wastes from blood plasma

Classification (structural)
Epithelial tissue can be structurally divided into two groups depending on the number of layers of which it is composed. Epithelial tissue that is only one cell thick is known as simple epithelium. If it is two or more cells thick, it is known as stratified epithelium.

Simple epithelium is one cell thick, that is, every cell is in direct contact with the underlying basement membrane. It is generally found where absorption and filtration occur. The thinness of the epithelial barrier facilitates these processes. Simple epithelial tissues are generally classified by the shape of their cells. Simple epithelium can be subdivided according to the shape and function of its cells.

Simple Squamous Epithelium (pavement)

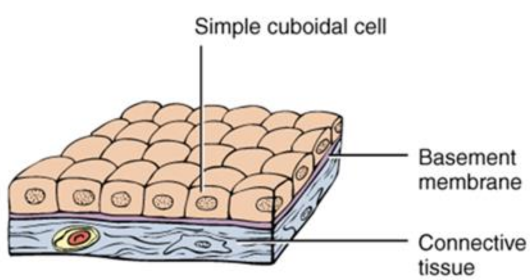
This epithelium is called simple because it is composed of one layer of cells. It is called squamous because the cells are flat. This epithelium type is very thin and allows substances to move easily across it. This type of epithelium is found lining the air sacs of lungs where oxygen and gas move across it. It also forms the walls of capillaries (another site where substances move in and out of blood) and lining the walls of blood vessels in general.



Single layer of flat cells

The shape of the nucleus usually corresponds to the cell form and help to identify the type of epithelium. Squamous cells, for example, tend to have horizontal flattened, elliptical nuclei because of the thin flattened form of the cell. They form the lining of cavities such as the mouth, blood vessels, heart and lungs and make up the outer layers of the skin. Simple squamous epithelium is found lining areas where passive diffusion of gases occur, including the walls of capillaries, the linings of the alveoli of the lungs, and the linings of the pericardial, pleural, and peritoneal cavities.

Simple Cuboidal Epithelium. This type of epithelium consists of one layer of cube-shaped cells. This epithelium covers the ovaries and lines tubules of the kidneys. It also lines the ducts of many glands. **Single layer of cube-shaped cells viewed**

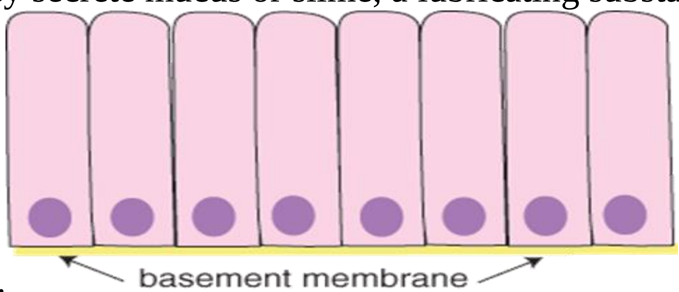


from the side

As their name implies, cuboidal cells are roughly square or cuboidal in shape. Each cell has a spherical nucleus in the centre. Cuboidal epithelium is found in glands and in the lining of the kidney tubules as well as in the ducts of the glands. They also constitute the germinal epithelium which produces the egg cells in the female ovary and the sperm cells in the male testes.

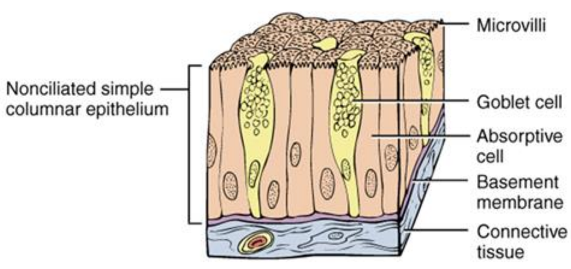
Simple Columnar Epithelium

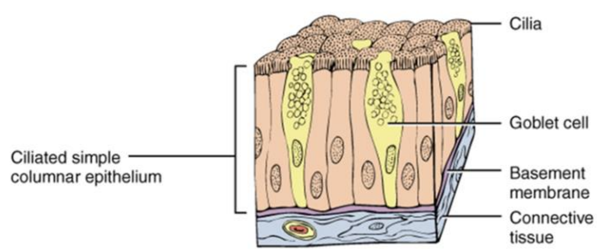
This type of epithelium consists of one layer of tall cells. This epithelium also contains Goblet cells which are mucus secreting cells. It is most commonly found lining many organs of the digestive tract. The cells of the epithelium often possess microvilli which are finger-like projections of a cell membrane. These microvilli increase the surface area of these cells so they can secrete and absorb a large amount of substances. The cells are elongated and column-shaped. The nuclei are elongated and are usually located near the base of the cells. Columnar epithelium forms the lining of the stomach and intestines. Some columnar cells are specialised for sensory reception such as in the nose, ears and the taste buds of the tongue. Goblet cells (unicellular glands) are found between the columnar epithelial cells of the duodenum. They secrete mucus or slime, a lubricating substance which keeps the surface smooth.



Ciliated Columnar Epithelium

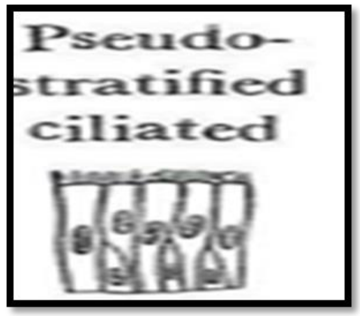
These are simple columnar epithelial cells, but in addition, they possess fine hair-like outgrowths, cilia on their free surfaces. These cilia are capable of rapid, rhythmic, wavelike beatings in a certain direction. This movement of the cilia in a certain direction causes the mucus, which is secreted by the goblet cells, to move (flow or stream) in that direction. Ciliated epithelium is usually found in the air passages like the nose. It is also found in the uterus and Fallopian tubes of females. The movement of the cilia propel the ovum to the uterus.





Pseudostratified Columnar Epithelium

This type of epithelium is termed "falsely layered". Pseudo is the root for false and stratified means layered. This epithelium looks like it is many layers of tall cells but it really is just one layer of tall cells. The layering effect result from the nuclei of the cells lining up at different levels in the cells. Many organs of the respiratory tract (trachea, bronchi) are lined with this type of epithelium. This type of epithelium also contains Goblet cells. The cells of this epithelium often contain cilia. The cilia constantly move mucus with trapped dust out of the respiratory tract to the throat where it is swallowed.



Pseudostratified Columnar.Single cell layer ,all cells attach to basement membrane but not all reach free surface,nuclei at varying depths

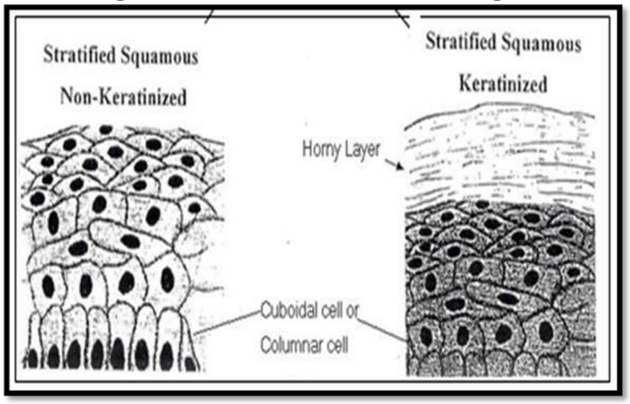
<u>Stratified epithelium</u>

Where body linings have to with stand wear and tear, the epithelia are composed of several layers of cells and are then called compound or stratified epithelium. The top cells are flat and scaly and it may or may not be keratinized (i.e. containing a tough, resistant protein called keratin). The mammalian skin is an example of dry, keratinised, stratified epithelium. The lining of the mouth cavity is an example of an unkeratinisied, stratified epithelium.

There are three principal morphologies associated with epithelial cells. Squamous epithelium has cells which are wider than they are tall (flat and scale-like). Cuboidal epithelium has cells whose height and width are approximately the same (cube shaped). Columnar epithelium has cells taller than they are wide (column shaped). In addition, the morphology of the cells in transitional epithelium may vary from squamous to cuboidal, depending on the amount of tension on the epithelium.

<u>Stratified Squamous Epithelium</u>

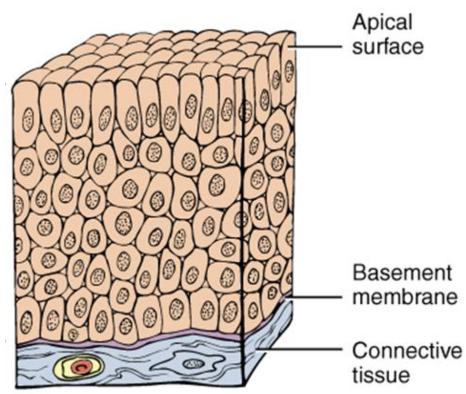
This type of epithelium is made up of many layers of cells (stratified). The cells on the free surface of this epithelium are flat hence the name squamous. This type of epithelium forms the outer layer of skin. As part of skin, a protein called keratin accumulates in the cells of this epithelium. Keratin makes the tissue water-proof and impermeable to most bacteria and viruses. This type of epithelium also lines the mouth, throat, anus, and vagina: however in these organs the epithelium does



not accumulate keratin.

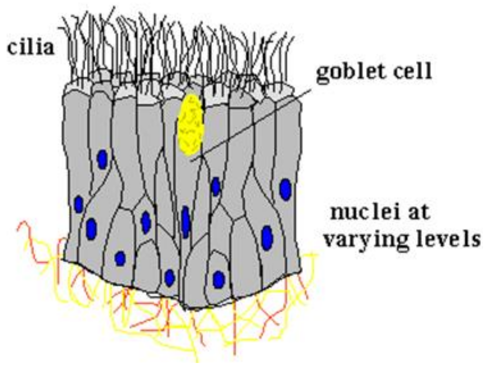
Stratified Cuboidal Epithelium

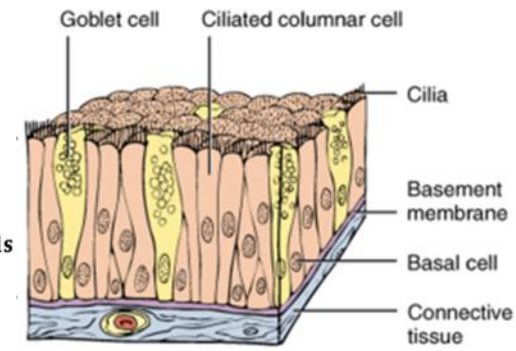
This epithelium consists of layers of cube-shaped cells. This type of epithelium lines the larger ducts of glands. It also lines the seminiferous tubules of the testes.



Stratified Columnar Epithelium

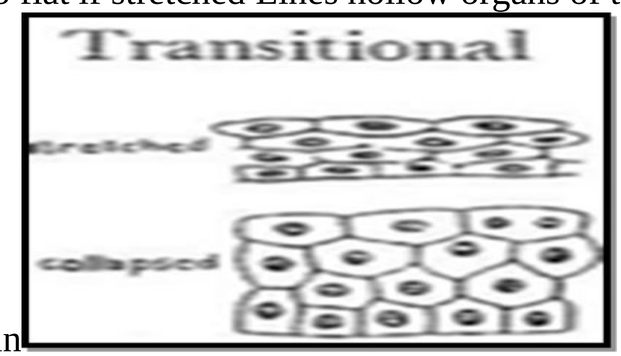
This epithelium is made of several layers of tall cells. This type of epithelium is found lining the urethra of the male, the vas deferens (part of male reproductive tract) and in parts of the pharynx (throat).





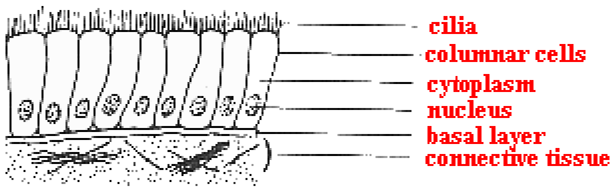
Transitional Epithelium

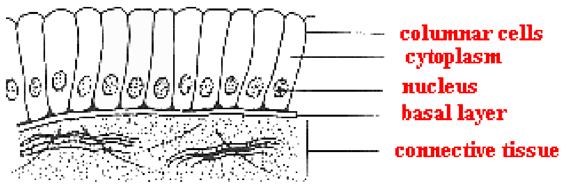
This epithelium is stratified (made of several layers of cells). It is called transitional because the cells closest to the free surface change their shapes regularly. This type of epithelium is found most commonly lining the urinary bladder. When the bladder is full and distended (stretched) the cells of this epithelium get stretched and tend to flatten. However, when the bladder is empty the cells are not stretched and tend to have a cube-like shape. Multilayered ,Surface cells varying in shape from round to flat if stretched Lines hollow organs of the urinary tract that expand from within

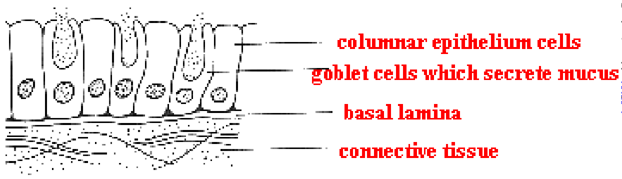


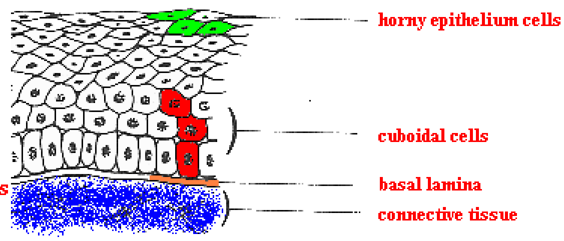
Sensing the extracellular environment.

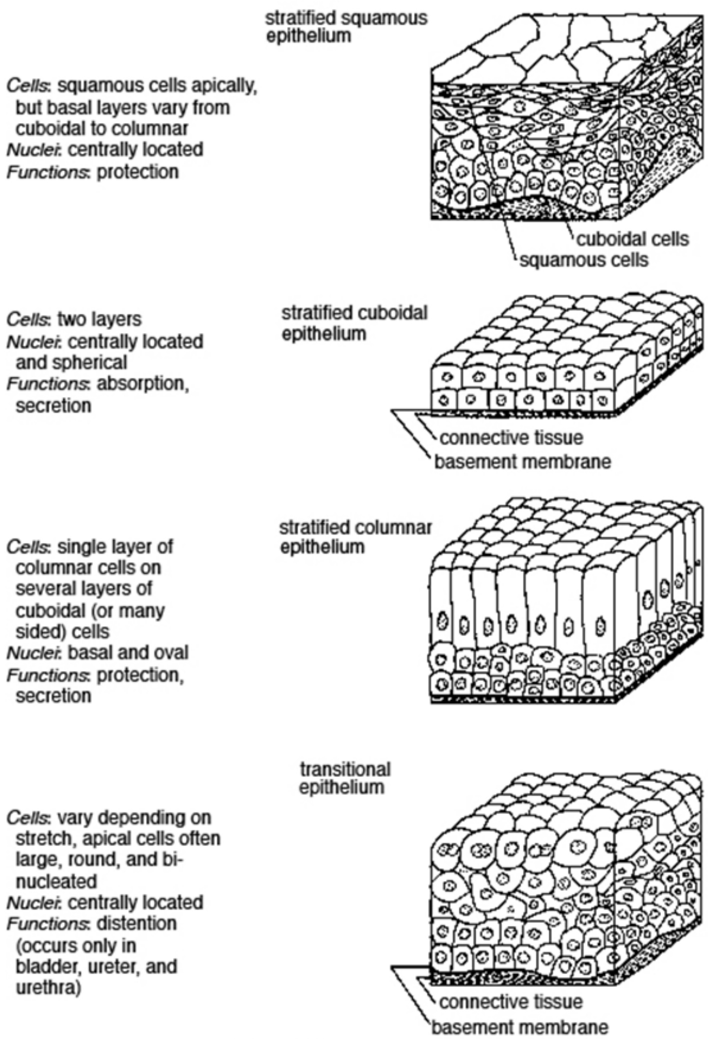
Some epithelial cells are ciliated, and they commonly exist as a sheet of polarised cells forming a tube or tubule with cilia projecting into the lumen." Primary cilia on epithelial cells provide chemosensation, thermosensation and mechanosensation of the extracellular environment by playing "a sensory role mediating specific signalling cues, including soluble factors in the external cell environment, a secretory role in which a soluble protein is released to have an effect downstream of the fluid flow, and mediation of fluid flow if the cilia are motile.


