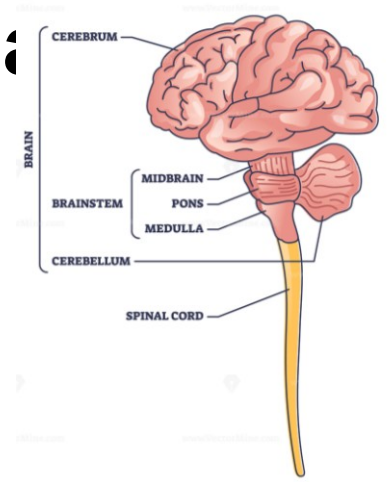
Nervous system, Endocrine system, Sense orga (selected parts)



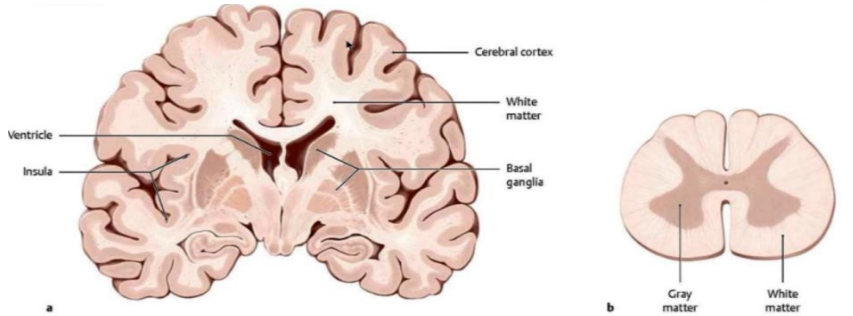
Central nervous system:

Main structures are cerebrum, cerebellum and spinal cord.

On the surface the CNS is covered by a layer of connective tissue.

Nervous tissue in the CNS consists of neurons and glial cells and contains very little connective tissue.

CNS tissues can be distinguished into gray and white matter.



Distribution of gray and white matter in the CNS

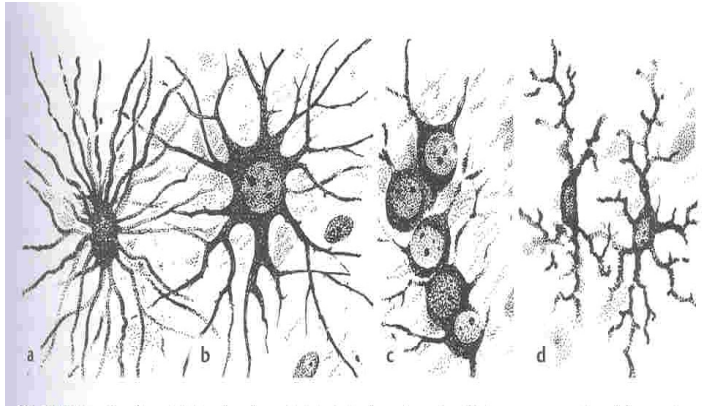
Gray matter: bodies of neurons, predominantly unmyelinated fibers,

glial cells: -protoplasmic astrocytes - oligodendrocytes –microglia

White matter: predominantly myelinated fibers,

glial cells: - fibrillar astrocytes - oligodendrocytes – microglia

Astrocytes:
a-fibrillar
b-protoplasmic
c- oligodendrocytes
d- microglia



Nervous system

Gray matter: in the cerebral cortex, nuclei within the white matter of the brain, in the cortex of the cerebellum, within the spinal cord, and in the ganglia of the PNS

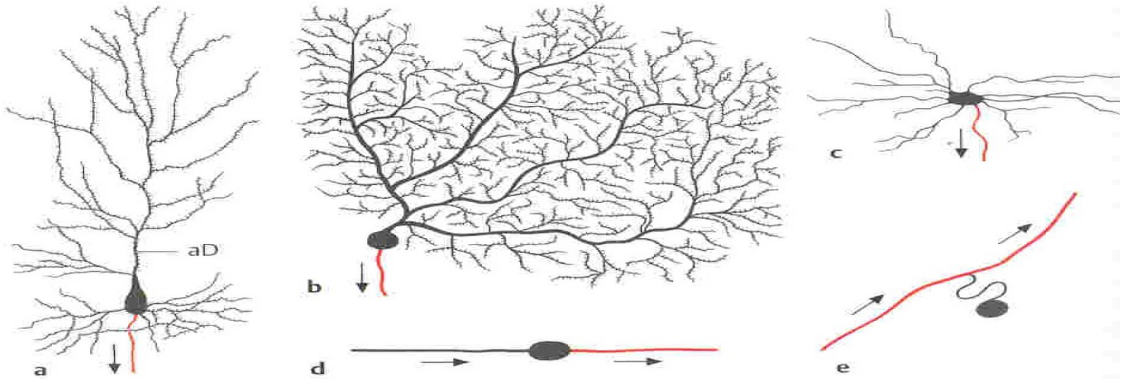
There are several types of neurons in the cortex.

Small and medium multipolar neurons in the nuclei

White matter: centrally in the brain tissue and on the surface of the spinal cord

Nuclei of the brain:

- *located in the deeper layers of the brain*
- *areas of various shapes with large number of neuron bodies*



Different types of neurons: a- pyramidal neuron b-Purkinje cell, c-multipolar neuron, d- bipolar neuron e-pseudounipolar neuron

Nervous system

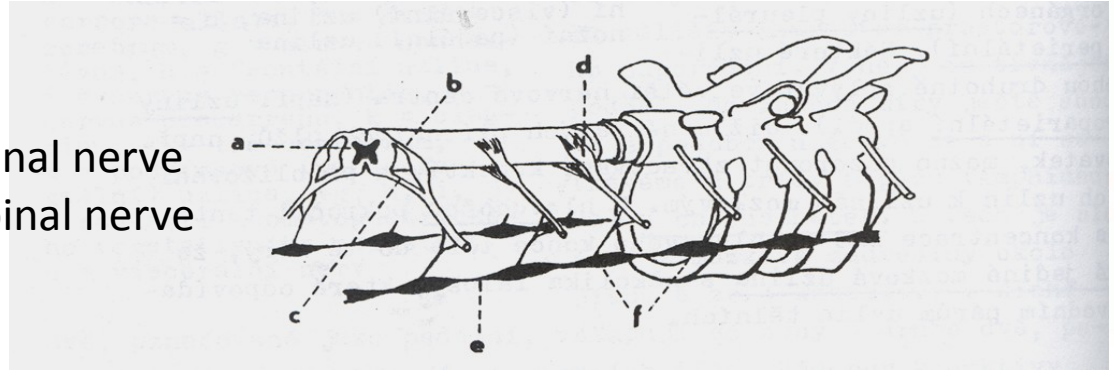
Ganglia: oval-shaped, small, contain neurons and satellite glial cells.

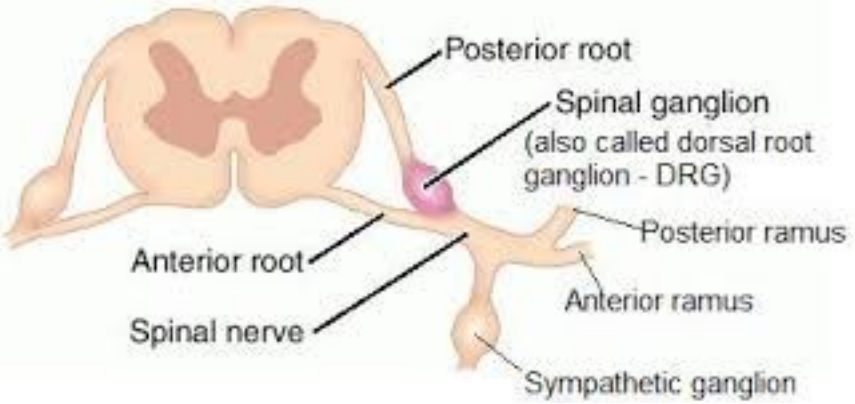
Sensory ganglia: they are at the cranial nerves and at the dorsal roots of the spinal cord. They contain pseudounipolar neurons, satellite cells and are surrounded by capsule.

They conduct impulses (information from sensory organs, skin, muscles) to the brain and spinal cord

Autonomic ganglia: they are on the autonomic nerves and in the walls of the organs and control the activity of visceral organs. Neurons are multipolar, there are fewer satellite cells, and the capsule is only thin.

a spinal cord
b dorsal root of the spinal nerve
c ventral root of the spinal nerve
d spinal ganglion
e truncus sympaticus
f sympathic ganglia



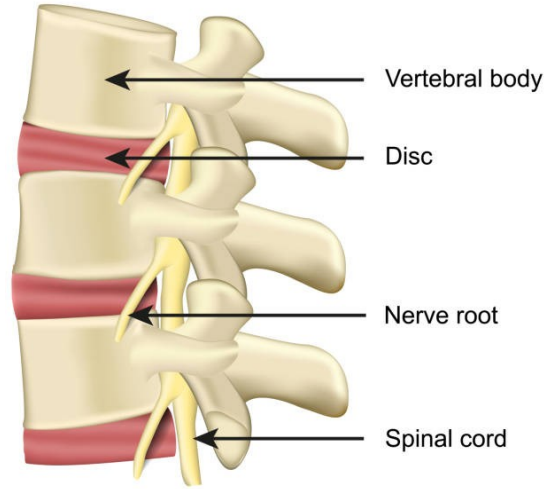


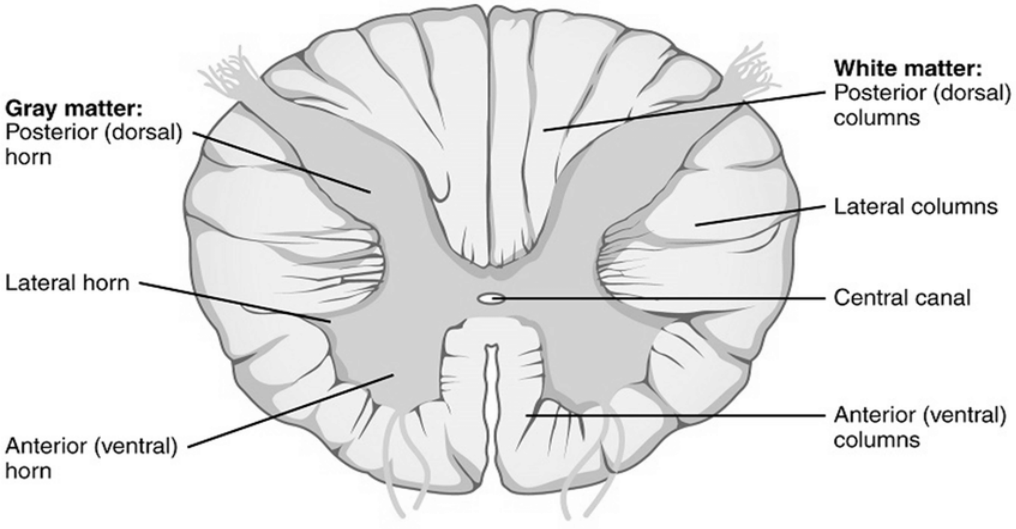
Nervous system

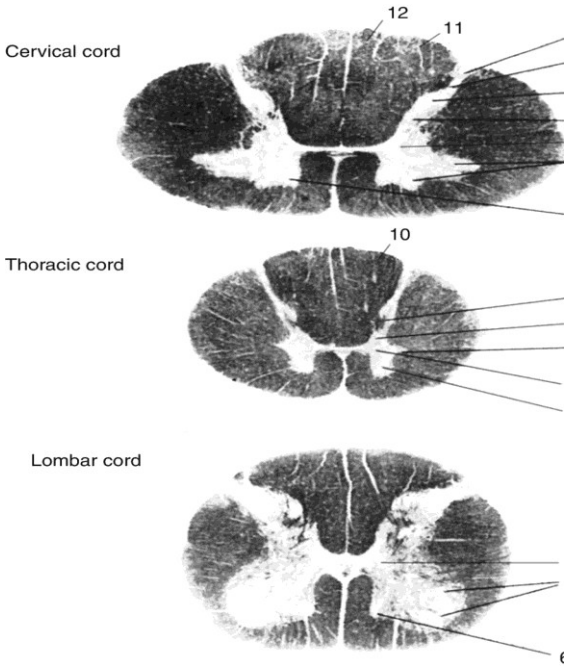
Spinal cord

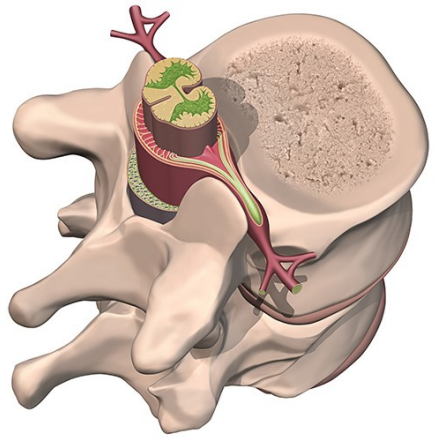
White matter is on the periphery, gray inside.

