Epithelial tissue (epithelium)

General characteristics of epithelium

- Is avascular tissue (without blood supply – cells receive nourishment by diffusion from a highly vascular area of loose connective tissue just below the basement membrane called the **lamina propria**)
- is highly cellular tissue – cells are arranged to form cohesive sheet or groups with no or little extracellular matrix
- displays a free surface – usualy luminal surface (turned to the lumen)
- opposite (basal) surface adheres to extracellular basement membrane or lamina basalis
- epithelial cells display polarity – apical (luminal), lateral and basal surfaces with structural specialization
- epithelial cells are specialised for absorption, secretion or to act as barrier
- lateral surfaces display junctional complexes for intercellular cohesion and communication

One type of epithelium may change into another type – metaplasia (*examples: pseudostratified ep. of respiratory passages transforms into stratified squamous ep. on the surface of epiglottis and soft palate*)

Membrane specializations of epithelia

Lateral surface

Specialised structures are present in epithelia which link individual cells together. Two main adhesion types are distinguished:

1. Cell membrane proteins acting as specialised cell adhesion molecules (CAMs)
2. Specialised areas of the cell membrane incorporated into cell junctions.

Three types are recognized: occluding junctions, anchoring or adherence junctions and communicating junctions.

- Occluding junctions bind cell together to form an impermeable barrier
  - **Zonula occludens** or tight junction
- Anchoring junctions link the cytoskeleton of cells to each other and two underlying tissues
  - **Zonula adherens** provides mechanical strength
  - Macula adherens or **desmosomes** provides mechanical strength in tissues where there are tensile or shearing stresses, eg skin
- Communications junctions allow direct cell-cell communication
  - Gap junction or **nexus** allow rapid communication for coordinated action

Luminal (free, apical) surface

- **Microvilli** – short finger-like projection of the cell membrane to increased surface area (regularly arranged microvilli in intestines – **striated border**, in kidney tubules – **brush border**)
- **Cilia** – hair-like surface projections of cells involved in transport
- Glycocalyx – thin extracellular layer consisting of protein glycoprotein and sugar residues; stains PAS positive; can act as enzyme, CAM or for cell recognition

Basal surface

Basal invaginations or folds – greatly enhance surface area; folded membrane with ions pumps + mitochondria form **basal labyrinth** in kidney tubules.

Basal lamina – basement membrane

Epithelial tissues are physically separated from underlying connective tissues by a **basement membrane** or basal lamina. The portion of an epithelial cell attached to the basement membrane is called its basal surface. The opposite side - facing the external environment, or lumen of a body cavity, is its apical surface. Basement membranes are composed of a special type of collagen and a substance called laminin (see below). The basement membrane helps epithelial cells orient themselves in relation to other tissues. After epithelial injury (e.g., an abrasion), the basement membrane serves as a scaffolding upon which new cells attach themselves during healing.

Cassification of epithelia

I. surface epithelium – is 1 or more layers of cells arranged into sheet;

	According to number of layers	According to shape of cells in the outermost layer
SURFACE EPITHELIUM	⇨ simple layerd	– squamous
		– cuboid
		– columnar
		– pseudostratified columnar
	⇨ stratified	– squamous non-cornified (non-keratinized)
		– squamous cornified (keratinized)
		– columnar
		– transitional

SIMPLE EPITHELIA – **only 1 (single) layer on basement membrane**

Squamous – single layer of flattened thin cells with little cytoplasm and prominent nucleus. (In the smallest tubules and ducts of different organs, Henle´s loop or Bowman´s capsule in kidney) Endothelium – squamous epithelium in cardiovascular system. Mesothelium - squamous epithelium of mesodermal origin lining serous membranes and cavities.

