# The Nervous System

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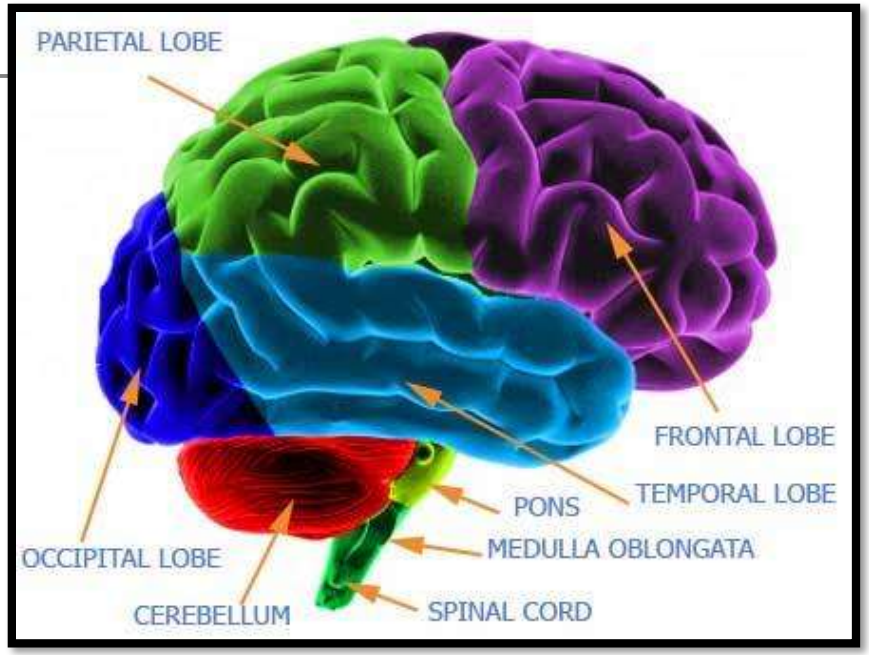
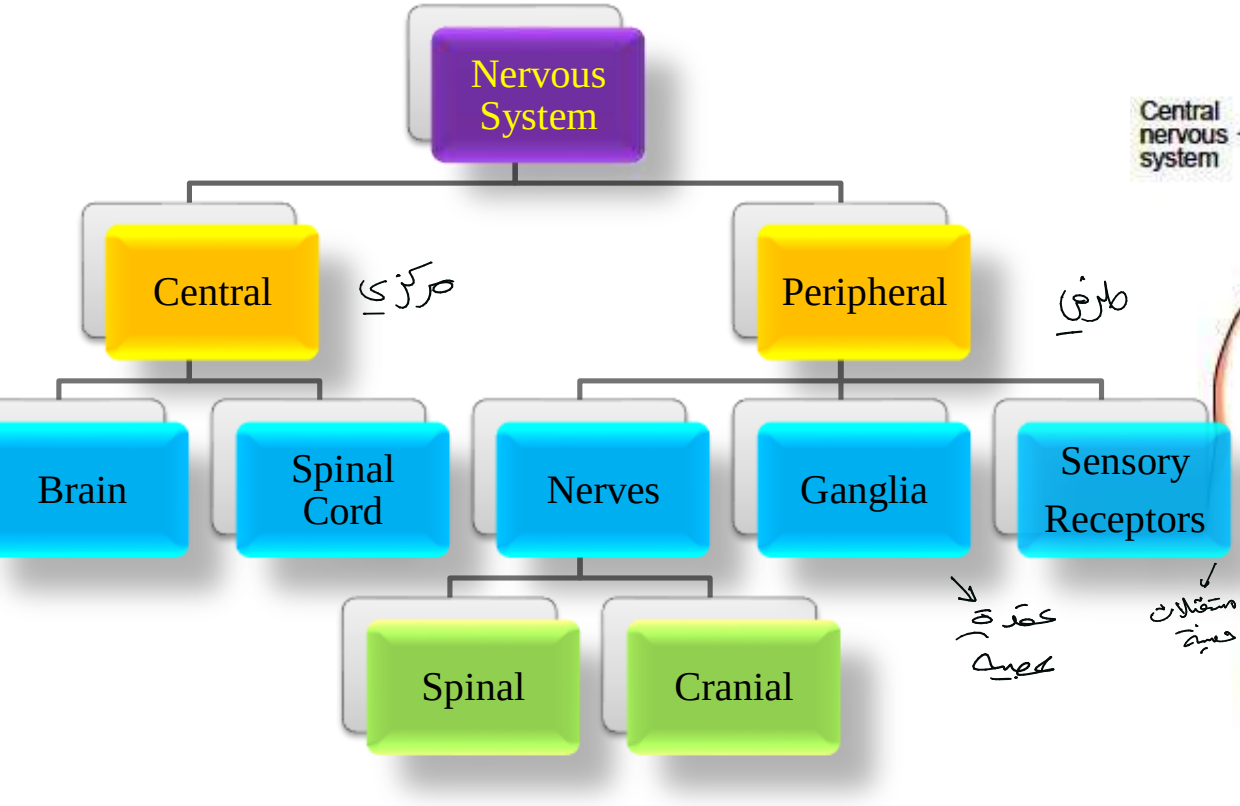
(2021)