cilia
columnar cells
cytoplasm
nucleus
basal layer
connective tissue


columnar cells
cytoplasm
nucleus
basal layer
connective tissue

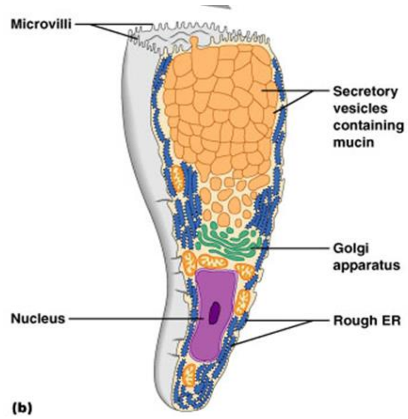

columnar epithelium cells
goblet cells which secrete mucus
basal lamina
connective tissue


horny epithelium cells
cuboidal cells
basal lamina
connective tissue

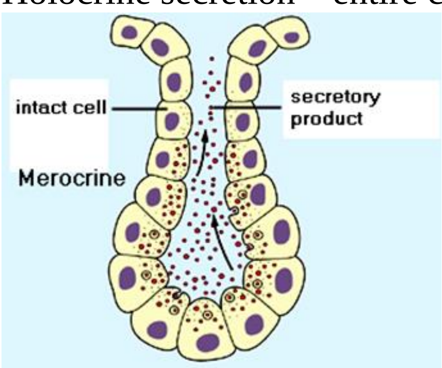


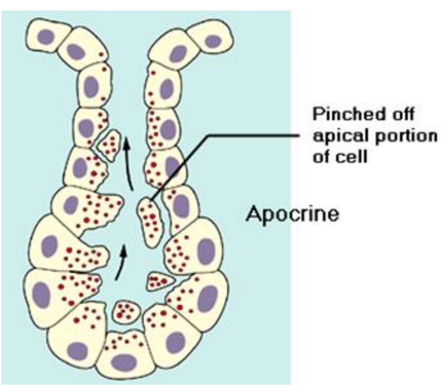
Epithelial Tissues

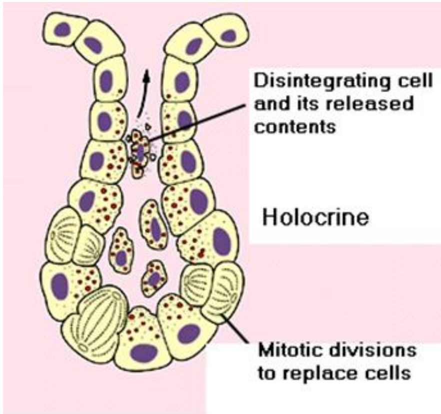
Unicellular Exocrine Glands
(The Goblet Cell)
Goblet cells produce mucin
Mucin + water → mucus
Protects and lubricates many internal body surfaces
Epithelial cells that synthesise and secrete
mucus also known as unicellular exocrineglands
Goblet cells are modified columnar epithelial
cells that synthesise and secrete mucus
Scattered among cells of many simple
epithelia, especially respiratory & GI tracts
Apical cytoplasm contains mucigen granules
Mucigen is composed of neutral and acidic
proteoglycans called mucopolysaccharides



Multicellular Exocrine Glands
Classified by structure (branching & shape) of duct
Can also be classified by mode or type of secretion
Merocrine secretion – secretory vesicles released via exocytosis (saliviary glands)
Apocrine secretion – apical portion of the cell is lost, cytoplasm + secretory product (mammary glands)
Holocrine secretion – entire cell is destroyed during secretion (sebaceous gland)







May also be classified by types of secretions from exocrine glands
Serous
mostly water but also contains some enzymes
Ex. parotid glands, pancreas
Mucous
mucus secretions
Ex. sublingual glands, goblet cells
Mixes
serous & mucus combined
Ex. submandibular gland

Glandular Epithelium

As stated above, secretion is one major function of epithelial cells. Glands are formed from the invagination / in folding of epithelial cells and subsequent growth in the underlying connective tissue. There are two major classifications of glands: endocrine glands and exocrine glands. Endocrine glands secrete their product into the extracellular space where it is rapidly taken up by the blood vascular system. The exocrine glands secrete their products into a duct that then delivers the product to the lumen of an organ or onto the free surface of the epithelium.
Columnar epithelium with goblet cells is called glandular epithelium. Some parts of the glandular epithelium consist of such a large number of goblet cells that there are only a few normal epithelial cells left. Columnar and cuboidal epithelial cells often become specialized as gland cells which are capable of synthesizing and secreting certain substances such as enzymes, hormones, milk, mucus, sweat, wax

and saliva. Unicellular glands consist of single, isolated glandular cells such as the goblet cells. Sometimes a portion of the epithelial tissue becomes invaginated and a multicellular gland is formed. Multicellular glands are composed of clusters of cells. Most glands are multicellular including the salivary glands.

Exocrine glands are those that are directly connected to the epithelial apical surface via a pore; for this reason, they secrete material directly onto the apical surface of the epithelium. Therefore, an exocrine gland dips down below the surface, but it is still lined with epithelial tissue since it faces a space. One example of an exocrine gland is a sweat gland.

exocrine gland can have a simple shape or a compound shape- the difference between these two shapes is that the major duct to the surface is unbranched in a simple gland, whereas it is branched in the compound gland.
A branched gland just means that if you look at the deepest end of a duct, its tip is branched into several secretory endings.
Finally, the shape of the secretory regions of the gland can be rounded, called alveolar, or elongate, called tubular. If it is a tubular gland, and the tubular end bends around a bit, it is called a coiled tubular gland.

Secretions of a gland: There is specific terminology related to exactly what a gland secretes

merocrine glands: only dissolved materials are secreted (via exocytosis)

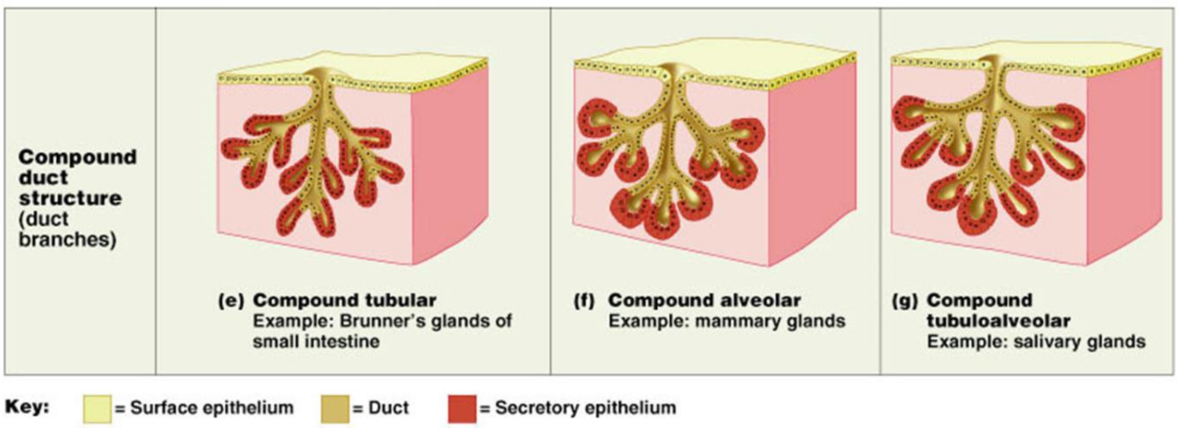
apocrine glands: pieces/chunks of cells get pinched off in the secretion

holocrine glands: entire cells are secreted
Connective tissue has non-living extra-cellular material (matrix) between its cells

A gland is one or more cells that makes and secretes an aqueous fluid
Classified by:
Site of product release – endocrine or exocrine
Relative number of cells forming the gland – unicellular or multicellular
Ductless glands that produce hormones.Secretes their products directly into the blood rather than through ducts
Secretions include amino acids, proteins, glycoproteins, and steroids
More numerous than endocrine glands
Secrete their products onto body surfaces (skin) or into body cavities

Examples include mucous, sweat, oil, and salivary glands
The only important unicellular gland is the goblet cell
Multicellular exocrine glands are composed of a duct and secretory unit

Classified according to:
Simple or compound duct type
Structure of their secretory units



Merocrine – products are secreted by exocytosis (e.g., pancreas, sweat, and salivary glands)
Holocrine – products are secreted by the rupture of gland cells (e.g., sebaceous glands)
Roles: as interfaces and as boundaries
The protein product is made in rough ER, packed into secretory granules by Golgi apparatus, released from the cell by exocytosis.
Epithelium-walled duct and a secretory unit
Examples of exocrine gland products
Many types of mucus secreting glands
Sweat glands of skin,Oil glands of skin,Salivary glands of mouth
Liver (bile),Pancreas (digestive enzymes),Mammary glands (milk)
Endocrine glands
Ductless glands
Release hormones into extracellular space.Hormones are messenger molecules.Hormones enter blood and travel to specific target organs

Figure 4.5 Types of multicellular exocrine glands.

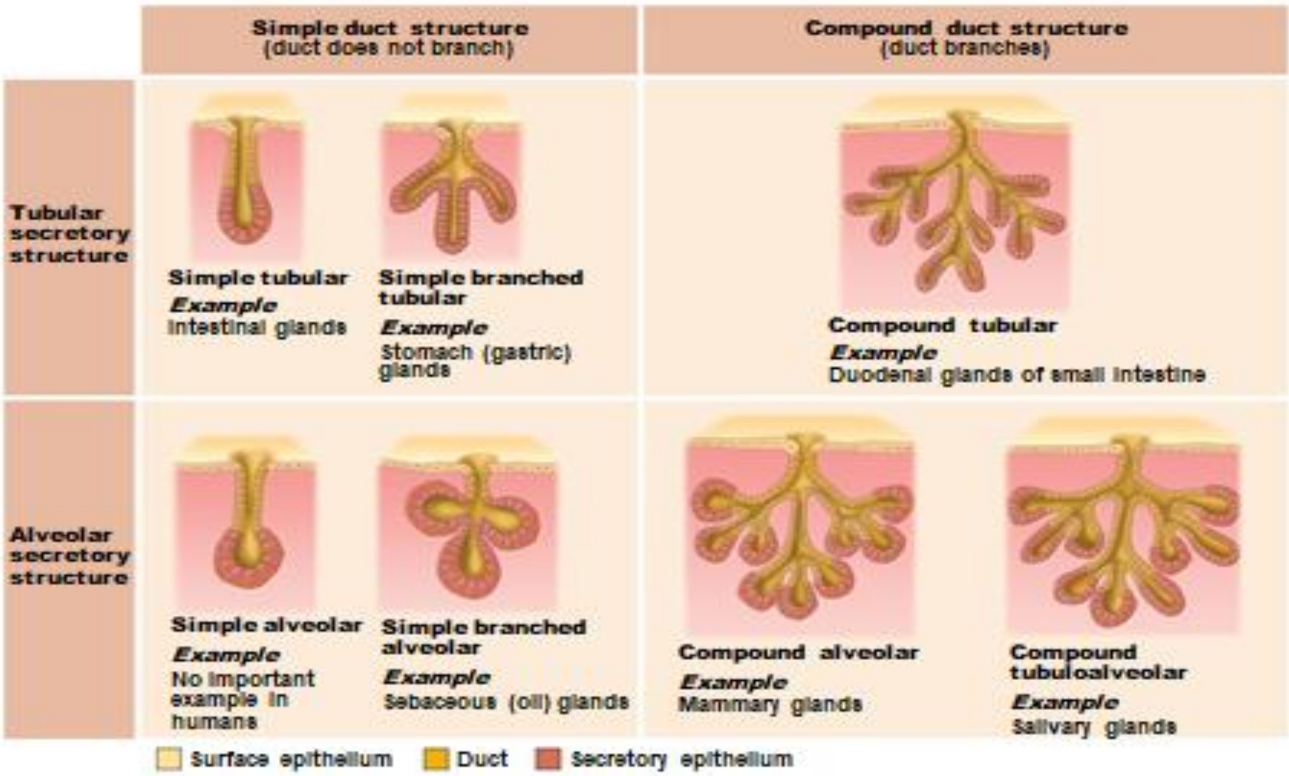
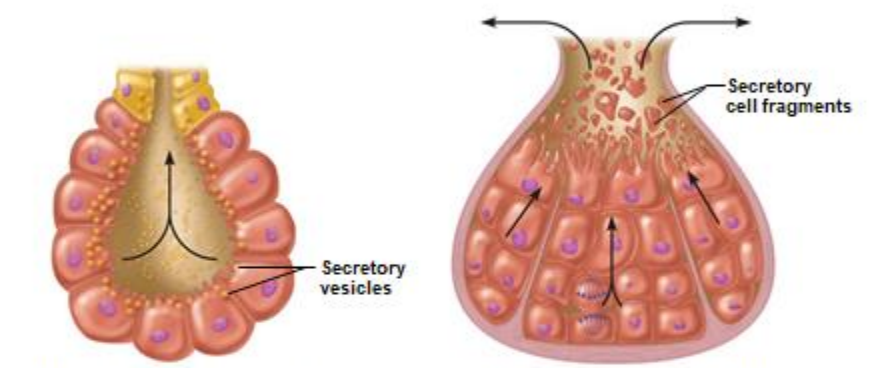


Figure 4.6 Chief modes of secretion in human exocrine glands.



(a) Merocrine glands secrete their products by exocytosis.

(b) In holocrine glands, the entire secretory cell ruptures, releasing secretions and dead cell fragments.

Goblet cells

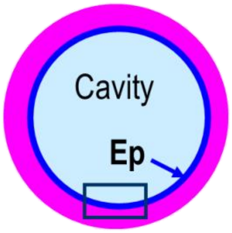
Epithelial cells that synthesize and secrete mucus also known as unicellular exocrine glands
Goblet cells are modified columnar epithelial cells that synthesize and secrete mucus Scattered among cells of many simple epithelia, especially respiratory & GI tracts Apical cytoplasm contains mucigen granules Mucigen is composed of neutral and acidic proteoglycans called mucopolysaccharides

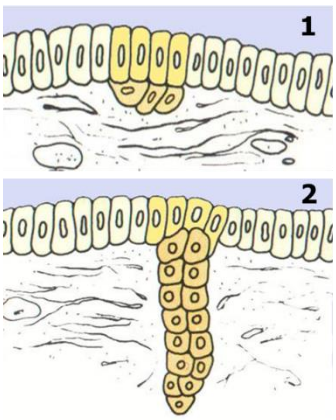
Exocrine glands: discharge secretory product via a duct onto an epithelial surface
Composed of highly specialized epithelial cells
Invaginations of epithelium surfaces which discharge secretory product
Continuous basal rate of secretion, modulated by nervous and hormonal influences
Exocrine glands can be divided into the secretory component and the duct.
The duct system may be branched (compound gland) or unbranched (simple gland)
Vary from microscopic (eg sweat glands of the skin) to large solid organs (eg. Liver)
Secretory component may be tubular or acinar (roughly spherical).
Secretory component may also be coiled or branched

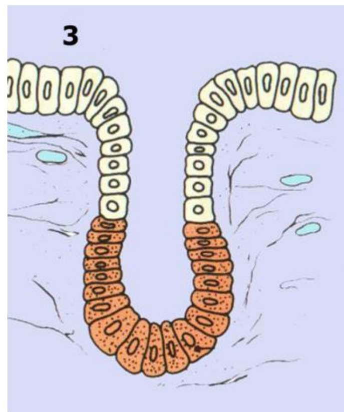
Glands

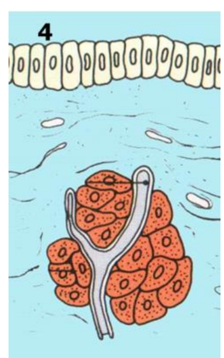
Epithelial specialization for secretion.
A patch of epithelial cells
Or
A downgrowth that proliferates.
Microscopic, part of an organ
Or
A large organ by itself.
In either case, elements of supporting connective tissue exist.