Gray matter is shaped like the letter H or "butterfly"

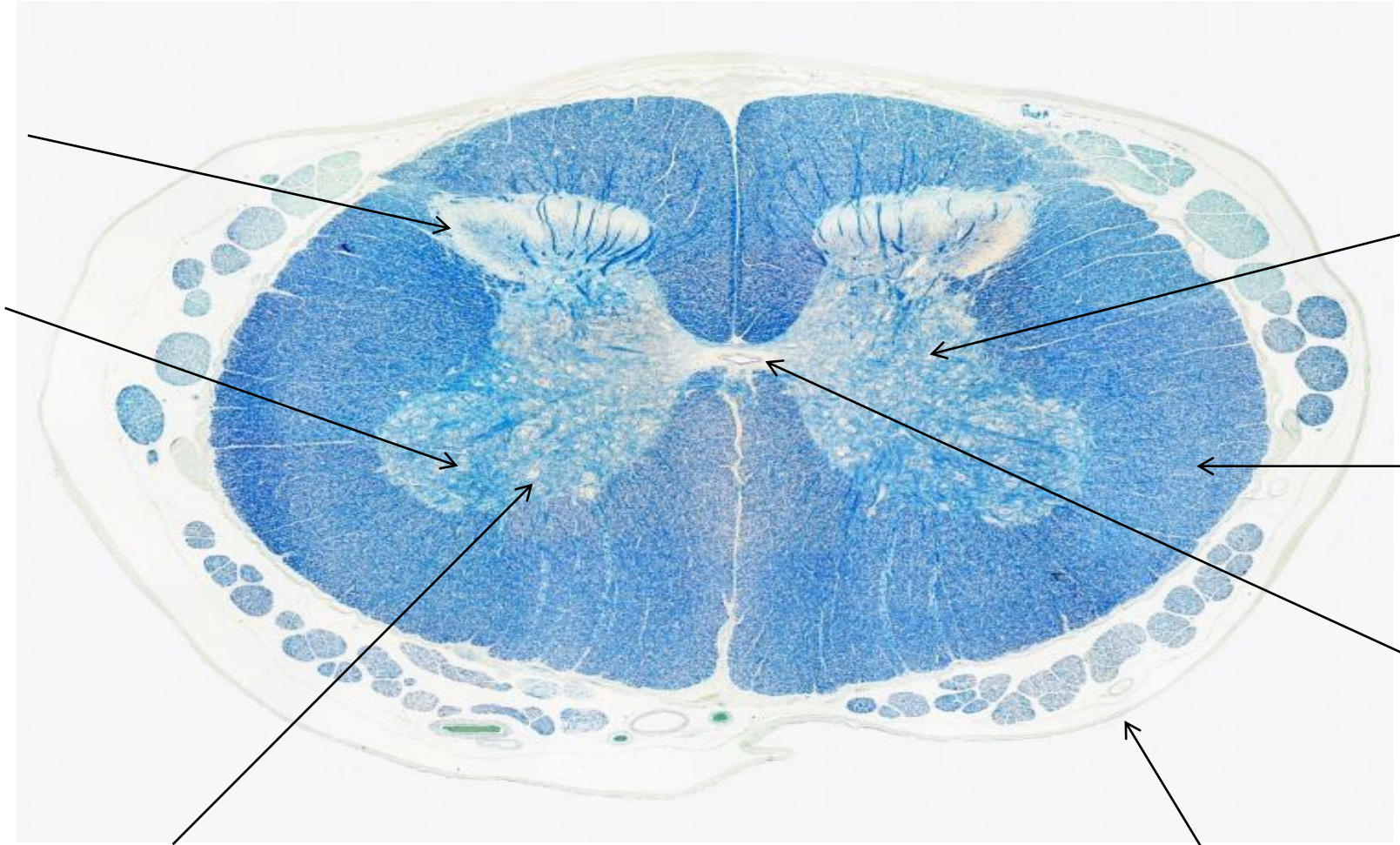








Spinal cord, transversal section



Posterior horn

Anterior horn

Grey matter

White matter

Central canal,
ependymal cells

Cell bodies of motor neurons

Spinal nerve roots

Nervous system

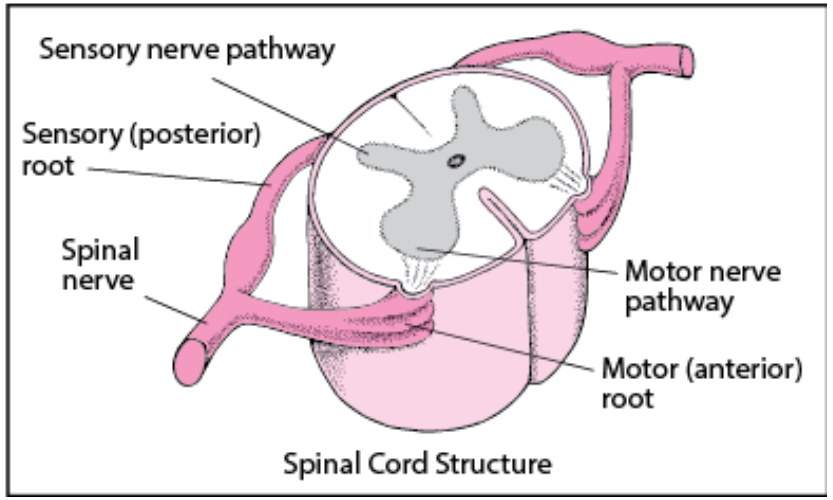
Spinal cord

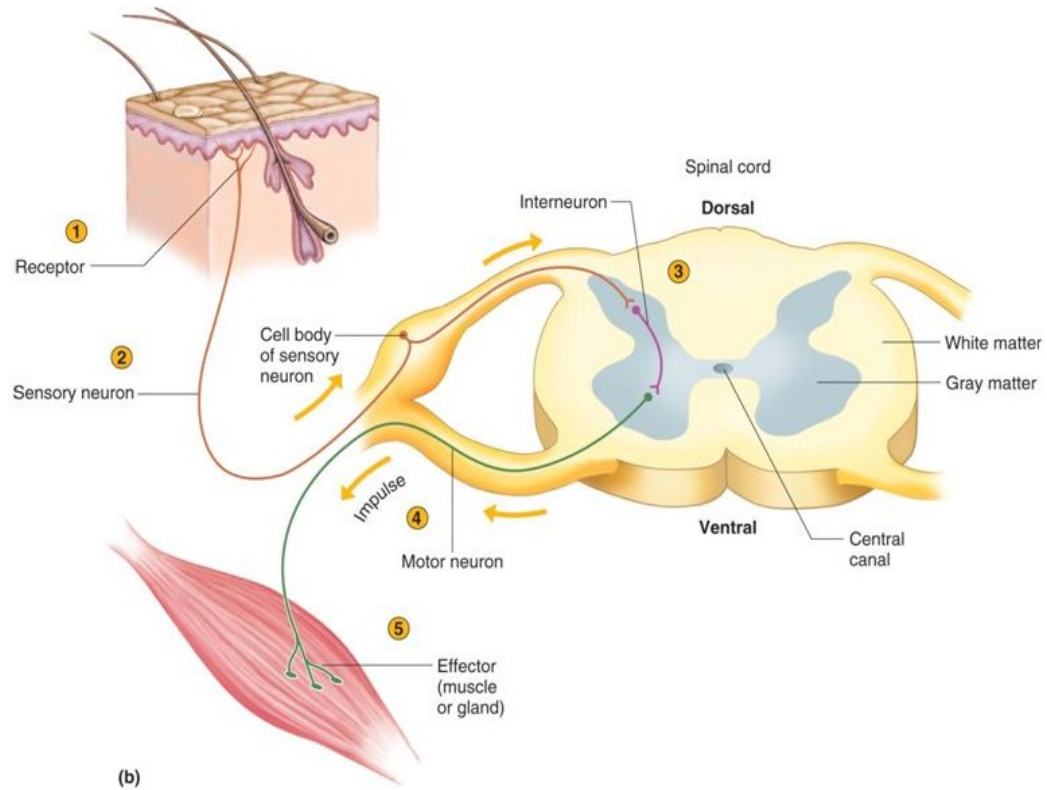
Anterior (ventral) horns contain the bodies of large motor neurons.

The axons of these neurons exit the spinal cord in the ventral roots of the spinal nerves.

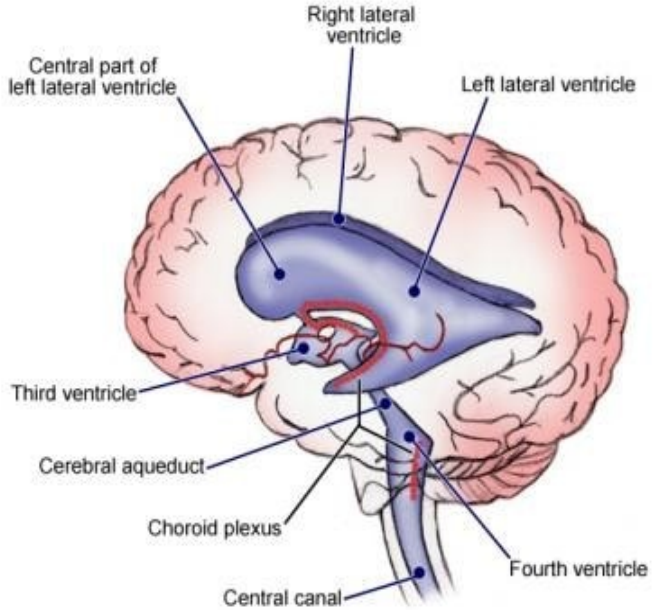
Motor neurons innervate and control skeletal muscle movements.

Posterior (dorsal) horn receive sensory stimuli from the body, that come through the so-called spinal ganglia.





Nervous system



Spinal cord, ependymal cells, cerebrospinal fluid

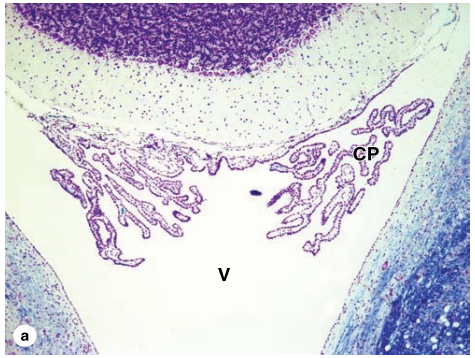
Central canal: in the middle of the spinal cord, is connected to the ventricles of the brain, is lined with ependymal cells.

Ependymal cells: columnar or cuboidal, may have cilia that facilitate the movement of cerebrospinal fluid, they have microvilli that increase their surface area.

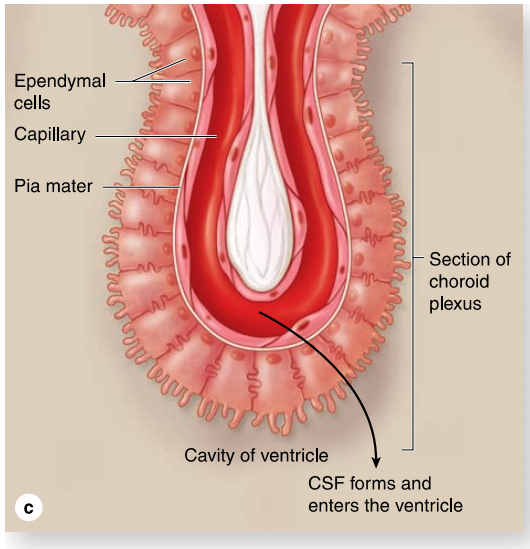
Cerebrospinal fluid: clear liquid, contains sodium, potassium, chlorine ions, very little protein. There are no cells, only rarely there may be lymphocytes.

Cerebrospinal fluid originates in the choroid plexus-
a highly vascularized tissue located in the cerebral ventricles.

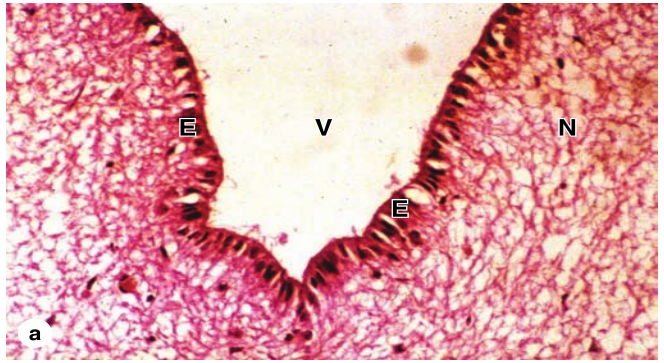
Choroid plexus in the
the cerebral ventricle.



(**E**). X150. **(c)** The choroid plexus is specialized for transport of water and ions across the capillary endothelium and ependymal layer and the elaboration of these as CSF.