# Overview

- *The nervous system is the system that **controls** the various functions of the body by the means of **electrical impulses.***



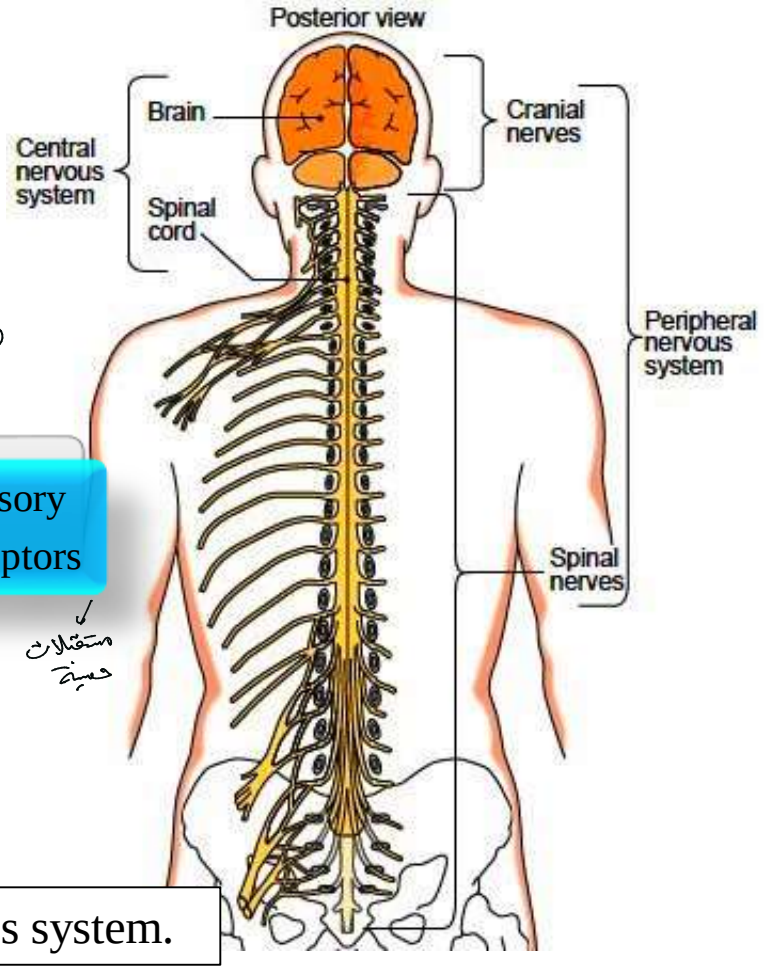




Fig.1: Divisions of the nervous system.