Gland – From an Epithelium







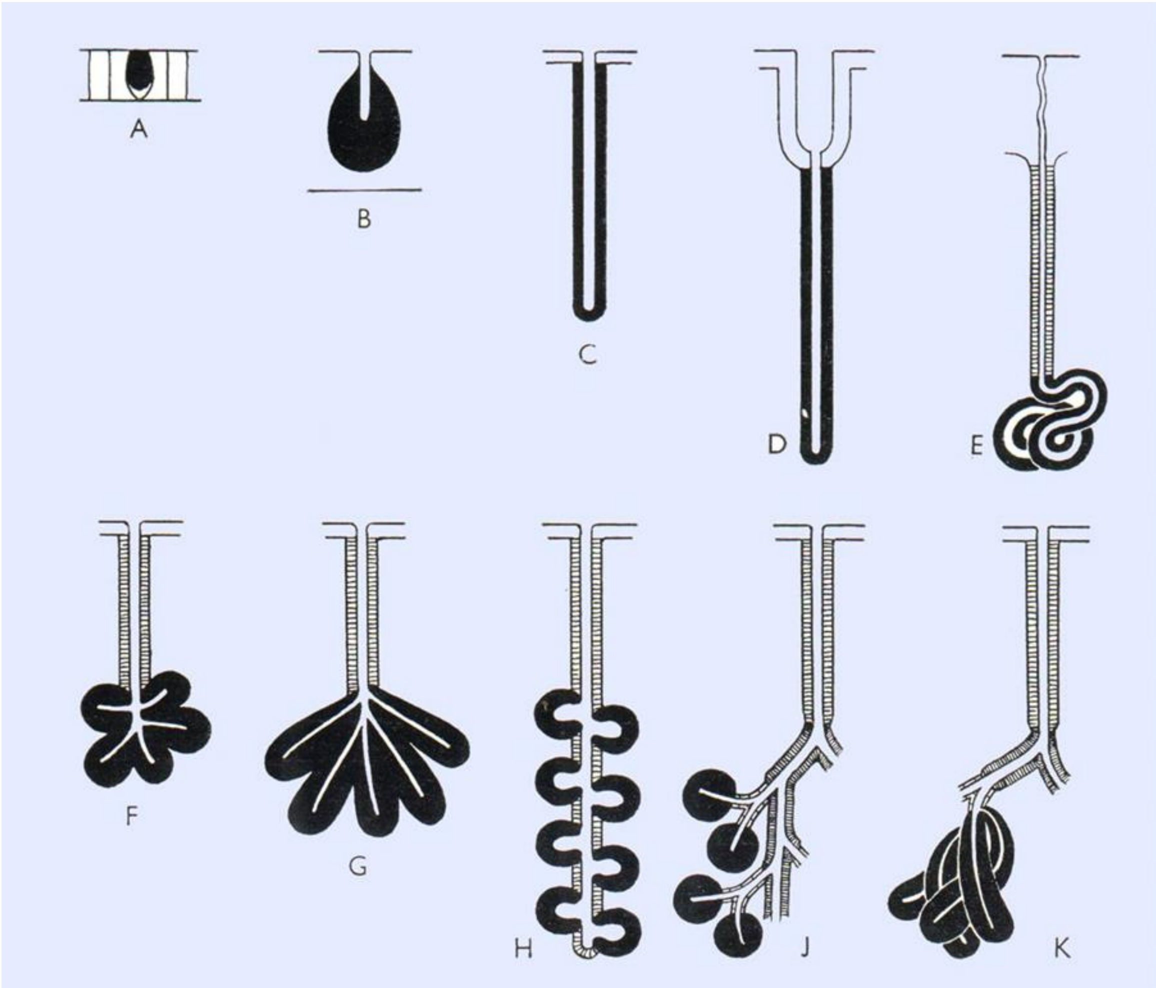


A portion of an epithelium grows into the underlying supporting connective tissue. The down growth develops into a secretory portion and a duct. This is an exocrine gland.

If the duct disappears, an extensive capillary
network collects the secretions in an ‘endocrine’
Gland (4).

Types of Glands

Glands can be classified in may overlapping ways.
Exocrine (with ducts) and endocrine (ductless).
Exocrine glands :
Simple (single duct) and compound (branched duct system).
Type of secretion – serous, mucous or mixed.
Mode of secretion – extent of cytoplasmic loss.
Rather than making it a learning issue, it is fruitful to understand these terms as we come across them.
Besides, there are glands that defy the concepts of classification! The following diagram serves to illustrate some of the types of glands. Some of the terms are purely descriptive!



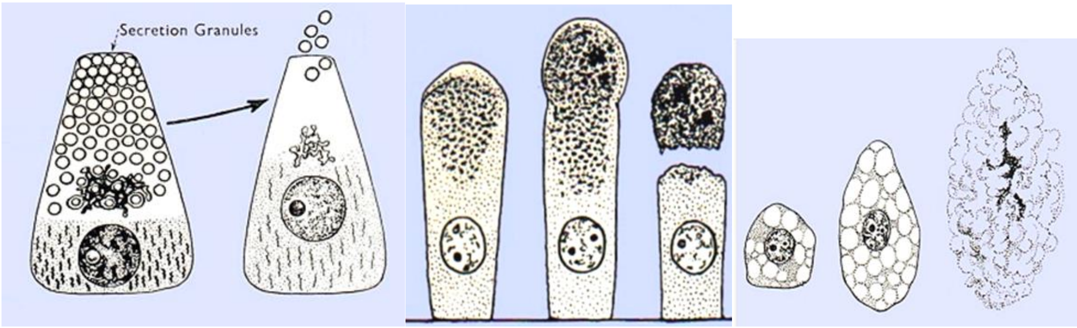
A is a ‘unicellular’ gland
(a goblet cell!).

B and C may be ignored! – They represent glands with no specialised duct portion.

D is a simple tubular gland.
E is a simple, coiled tubular gland.

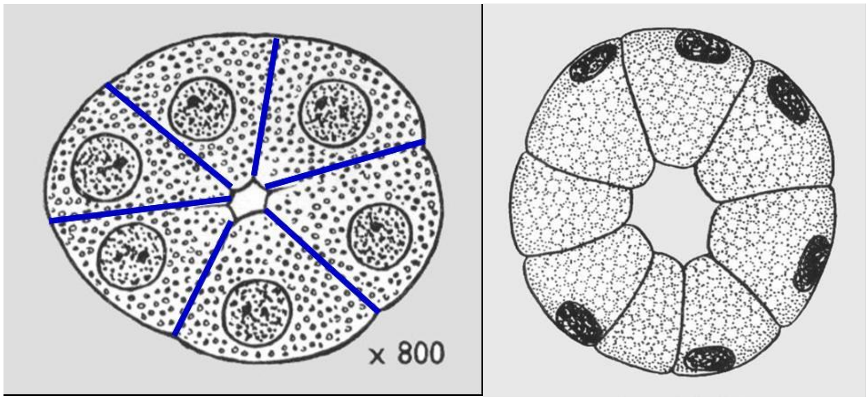
In F and G, the duct is single, but the secretory portions are branched.
H is an unusual gland of a type found in the eyelid.

J and K are compound glands.
Round secretory units are described as acini or alveoli. It is also possible to see 'tubuloacinar' secretory portions.



Merocrine (eccrine) gland
Little or no loss of cytoplasm.
Apocrine gland
Partial loss of (apical) cytoplasm.
Holocrine gland
Entire cell disintegrates to release secretion.

A glandular unit with serous secretions shows round nuclei, well-stained cytoplasm and a small lumen. Usually the basal portion of the cytoplasm is basophilic due to rER, the apical portion with secretory granules is acidophilic.
A mucous unit has cells loaded with lightly stained mucus in the cytoplasm. This pushes the nuclei towards the outer side.



Larger Glands

A larger gland is histologically a complex three-dimensional structure with secretory units and branches of ducts sectioned in various planes. These details will be studied with the digestive system where we come across a variety of glands.
It is, however, worth noting that such a proliferation of epithelial cells compresses the connective tissue. Such partitions of connective tissue separate parts of glands of varying sizes, called lobes and lobules. The connective tissue framework is called the stroma, the epithelial element is the parenchyma. These terms are met with in many solid structures.

Connective tissue

Most abundant & widely distributed tissue
Originate from embryonic tissue called mesenchyme
Consists of two basic elements:
Cells and Extra-cellular matrix
Cells widely separated from each other in a matrix that is produced by the cells (cells are scattered).
The matrix generally consists of fibers .The matrix may be solid (as in bone), gelatinous or liquid (as in blood).

Functions of connective tissue

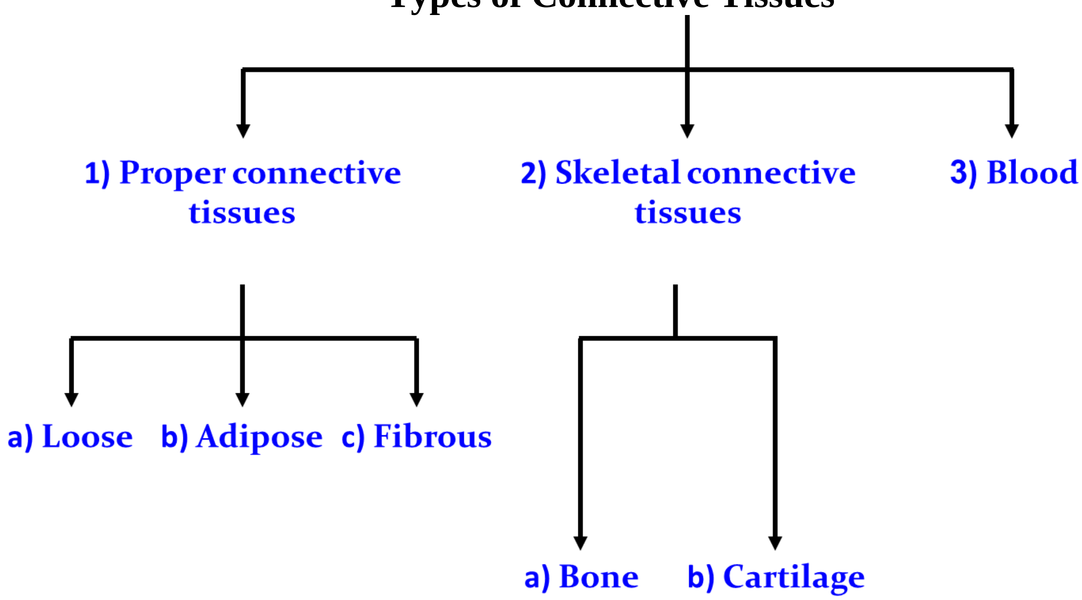
Bind and support other tissues.
Protect, support and bind together other tissues Bones, ligaments, tendons
Areolar cushions; adipose insulates and is food source
Blood cells replenished; body tissues repaired
Cells separated from one another by large amount of nonliving extracellular matrix
Support and binding of other tissues
Holding body fluids
Defending the body against infection
macrophages, plasma cells, mast cells, WBCs
Storing nutrients as fat.

Connective tissue Cells

Fibroblasts: Secrete both fibers and ground substance of the matrix (wandering)
Macrophages: Phagocytes that develop from Monocytes (wandering or fixed)

Plasma Cells: Antibody secreting cells that develop from B Lymphocytes (wandering)
Mast Cells: Produce histamine that help dilate small blood vessels in reaction to injury (wandering)
Adipocytes: Fat cells that store triglycerides, support, protect and insulate (fixed)
There are three types of connective tissues fibers, which are all proteins:
Collagen Fibers: Large fibers made of the protein collagen and are typically the most abundant fibers. Promote tissue flexibility.
Elastic Fibers: Intermediate fibers made of the protein elastin. Branching fibers that allow for stretch and recoil
Reticular Fibers: Small delicate, branched fibers that have same chemical composition of collagen. Forms structural framework for organs such as spleen and lymph nodes.

Types of Connective Tissues



1- Proper Connective Tissues

A- Loose (areolar) Proper Connective Tissue

Binds epithelia to underlying tissues and functions a holding organs in place.
It has all three fiber types.
It has two cell types:

1- Fibroblasts

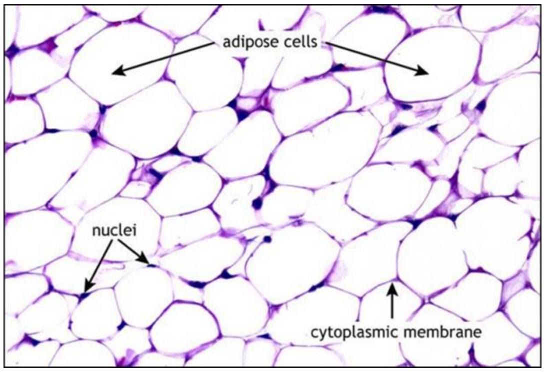
Are responsible for making the extracellular fibers.

2- Macrophages

Are amoeboid cells that swallow and digest microbes, and cellular debris by phagocytosis

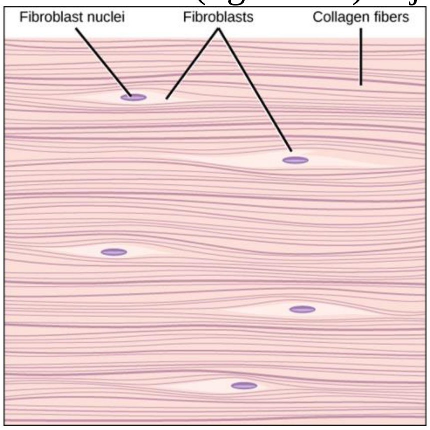
B- Adipose Proper Connective Tissue

Function as storage cells for adipose (lipids).
Adipose cells contain a large vacuole which in the live cell contains lipids.
Cell nucleus and cytoplasm are pushed out to edge of cell membrane.



C-Fibrous Proper Connective Tissue

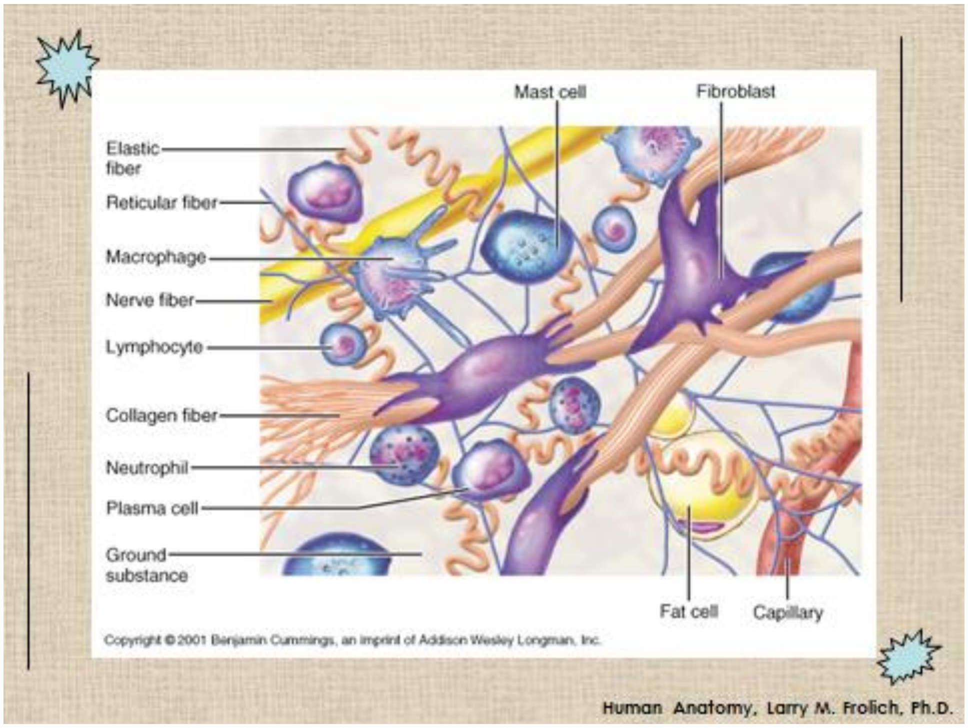
It contains large number of collagenous fibers.
The functions of this tissue are to attach muscles to bones (tendons الأوتار), and connect bones to other bones (ligaments) at joints

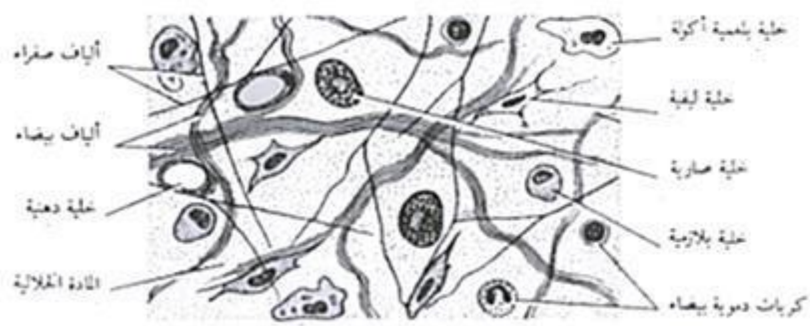


Extracellular Matrix explained

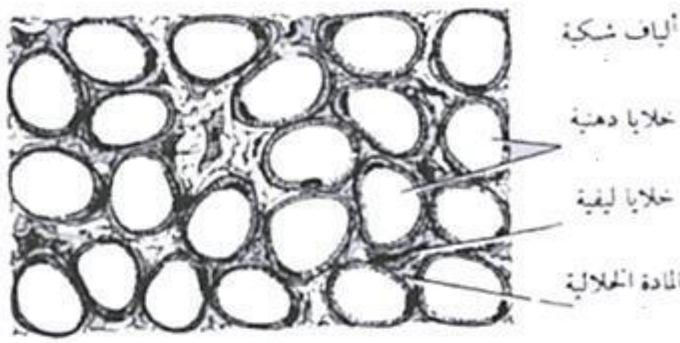
Nonliving material between cells
Produced by the cells and then extruded
Responsible for the strength
Two components
Ground substance.Of fluid, adhesion proteins, proteoglycans

Liquid, semisolid, gel-like or very hard
Fibers: collagen, elastic or reticular





نسيج ضام فجوي



نسيج ضام دهني

نسيج ضام ليفي

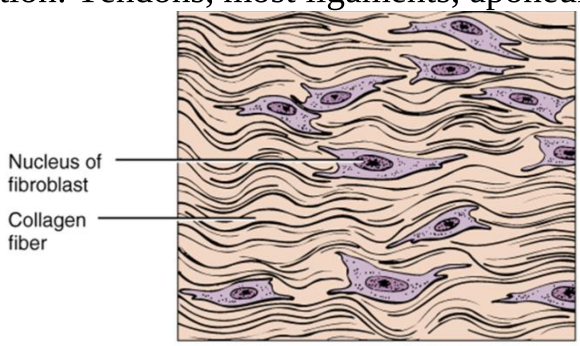
Connective tissue proper: loose connective tissue, areolar
Description: Gel-like matrix with all three fiber types; cells: fibroblasts, macrophages, mast cells, and some white blood cells.