Cuboidal - cell height, width and depth are the same, round centrally placed nucleus. (In renal tubules and small glanular ducts)

Columnar - cell height greater than width, nucleus elliptical or cigar shaped. (In the intestines, in the oviduct)

Pseudostratified – **single layer** but nuclei situated at different levels in the cell. All cells are in contact with the basement membrane, but not all cells reach the apical surface. Both conditions create the illusion of several cell layers. (In the respiratory passages – nasal cavity, larynx, trachea, bronchi)

STRATIFIED EPITHELIUM – consists of basal layer on basement membrane, several layers of polyhedral cells and surface layer. According to the shape of cells in this layer the epithelium is named (squamous, columnar, transitional)

Stratified squamous – resiting to mechanical influences (press)
– non-keratinised (mouth cavity, vocal cords, vagina, anus)
– keratinised (epidermis of the skin) – the cells are released continously from the surface

Stratified columnar – 2 or more layers of cells, columnar cells form the upper layer (two-layered in ductus epididymis and ductus deferens, more-layered male urethra, conjunctive)

Transitional - stratified, top layer dome or umbrella shaped. (only in some urinary passages – renal pelvis, ureter and urinary bladder). Epithelium change the shape of cells and number of layers according to wall conditions of urinary passages – distansion or contraction

Epithelia with special functions:
resorptive, sensory, respiratory, myoepithelial cells

glandular epithelium – multicellular epithelial structures that specialize in synthesizing and secreting complex molecules.

CLASSIFICATION OF GLANDS

GLANDULAR EPITHELIUM	⇨ unicellular	Single cells in coverinrg epithelium – (Paneth cells, goblet cells, enteroendocrine cells, Leydig cells)
	⇨ multicellular	Accordin of mechanism of secretion endocrine exocrine – merocrine, apokrine,holocrine According to loclalization intraepithelial ⇔ extraepithelial According to arrangement of ducts simple ⇔ branched ⇔ compound According to type of secretory portions tubular⇔alveolar (acinar)⇔tuboalveolar According to product properties mucous ⇔ serous ⇔ mixed

According of mechanism of secretion

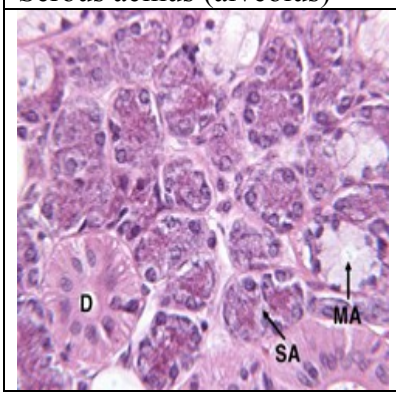
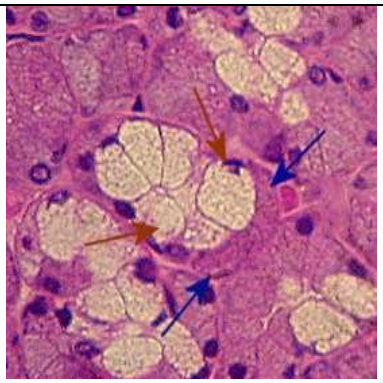
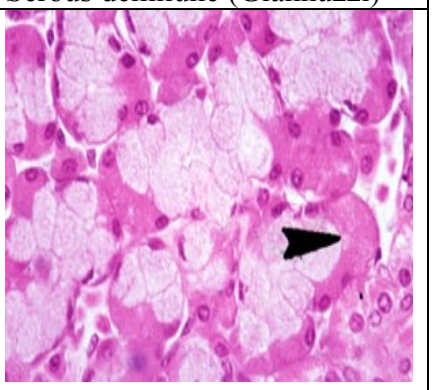
endocrine – glands withou ducts, product is released into the blood through the wall of capilareis
exocrine – secretory cells of exocrine glands release their products into ducts in three different ways:

merocrine	apocrine	holocrine
- membrane-bound secretory granules are moved to the apical surface where they coalesce with the membrane on to release the product.	- the apical portions of cells are pinched off and lost during the secretory process.	- secretory cell degenerates and as it breaks apart, the contents of the cell become the secretory product.