# The Central Nervous System (CNS)

- Formed of the brain and spinal cord
- Formed of millions of nerve cells (neurons) and supporting cells (glia cells).
- Well protected within the skull and vertebral column.
- **Functions:**

1. **Initiates motor commands (movement and secretions).**
2. **Receives and perceives sensory information.**
3. **Responsible for our emotions, personality, behavior, memory and others.**

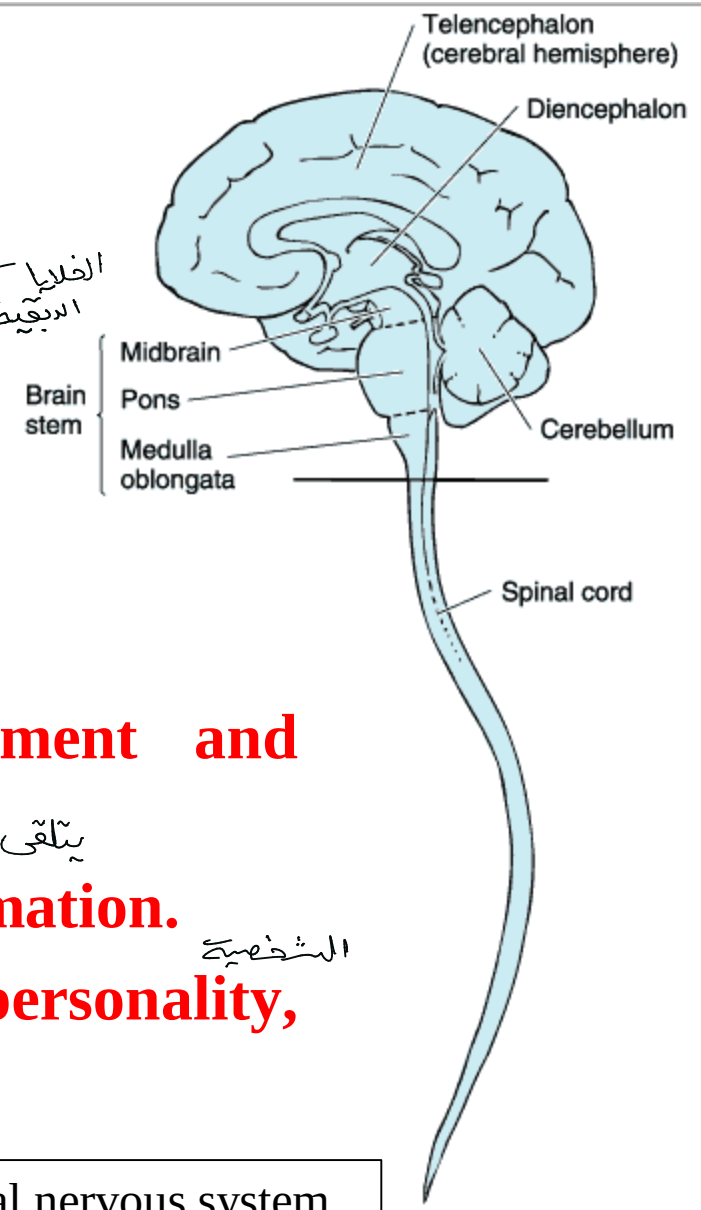



Fig.2: The central nervous system.

# The Peripheral Nervous System (PNS)

- Formed of the peripheral nerves (cranial and spinal), the ganglia, and the sensory receptors.

- The nerves may be sensory (carry information to CNS) or motor (carry orders from the CNS)

- **Ganglia** are collection of neurons outside the central nervous system.

- **Sensory receptors** are parts of neurons or specialized structures that can detect changes in the internal or external environment. The skin, for example, contains several types of receptors that detect pain, touch and heat.

يقسم PNS من الناحية الوظيفية إلى:

- Functionally, the PNS can be divided into:

- **Somatic part**: connected to skin, muscles, joints and the special senses. We are fully conscious of this part. Our voluntary movements and our sensation of pain and touch are controlled by this part.

- **Autonomic Nervous System**: this part usually operates without conscious control, as it controls all of our involuntary actions, like our heart rate, respiratory rate and blood pressure.

- **Enteric part**: controls the secretions and movements of the various parts of the digestive system unconsciously.

# Histology Of The Nervous System

- The nervous tissue is formed of two types of cells:

1. The nerve cell – Neurons
2. Supporting cells –Neuroglia or Glia cells

- In the nervous tissue, there is ***a very small amount of extracellular matrix*** found around the blood vessels.
- The space between the cells is filled with **neuropil** which is formed of the processes of both neurons and glia cells and some fluid.