Function: Wraps and cushions organs; its macrophages phagocytize bacteria; plays important role in inflammation; holds and conveys tissue fluid.
Location: Widely distributed under epithelia of body, e.g., forms lamina propria of mucous membranes; packages organs; surrounds capillaries.

Connective tissue proper: loose connective tissue, adipose
Description: Matrix as in areolar, but very sparse; closely packed adipocytes, or fat cells, have nucleus pushed to the side by large fat droplet.
Function: Provides reserve food fuel; insulates against heat loss; supports and protects organs.
Location: Under skin in subcutaneous tissue; around kidneys and eyeballs; within abdomen; in breasts.

Connective tissue proper: loose connective tissue, reticular
Description: Network of reticular fibers in a typical loose ground substance; reticular cells lie on the network.
Function: Fibers form a soft internal skeleton (stroma) that supports other cell types including white blood cells, mast cells, and macrophages.
Location: Lymphoid organs (lymph nodes, bone marrow, and spleen).

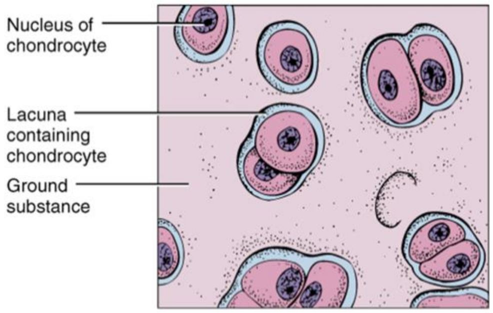
Connective tissue proper: dense connective tissue, dense regular
Description: Primarily parallel collagen fibers; a few elastic fibers; major cell type is the fibroblast.
Function: Attaches muscles to bones or to muscles; attaches bones to bones; withstands great tensile stress when pulling force is applied in one direction.
Location: Tendons, most ligaments, aponeuroses.



Dense regular connective tissue

Connective tissue proper: dense connective tissue, dense irregular
Description: Primarily irregularly arranged collagen fibers; some elastic fibers; fibroblast is the major cell type.
Function: Withstands tension exerted in many directions; provides structural strength.
Location: Fibrous capsules of organs and of joints; dermis of the skin; submucosa of digestive tract.

Connective tissue proper: dense connective tissue, elastic
Description: Dense regular connective tissue containing a high proportion of elastic fibers.
Function: Allows tissue to recoil after stretching; maintains pulsatile flow of blood through arteries; aids passive recoil of lungs following inspiration.
Location: Walls of large arteries; within certain ligaments associated with the vertebral column; within the walls of the bronchial tubes.

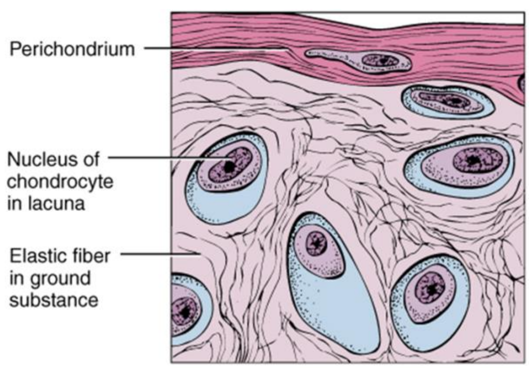


Cartilage: hyaline

Hyaline cartilage

Description: Amorphous but firm matrix; collagen fibers form an imperceptible network; chondroblasts produce the matrix and when mature (chondrocytes) lie in lacunae.
Function: Supports and reinforces; serves as resilient cushion; resists compressive stress.
Location: Forms most of the embryonic skeleton; covers the ends of long bones in joint cavities;forms costal cartilages of the ribs; cartilages of the nose, trachea, and larynx.

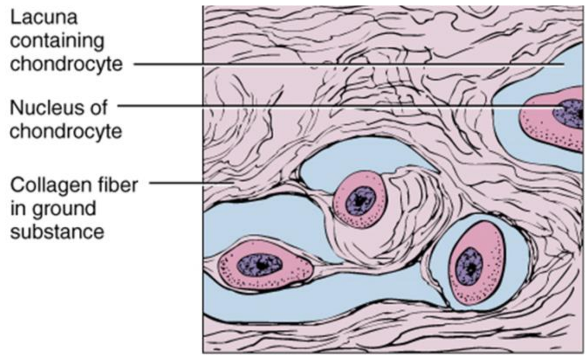
Cartilage: elastic



Elastic cartilage

Description: Similar to hyaline cartilage, but more elastic fibers in matrix.
Function: Maintains the shape of a structure while allowing great flexibility.
Location: Supports the external ear (pinna); epiglottis.

Cartilage: fibrocartilage



Fibrocartilage

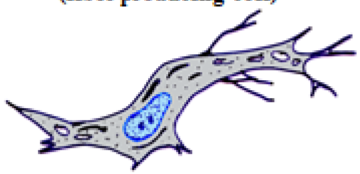
Description: Matrix similar to but less firm than that in hyaline cartilage; thick collagen fibers predominate.
Function: Tensile strength allows it to absorb compressive shock.
Location: Intervertebral discs; pubic symphysis; discs of knee joint.

Bone (osseous tissue)

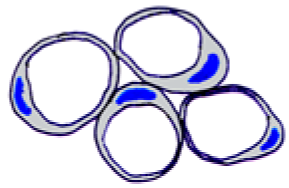
Description: Hard, calcified matrix containing many collagen fibers; osteocytes lie in lacunae. Very well vascularized.
Function: Supports and protects (by enclosing); provides levers for the muscles to act on; stores calcium and other minerals and fat; marrow inside bones is the site for blood cell formation (hematopoiesis).
Location: Bones

FIXED CONNECTIVE TISSUE CELL TYPES

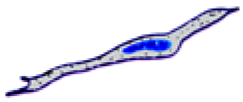
Fibroblast
(fiber producing cell)



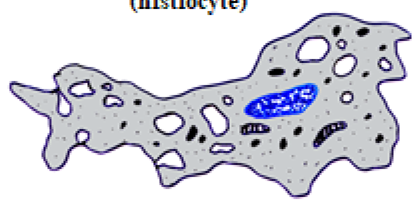
Adipocytes
(fat storage)



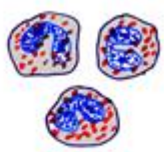
Fibrocyte
(mesenchymal- pluropotent)



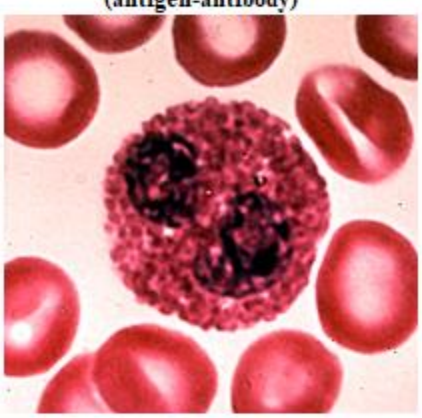
Fixed Macrophage
(histiocyte)



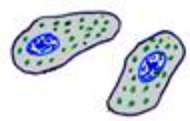
EOSINOPHILES



actively phagocytic
destroy immune complexes
(antigen-antibody)

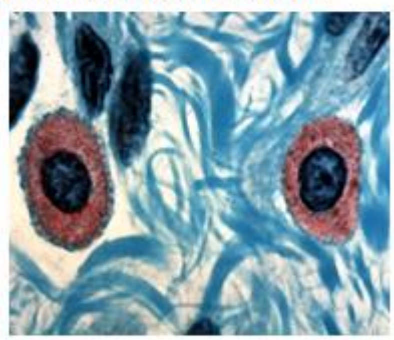


MAST CELLS



Secretion Products:

1. Slow-reaction substance of anaphalaxis
2. Heparin- anticoagulant
3. Histamine- stimulates inflammation
4. Serotonin- vasoconstrictor
5. Eosinophil Chemotactic Factor



Muscle Tissue

Introduction to Muscle

Movement is a fundamental characteristic of all living things
In animals, muscular tissues capable of shortening– How (molecular mechanism)?
Three types of muscle tissue--

Focuses of this chapter– structure, contraction, and metabolism of skeletal muscle at the cellular/molecular levels

Characteristics of ALL Muscle Cells

Changes--
Responsiveness (excitability)
Respond to stimuli with electrical changes; in what cells?
Conductivity
2 Purposes– more than a local electrical change; leading to muscle contraction
Consequences– of muscles
Contractility –shortens when stimulated; pull on bones and other tissues
Extensibility -- capable of being stretched; in other cells— What happen?

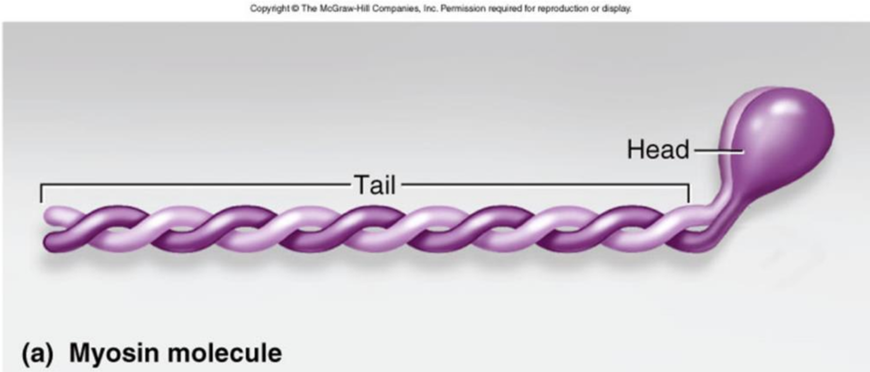
Elasticity -- returns to its original resting length after being stretched

Skeletal muscle fiber

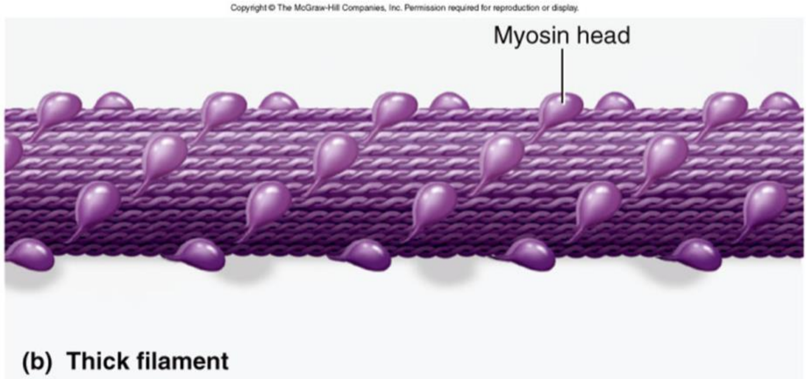
Muscle fiber – one skeletal muscle cell
Myofibril –forming an internal subdivision of a cardiac or skeletal muscle cell
Myofilament – a protein microfilament responsible for the contraction of a muscle cell;
3 kinds—
Sarcoplasm (cytoplasm) is filled with
Myofibrils
Glycogen– purpose?
Pigment (myoglobin)—binding oxygen
Sarcoplasmic reticulum = smooth ER
network around each myofibril; function? Store calcium
terminal cisternae–
triad =
Multiple flattened nuclei inside cell membrane

fusion of multiple myoblasts during development

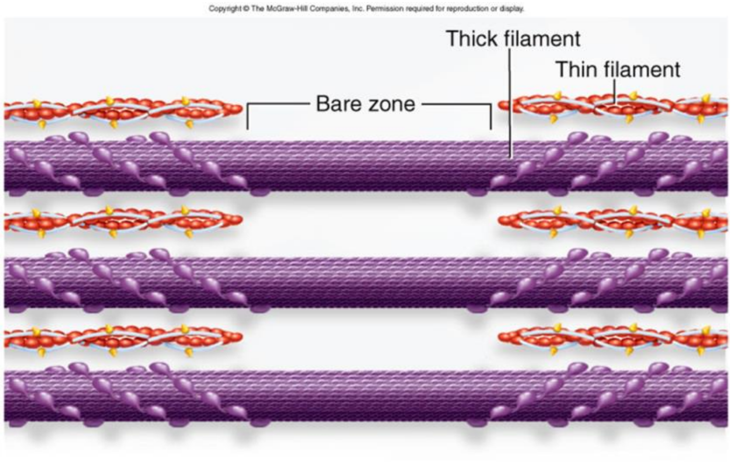
Sarcolemma – plasma membrane; having tubular infoldings (transverse (T) tubules) that penetrate the interior of the cell
carry electric current to interior of the cell
This current signals the SR when to release calcium ions into cytoplasm
Each thick filament is made of 200 to 500 _________ molecules– each in turn has 2 entwined polypeptides (the heads similar to golf clubs) for each myosin molecule
Arranged in a bundle of "golf clubs" with heads directed outward in a spiral array around the bundled tails
Central area of the thick filament is a __________ with no heads (of myosin molecules)



Myosin molecules to form thick filament—see next slide



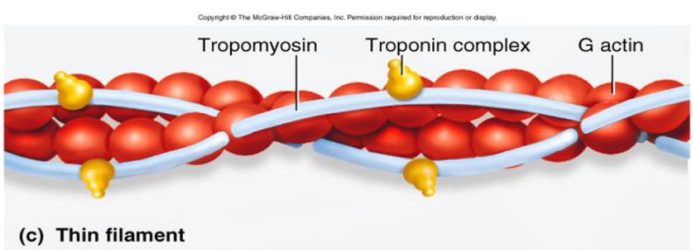
Full picture of the thick filament—see next slide



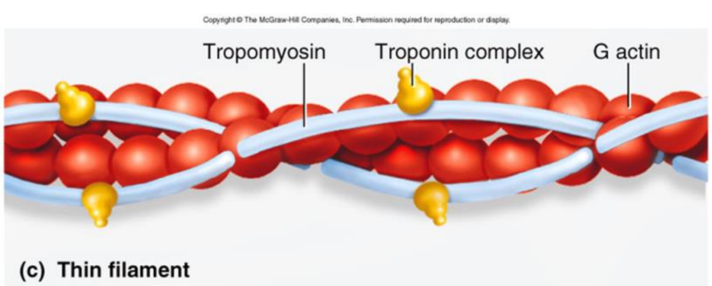
(d) Portion of a sarcomere showing the overlap of thick and thin filaments

Overlap of Thick and Thin Filaments

Three kinds of myofilament –
2. Thin Filaments
(in red) 2 intertwined strands (fibrous (F) actin)
Each bead is a globular (G) actin with an active site; capable of binding the head of a __________
(in white) Groove holds ____________ molecules
each can block 6 or 7 active sites of G actins
(in yellow) calcium-binding _________ molecule on each tropomyosin molecule

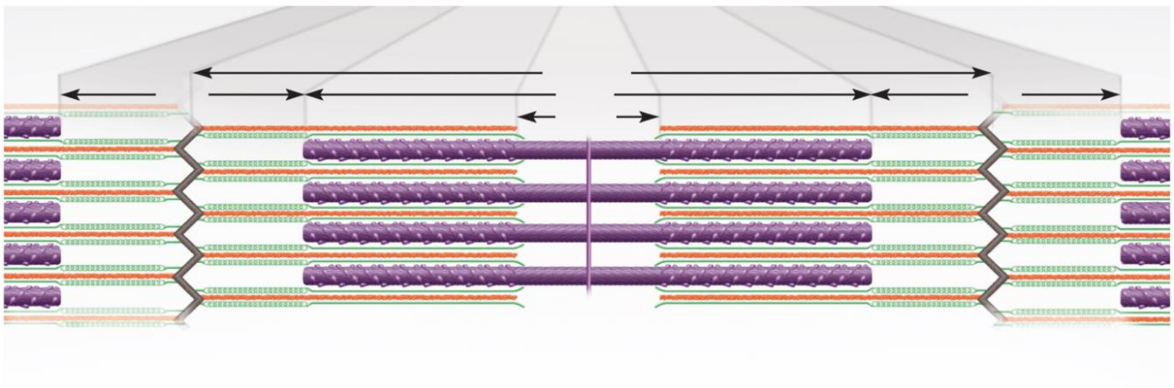


(c) Thin filament



(c) Thin filament

Three kinds of myofilament –
3. Elastic Filaments
Springy proteins called ________________
Anchor each thick filament to Z disc
Prevents overstretching of sarcomere