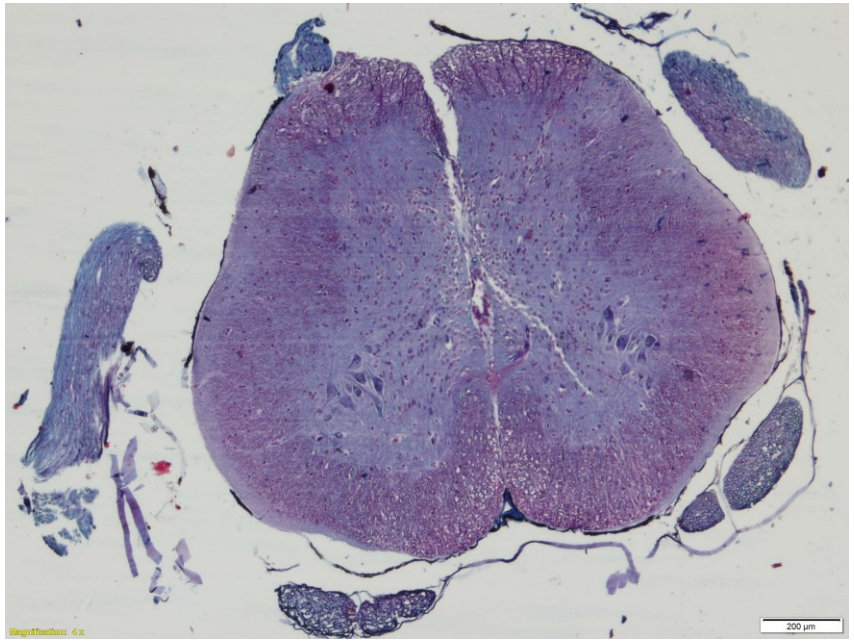
Spinal cord



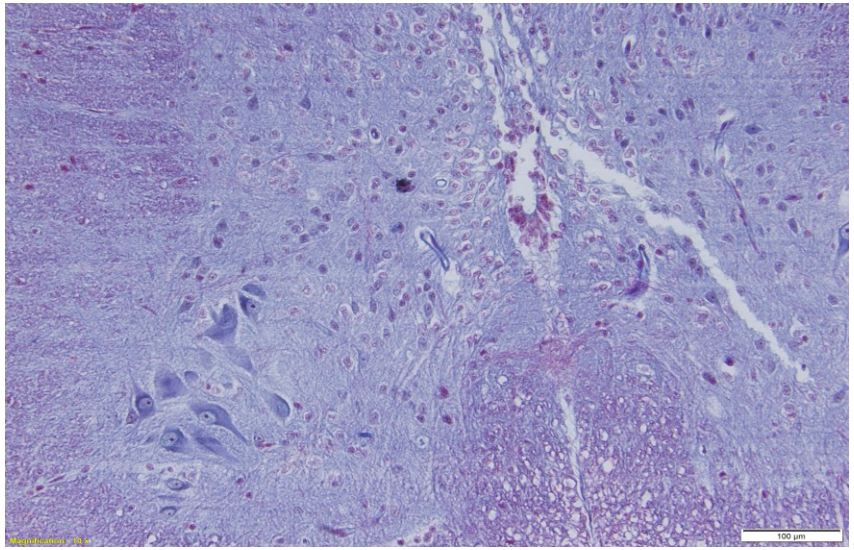
Spinal cord

E ependymal cells,
V ventricle
N nervous tissue (neuropil)
C central canal

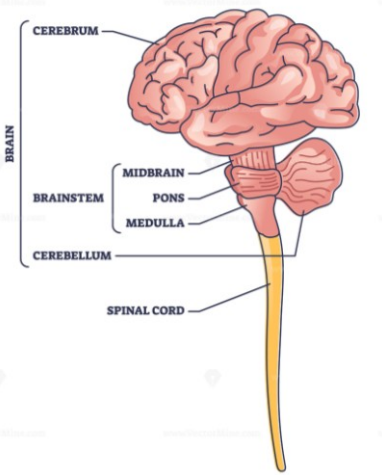
Transverse section of the spinal cord



Detail of the anterior horn of the spinal cord and cell bodies of motor neurons



Nervous system



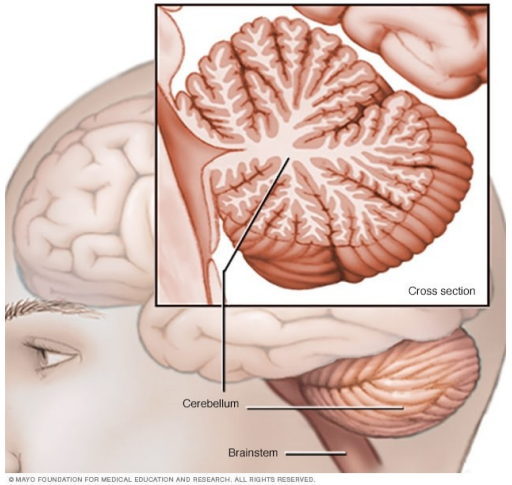
Cerebellum:

Gray matter in the cortex, white matter inside,
Coordinates the activity of muscles and movements and the balance of the body

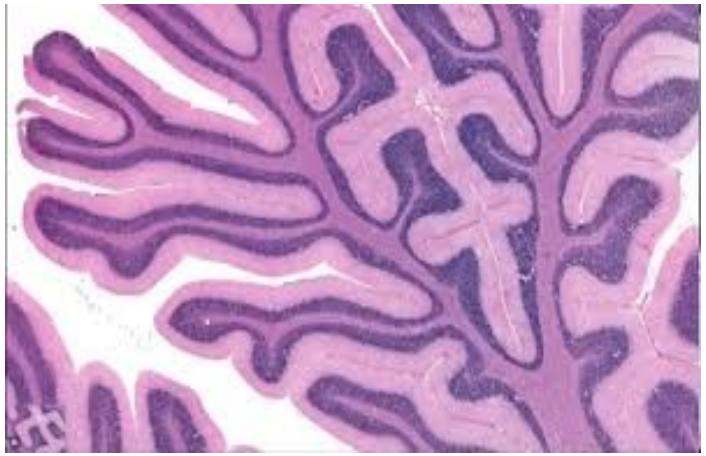
There are three distinguishable layers of tissue in the grey matter of the cortex:

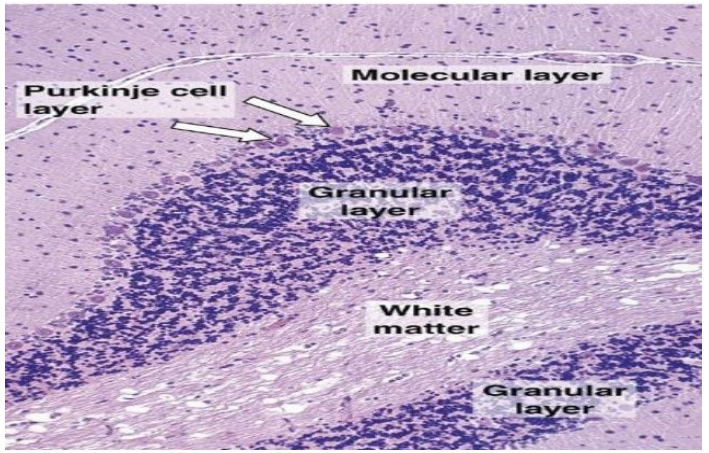
Outer molecular layer: neuropil (protrusions of neurons) and few cell bodies of neurons.
Middle layer of large neurons - Purkinje cells - highly branched in the molecular layer
Inner granular layer - there are many small neurons here.

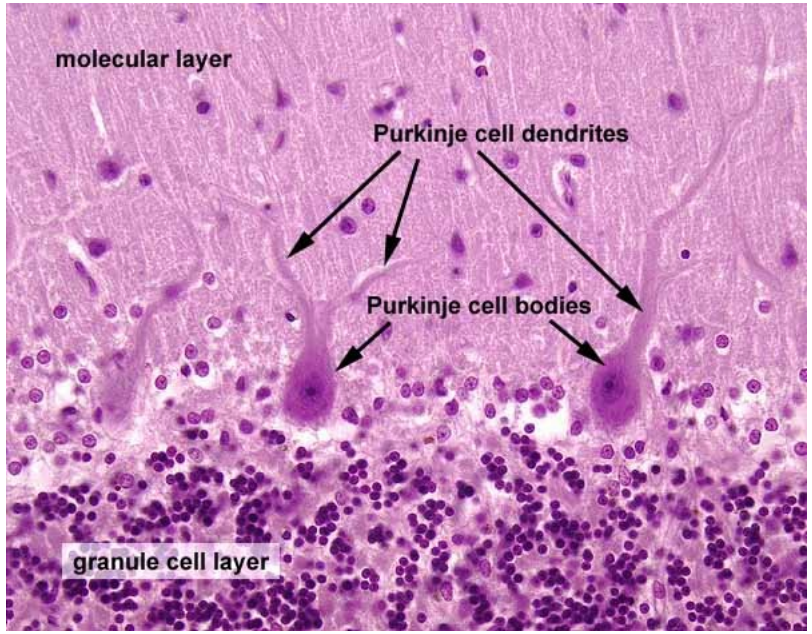
White matter: creates thin areas inside the lobes

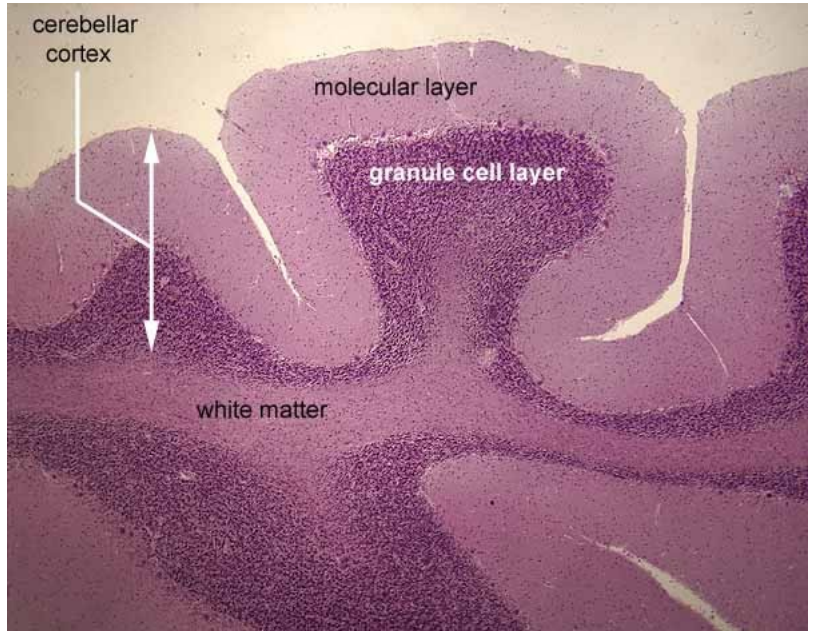


Cerebellum

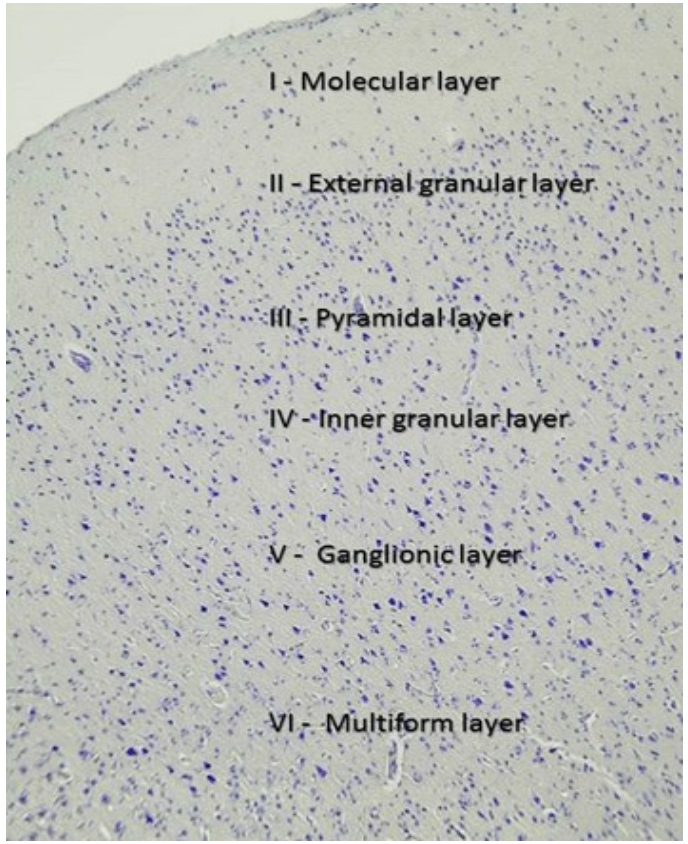



Purkinje cell layer
Molecular layer
Granular layer
White matter
Granular layer


molecular layer
Purkinje cell dendrites
Purkinje cell bodies
granule cell layer


cerebellar cortex
molecular layer
granule cell layer
white matter

Nervous system

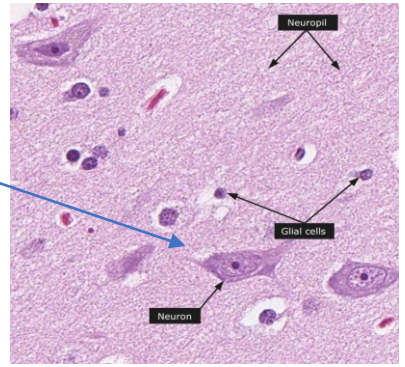


Cerebral cortex

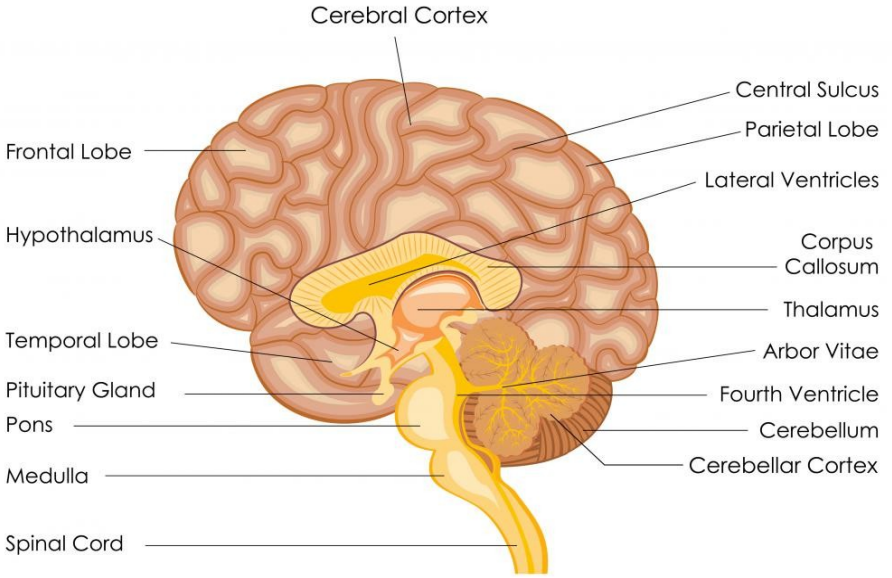
In humans, it is made up of approximately 9 billion neuron cells.
6 layers of neurons of different shapes and sizes are distinguished here:

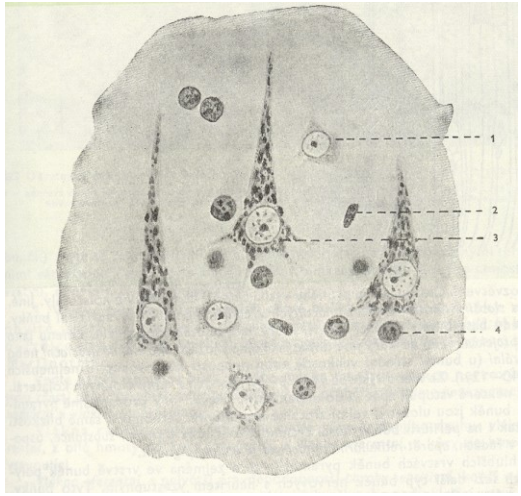
I Molecular layer – glial cells, neurons – Cajal cells, neuron processes
II External granular layer – small granular neurons
III Outer pyramidal layer – small and medium pyramidal cells
IV Internal granular layer – small granular neurons
V Inner pyramidal layer or (Ganglionic) large pyramidal cells - Betz cells
VI Multiform layer – spindle-shaped neurons