# Neurons

- Functional unit of nervous system.
- Have capacity to produce action potentials.
- ***Cell body:***
  - Single nucleus with prominent nucleolus
  - *Nissl bodies* formed of rough endoplasmic reticulum & free ribosomes for protein synthesis.
  - Neurofilaments give cell shape and support
- ***Cell processes*** = dendrites & axons
- ***Mature neurons cannot divide. A damaged neuron cannot be repaired and is replaced by fibrous tissue.***

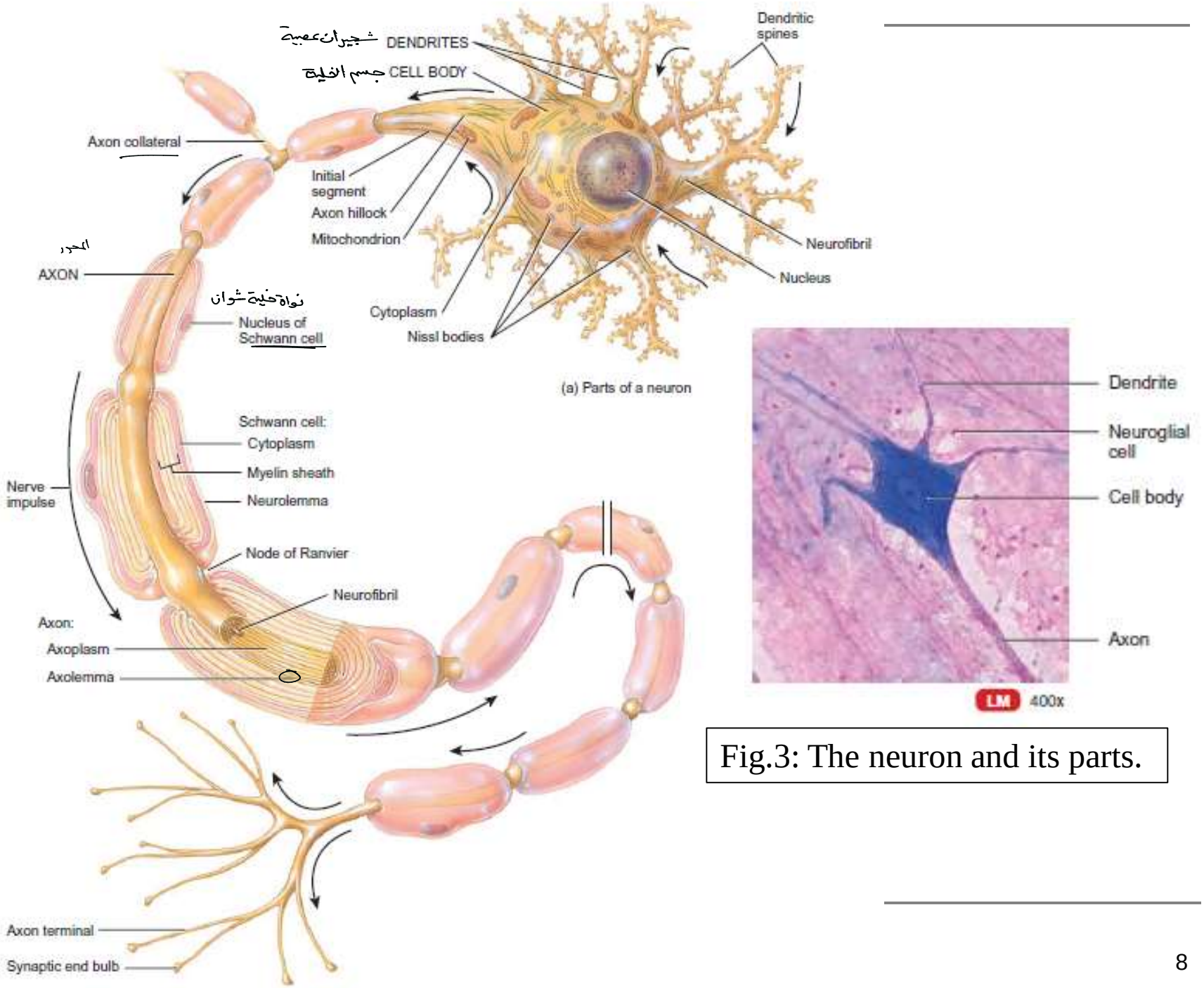



Fig.3: The neuron and its parts.