According to

type of secretory units	to product properties	simple	branched	compound
tubular	are usually mucous			
alveolar (acinar)	are usually serous			
tuboalveolar	mixed			

Secretory units

Serous acinus (alveolus)	Mucous tubule	Serous demilune (Giannuzzi)
		

Functions of epithelia:

- **Barrier:** Epithelial tissue commonly functions as a covering or lining for organs and other tissues (e.g., skin, mucous membranes, pleural cavity, etc.). Epithelial cells serve as selective barriers between the environment and the internal structures of the body. They protect underlying tissues from drying, and from mechanical and chemical injury. Tight junctions between individual cells play an important role in the barrier function of epithelium. Some barrier epithelial cells have motile **cilia** that propel fluid or particulate matter over tissue surfaces (e.g., cells lining the bronchi).
- **Absorption:** Epithelial cells are found in those organs (e.g., intestine) which are involved in absorption of substances important for life. These cells often **microvilli** which increase cell surface area in order to facilitate absorption.
-
- **Secretion:** The secretory cells of endocrine and exocrine glands are epithelia.

- **Sensory:** Many of the more complex sensory receptors of the nervous system are derived from specialized epithelia called neuroepithelia (e.g., the rods and cones of the retina, olfactory receptors of the nose, taste receptors on the tongue, etc.). Sensory receptors function by converting mechanical, chemical, or electromagnetic signals from the environment into nerve impulses which can be processed by the nervous system.
- **Contractility:** Some very specialized epithelial cells (myoepithelia) contain the contractile proteins myosin and actin similar to muscle. Myoepithelia are associated with the ducts of sweat, salivary, lacrimal, amd mammary glands and assist in the secretory process.

Origin: Epithelial tissues are derived from all three primary germ cell layers.

- **Ectoderm:** The epithelial cells of the skin and oral cavity (epidermis) are derived from ectoderm. Epithelial cells covering the cornea and lens, as well as sensory receptors of the eyes, ears, and nose, are also ectodermal in origin.
- **Mesoderm:** The epithelial lining of blood vessels (endothelium) is derived from mesoderm. The epithelial lining of the pleural and peritoneal cavities (mesothelium) also originate from mesodermal cells.
- **Endoderm:** The epithelial lining of the respiratory system and digestive tracts - as well as the functional cells (parenchyma) of the liver, pancreas, gallbladder, thyroid, and parathyroid, are derived from endoderm.

Muscle Tissue

Muscle tissue is characterized on the basis of a functional property:

- the ability of muscle cells to contract.
- the bulk of the cytoplasmic volume consists of the contractile protein filaments **actin** and **myosin**.
- muscle is responsible for movement of the body and changes in the size and shape of internal organs.

Three types of muscle tissue can be identified histologically:

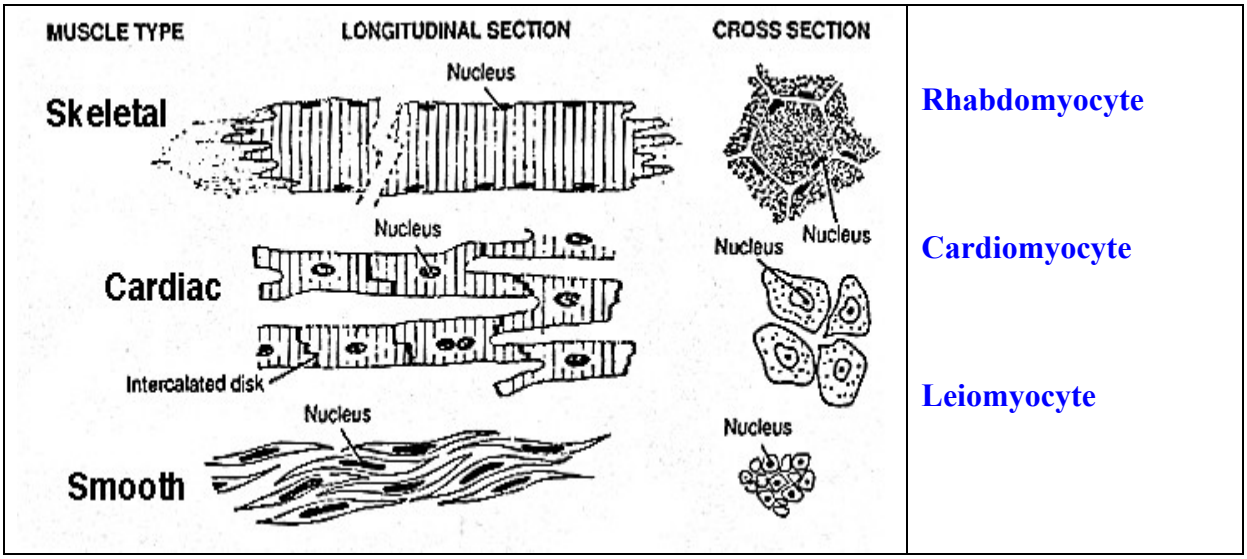
- **skeletal muscle**
- **cardiac muscle**
- **smooth muscle**

The fibres of skeletal muscle and cardiomyocytes (cells of cardiac muscle) exhibit cross striations at the light microscope level and they are both referred to as striated muscle.