Pyramidal neurons - integration of information and initiation of motor movements of skeletal muscles

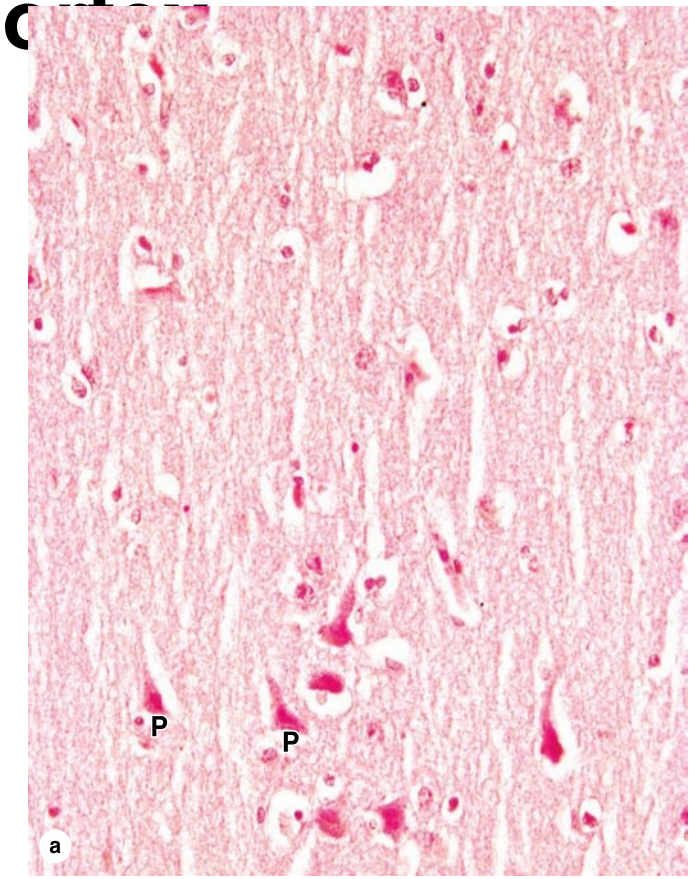


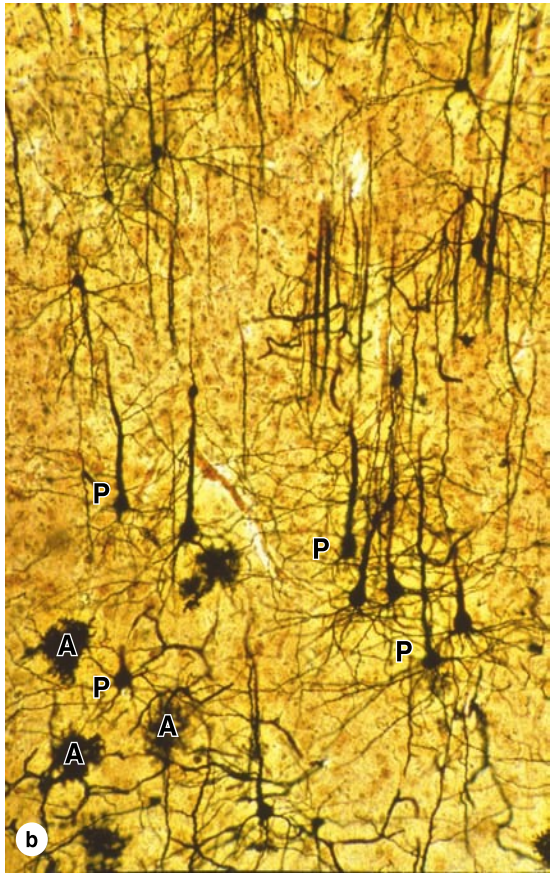
Nervous system, cerebral co





Pyramidal cells:
triangular shape
body size up to 100µm
bright nukleus
clearly visible nucleolus
Nissl substance = ER

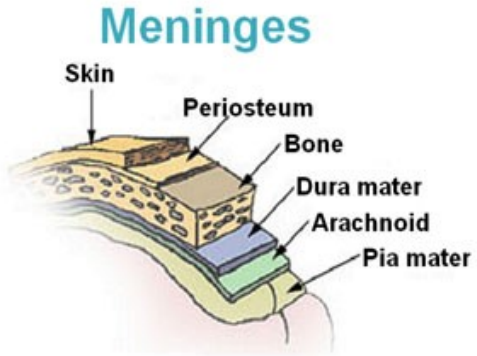




(a) Important neurons of the cerebrum are the pyramidal neurons (**P**), which are arranged vertically and interspersed with numerous smaller glial cells, mostly astrocytes, in the eosinophilic neuropil. X200. H&E.

(b) From the apical ends of pyramidal neurons (**P**), long dendrites extend in the direction of the cortical surface, which can be best seen in thick silver-stained sections in which only a few other protoplasmic astrocytes (**A**) cells are seen. X200. Silver.

Nervous system, meninge



Dura mater -- outer layer lining skull
Arachnoid (mater) -- contains blood vessels
Subarachnoid space -- filled with CSF
Pia mater -- covers brain

Connective tissue between bone of skull and vertebral column and nervous tissue.

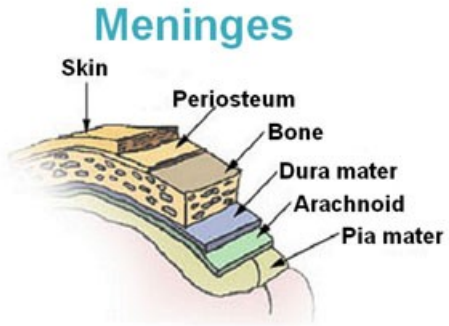
Three meningeal layers:

Dura mater: dense connective tissue
In the skull it is firmly connected to the periosteum (except for a few small areas).
In the spinal cord, there is a so-called epidural space between the dura mater and the periosteum of the vertebrae. The epidural space is filled with blood vessels and loose connective tissue. So-called epidural anesthesia can be given in this space during some operations.

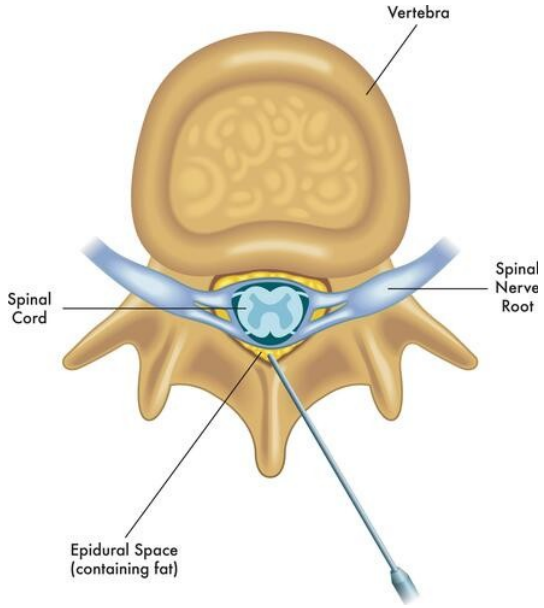
Arachnoid: a thin layer of connective tissue, ligaments and system of trabeculae composed of collagen and fibroblasts. Between the trabeculae there is a subarachnoid space filled with cerebrospinal fluid.
This space is connected to the cerebral ventricles, the fluid can circulate between the two places

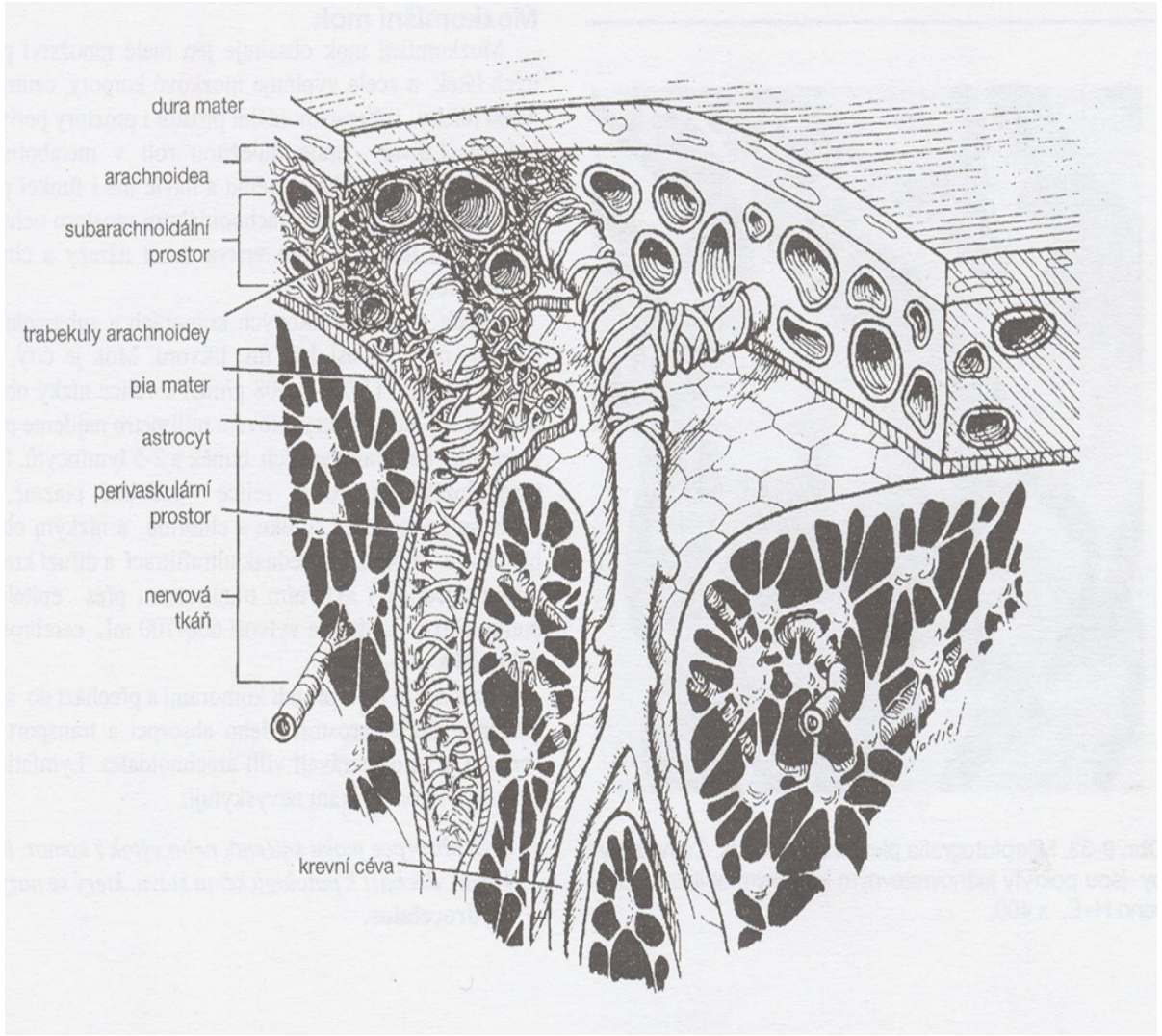
Nervous system, meninges

Pia mater: thin layers of connective tissue on the surface of nerve tissue. Together with the blood vessels, it penetrates into the deeper layers of the CNS. There is no more pia mater around the capillaries.



Dura mater -- outer layer lining skull
Arachnoid (mater) -- contains blood vessels
Subarachnoid space -- filled with CSF
Pia mater -- covers brain



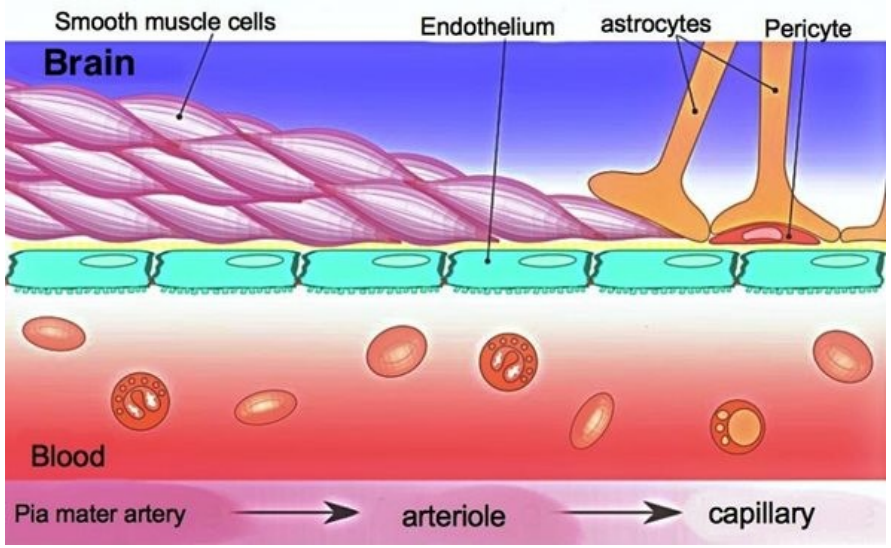


Nervous system, blood-brain barrier (BBB)

Limited transfer of substances from the blood to the CNS. It is a functional barrier that allows much tighter control of the passage of substances from the blood into the nervous tissue, than in other types of tissue.

The main structural component of the BBB are endothelial cells of capillaries:

- there are many tight junctions
- the basement membrane is continuous
- few pinocytic vesicles
- around the capillaries is another layer of astrocyte projections



Endocrine Glands

Secretory cells arise by differentiation from epithelial cells an form multicellular glands. Secretion products - hormones are released into the blood - endocrine glands have no special ducts but contain many capillaries.