Dendrites و Axon بين المقارنة

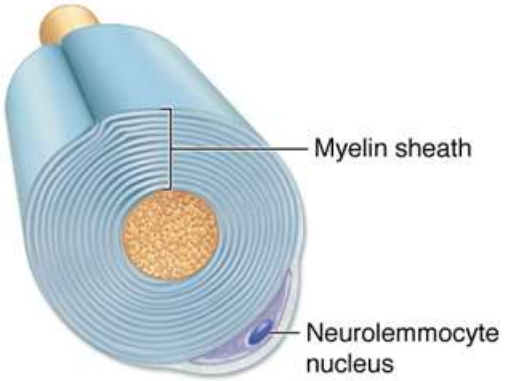
| | Dendrites | Axon = nerve fiber |
|---|---|---|
| 1 | Mostly multiple branches | A Single branch |
| 2 | Usually short | Usually the longest branch and is called ***nerve fiber*** |
| 3 | Taper as they extend away from cell body (تتناقص مع ابتعادها عن الخلية بقل الـ diameter) | Has a fixed diameter ← له قطر محدود |
| 4 | Branch profusely (تفرعات كثيرة) | (لا تفرعات قريبة من جسم الخلية)<br>▪ No branches near cell body<br>▪ Collateral branches along course<br>▪ Terminal branches |
| 5 | Not covered by a myelin sheath | Some are covered by a myelin sheath |
| 6 | Conduct impulse towards cell body | Conducts impulse away from cell body |

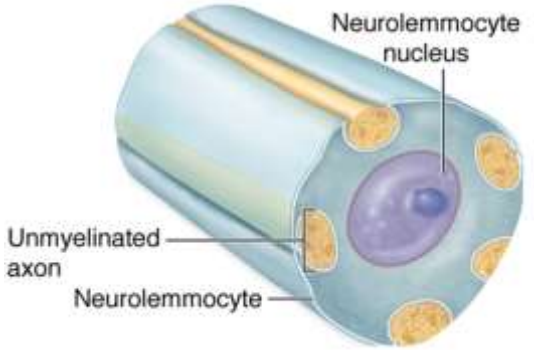
# Glia cells

| Location | Cell | Function |
|---|---|---|
| CNS | Astrocytes | • Part of blood-brain barrier<br>• Provide nutrients for neurons<br>• Form scar tissue after injury |
| | Oligodendrocytes | Form myelin sheath |
| | Microglia cells | Defense (by phagocytosis) |
| | Ependymal cells | Line cavities |
| | | |
| PNS | Schwann cells (Neurolemmocytes) | Form myelin sheath |
| | Satellite cells | Support neurons in dorsal root ganglia |

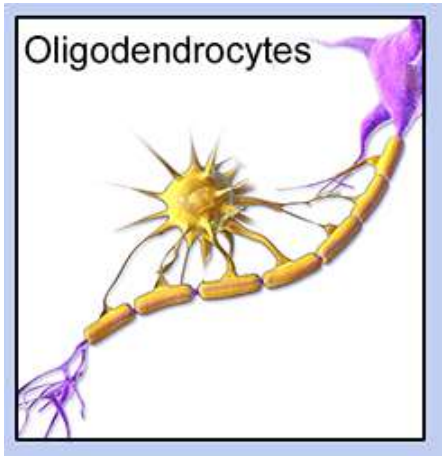
# Myelination

- The process by which a nerve fiber (axon) is surrounded by multiple layer of cell membrane (myelin sheath)




| PNS | CNS |
|---|---|
| Done by Schwann cells | Done by oligodendrocyte |
| The entire cell wraps around the axon | The process of the cell wraps around the axon |
| Unmyelinated axons are also surrounded by cell membrane of Schwann cell | Unmyelinated fibers are not surrounded by anything |



# Histology of a nerve

bundles of nerve fibers and their covering

- **Nerve**: a group of bundles of nerve fibers and their covering connective tissue layers.

a group of bundles of nerve fibers and their covering connective tissue layer

- The whole nerve is surrounded by the **epineurium.**
- Each bundle is surrounded by the **perineurium,** which forms a blood-nerve barrier.
- Each nerve fiber (axon) is surrounded by myelin sheath and an areolar connective tissue **endoneurium.**