3 kinds of myofilament in three colors—
Purple ones— _____________ filaments
Red ones— ____________ filaments
Green ones-- _____________ filaments

Contractile & Regulatory Proteins
Myosin and actin are contractile proteins; do the work of shortening the muscle fiber
________________ and _____________ are regulatory proteins; Function—
Striations = Organization of Filaments

Striations-- Dark A bands alternating with lighter I bands

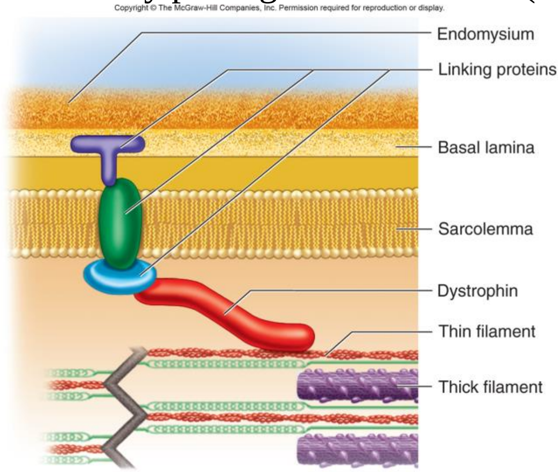
A band is thick filament region— Dark/Light (Circle one)
central H band area is lighter, contains no thin filaments

I band is thin filament region— Dark/Light (Circle one)
bisected by Z disc protein, anchoring elastic and thin filaments
from one Z disc (Z line) to the next is a sarcomere

Relaxed & Contracted Sarcomeres

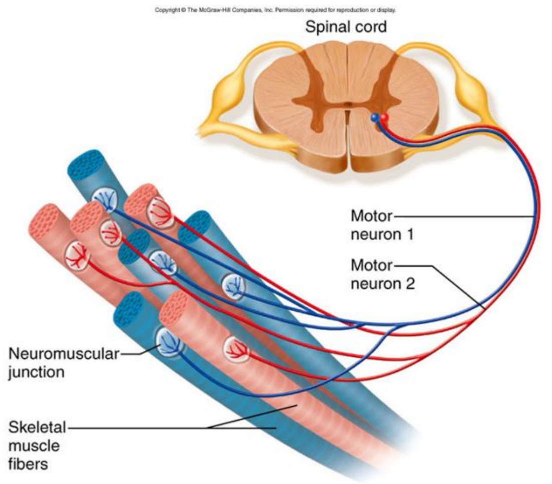
Muscle cells shorten because their individual Sarco________________ shorten

Details--
Do myofilaments change length? Yes/No
Z discs/sarcomeres? Yes/No
Eventually pulling on sarcolemma (cell mem.) via proteins (especially dystrophin)



Nerve-Muscle Relationships

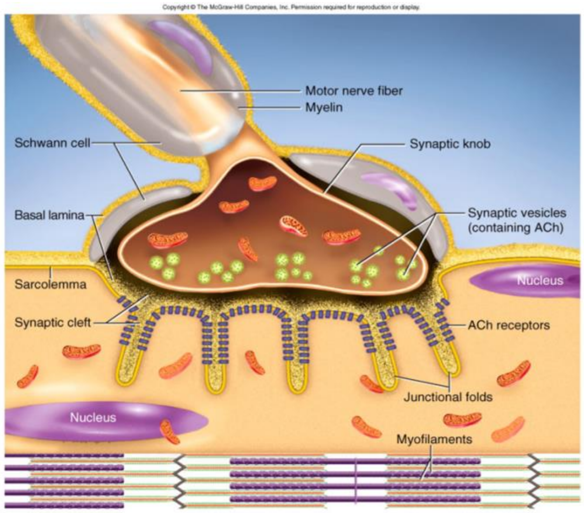
Skeletal muscles are innervated by somatic motor neurons
Where are motor neurons' cell bodies? In ______________________________
Axons reach these muscle fibers
At its distal end, each axon branches about 200 times; each branch reaches a different fiber (cell)
Each motor neuron and all the muscle fibers it innervates are called a
Motor neuron originated from



Motor Units

A motor neuron and the muscle fibers it innervates
A muscle (whole muscle) is innervated by _________ motor units; advantages?
Where are the muscle fibers innervated by one motor neuron?
Small motor units--Fine control
small motor units contain as few as 3-6 muscle fibers per nerve fiber
Example– eye muscle
Large motor units--Strength control
gastrocnemius muscle has 1000 fibers per nerve fiber

Neuromuscular Junctions (NMJ
Functional connection between nerve fiber and target cell called synapse; if the target cell is a muscle fiber, the synapse is called NMJ
Neurotransmitter (acetylcholine/ACh) released from nerve fiber stimulates muscle cell
Components of NMJ– Fig. 11.7 (next slide)
A-synaptic knob (with vesicles present; B)
C-synaptic cleft (a tiny gap)
D-motor end plate
E-junctional folds



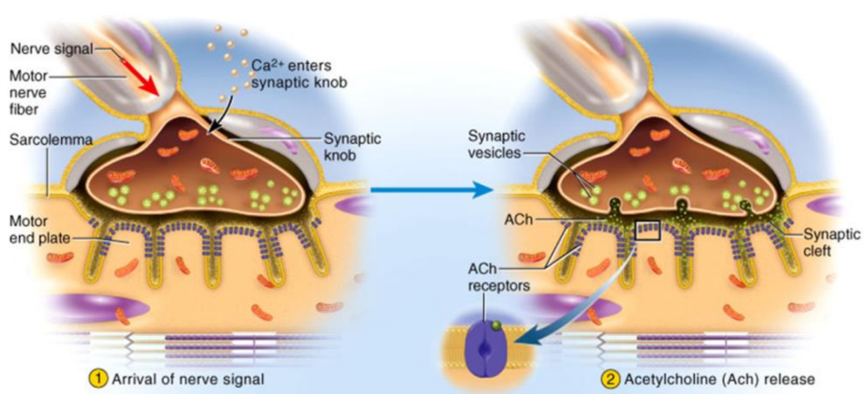
A) synaptic knob-- a swollen end of a nerve fiber
B) synaptic vesicles-- ________________
C) synaptic cleft-- tiny gap ________________________________
D) motor end plate— depression region of sarcolemma where a ______________ rests
Features– increases surface area for Ach receptors and contains Acetylcholinesterase
E) junctional folds— infoldings in sarcolemma; many Ach receptors present here too

Neuromuscular Toxins on Muscle:
Spastic paralysis (& possible suffocation)
Symptom: a continual contraction of the muscle
Caused by pesticides (cholinesterase inhibitors)
Mechanism: binds to acetylcholinesterase and prevents it from degrading ACh
Tetanus (lockjaw) is another spastic paralysis caused by toxin of Clostridium tetani bacteria
blocks glycine release in the spinal cord and causes overstimulation of the muscles
Flaccid paralysis (limp muscles, cannot contract) due to curare that competes with Ach receptor sites
respiratory arrest (thoracic muscles cannot contract)

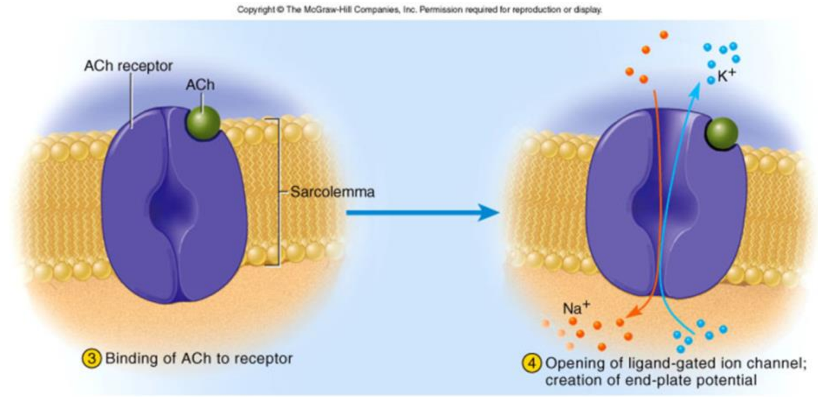
Electrically excitable cells
In what specific cells?
At rest, plasma membrane is charged

difference in charge across the membrane = resting membrane potential (-90 mV in cells)
Why?
Stimulation opens ion gates in membrane
When strong enough, results in action potential production
Details
Depolarization-- Na+ ion gates open; sodium ions enter
Repolarization followed-- K+ rushes out of cell
An action potential spreads—
Where? Cell surface of nerve fibers/sarcolemma

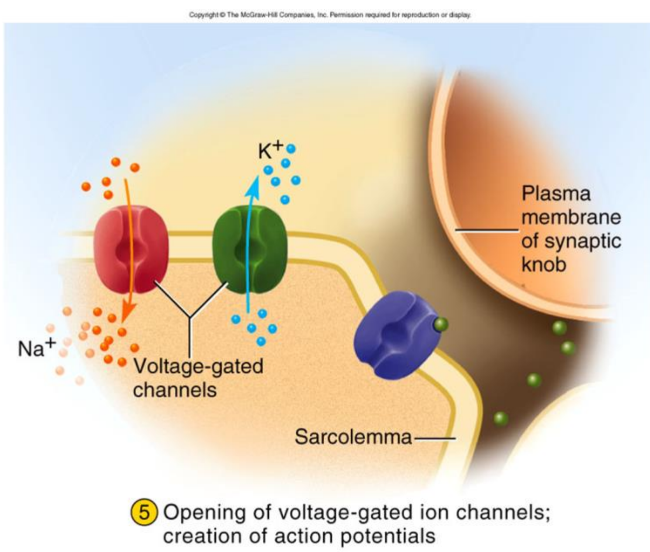
Muscle Contraction and Relaxation
Four phases involved in this process
A. excitation = nerve action potentials lead to action potentials in muscle fiber
B. excitation-contraction coupling = action potentials on the sarcolemma activate myofilaments
C. contraction = shortening of muscle fiber
D. relaxation = return to resting length
Images will be used to demonstrate the steps of each of these actions
Excitation (steps 1-5)–
These events link action potentials in the nerve fiber to the generation of action potentials in the muscle fiber.



Nerve signal opens voltage-gated Calcium channels. Calcium stimulates exocytosis of synaptic vesicles containing _____; then ACh release into synaptic cleft



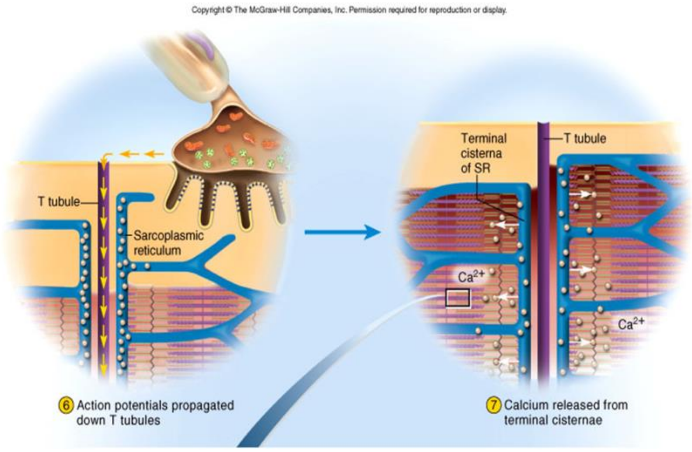
Binding of ACh to receptor proteins opens Na+ and K+ channels resulting in an end-plate potential (EPP), RMP from -90mV to +75mV and back to -90mV



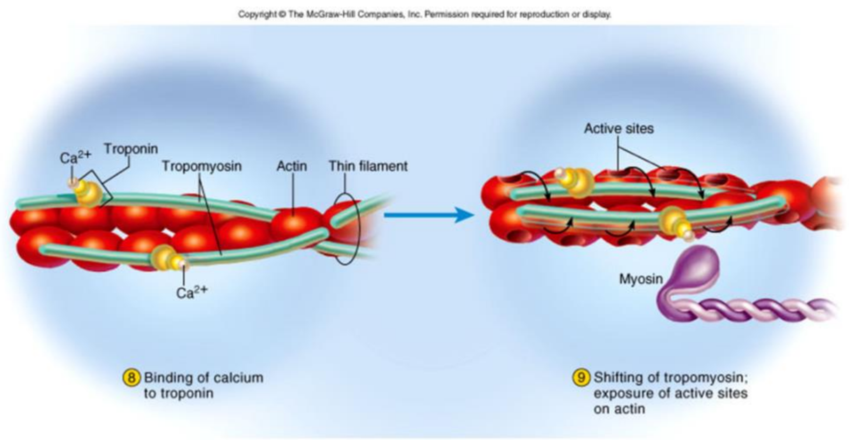
Voltage change in end-plate region (EPP) opens nearby voltage-gated channels producing an action potential (cell?)

Excitation-Contraction Coupling (steps 6-9)–

These events link action potentials in the muscle fiber to the release and binding of calcium ions



Action potential spreading over sarcolemma and down T-tubules, causing calcium gates to open in SR; Purpose? Calcium enters . . .

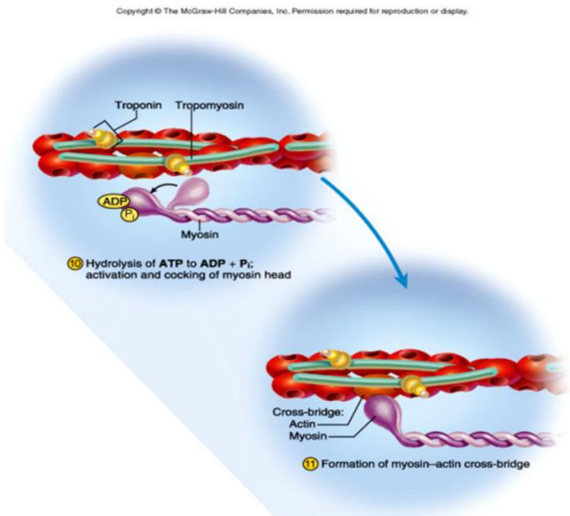


Calcium released by SR binds to ___________

Troponin-tropomyosin complex changes shape and exposes _____________on actin filaments

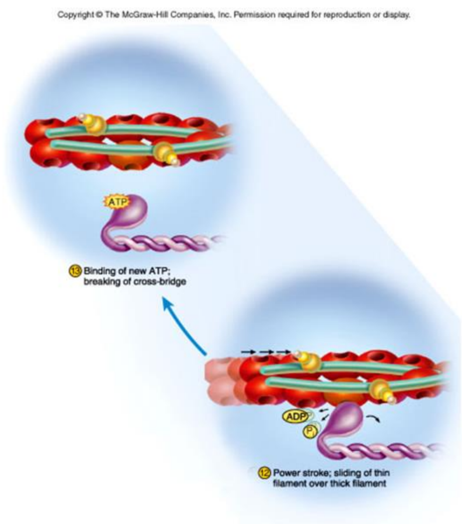
Contraction (steps 10-13)–

The sliding filament mechanism of contraction



Myosin ATPase in myosin head hydrolyzes an ATP molecule, activating the head and "cocking" it into an extended position

It binds to actin active site forming a cross-bridge

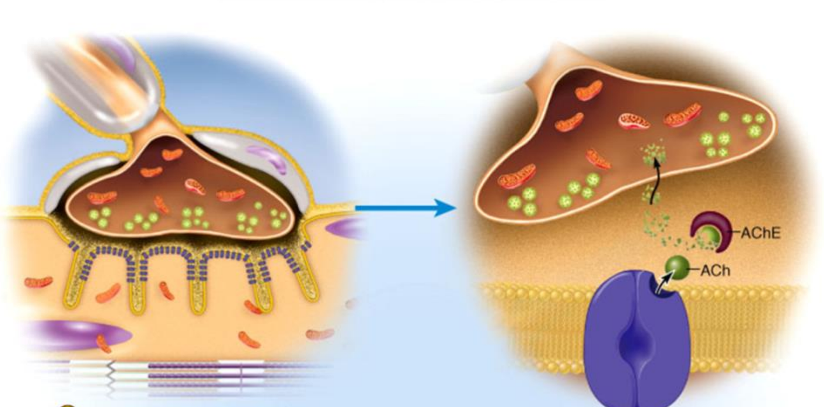


Step 12--myosin head releases ADP/phosphate as
it pulls the thin
filament past the thick one

Step 13--With the binding of more ATP, the myosin head releases and extends to attach to a new active site

Relaxation of a muscle fiber (steps 14-18)–

These events lead from the cessation of a nerve signal to the release of thin filaments by myosin

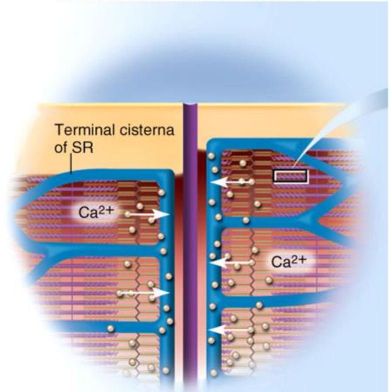


⑭ Cessation of nervous stimulation and ACh release

⑮ ACh breakdown by acetylcholinesterase (AChE)

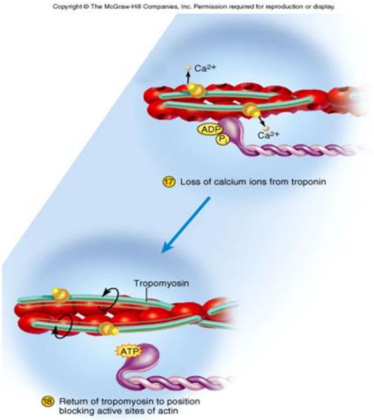
Nerve stimulation ceases and acetylcholinesterase removes ACh from receptors. Stimulation of the muscle cell ceases.