Terms:
Plasmamembrane of muscle cells – **sarcolemma**
Cytoplasm of muscle cells – **sarcoplasm**
Smooth endoplasmic reticulum – **sarcoplasmic reticulum**

Muscles consist of muscle cells and connective tissue:

Muscle cells



Connective tissue

Connective tissue surrounds muscle fibres. Individual muscle fibres are surrounded by a delicate layer of reticular fibres called the **endomysium**. Groups of fibres are bundled into fascicles by a thicker CT layer called the **perimysium**. The collection of fascicles that constitutes one muscle is surrounded by a sheath of dense CT called the **epimysium**, which continues into the tendon. Blood vessels and nerves are found in the CT associated with muscle. The endomysium contains only capillaries and the finest nerve branches. **All three layers merge together at end of a gross muscle to form a tendon.**

Three basic layers

- **endomysium - surrounds each cell (fiber)**
- **perimysium - surrounds a group of cells forms a fascicle**
- **epimysium - surrounds entire gross muscle**

Endomysium

- thin delicate connective tissue
- blends with muscle cell membrane

Perimysium

- ordinary loose connective tissue
- divides groups of muscle cells into bundles within the gross muscle

Epimysium

- capsule = dense irregular connective tissue

I. Skeletal Muscle

General Features

- Called skeletal muscles or somatic (body) musculature
- Rapid contractions
- Voluntary innervation
- Striations visible with light microscope (LM)

Skeletal muscle is attached to the skeleton and controls motor movements and posture. There are a few instances where this type of muscle is restricted to soft tissues: the tongue, pharynx, diaphragm and upper part of the esophagus.

Skeletal muscle fiber structure

Striated skeletal muscle cells = **muscle fibers** = a multinucleated **syncytium** formed by the fusion of individual small muscle cells precursors – myoblasts, during development.

- Striated skeletal muscle cell = **fiber** (syncytium)
- Cylindrical with tapered ends
- Length – several cm, thickness - about 10-100 µm in diameter

- Multinucleated – nuclei are located peripherally, immediately under the plasma membrane (sarcolemma)
- Striations - alternating light and dark bands - visible with LM

A part of sarcoplasm of muscle fiber:

Sarcolemma with invaginations: T-tubules.
Sarcoplasm: nuclei, small GA, mitochondria, glycogen; sarcoplasmic reticulum network surrounds myofibrils and arround Z-lines forms terminal cisternae.
T-tubule + 2 terminal cisternae = **TRIAD at the level of Z-line**

The sarcoplasm of striated **muscle fiber** contains longitudinally arrayed **myofibrils** which are made up of the **myofilaments: myosin** (thick myofilaments) and **actin** (thin myofilaments).

The striations reflect the arrangement of actin and myosin myofilaments into contractile units. The individual contractile units are called **sarcomeres**. Each myofibril consists of many sarcomeres arranged end to end. The entire muscle exhibits cross-striations because sarcomeres in adjacent myofibrils and muscle fibers are in register. The most obvious feature in longitudinal sections of skeletal muscle is the alternating pattern of dark and light bands, called respectively the **A (anisotropic)** and **I (isotropic) band**. The I band is bisected by a dense zone called the Z line, to which the thin **actin filaments** of the I band are attached.