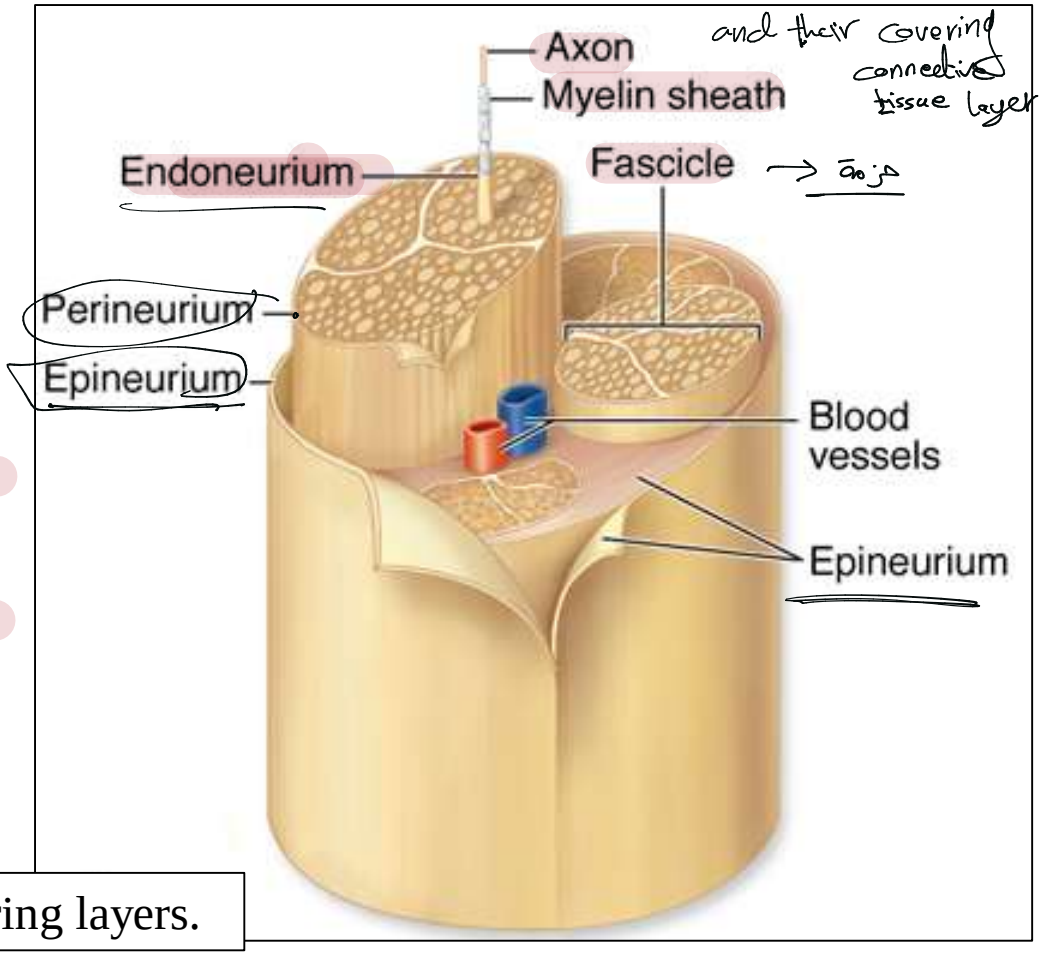



Fig.4: Peripheral nerve and its covering layers.

# The Central Nervous System - The Brain

- The brain is the part of the nervous system present within the skull. It's covered by protective layers called the meninges.