Relaxation



⑯ Reabsorption of calcium ions by sarcoplasmic reticulum

Active transport needed to pump calcium back into SR (ATP needed)
Calcium binds to ______________
ATP is needed for muscle relaxation (as well as muscle contraction)



Step 17: ATP binding--
Loss of calcium from sarcoplasm moves troponin-tropomyosin complex over active sites
Step 18: Muscle fiber returns to resting length

Impact of calcium ions in muscle contraction

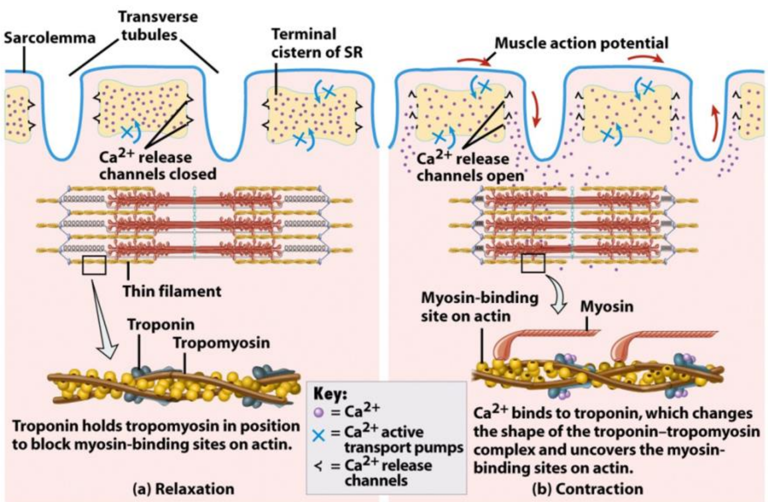
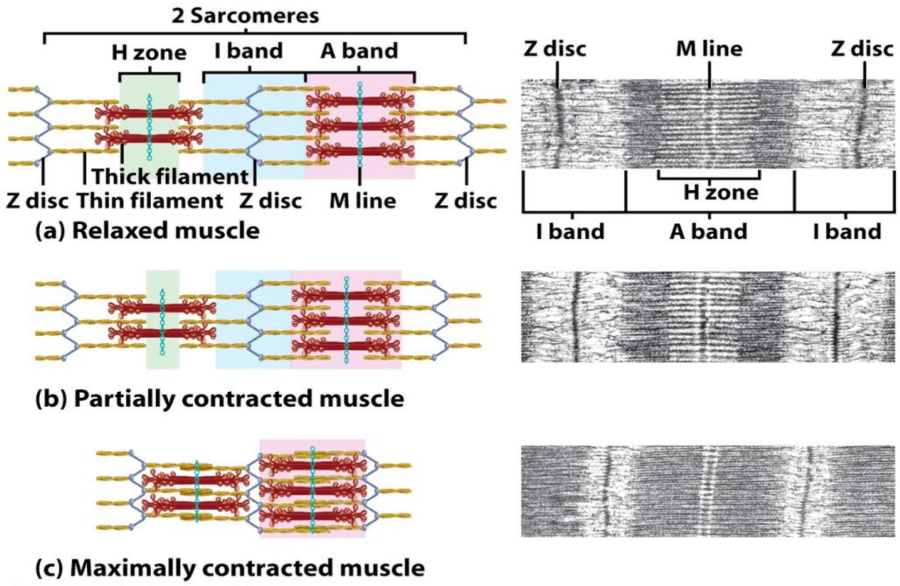


Figure 10-8 Principles of Anatomy and Physiology, 11/e

What are shortened during muscle contraction?
A band, H-zone, I band, actin, myosin, sarcomeres?



Rigor Mortis (death rigor)

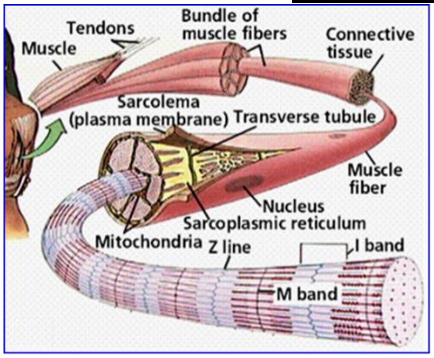
Symptom: stiffening of the body beginning 3 to 4 hours after death
Causes: Calcium activates myosin-actin cross-bridging and muscle contracts, but can not relax.
Mechanisms: muscle relaxation requires ______ and ATP production is no longer produced after death
Thick and thin filaments remain rigidly cross-linked. Fibers remain contracted until myofilaments decay, proteins break down.

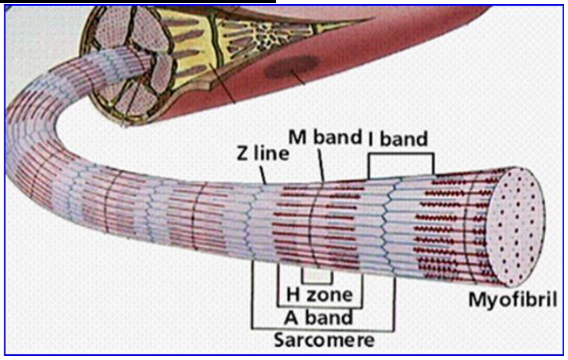
Length-Tension Relationship

Amount of tension generated depends on length of muscle before it was stimulated:
length-tension relationship (see graph next slide)
Overly contracted (weak contraction results)
thick filaments too close to Z discs and can't slide
Too stretched (weak contraction results)
little overlap of thin and thick does not allow for very many cross bridges to form
Optimum resting length produces greatest force when muscle contracts
Ex. CNS maintains optimal length producing muscle tone or partial contraction

Is composed of long cells called muscle fibers that are capable of contracting when stimulated by nerve impulses.

It has large numbers of myofibrils made of the contractile proteins actin and myosin .
Muscle is the most abundant tissue in most animals**,**



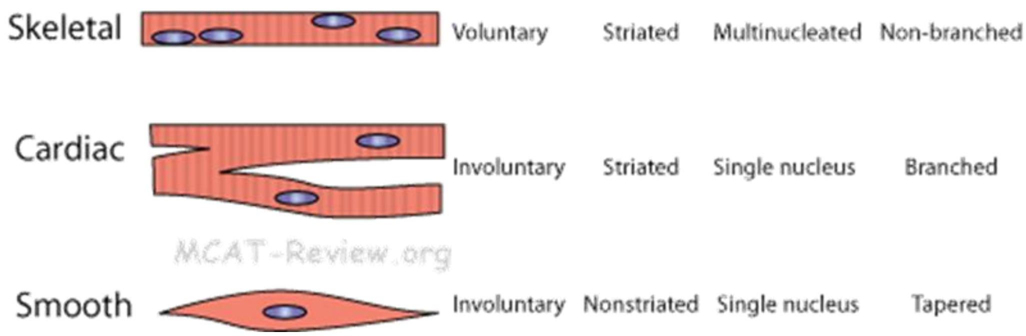


Abundant, dense tissue 40-50% of body weight
High metabolic activity high energy use/output;O2 consumption; CO2 production
Contractility ,muscle tissue shortens producing force."Muscles can only contract!"
Excitability, responds to nerve impulses by contracting.
Extensibility, can be stretched by outside force (such as by another muscle).
Elasticity.recoils after being stretched.

There are three types of muscle tissue in the vertebrate body:
Skeletal muscle:
- It attaches to bones by tendons, skeletal muscle is responsible for voluntary movements.
- Also called striated muscle.

Cardiac muscle:
- forms the contractile wall of the heart.
- Cardiac cells are branched.

Smooth muscle:
No striations,
Is found in the walls of the digestive tract, urinary bladder, arteries, and other internal organs. Its cells are spindle-shaped.



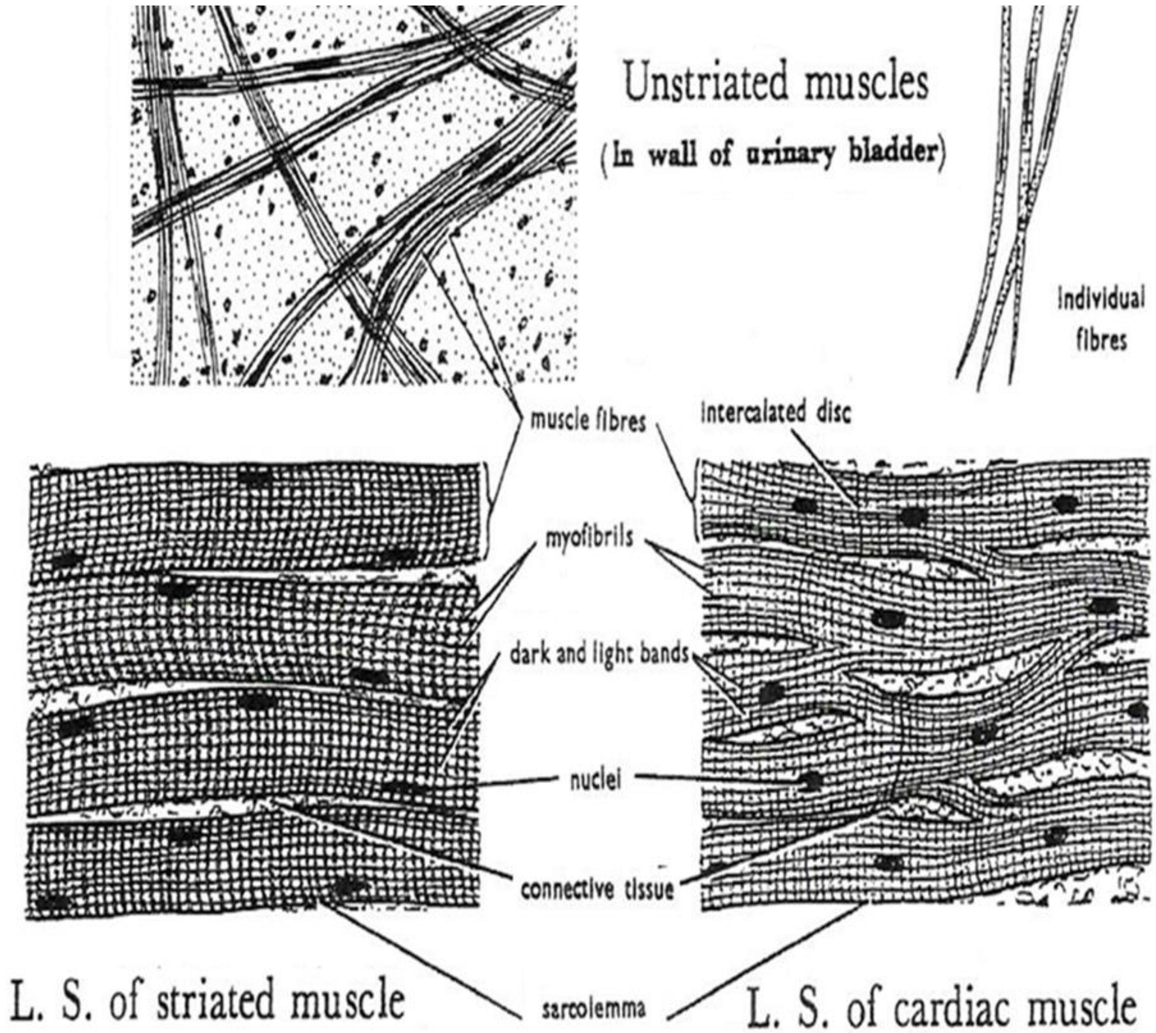
Functions of Muscle Tissue
Produce movement by contracting
Locomotion & manipulation
Movement of blood, food, urine, etc. through hollow organs
Maintenance of posture
Stabilize joints
so that other muscles can produce movement or maintain posture
Heat production
Maintenance of body temperature.
Skeletal Muscle
Long, cylindrical cells, Multinucleate, Obvious striations, attached to skeleton.
Covered by plasma membrane (sarcolemma),Striated.
Function
Voluntary movement
Manipulation of environment
Facial expression
Location,Skeletal muscles attached to bones (occasionally to skin)
Cardiac Muscle Tissue: Striated, involuntary, walls of heart
Bundles form thick myocardium
Cardiac muscle cells are single cells (not called fibers)
Cells branch
Cells join at intercalated discs
1-2 nuclei in center
Here "fiber" = long row of joined cardiac muscle cells
Inherent rhythmicity: each cell! (muscle cells beat separately without any stimulation)

Function
Contracts to propel blood into circulatory system
Characteristics

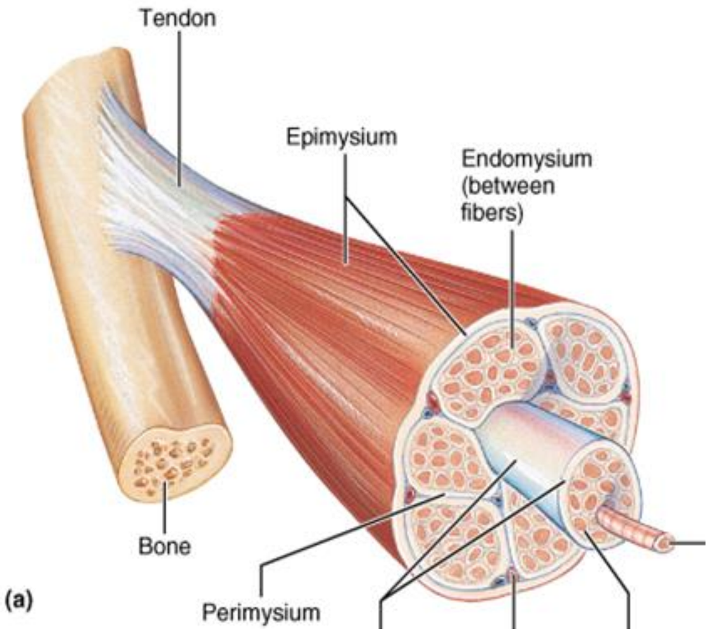
Branching cells
Uni-nucleate
Intercalated discs
Location
Occurs in walls of heart
Smooth Muscle Tissue: Non-striated, involuntary, wrapping of hollow organs
Stomach, intestines, arteries, bladder, vas deferens, uterus, etc.
Spindle-shaped cells with central nuclei. Arranged closely to form sheets.
No striations.Thin cells pointed at ends,wrapping of hollow organs

Muscles are spindle-shaped cells
One central nucleus
Grouped into sheets: often running perpendicular to each other
Peristalsis
No striations (no sarcomeres)
Contractions are slow, sustained and resistant to fatigue
Does not always require a nervous signal: can be stimulated by stretching or hormones

Function
Propels substances along internal passageways
Involuntary control
Location
Mostly walls of hollow organs
6 major locations:
inside the eye 2. walls of vessels 3. respiratory tubes
4. digestive tubes 5. urinary organs 6. reproductive organs

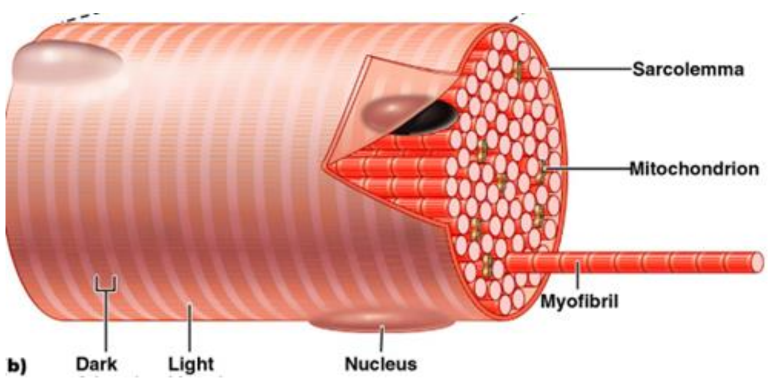


Gross structure of a skeletal muscle:
Tendons connect muscle to bone, transmit force.
Origin = attachment to more stationary (proximal) bone
Insertion = attachment to more mobile (distal) bone
Belly = muscular tissue
Head = one of multiple origins (-ceps)



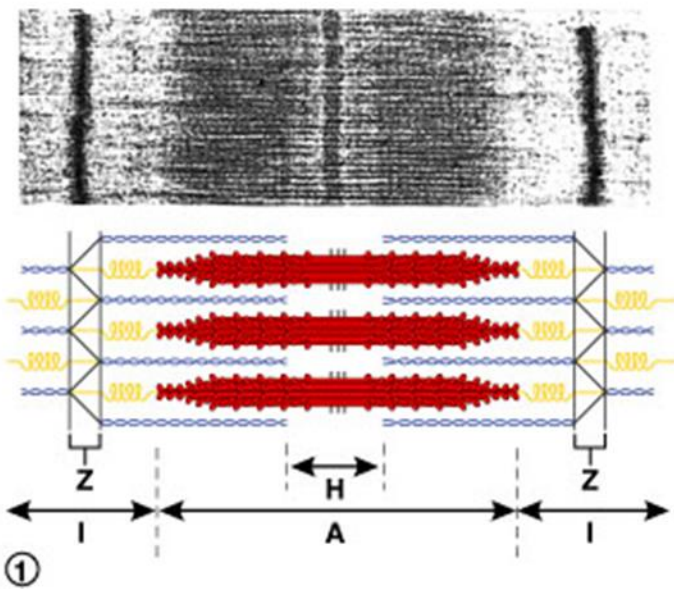
Naming of muscles

Muscle Groups
Agonist (prime mover) vs. Antagonist
Muscles can only CONTRACT !!
Muscle must be stretched by antagonist(s) before it can contract again.
Synergist(s) = muscle(s) that works with prime mover.
Fixator(s) = muscle(s) that stabilizes body part.
Prevents one kind of motion so another can happen.