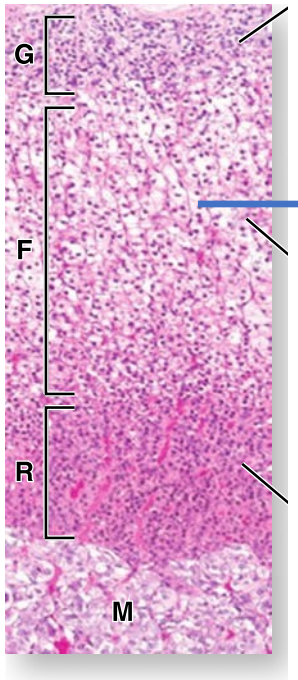
Arrangement of endocrine tissues: secretory cells in endocrine glands can create:

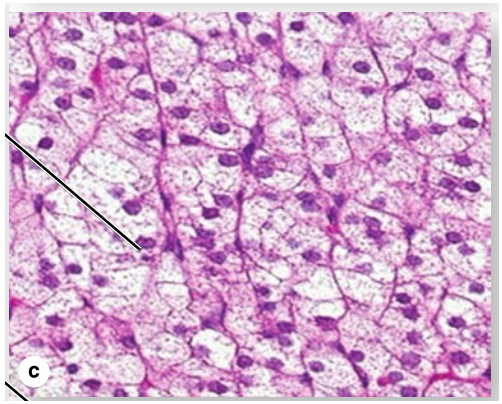
1. Cords or clusters - Adrenal glands- suprarenal, Islets of Langerhans
2. Follicles - Thyroid gland
3. Diffusion type - Leydig cells in testis - *secretory cells may be spread between cells of other tissue*

Hormone molecules can be:

Hydrophilic: proteins (insulin), glycoproteins (pituitary gonadotropic hormone, peptides (oxytocin) or modified amino acids (tyroxin)

Hydrophobic: steroid hormones (glucocorticoid – kortisol) - in plasma bind to transport proteins.

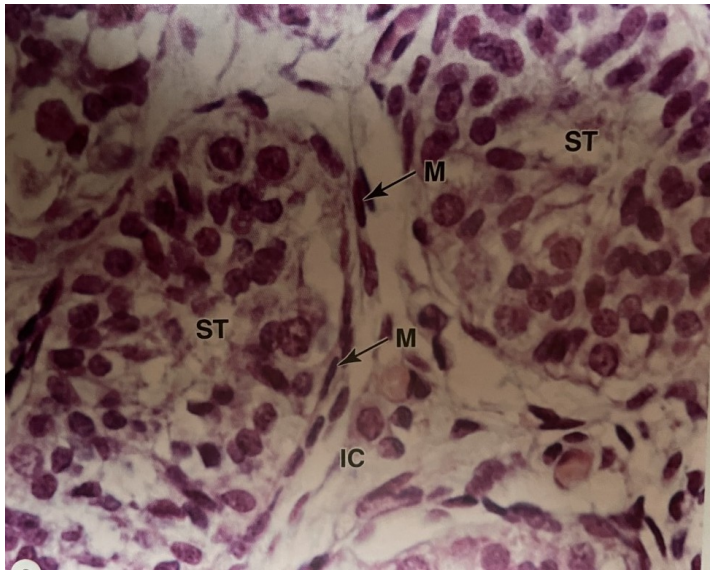


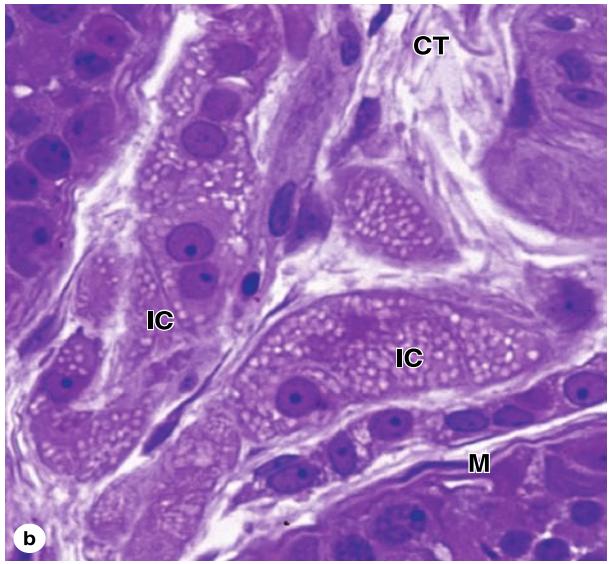


1. Cords type - adrenal glands- suprarenal
R,F,G – zonae
glomerulosa, fasciculata, reticularis,
M medulla

2. Follicles type - thyroid gland
L lumen

3. Diffusion type - Leydig cells in testis
seminiferous tubules ST of the testes
M myoepitel cell, IC –interstitial cell (Leydig cell)





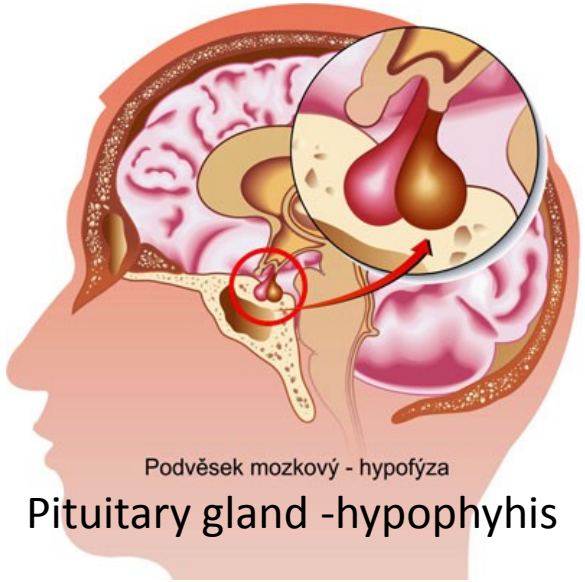
Pituitary gland – hypophysis

weighs 0.5 g

Lies below the brain in a small cavity of the sphenoid bone (sella turcica)

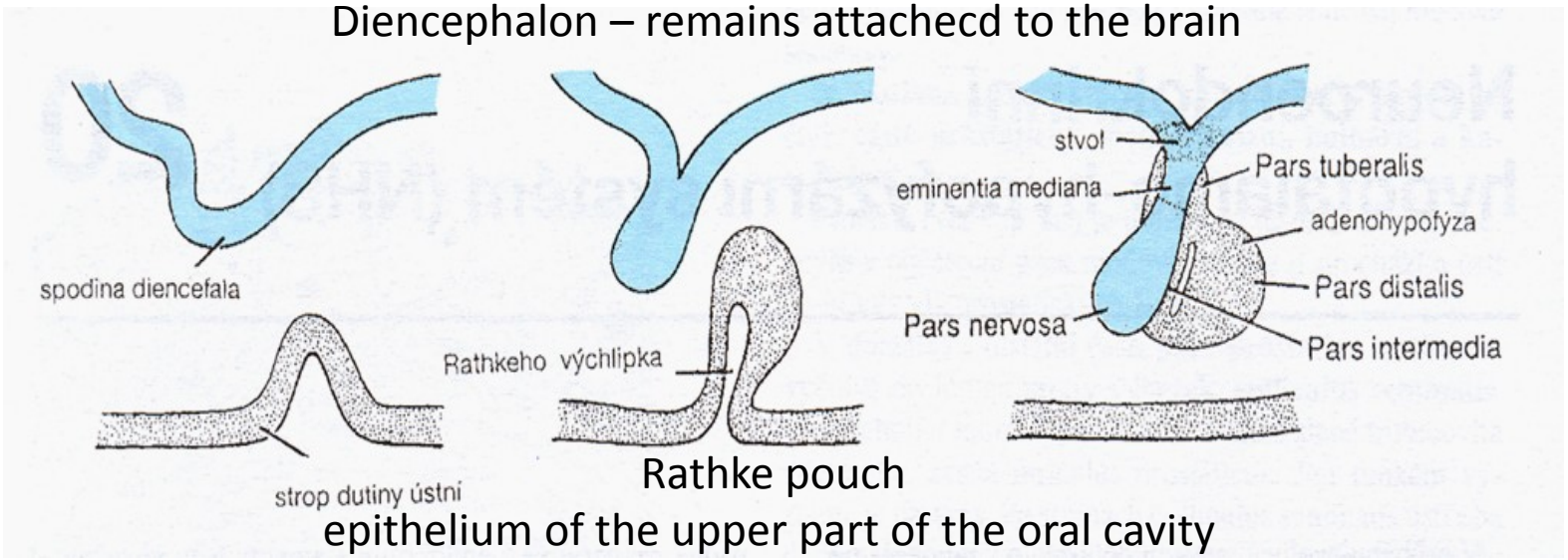
In embryonic development, it arises from:

- the diencephalon (neurohypophysis, or posterior part)
- the ectoderm of the oral cavity (adenohypophysis, anterior part)



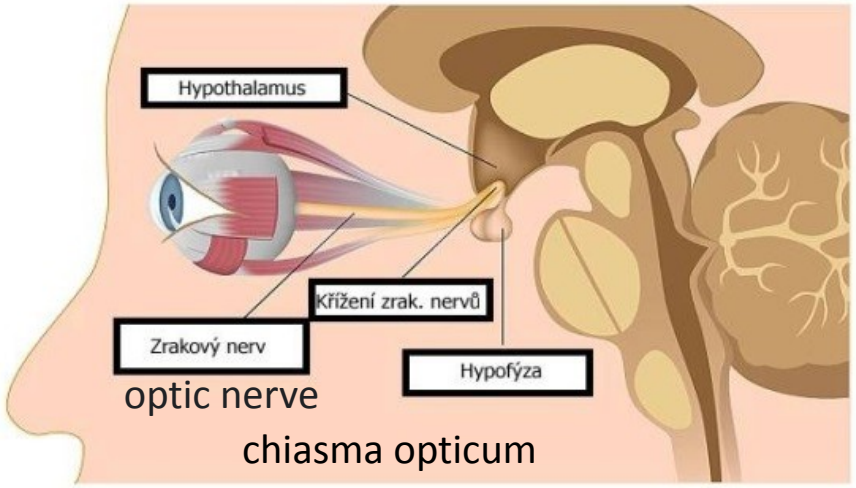
Pituitary gland -hypophyhis

Diencephalon – remains attachecd to the brain



Rathke pouch

epithelium of the upper part of the oral cavity

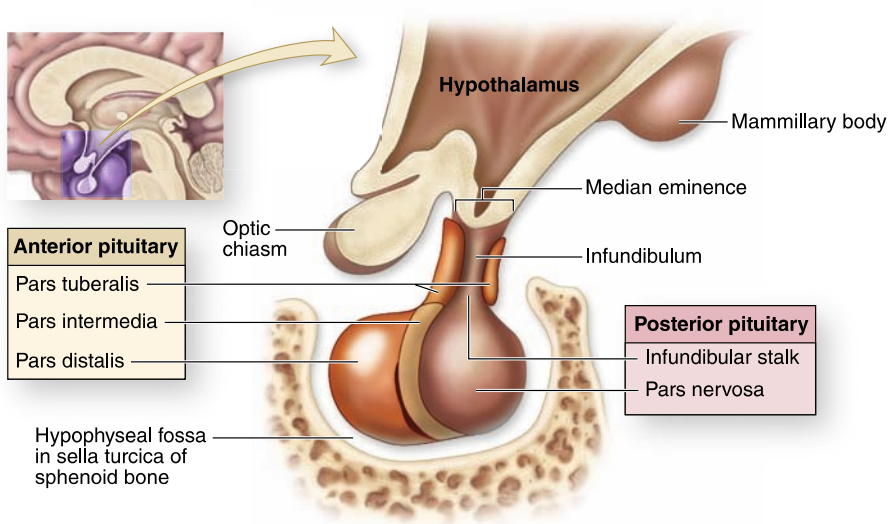


optic nerve

chiasma opticum

Pituitary gland – hypophysis

The pituitary gland is developmentally, anatomically and functionally connected to the hypothalamus.
Hypohtalamic-Hypophyseal Tract



Hypothalamic products:
releasing and inhibitory peptides are formed in the hypothalamus, which regulate the function of the pituitary gland = regulate the production and release of hormones in the pituitary gland

Neurohypophysis is composed of unmyelinated axons (and branched glial cells (pituicytes).
The bodies of these neurons are in the supraoptic and paraventricular nuclei in the hypothalamus
Neurons are modified (many proteosynthetic organelles) and have a secretory function, but have ability to conduct action potential.
Secretory neurons produce antidiuretic hormone and oxytocin.

Pituitary gland – hypophysis

Adenohypophysis

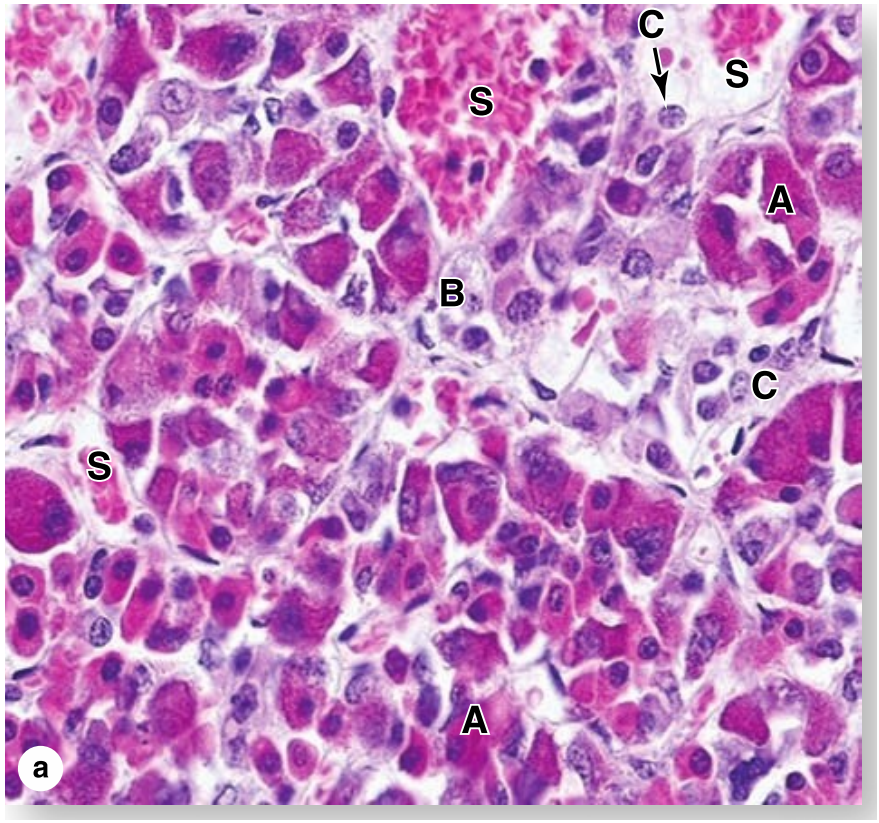
Pars distalis – the most important for hormonal production.