- Myofibrils - tubular arrangement within cells - Thick myofilaments = Myosin - contractile protein - Thin myofilaments = Actin - contractile protein - Intermediate filaments = Z line - structural proteins - Myofilaments align in overlapping arrangement Dark = **A band** area with of overlap myosin and actin; **H zone** = in the middle of A band with no actin overlap Light = **I band** - primarily actin **Z line** - structural protein holding actin at I band **Sarcomere** = area between two Z lines - the contractile unit	

II. Cardiacl Muscle

General Features

- Wall of heart
- Contracts rapidly
- Autonomic (involuntary) innervation - cardiac muscle is regulated by autonomic and hormonal stimuli
- Lacks residual stem cells and therefore cannot regenerate after damage
- Cardiac muscle exhibits striations because it also has actin and myosin myofilaments arranged into sarcomeres. Generally these striations do not appear as well-defined as in skeletal muscle.

Cardiac muscle cells = cardiomyocytes

- Cells are columnar, the end(s) can be branched -Cells are end-to-end arranged into fibers - Fibers branch and anastomose - Moderate length, about 100 µm - Moderate diameter, 10-50 µm - Striation is present and visible with LM - Single nucleus (rarely 2 nuclei) - centrally placed - Intercalated discs join ends of cells together – desmosomes and gap junctions (nexuses)	

A number of features distinguish cardiac from skeletal muscle:
- cardiac muscle cells have only one or two nuclei, which are centrally located
- myofibrils separate to pass around the nucleus, leaving a perinuclear clear area
- 1 T-tubule + **1** terminal cisterna of sarcoplasmic reticulum = **DIAD et the level of border between A and I band**, there are no triads (1 T-tubule – 2 cisternae) as in skeletal muscle fibers

As in skeletal muscle, individual muscle fibres are surrounded by delicate connective tissue. Numerous capillaries of coronary circulation are found in the connective tissue around cardiac muscle fibres.

Cardiac muscle cells are joined to one another in a linear array. The boundary between two cells abutting one another is called an **intercalated disc**. Intercalated discs consist of several types of cells junctions whose purpose is to facilitate the passage of an electrical impulse from cell to cell and to keep the cells bound together during constant contractile activity.

Specialized fibres, called **Purkinje fibres**, arise from the atrioventricular node and travel along the interventricular septum toward the apex of the heart, sending branches into the ventricular tissue. Purkinje fibres are of larger diameter than ordinary cardiac fibres, with fewer myofibrils and an extensive, well-defined clear area around the nucleus. They conduct impulses at a rate about four times faster than that of ordinary cardiac fibres and serve to coordinate the contraction of the atria and ventricles.

III. Smooth Muscle

General Features

- Walls of hollow viscera
- Contracts slowly
    - often prolonged sustained contractions
- Autonomic (involuntary) innervation

Smooth muscle is the intrinsic muscle of the internal organs and blood vessels. It is also found in the iris and ciliary body of the eye and associated with hair follicles (arrector pili). **No striations** are present in smooth muscle due to the different arrangement of actin and myosin filaments. Like cardiac muscle, smooth muscle fibres are intrinsically contractile but responsive to autonomic and hormonal stimuli. They are specialized for slow, prolonged contraction.

Each csll is fusiform in shape with a thicker central portion and tapered at both ends. The single nucleus is located in the central part of the cell. Cells range enormously in size, from 20 (in wall of small blood vessels) to 500 (in wall of uterus during pregnancy) micrometers. Smooth muscle cells lie over one another in a staggered fashion (tapered part of one cell over thicker part of another).

One distinguishing physiological feature of smooth muscle is its ability to secrete connective tissue matrix. In the walls of blood vessels and the uterus in particular, smooth muscle fibres secrete large amounts of collagen and elastin.

Smooth muscle cells = leiomyocytes

- Spindle shape cells - elongated and tapered - Moderate length - about 100-200 µm - Thin diameter - about 5-10 µm - Single nucleus - centrally placed - NO striations – aktin and myosin myofilaments are not arranged into	

myofibrils, aktin filaments are attached to darc bodies (analogic to Z-lines) - Cells are typically arranged in bundles or sheets - intercellular junctions: desmosomes, nexuses	

Mechanism of contraction of striated muscles

The **sarcoplasmic reticulum (SR)**, a specialized form of the smooth endoplasmic reticulum, is system of structurally and functionally specialized for the rapid release of calcium ions under appropriate conditions. **SR** forms a network of tubules and cisternae around the myofibrils. Flattened cisternae also called terminal cisternae, are in contact with an invagination of the sarcomalemma called the Transverse tubule. The T-tubule and two adjacent terminal cisternae constitute a **triad** which lie over the middle of the I-band (at the Z-line) in skeletal muscle, while T-tubule and one terminal cisterna form **diad** at the border between I and A band in cardiac muscle.