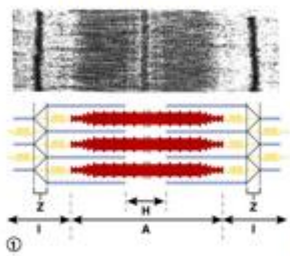
Myofibrils

Made of three types of filaments (or myofilaments):
Thick (myosin)
Thin (actin)
Elastic (titin)

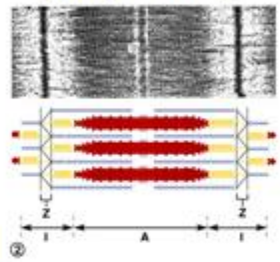


Sliding Filament Model

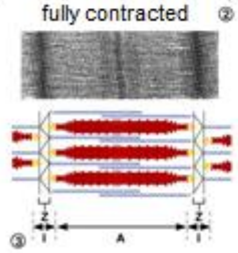
__relaxed sarcomere__



partly contracted



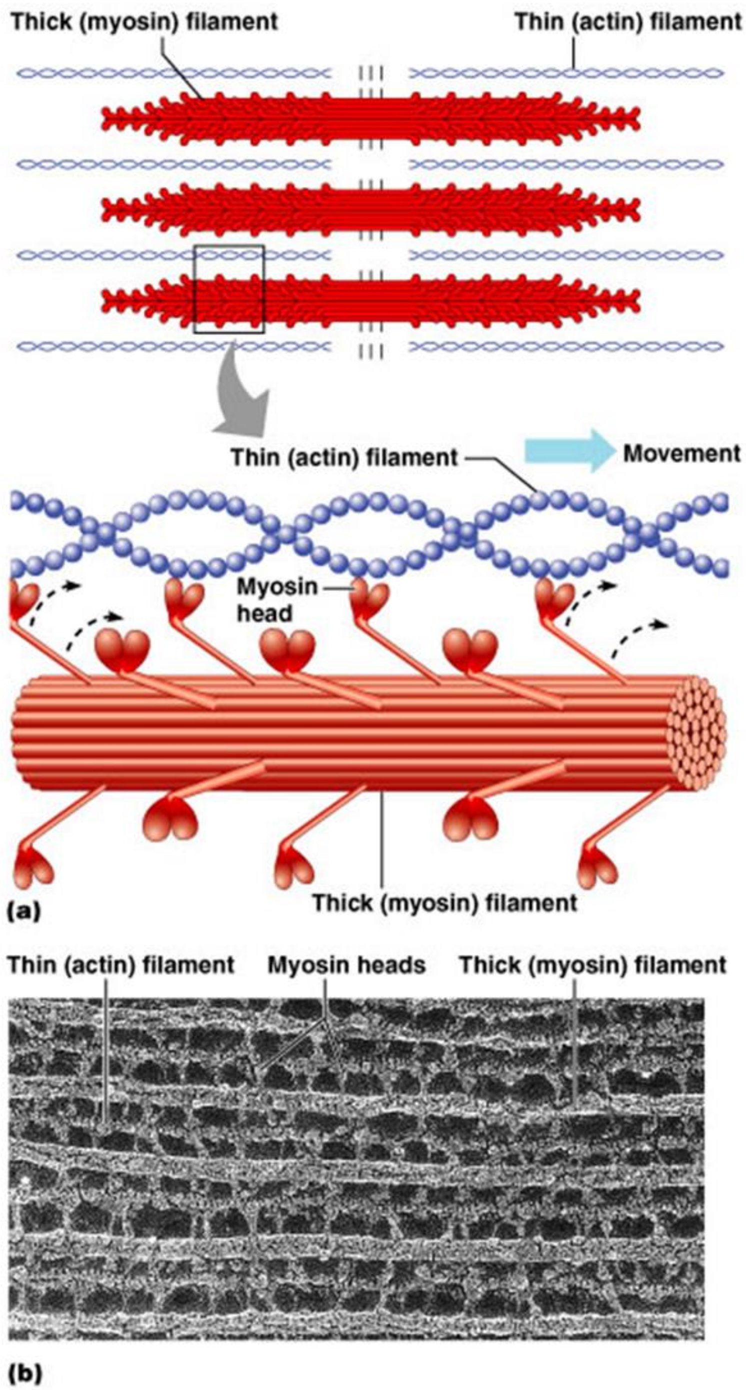
fully contracted

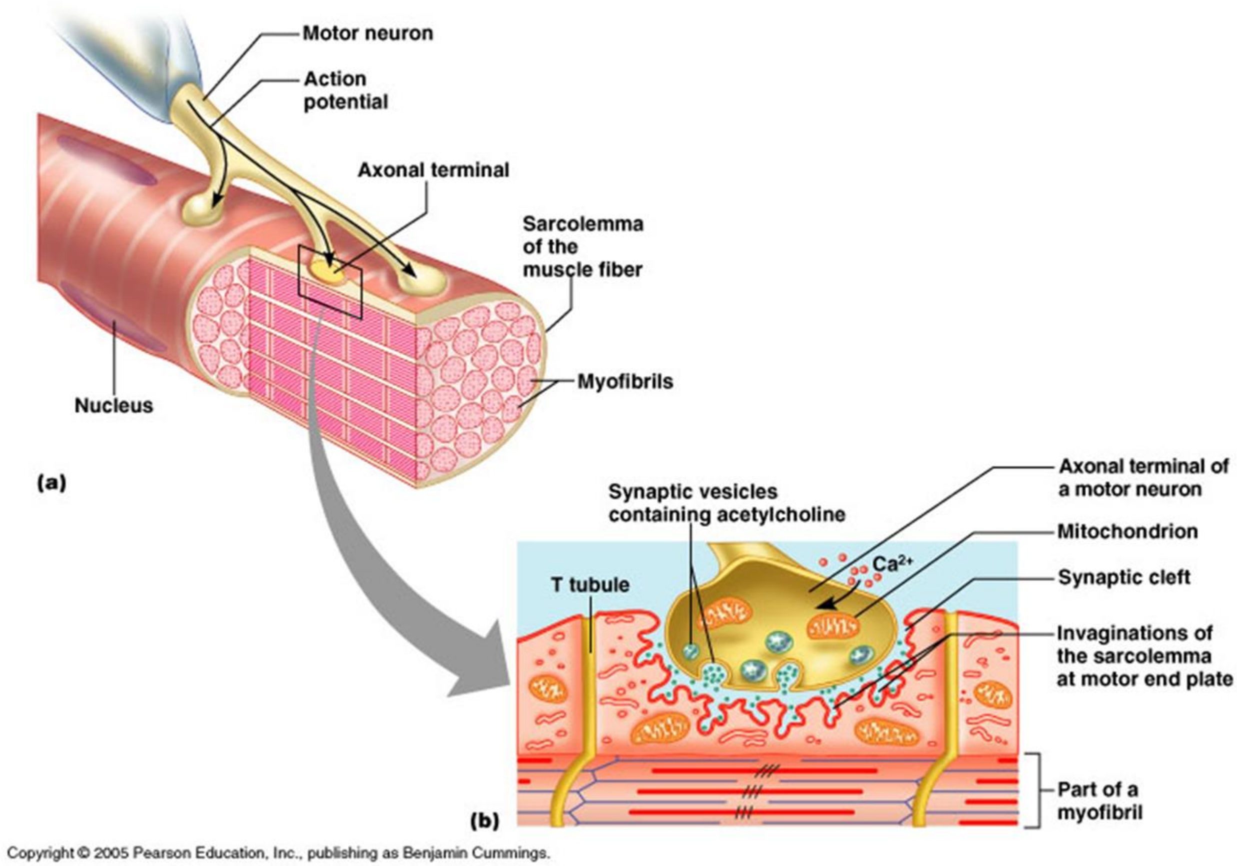


Sarcomere shortens because actin pulled towards its middle by myosin cross bridges

Titin resists overstretching

"A" band constant because it is caused by myosin, which doesn't change length


Thick (myosin) filament
Thin (actin) filament
Thin (actin) filament
Movement
Myosin head
Thick (myosin) filament
(a)
Thin (actin) filament
Myosin heads
Thick (myosin) filament
(b)



Types of skeletal muscle fibers

Fast, slow and intermediate
Whether or not they predominantly use oxygen to produce ATP (the energy molecule used in muscle contraction)
Oxidative – aerobic (use oxygen)
Glycolytic – make ATP by glycolysis (break down of sugars without oxygen=anaerobic)
Fast fibers: “white fibers” – large, predominantly anaerobic, fatigue rapidly (rely on glycogen reserves); most of the skeletal muscle fibers are fast
Slow fibers: “red fibers” – half the diameter, 3X slower, but can continue contracting; aerobic, more mitochondria, myoglobin

Intermediate: in betweenA skeletal muscle contracts when its motor units are stimulated
Amount of tension depends on
the frequency of stimulation
the number of motor units involved
Single, momentary contraction is called a muscle twitch
All or none principle: each muscle fiber either contracts completely or not at all
Amount of force: depends on how many motor units are activated
Muscle tone
Even at rest, some motor units are active: tense the muscle even though not causing movement: “resting tone
Muscle hypertrophy
Weight training (repeated intense workouts): increases diameter and strength of “fast” muscle fibers by increasing production of
Mitochondria
Actin and myosin protein
Myofilaments containing these contractile proteins
The myofibril organelles these myofilaments form
Fibers enlarge (hypertrophy) as number and size of myofibrils increase

[Muscle fibers (=muscle cells) don’t increase in number but increase in diameter producing large muscles]

Endurance training (aerobic): doesn’t produce hypertrophy

Muscle atrophy: loss of tone and mass from lack of stimulation
Muscle becomes smaller and weaker

Note on terminology: in general, increased size is hypertrophy; increased number of cells is hyperplasia

NERVOUS TISSUE

All living cells have the ability to react to stimuli. Nervous tissue is specialized to react to stimuli and to conduct impulses to various organs in the body which bring about a response to the stimulus. Nerve tissue (as in the brain, spinal cord and peripheral nerves that branch throughout the body) are all made up of specialized nerve cells called neurons. Neurons are easily stimulated and transmit impulses very rapidly. A nerve is made up of many nerve cell fibers (neurons) bound together by connective tissue. A sheath of dense connective tissue, the epineurium surrounds the nerve. This sheath penetrates the nerve to form the perineurium which surrounds bundles of nerve fibers. blood vessels of various sizes can be seen in the epineurium. The endoneurium, which consists of a thin layer of loose connective tissue, surrounds the individual nerve fibers.

Nervous tissue is the fourth basic tissue type of the body and is organized into two basic systems: the Central Nervous System (CNS) and the Peripheral Nervous System (PNS). The peripheral system responds to stimuli and sends impulses to the central system (brain and spinal cord). These impulses are interpreted by the CNS and then other impulses initiated in the CNS travel back through the PNS to effector organs to produce the proper response.

Nervous tissue : Contains specialized cells that conduct impulses conducting cells, called neurons, transmit impulses from one region of the body to another. No conducting cells, neuroglia, are a type of nervous system connective tissue.
Defined: The nervous system is the master controlling system of the body. It is designed to constantly and rapidly adjust and respond to stimuli the body receives. It includes the brain, cranial nerves, spinal cord, and associated peripheral nerves.

Properties of Neurons

Excitability (irritability): ability to respond to environmental changes or stimuli.
Conductivity: respond to stimuli by initiating electrical signals that travel quickly to other cells at distant locations.
Secretion: Upon arrival of the impulse at a distant location the neuron usually secretes a chemical neurotransmitter at a synapse that crosses the synaptic gap and stimulates the next cell.

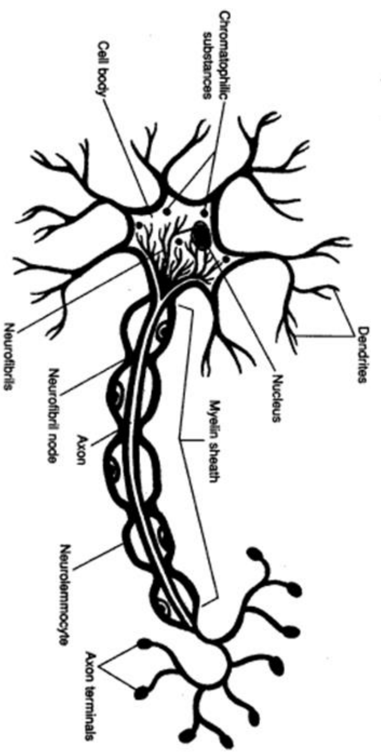
Functions of Nerve Tissue

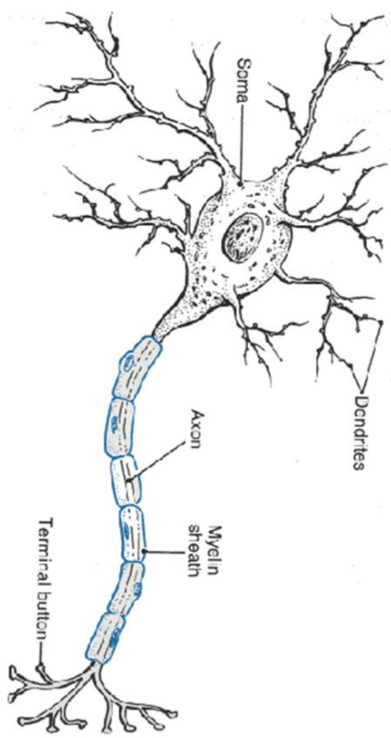
Nervous tissue allows an organism to sense stimuli in both the internal and external environment. The stimuli are analyzed and integrated to provide appropriate, co-ordinated responses in various organs.
The afferent or sensory neurons conduct nerve impulses from the sense organs and receptors to the central nervous system.
Internuncial or connector neurons supply the connection between the afferent and efferent neurons as well as different parts of the central nervous system.
Efferent or somatic motor neurons transmit the impulse from the central nervous system to a muscle (the effector organ) which then react to the initial stimulus.
Autonomic motor or efferent neurons transmit impulses to the involuntary muscles and glands.
The Nervous system has three major functions:
Sensory – monitors internal & external environment through presence of receptors

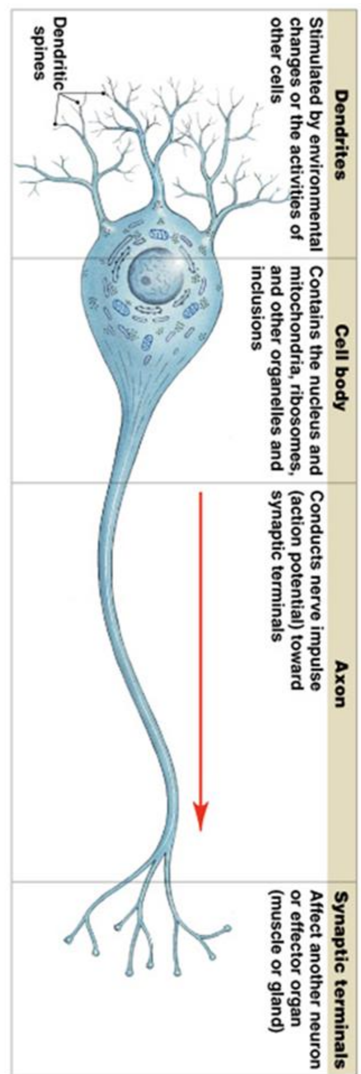
Integration – interpretation of sensory information (information processing); complex (higher order) functions