Contains cords of secretory cells and fenestrated capillaries. The cells are of two types: chromophilic (more stained) contain granules with hormones and chromophobic (less stained)

According to their affinity for basic or acidic dyes, chromophilic cells are divided in:

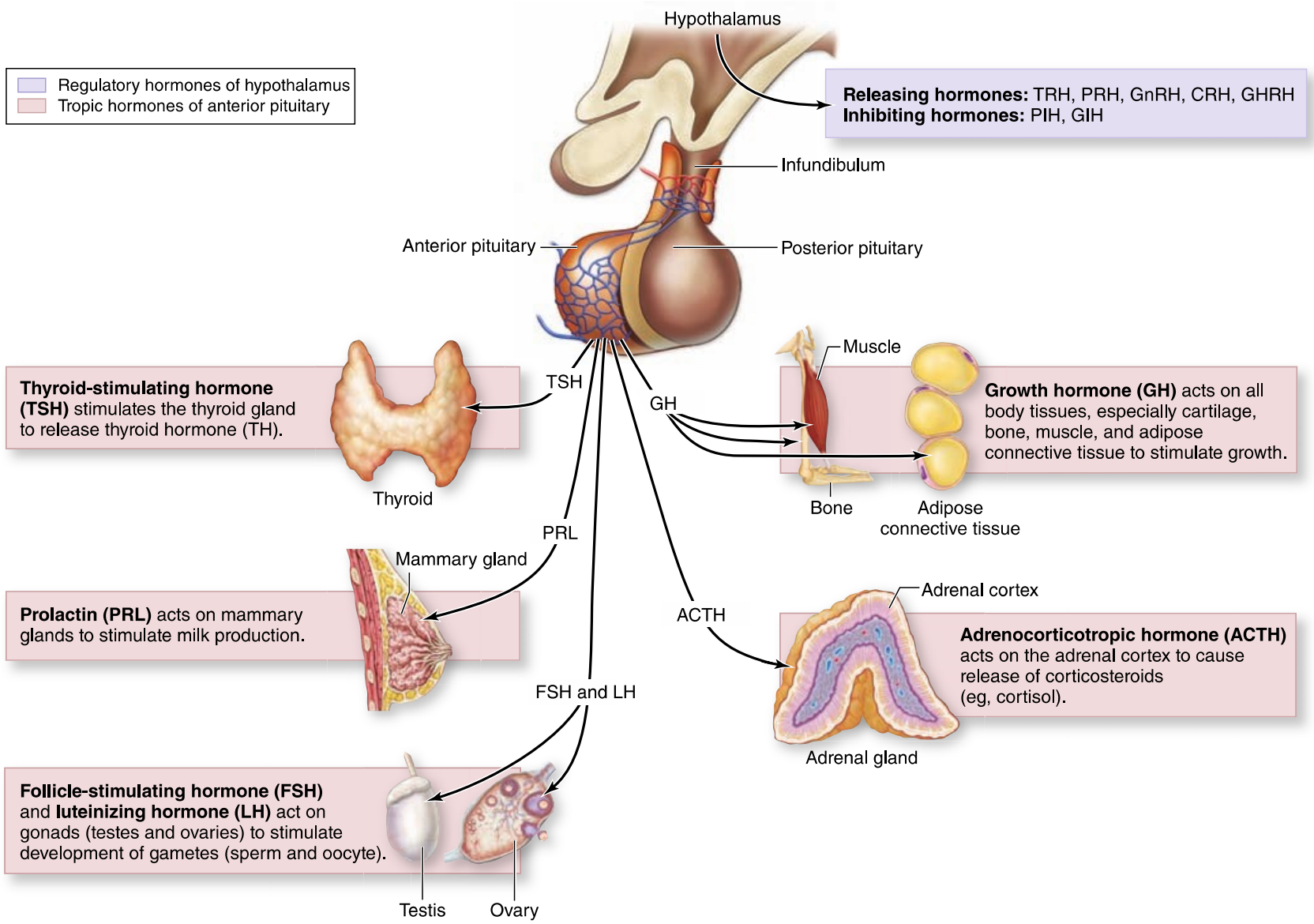
acidophils (produce somatotropin and prolactin

basophilic (produce corticotropin, thyrotropin and gonadotropin)



C chromobhobes
A acodophil cells
B basophil cells
S sinusoiss

Summary - hormonal production of the pars distalis of the adenohypophysis



Adrenal glands - suprarenales

Paired glands, on the upper field of kidneys. Size 6 x 2 cm. Consist of outer cortex and inner medulla.

Embryonic origin: cortex - arises from the mesoderm of the medulla from the neural crest

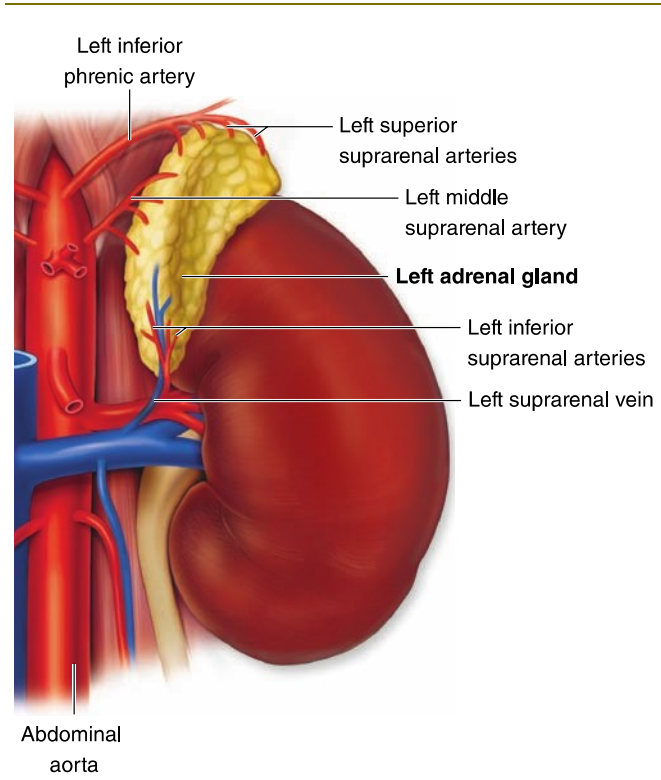
The cells form cords and there are many capillaries in them

Cortex: cells have characteristic features of steroid-secreting cells:

Cell nucleus in the middle, lipid droplets in the cytoplasm, highly developed smooth endoplasmic reticulum. Mitochondria are spherical in shape.

Both the ER and mitochondria contain enzymes for the synthesis of cholesterol and its conversion into steroid hormones.

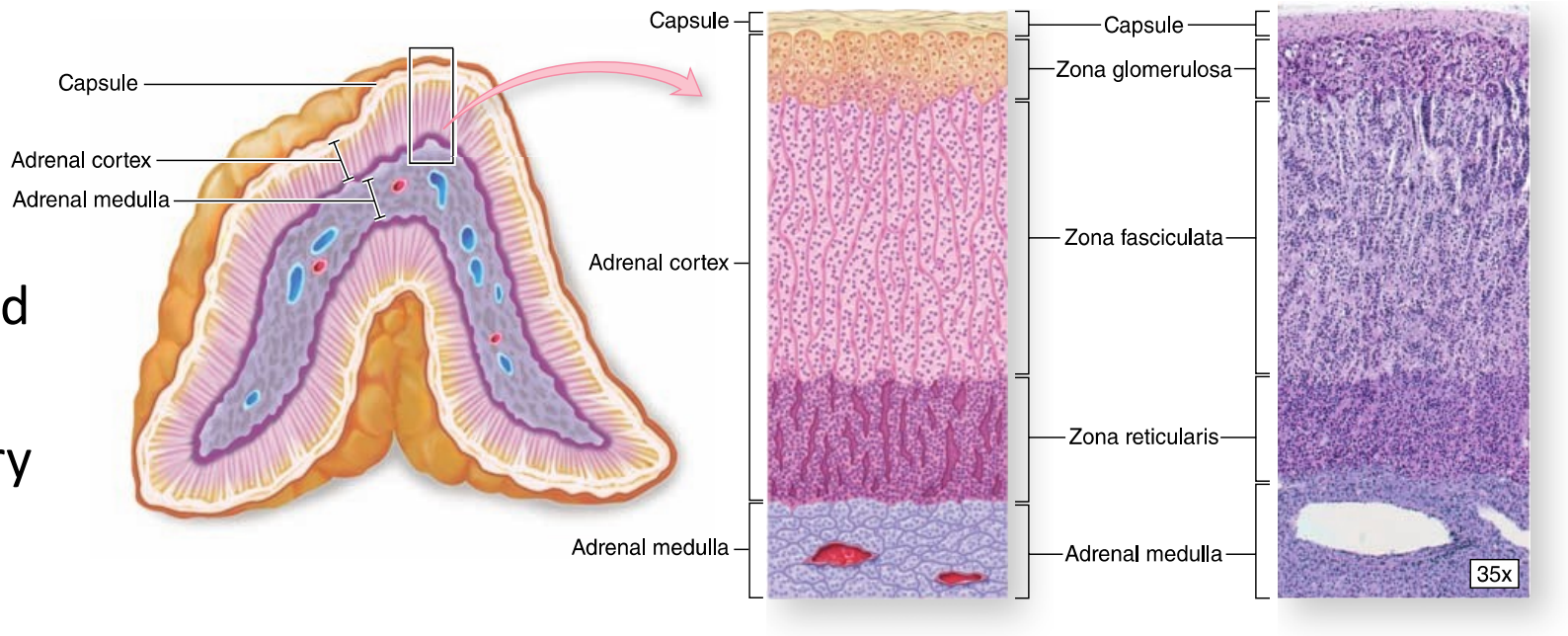
Hormones are not stored in adrenal tissue - they freely diffuse across cell membranes into the blood



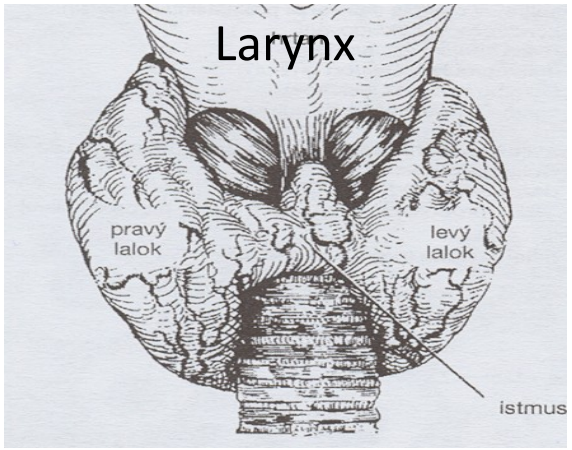
Adrenal glands - suprarenales

zona glomerulosa - mineralocorticoids - aldosterone are formed here. stimulates the resorption of Na^+ in the distal tubules of the kidneys.
zona fasciculata - glucocorticoids, mainly cortisol - affects the metabolism of carbohydrates and fats and suppresses immune reactions.
zona reticularis – a small amount of testosterone precursor

The medulla consists of large polyerdic cells. They are modified neurons that do not have axons or dendrites and have a secretory function. It produces adrenaline and noradrenaline.

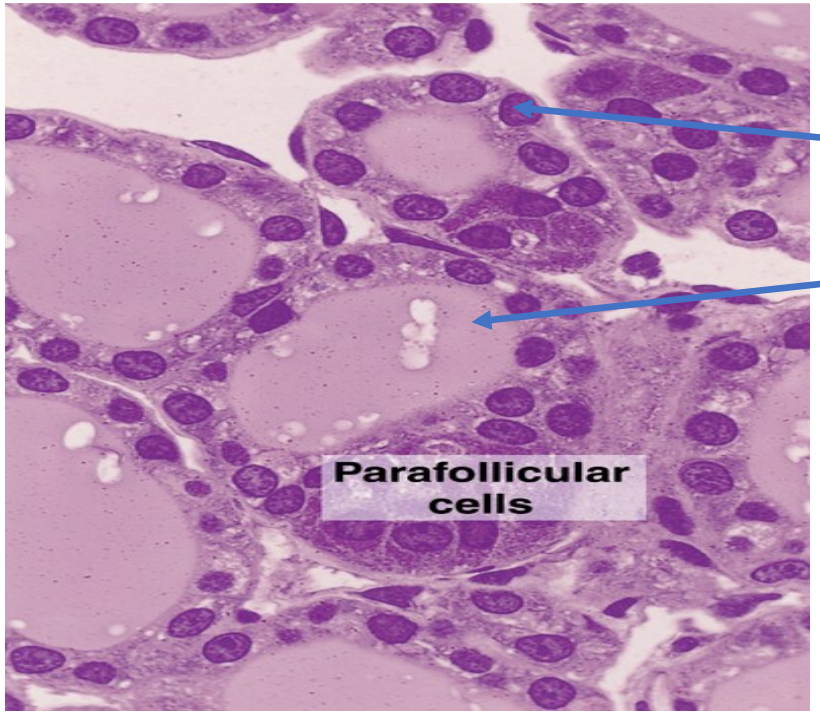


Thyroid gland



The thyroid gland is located on the sides of the larynx
Synthesis of thyroxine, tri-iodothyronine and calcitonine.