The wave of depolarization conducted along the sarcolemma and to the interior of the fiber by the T-tubule causes the **SA** to release calcium ions, which can then diffuse among the myofilaments and initiate contraction by binding to troponin. This binding then causes the tropomyosin to change its association with actin so as to expose reactive sites capable of interacting with myosin heads. The myosin and actin filaments of a sarcomere overlap with the same relative polarity on either side of the midline. The actin filaments are anchored to the Z disc and the myosin filaments are bipolar. During contraction, the actin and myosin filaments slide past each other without shortening. The sliding motion is driven by the myosin heads walking toward the actin filament. All sarcomeres in myofibrils are shortened (distance between Z-lines shortens) during contraction.

The contraction needs energy (ADP → ATP, glycogen).

After contraction, the calcium moves back into the cisternae of the sarcoplasmic reticulum. Tropomyosin then covers the reactive sites on the actin myofilaments (blocks the actin site) and relaxation occurs.

Nervous Tissue (NT)

- highly specialized tissue
- forms, receives and sorts signals (irritability)
- transmits electrical impulses (conductivity)

Functions of Nerve Tissue

- Nervous tissue *allows an organism to sense stimuli in both the internal and external environment*.
- The stimuli are *analysed 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*.

- NT forms central and peripheral nerve system (CNS and PNS)
- NT consists of nerve cells = **NEURONS** and associated supporting cells = **NEUROGLIA;** neurons are specifically designed to transmit electrical impulses and to receive and process information; neuroglial cells are non-conducting cells that are in intimate physical contact with neurons. They provide physical support, electrical insulation and metabolic exchange with the vascular system.
- NT originates from ectoderm

NEURON

Nerve cells are very variable in appearance, shape and size, but all neurons have a cell body, also called soma or **perikarion**, and processes extending from the nerve cell to communicate with other cells. There are two types of processes: **dendrites** that receive impulses and **axons (neurits)** that transmit impulses. All nerve cells have one axon, which is usually the longest process that extends from the cell and one or more (hundreds) dendrites, these are generally shorter and thicker than the axon. The junction where a nerve cell communicates with another nerve cell or an effector cell (eg. muscle fibre) is called a **synapse,** which can be chemical or electric. The terminal part of the axon with chemical synapses releases substances called a **neurotransmitter** which acts on the membrane of the other cell.

Cell body – PERIKARION: contains nucleus and most cytoplasm with organelles:

- nucleus – round or oval, very light, with prominent nucleolus
- rough ER (called Nissl´ substance) – involved in synthesis of proteins (neurotransmitters)
- other usual organelles (mitochondria, Golgi apparatus, lysosomes)
- neurofibrils – neurofilaments and neurotubules
- pigment lipofuscin

DENDRITES – input structure – receive signals; number of dendrites: one – several hundreds

- short, branched processes with structure similar to perikarion (cytoplasm + organelles + neurofibrils)
- incoming signals summate to initiate action potential highly branched tree structure

Classification of neurons according to number of processes (dendrites):

1. Multipolar neuron – several dendrites extend from body found in brain & spinal cord
2. Bipolar neuron – one dendrite and one axon (in retina of eye)
3. Unipolar neuron – one process only, link to axon (sensory neurons)
4. Pseudounipolar neuron – one short process divides later into dendrite and axon (spinal ganglia)

AXON **– only one**

- no protein synthesis here
- Trigger zone - where nerve impulses arise
- Axon hillock – the cone-shaped base of the axon, its cytoplasm is free of rER (Nissl substance)
- Axons terminal - end with fine branching with „terminal boutons“ – mitochondria and synaptic vesicles containing neurotransmitters
- Axon hillock and terminal are not covered with oligodendrocytes (in CNS) or Schwann cells (in PNS)
- Serves for impulses transmission and for axonal transport of neurotransmitters and nutrients

Classification of neurons according to length of axon:

1. Golgi type I – long axon (up to 1 m) – somatic motor neurons
2. Golgi type II - short axon (in μm)

Classification of neurons according to function:

1. sensitive neurons – (afferent) conduct informations from receptors to CNS
2. motor neurons – (efferent) conduct infirmations from CNS to effector cells: somatomotor to skeletal muscle and visceromotor to smooth muscle cells, cardiomyocytes or glandular cells
3. interneurons (97 %)

Sheaths of axons:

Schwann sheath (neurilemma) – Schwann cells surround the axon (gray fibers) **Myelin sheath** – lipoprotein product of Schwann cells in PNS and oligodendrocytes in CNS - electrically insulates axon - inreases speed of nerve impulse - wraps around one axon many times and has a lamellar appearance	

Many axons are wrapped in a lipid-rich covering called **myelin**. This myelin sheath insulates the axon from the surrounding extracellular component and increases the rate of electrical conduction. The myelin sheath is discontinuous at intervals called the **nodes of Ranvier**. The area covered with myelin is called **internodal area (internodium)**. In myelinated axons, the voltage reversal (that is, the impulse propagation) can occur only at the nodes, and the impulse "jumps" from node to node. This is called **saltatory conduction**. In unmyelinated axons, the impulse is conducted more slowly, moving as a wave of voltage reversal along the axon.

Synapses

- NEURON – NEURON

- Presynaptic neuron - conducts signal to a synapse // synaptic vesicles with neurotransmiter
- Synaptic cleft (20-30 nm thick)
- Postsynaptic neuron - conducts signal from a synapse // receptors on cell membrane

- Axodendritic (1) - Axosomatic (2) - Axoaxonal (3) - Dendrodendritic synapses	

- NEURON – EFFECTOR CELL

Effector cells – muscle cells (in smooth muscle = **neuromuscular spindle**, in skeletal muscle = **motor-end-plate**), cardiomyocytes, glandular cells

Chemical Synapses

- Presynaptic cell releases neurotransmitters from synaptic vesicles
- Act on the postsynaptic cell (help initiate AP)
- Neurotransmitters can excite or inhibit
- Neurotransmitters (acetylcholine, serotonin, norepinepherine and epinephrin, dopamine, GABA, …)

- Neurotransmiter must be removed to prevent continual firing of neurons
- Enzymatically - acetylcholineresterase
- Many pharmaceuticals and drugs modulate this effect
- Cocaine block removal of dopamine

Electrical Synapses

- Without synaptic vesicles; synaptic cleft – only 2 nm thick
- Depolarizating wave continues from presynaptic to postsynaptic membrane
- Morphologically (in electron microscope) it looks like communicatin intercellular connection: gap junction (nexus)

SUPPORT CELLS PLAY A VITAL ROLE

Support cells are essential to the function and survival of nerve cells. The CNS and PNS each have their own specific types of support cells.

Support cells in the CNS:

The general term for support cells in the CNS is **glia** or **neuroglia** (glial cells, neuroglial cells). There are four types of neuroglial cells. (1) **Oligodendrocytes**, the myelin-secreting cells of the CNS. (2) **Astrocytes**, which provide physical and metabolic support for nerve cells. (3) **Microglia**, (microglial cells), which are the phagocytes of the CNS. (4) **Ependyma** (ependymal cells) lining brain cavities and central canal in spinal cord.

Oligodendrocytes. As their name implies, oligodendrocytes have few processes. They are often found in rows between axons. The myelin sheath around axons is formed by concentric layers of oligodendrocytes plasma membrane. Each oligodendrocyte gives off several tongue-like processes that find their way to the axon, where each process wraps itself around a portion of the axon, forming an internodal segment of myelin. Each process appears to spiral around its segment of the axon in a centripetal manner, with the continued insinuation of the leading edge between the inner surface of newly formed myelin and the axon. One oligodendrocyte may myelinate one axon or several. The nucleus-containing region may be at some distance from the axon(s) it is myelinating. In the CNS, nodes of Ranvier (between

myelinated regions) are larger than those of the PNS, and the larger amount of exposed axolemma makes saltatory conduction more efficient.