- The brain is formed of:

1) The Cerebrum
2) The Diencephalon
3) The Cerebellum
4) The Brainstem

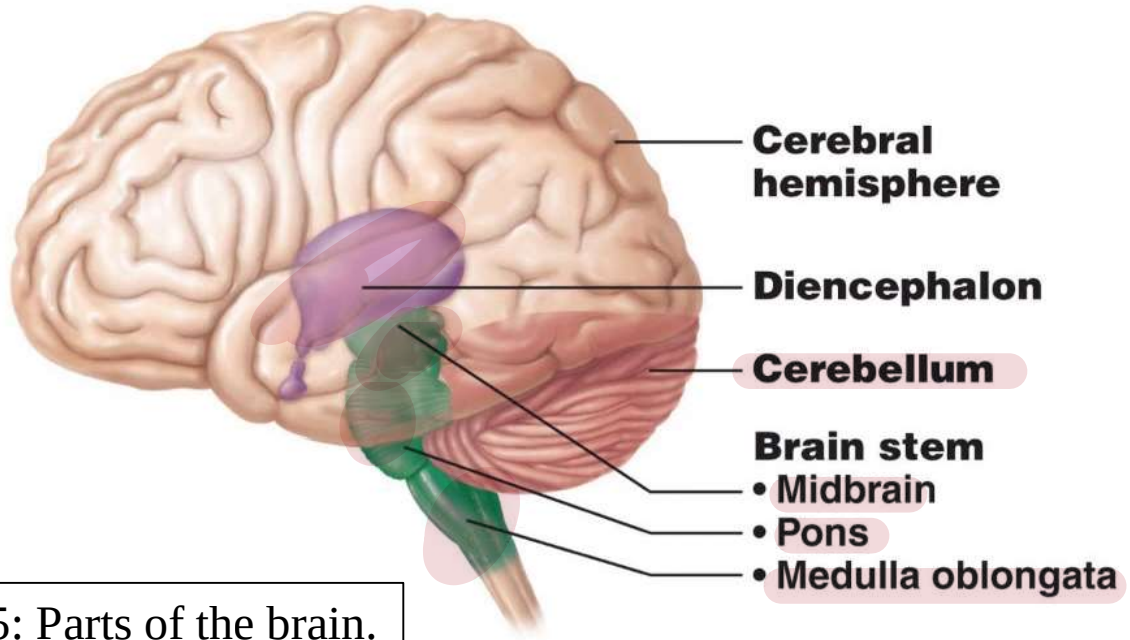



Fig.5: Parts of the brain.

البطيني يحل على تبطين التجاويف في ال brain

# Ventricular system

- Within the different parts of the brain, there are several cavities lined by ependymal cells and filled with cerebrospinal fluid.