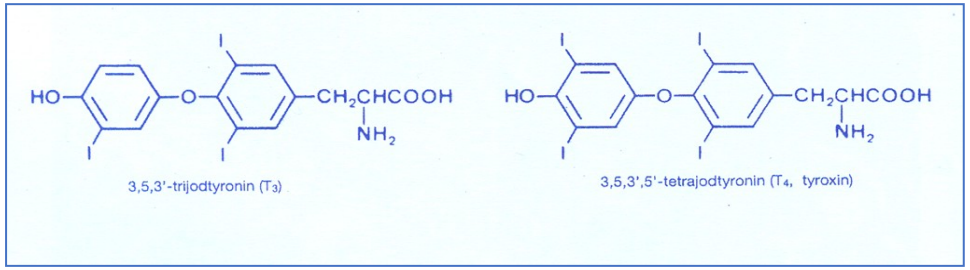
There is a supply of hormones in the colloid for 3 months.



The follicle wall is made of simple epithelium.

The lumen of the follicles is filled with gelatinous colloid.

The tissue consists of thyroid follicles.

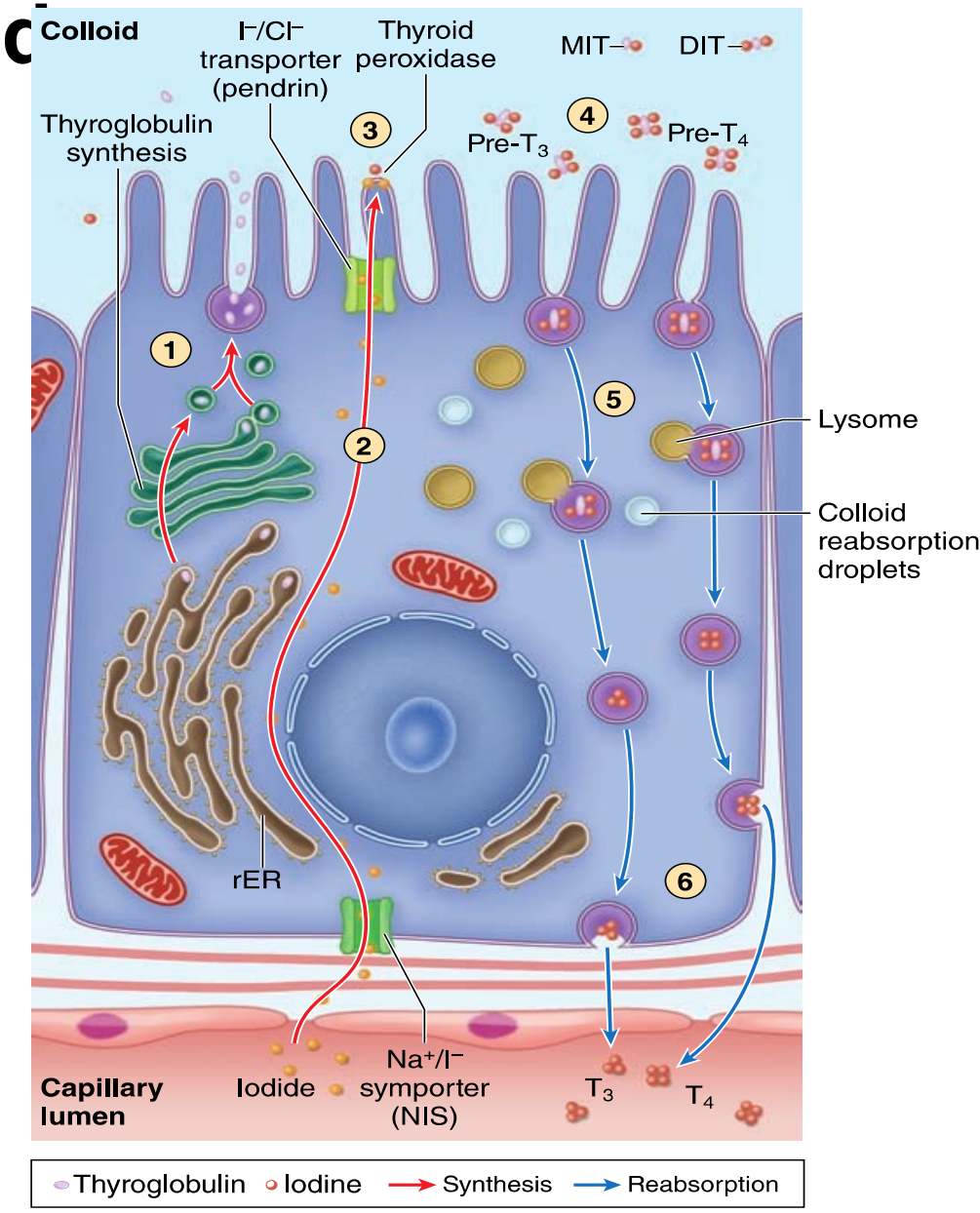


Thyroid gland

Hormone synthesis is a complex process that involves:

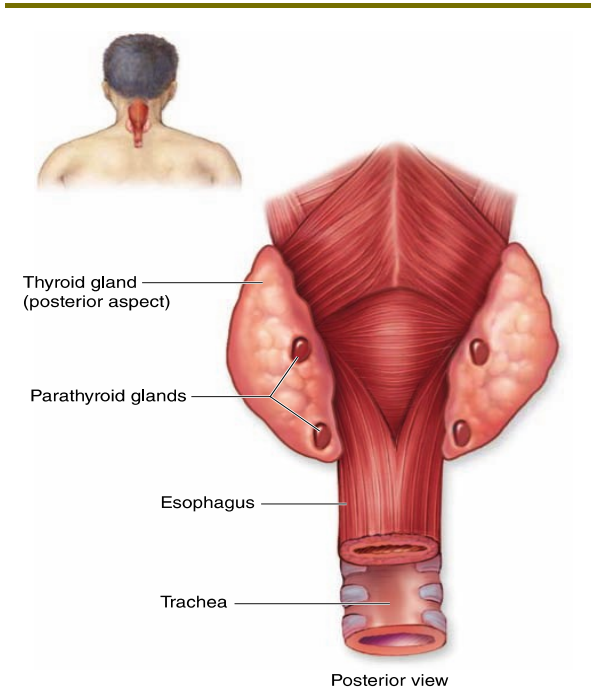
- thyroglobulin protein synthesis
- transport of iodide from blood to follicle cells
- binding of iodine to tyrosine in the thyroglobulin molecule
- endocytosis of iodinated thyroglobulin
- degradation of thyreoglobulin in the lysosomes
- release of T_3 and T_4 from the follicle cells into the blood

Parafollicular cells: larger than follicular cells and have calcitonin granules in the cytoplasm. Calcitonin reduces the concentration of calcium in the blood, inhibits the activity of osteoclasts.

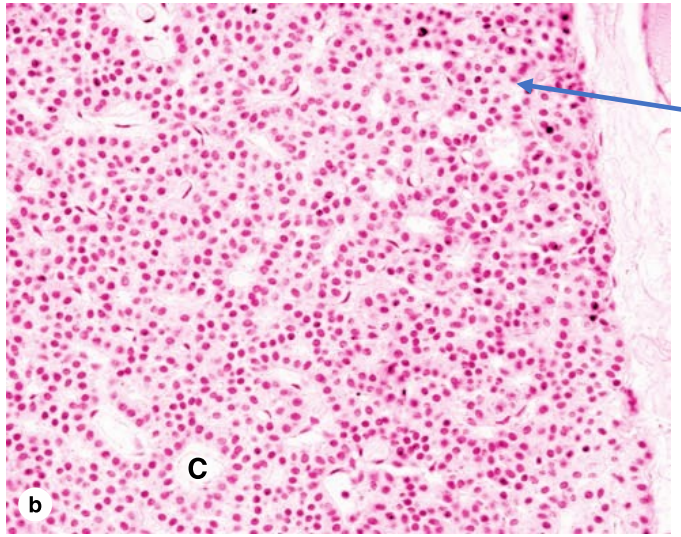


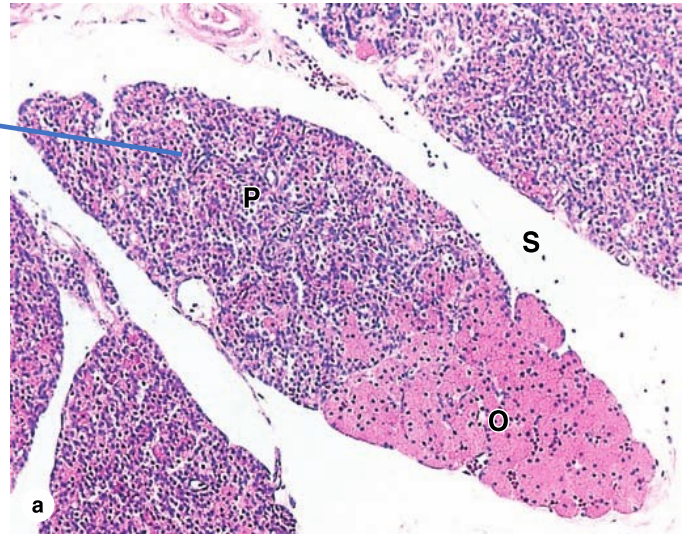
Parathyroid glands

Four small formations on the back of the thyroid gland,
in the connective tissue.
Secretory cells are called principal (chief) - polygonal and pale-staining cytoplasm that contains parathyroid hormone granules.
Parathyroid hormone increases the concentration of calcium in the blood.
Oxyphil cells - larger, lighter, more common in older people, have less parathyroid hormone production.



P principal cells
S septa
O oxyphil cells
C capillaries





Pancreatic islets

The pancreas has an exocrine part (digestive enzymes) and an endocrine part - islets of Langerhans. Islets are round formations 20 micrometers in size, there are more than a million in the pancreas, each contains several hundred secretory cells.

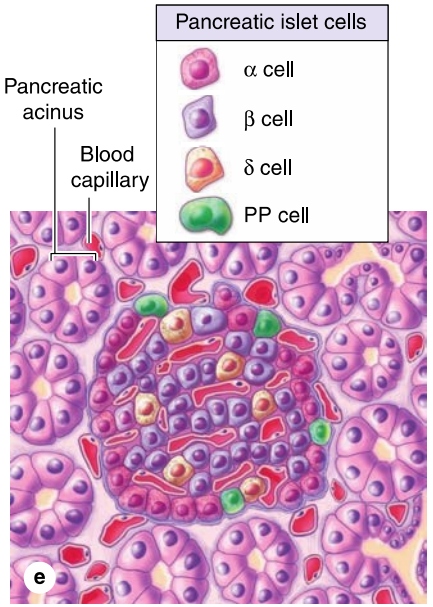
Islets are covered with a thin layer of connective reticular tissue and contain the following cells:

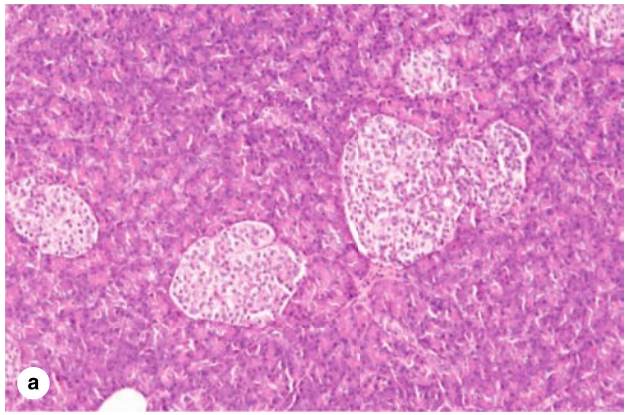
A cells produce glucagon and are peripherally

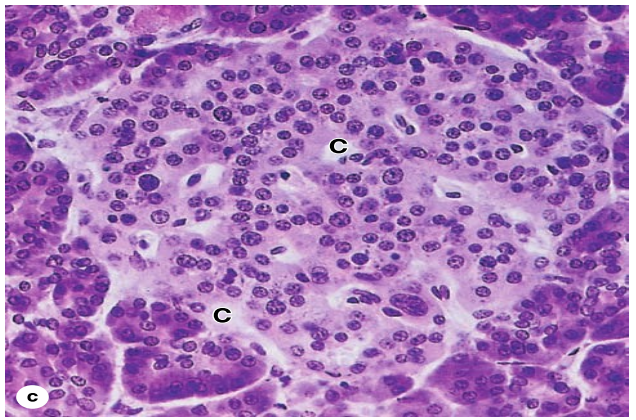
B cells produce insulin and are centrally