Unmyelinated axons in the CNS are truly bare, that is they are not embedded in any glial cell process. (In contrast to the situation in the PNS, described below.)

Astrocytes. Astrocytes are the largest of the neuroglial cells. They have elaborate processes that extend between neurons and blood vessels. The ends of the processes expand to form end feet, which cover large areas of the outer surface of the blood vessel or axolemma. Astrocytes are believed to play a role in the movement of metabolites and wastes to and from neurons, and in regulating ionic concentrations within the neurons. They may be involved in regulating the tight junctions in the capillaries that form the blood-brain barrier. Astrocytes also cover the bare areas of neurons, at nodes of Ranvier and synapses. They may act to confine neurotransmitters to the synaptic cleft and to remove excess neurotransmitters.

Two kinds of astrocytes are identified, protoplasmic and fibrous astrocytes. Both types contain prominent bundles of intermediate filaments, but the filaments are more numerous in fibrous astrocytes. Fibrous astrocytes are more prevalent in white matter, protoplasmic ones in grey matter.

Microglia. These are the smallest of the glial cells, with short twisted processes. They are the phagocytes of the CNS, considered part of the mononuclear phagocytic system (see pg 110 in Ross et al.). They are believed to originate in bone marrow and enter the CNS from the blood. In the adult CNS, they are present only in small numbers, but proliferate and become actively phagocytic in disease and injury. Their alternate name, mesoglia, reflects their embyonic origin from mesoderm (the rest of the nervous system, including the other glial cells, is of neuroectodermal or neural crest origin).

Ependymal cells. Cuboidal to columnar cells in one layer lining the fluid-filled brain ventricles and central canal (canalis centralis) in spinal cord. Ependyma is involved in cerebrospinal fluid production in som regions (choroid plexus).

Support cells in the PNS:

The support cells of the PNS are called satellite cells and Schwann cells.

Satellite cells. Satellite cells surround the cell bodies of the neurons in ganglia (ganglion cells). These small cuboidal cells form a complete layer around the nerve cell body, but only their nuclei are visible in routine preparations. They help maintain a controlled microenvironment around the nerve cell body, providing electrical insulation and a pathway for metabolic exchange. In paravertebral and peripheral ganglia, nerve cell processes must penetrate between satellite cells to establish a synapse.

- Satelite cells – nutrition and isolation of neurons in ganglia

Schwann cells. Schwann cells are responsible for the myelination of axons in the PNS. A Schwann cell wraps itself, jelly roll-fashion, in a spiral around a short segment of an axon. During the wrapping, cytoplasm is squeezed out of the Schwann cell and the leaflets of plasma membrance of the concentric layers of the Schwann cell fuse, forming the layers of the myelin sheath. An axon's myelin sheath is segmented because it is formed by numerous Schwann cells arrayed in sequence along the axon. The junction where two Schwann cells meet has no myelin and is called the node of Ranvier (the areas covered by Schwann cells being the internodal regions).

The lack of Schwann cell cytoplasm in the concentric rings of the myelin sheath is what makes it lipid-rich. Schwann cell cytoplasm is however found in several locations. There is an inner collar of Schwann cell cytoplasm between the axon and the myelin, and an outer collar around the myelin. The outer collar is also called the sheath of Schwann or neurilemma, and contains the nucleus and most of the organelles of the Schwann cell. The node of Ranvier is also covered with Schwann cell cytoplasm, and this is the area where the plasma membranes of adjacent Schwann cells meet. (These adjacent plasma membranes are not tightly apposed at the node, so that extracellular fluid has free acess to the neuronal plasma membrane.) Finally, small islands of Schwann cell cytoplasm persist within successive layers of the myelin sheath, these islands are called Schmidt-Lanterman clefts.

Myelination (development of myelin sheath):

Not all nerve fibres is the PNS are covered with myelin, some axons are unmyelinated. In contrast to the situation in the CNS, unmyelinated fibres in the PNS are not completely bare, but are enveloped in Schwann cell cytoplasm. The Schwann cells are elongated in parallel to the long axis of the axons, which fit into grooves on the surface of the Schwann cell. One axon or a group of axons may be enclosed in a single groove. Schwann cells may have only one or up to twenty grooves. Single grooves are more common in the autonomic nervous system.