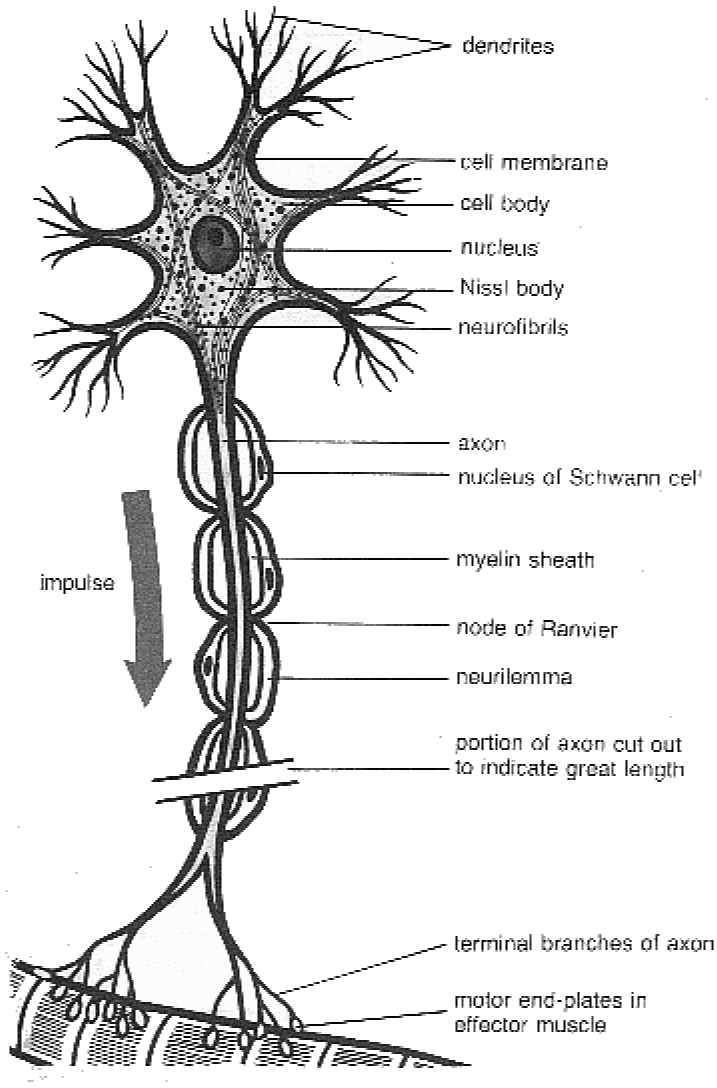
Motor – response to information processed through stimulation of effectors

The basic cell of the nervous system is called a neuron. Structurally, a neuron consists of: the cell body, containing the nucleus and synthetic organelles; the axon, a long cytoplasmic process associated with the cell body used to communicate with target organs; and the dendrites, shorter cytoplasmic processes off the cell body used to communicate between neurons.









Structure of a Motor Neuron

A motor neuron has many processes (cytoplasmic extensions), called dendtrites, which enter a large, grey cell body at one end. A single process, the axon, leaves at the other end, extending towards the dendrites of the next neuron or to form a motor endplate in a muscle. Dendrites are usually short and divided while the axons are very long and does not branched freely. The impulses are transmitted through the motor neuron in one direction, i.e. into the cell body by the dendrites and away from the cell body by the axon . The cell body is enclosed by a cell (plasma) membrane and has a central nucleus. Granules, called Nissl, bodies are found in the cytoplasm of the cell body. Within the cell body, extremely fine neurofibrils extend from the dendrites into the axon. The axon is surrounded by the myelin sheath, which forms a whitish, non-cellular, fatty layer around the axon. Outside the myelin sheath is a cellular layer called the neurilemma or sheath of Schwann cells. The myelin sheath together with the neurilemma is also known as the medullary sheath. This medullary sheath is interrupted at intervals by the nodes of Ranvier.

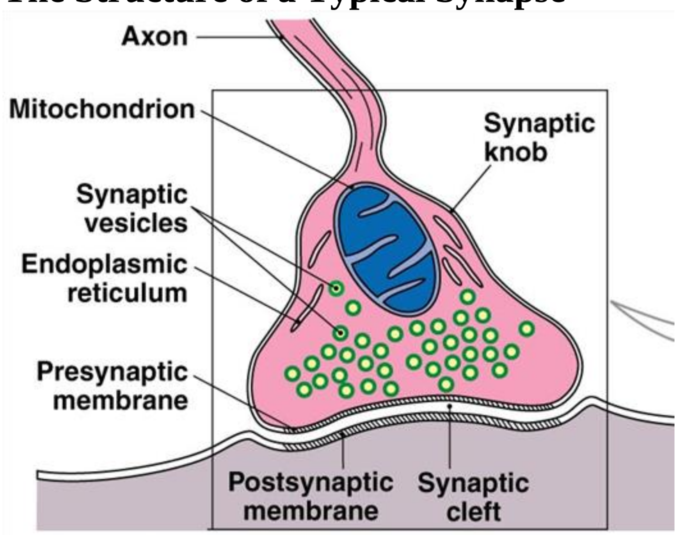
Nerve cells are functionally connected to each other at a junction known as a synapse, where the terminal branches of an axon and the dendrites of another neuron lie in close proximity to each other but never make direct contact.

Conduction across synapses

In order for neural control to occur, "information" must not only be conducted along nerve cells, but must also be transferred from one nerve cell to another across a synapse

Most synapses within the nervous system are chemical synapses, & involve the release of a neurotransmitter

The Structure of a Typical Synapse



Although the system forms a unit it can be divided into the following parts: the central nervous system (CNS) which consists of the brain and spinal cord, the nervous system consists of the nerves outside the CNS which connect the brain and spinal cord to the organs and muscles of the body and the automatic or involuntary nervous system consists of nerve centres and fibres inside as well as outside the central nervous system.

Spinal Cord

The spinal cord is composed of grey and white matter (Spinal Cord 1). The grey matter is composed of nerve cell bodies and in a cross-sectional cut appears as a darker stained "H"-like central area. The white matter, composed entirely of axonal projections, surrounds the grey matter and is lighter staining (Spinal Cord 2).

Brain

Like the spinal cord, the brain is composed of areas of grey and white matter. In some areas an addition outer gray layer is present. We will study two regions of the brain, in which this additional grey matter has a distinct morphology.

Cerebellar Cortex

This portion of the brain's gray matter is arranged into three layers (Cerebellar Cortex 1): (1) the superficial molecular layer containing mostly unmyelinated axons and few cell bodies; (2) a deeper layer of large flask-shaped cells called Purkinje cells (Cerebellar Cortex 2); and (3) an inner granular layer containing many small cell bodies. The purkinje cells send long dendritic projections into the molecular layer (Cerebellar Cortex 3). In total, the cerebral cortex consists of six layers with the inner most three represented by an inner granular layer, internal pyramidal layer, and polymorphic cell layer, the innermost layer containing cell bodies of many shapes.

The Meninges - Connective Coverings of the Brain

The brain is enclosed in three layers of connective tissue. The outer most (dura mater) consists of dense connective tissue. Underlying the dura is the arachnoid layer, often described as a "roof with pillars" made of dense connective tissue. Spaces within the arachnoid are filled with cerebrospinal fluid. The inner most layer, the pia mater, consists of loose connective tissue on the surface of the brain and lining channels which penetrate the brain carrying the vascular system (Pia Mater).

Glial Cells

Regular connective tissue types surround the components of the central nervous system, but they are not found within the tissue. The glial cells, derived from neuroectoderm, serve roles of connective tissue within the CNS tissue. Three types are found: (1) microglia, which represent macrophages of the CNS; (2) oligodendrocytes, which myelinate the axons within the CNS; and (3) astrocytes, which are a fibroblast-like supportive cell (Astrocytes). These cells are characterized as fibrous astrocytes with unbranched processes and protoplasmic astrocytes with branched processes.

Choroid plexus

The choroid plexus produces the cerebrospinal fluid. It consists of a small tuft of capillaries surrounded by epithelium which "hangs" in the brain ventricles (Choroid Plexus 1). The capillaries are covered by a layer of simple cuboidal epithelium, the ependymal cells, which also surround the ventricular space (Choroid Plexus 2).

Peripheral Nervous System

Nerve Fibers

Axonal projections travel in bundles through the body. These bundles are encapsulated in fibro connective tissue in a manner similar to that seen in muscle tissue. Entire nerve bundles are surrounded by the epineurium (Nerve Bundle 1). Branching from the epineurium and dividing the nerve bundle into fascicles is the perineurium (Nerve Bundle 2). Finally each individual axon is surrounded by the endoneurium (Nerve Bundle 3).

Ganglions

Usually more than one nerve is needed to reach from the CNS to or from the peripheral effector organs. These chains of nerve fibers interconnect in structures called ganglions (Ganglion 1). Within the ganglion very large cells are visible. These are the cell bodies of the neurons (Ganglion 2). Within the cell body you should be able to see the Nissl substance, an accumulation of the basophilic stain of ribosomes (Ganglion 3). The cell bodies are supported by small surrounding cells called capsule cells or amphicytes. Between this arrangement, you will find a number of bundles of axonal projections. Ganglions of the sympathetic system (Ganglion 4) are easily distinguished from others by the presence of lipofuscin pigment within the cytoplasm of the cell bodies (Ganglion).

Nervous tissues

There are three main types of neurons, which are classified according their function: Those that conduct impulses from the sensory organs to the central nervous system (brain and spinal cord) are called sensory (or afferent) neurons; those that conduct impulses from the central nervous system to the effector organs (such as muscles and glands) are called motor (or efferent) neurons. Interneurons (also known as connector neurons or association neurons) are those that connect sensory neurons to motor neurons.

Functional Classes of Neurons

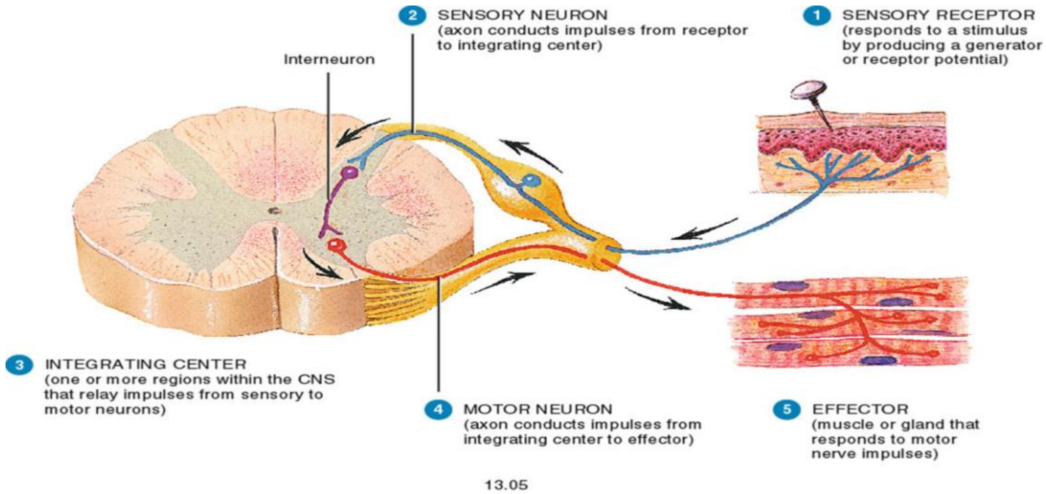
Sensory (afferent) neurons – afferent neurons are specialized to detect stimuli and transmit the information to CNS. They begin in any organ in the body, but end in the brain or spinal cord.

Interneuron (association neurons): lie entirely in the CNS. They receive signals from many different neurons and perform an integrative function “decision making” to respond to the different stimuli.

Motor (efferent) neurons – efferent neurons transmit the appropriate response from the interneuron to an end organ (muscle and gland cells) to carry out the body's response to the stimuli.

Astrocytes
create supportive framework for neurons
create "blood-brain barrier"
monitor & regulate interstitial fluid surrounding neurons
secrete chemicals for embryological neuron formation
stimulate the formation of scar tissue secondary to CNS injury
Oligodendrocytes
create myelin sheath around axons of neurons in the CNS. Myelinated axons transmit impulses faster than unmyelinated axons
Microglia
"brain macrophages"
phagocytize cellular wastes & pathogens

Ependymal cells
line ventricles of brain & central canal of spinal cord
produce, monitor & help circulate CSF (cerebrospinal fluid
Schwann cells
surround all axons of neurons in the PNS creating a neurilemma around them. Neurilemma allows for potential regeneration of damaged axons
creates myelin sheath around most axons of PNS
Satellite cells
support groups of cell bodies of neurons within ganglia of the PNS
Most axons of the nervous system are surrounded by a myelin sheath (myelinated axons)
The presence of myelin speeds up the transmission of action potentials along the axon
Myelin will get laid down in segments (internodes) along the axon, leaving unmyelinated gaps known as "nodes of Ranvier"
Regions of the nervous system containing groupings of myelinated axons make up the "white matter"
"gray matter" is mainly comprised of groups of neuron cell bodies, dendrites & synapses (connections between neurons)



Organization of the Nervous System

Two main divisions:

The Central Nervous System (CNS)

- Consists of the brain and spinal cord with tracts and nuclei

Nucleus = a collection of nerve cell bodies in the CNS.

Tract = bundle of nerve fibers within the CNS

The Peripheral Nervous System (PNS)

-Consists of ganglia, cranial nerves, spinal nerves and peripheral receptors

Ganglia = a collection of nerve cell bodies in the PNS

Nerve = bundle of nerve fibers in the PNS

Classification of neurons

Structural classification based on number of processes coming off of the cell body:

Anaxonic neurons

no anatomical clues to determine axons from dendrites functions unknown

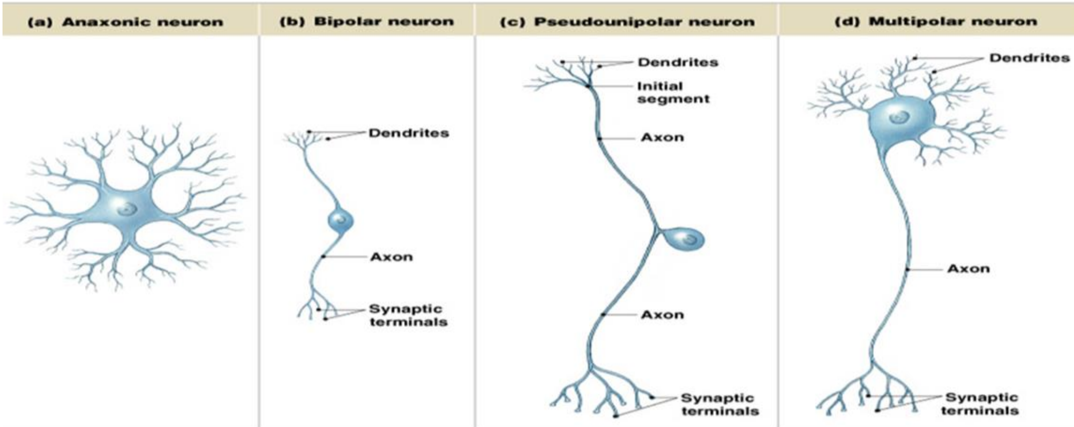
Unipolar Neurons. Sensory neurons have only a single process or fibre which divides close to the cell body into two main branches (axon and dendrite). Because of their structure they are often referred to as unipolar neurons.

Multipolar Neurons.

Motor neurons, which have numerous cell processes (an axon and many dendrites) are often referred to as multipolar neurons. Interneurons are also multipolar.

Bipolar Neurons.

Bipolar neurons are spindle-shaped, with a dendrite at one end and an axon at the other . An example can be found in the light-sensitive retina of the eye.



A diagram showing the different neurons

Classification of neurons
Functional classification based on type of information & direction of information transmission:
Sensory (afferent) neurons –
transmit sensory information from receptors of PNS towards the CNS
most sensory neurons are unipolar, a few are bipolar
Motor (efferent) neurons –
transmit motor information from the CNS to effectors (muscles/glands/adipose tissue) in the periphery of the body
all are multipolar
Association (interneurons) –
transmit information between neurons within the CNS; analyze inputs, coordinate outputs
are the most common type of neuron (20 billion)
are all multipolar
Neurons of the nervous system tend to group together into organized bundles

The axons of neurons are bundled together to form nerves in the PNS & tracts/pathways in the CNS. Most axons are myelinated so these structures will be part of "white matter"
The cell bodies of neurons are clustered together into ganglia in the PNS & nuclei/centers in the CNS. These are unmyelinated structures and will be part of "gray matter"

Reflexes

- Automatic responses to stimuli, i.e knee-jerk
- 5 main components
  - **Sensory receptor**
  - **Sensory neuron**
  - **Integration center**
  - **Motor neuron**
  - **Effector cells**