D cells produce somatostatin

PP cells produce pancreatic polypeptide







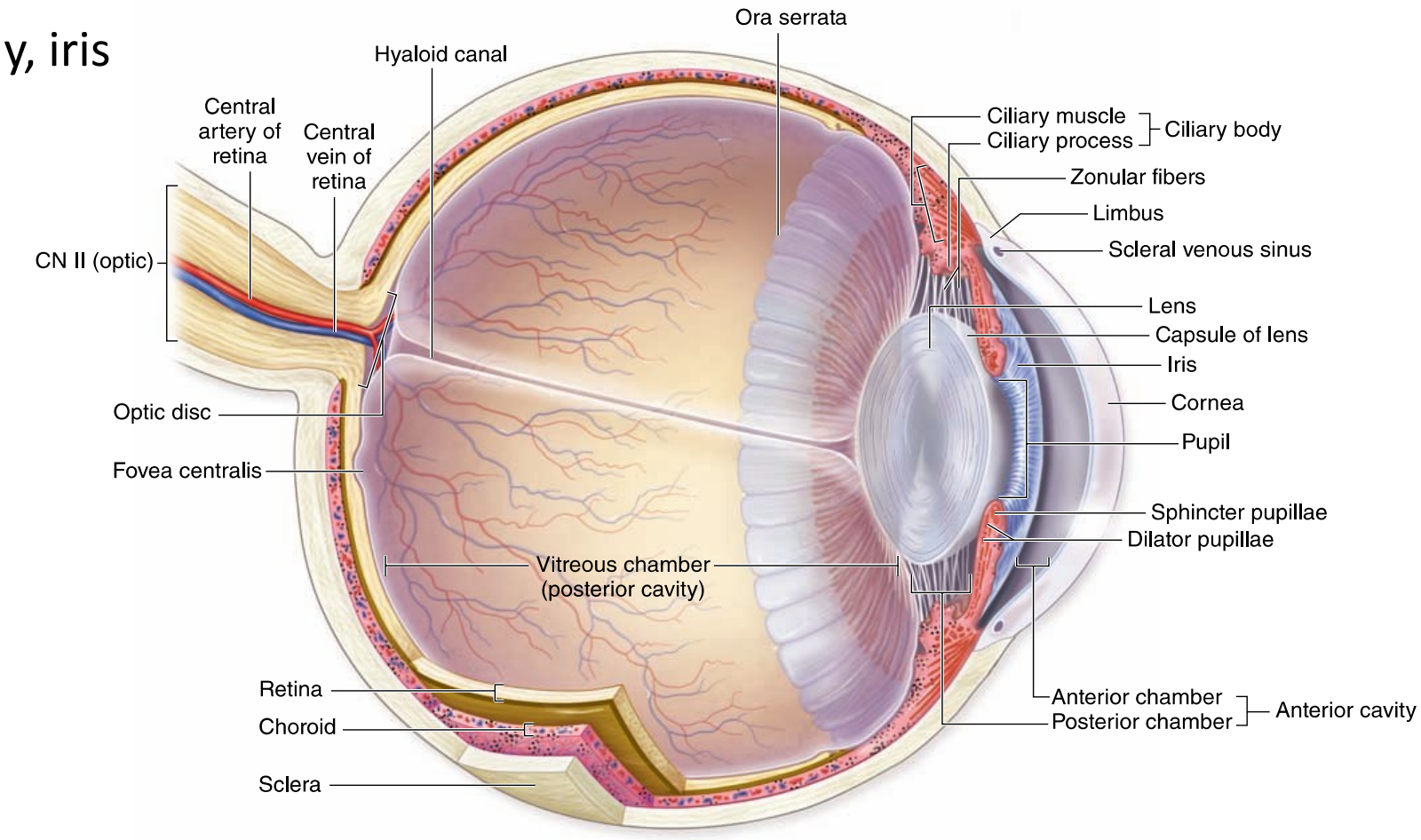
Pancreatic islets

Cell Type	Quantity (%)	Hormone Produced	Hormone Structure and Size	Hormone Function
α	~20	Glucagon	Polypeptide; 3500 Da	Acts on several tissues to make energy stored in glycogen and fat available through glycogenolysis and lipolysis; increases blood glucose content
β	~70	Insulin	Dimer of α and β chains with S-S bridges; 5700-6000 Da	Acts on several tissues to cause entry of glucose into cells and promotes decrease of blood glucose content
δ or D	5-10	Somatostatin	Polypeptide; 1650 Da	Inhibits release of other islet cell hormones through local paracrine action; inhibits release of GH and TSH in anterior pituitary and HCl secretion by gastric parietal cells
PP	Rare	Pancreatic polypeptide	Polypeptide; 4200 Da	Stimulates activity of gastric chief cells; inhibits bile secretion, pancreatic enzyme and bicarbonate secretion, and intestinal motility

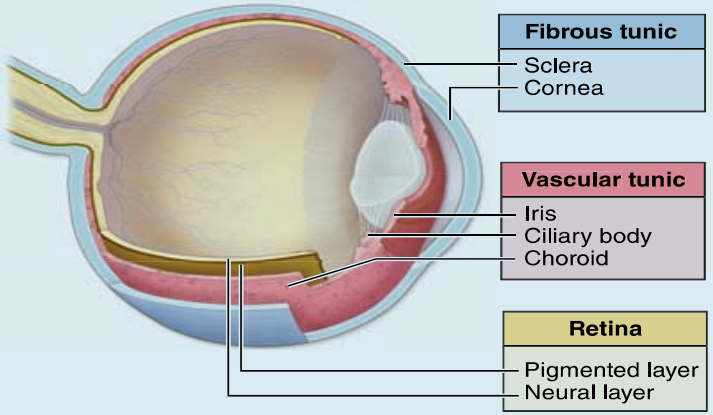
Sense organs: The eye

The eye consists of three basic layers:

- fibrous layer: cornea and sclera
- vascular layer: choroid, ciliary body, iris
- sensory layer: retina.



Sense organs: The eye



Structures	Components	Function
Fibrous Tunic (External Layer)		
Sclera	Dense irregular connective tissue	Supports eye shape Protects delicate internal structures Extrinsic eye muscle attachment site
Cornea	Two layers of epithelium with organized connective tissue in between	Protects anterior surface of the eye Refracts (bends) incoming light
Vascular Tunic (Middle Layer)		
Choroid	Areolar connective tissue; highly vascularized	Supplies nourishment to retina Pigment absorbs extraneous light
Ciliary body	Ciliary smooth muscle and ciliary processes; covered with a secretory epithelium	Holds suspensory ligaments that attach to the lens and change lens shape for far and near vision Epithelium secretes aqueous humor
Iris	Two layers of smooth muscle (sphincter pupillae and dilator pupillae) and connective tissue, with a central pupil	Controls pupil diameter and thus the amount of light entering the eye
Retina (Internal Layer)		
Pigmented layer	Pigmented epithelial cells	Absorbs extraneous light Provides vitamin A for photoreceptor cells
Neural layer	Photoreceptors, bipolar neurons, ganglion cells, and supporting Müller cells	Detects incoming light rays; light rays are converted to nerve signals and transmitted to the brain

Sense organs: The ey

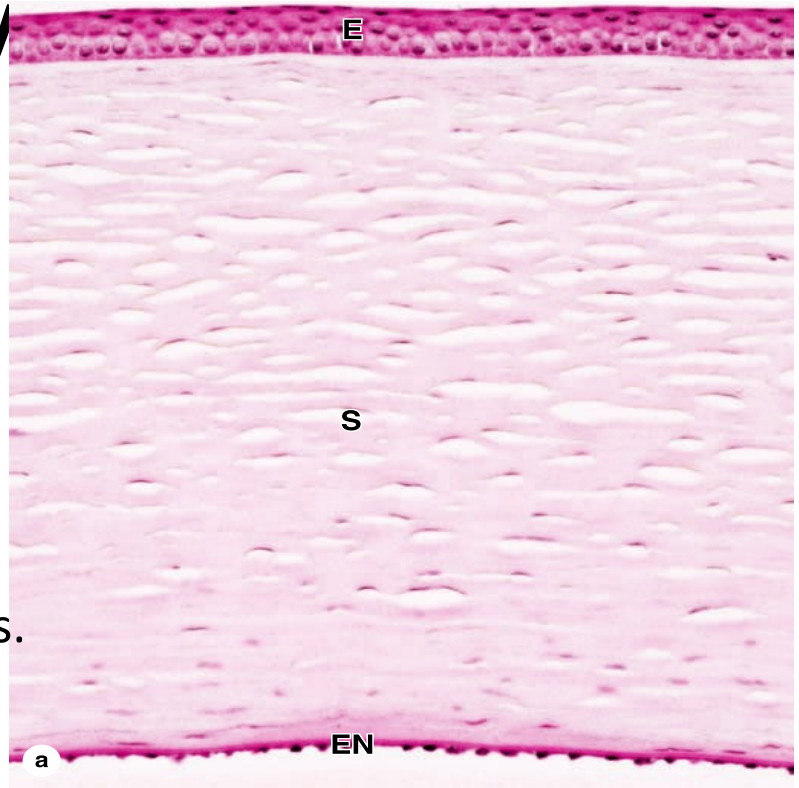
Histological characteristics of some parts of the eye:

Sclera: dense connective tissue,
Cornea: the front part of the sclera, is transparent and avascular.
The anterior epithelium of the cornea has a great regenerative capacity.

Choroid: loose well vascularized connective tissue
Ciliary body: contains smooth muscle and is important for accommodation
Iris: consists of fibroblasts, collagen connective tissue and many melanocytes.

Lens: the lens is a transparent, avascular, elastic tissue. On the surface is a capsule made of type IV collagen, under the capsule on the front side there is a simple epithelium. So-called lens fibers arise from the cells of this epithelium. They are long thin cells, they have special proteins crystallins in the cytoplasm and they do not have organelles or nuclei. The lens fibers are close together - it causes transparancy.

Vitreous body: transparent gel-like mass, contains water, mesenchymal cells that synthesize collagen fibrils and hyaluronan.

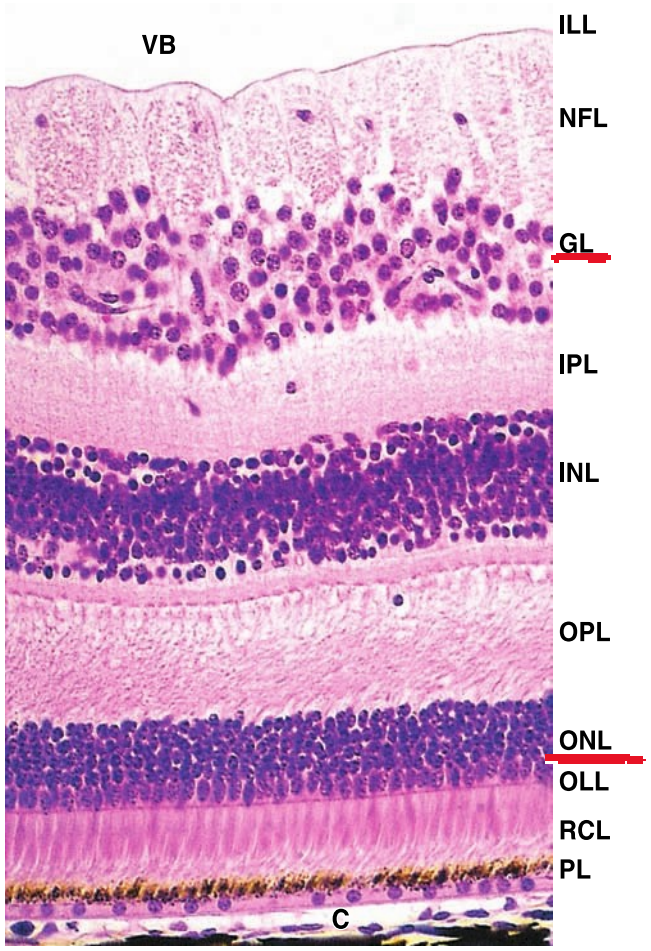


The anterior structure of the eye, the cornea has five layers. **(a)** The external stratified squamous epithelium (**E**) is nonkeratinized, five or six cells thick, and densely supplied with sensory-free nerve endings that trigger the blinking reflex. The stroma (**S**) comprises approximately 90% of the cornea's thickness, consisting of some 60 layers of long type I collagen fibers arranged in a precise orthogonal array and alternating with flattened cells called **keratocytes**. The stroma is lined internally by endothelium (**EN**). X100. H&E.

Histological characteristics of some parts of the eye:

Retina: complex structure, composed of 9 layers.
Three of these layers contain nerve cells: three neurons of the visual pathway.
(layers marked in red)

Light must pass through all the layers of the retina (in the direction of the arrow).
It reflects off the pigment epithelium and hits the rods and cones in the outer nuclear layer.
The nerve impulse then goes in the opposite direction in the ganglion layer. Axons of ganglion cells form the optic nerve.



Between the vitreous body (**VB**) and the choroid (**C**), the retina can usually be seen to consist of nine neural layers and a pigmented layer. Following the path of the light, these are:

- The inner limiting layer (**ILL**)
- The nerve fiber layer (**NFL**), containing the ganglionic cell axons that converge at the optic disc and form the optic nerve
- The ganglionic layer (**GL**), containing cell bodies of the ganglion cells and thicker near the retina's center than its periphery
- The inner plexiform layer (**IPL**), containing fibers and synapses of the ganglion cells and the bipolar neurons of the next layer
- The inner nuclear layer (**INL**), with the cell bodies of several types of bipolar neurons which begin to integrate signals from the rod and cone cells
- The outer plexiform layer (**OPL**), containing fibers and synapses of the bipolar neurons and rod and cone cells
- The outer nuclear layer (**ONL**), with the cell bodies and nuclei of the photosensitive rod and cone cells
- The outer limiting layer (**OLL**), a line formed by junctional complexes holding the rod and cone cells to the intervening Müller cells
- The rod and cone layer (**RCL**), which contains the outer segments of these cells where the photoreceptors are located
- The non-neural pigmented layer (**PL**), which has several supportive functions important for the function and maintenance of the neural retina. X150. H&E

Literature and image sources

Mescher A.L.: Junqueira‘s Basic Histology, Text and Atlas, 14th Edition,
Junqueira L. C., Carneiro J.: Základy histologie, H+H, 1997
Kerr J. B.: Atlas of Functional Histology, Elsevier, 1999
Knoz J.: Obecná zoologie I a II, SPN, 1984

http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookcircSYS.html
http://rocek.gli.cas.cz/Courses/courses.htm
http://www.sci.muni.cz/ptacek/
https://www.sciencedirect.com/topics/veterinary-science-and-veterinary-medicine/epiphyseal-plate
https://microbeonline.com/immunoglobulin-e-ige-antibodies/
https://biogennix.com/bone-healing/bone-anatomy-bone-fracture-repair-3-ways-to-categorize-bone/
https://musculoskeletalkey.com/spinal-cord/
https://www.merckmanuals.com/home/brain,-spinal-cord,-and-nerve-disorders/biology-of-the-nervous-system/spinal-cord
https://www.istockphoto.com/cs/ilustrace/spinal-cord-cross-section
https://qbi.uq.edu.au/brain/brain-anatomy/spinal-cord
n.pinterest.com/pin/histology-of-cerebrum-and-cerebellum--679128818789089515/
https://brainmadesimple.com/cerebral-cortex-and-lobes-of-the-brain/
https://www.alamy.com/stock-photo/epidural-space.html?sortBy=relevant
https://asm.org/Articles/2020/April/How-Pathogens-Penetrate-the-Blood-Brain-Barrier