(1) (2) سائل النخاع الشوكي

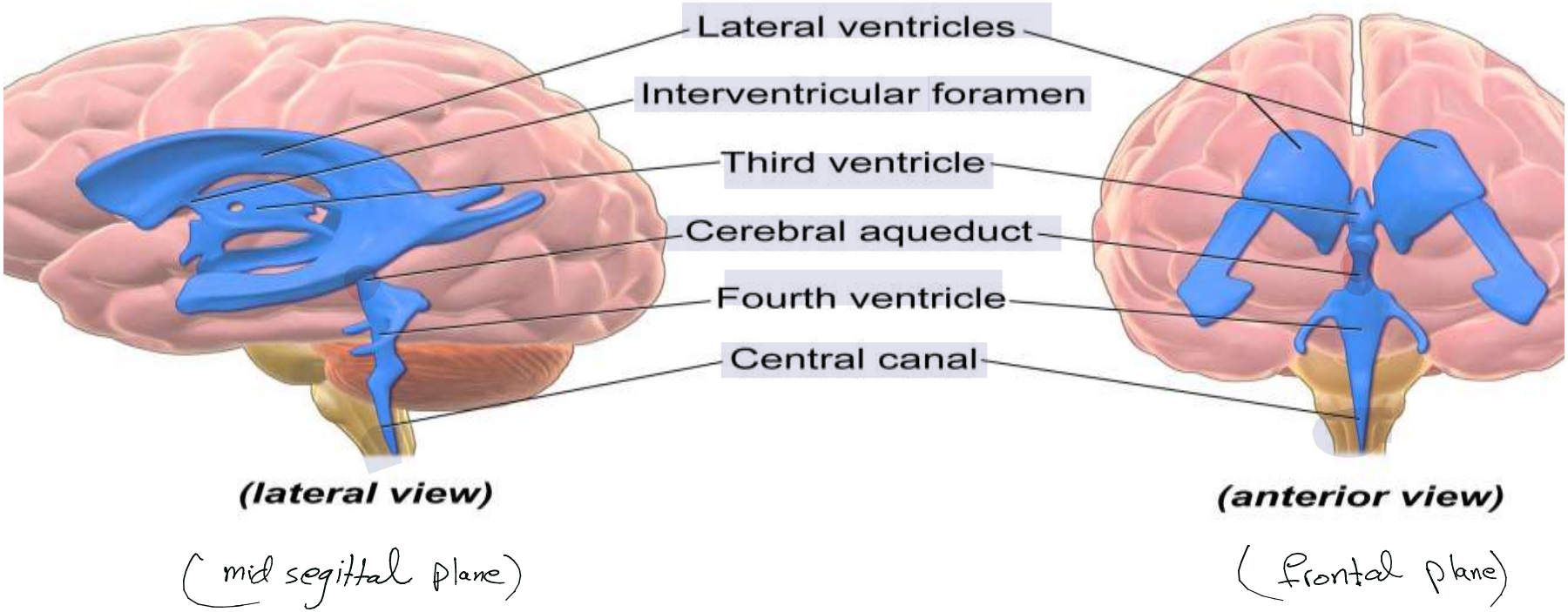



Fig.6: Ventricles of the brain.

# Cranial meninges

1. **Dura mater**: the hard outermost layer. Separated from the skull bones by the epidural space. The venous sinuses of the brain are located within the dura mater.
2. **Arachnoid mater** : the thin middle layer. Separated from the dura by the subdural space. Beneath the arachnoid, we have the large subarachnoid space.
3. **Pia mater**: thin innermost layer. Directly covers the brain.

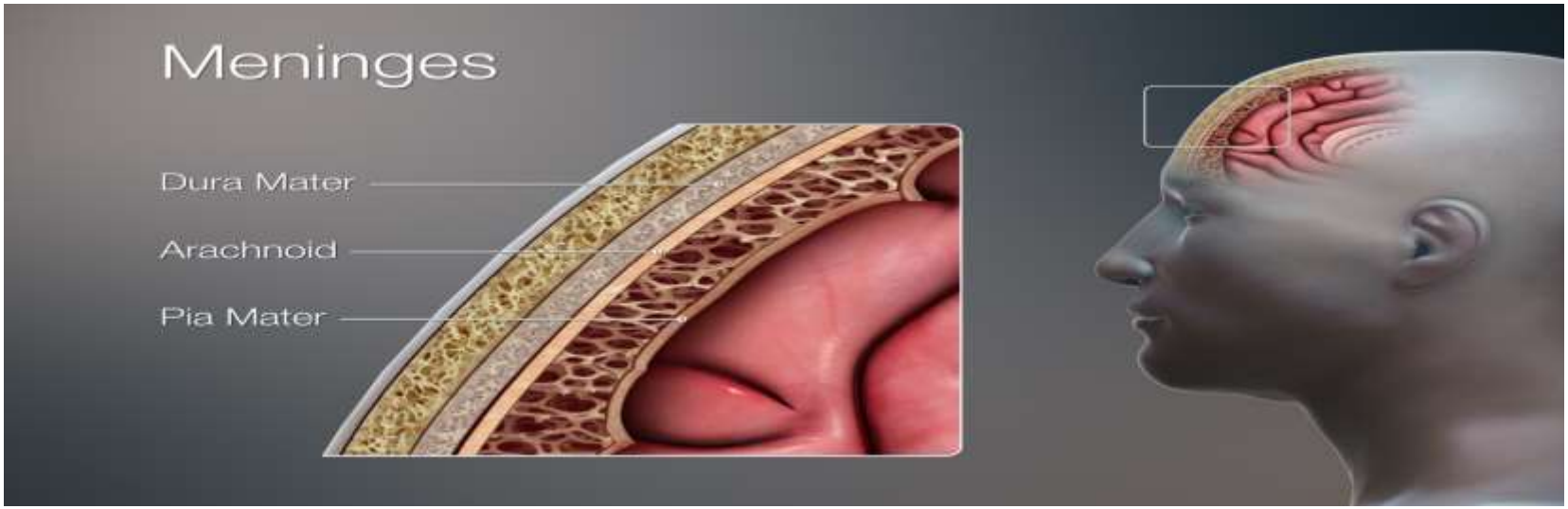
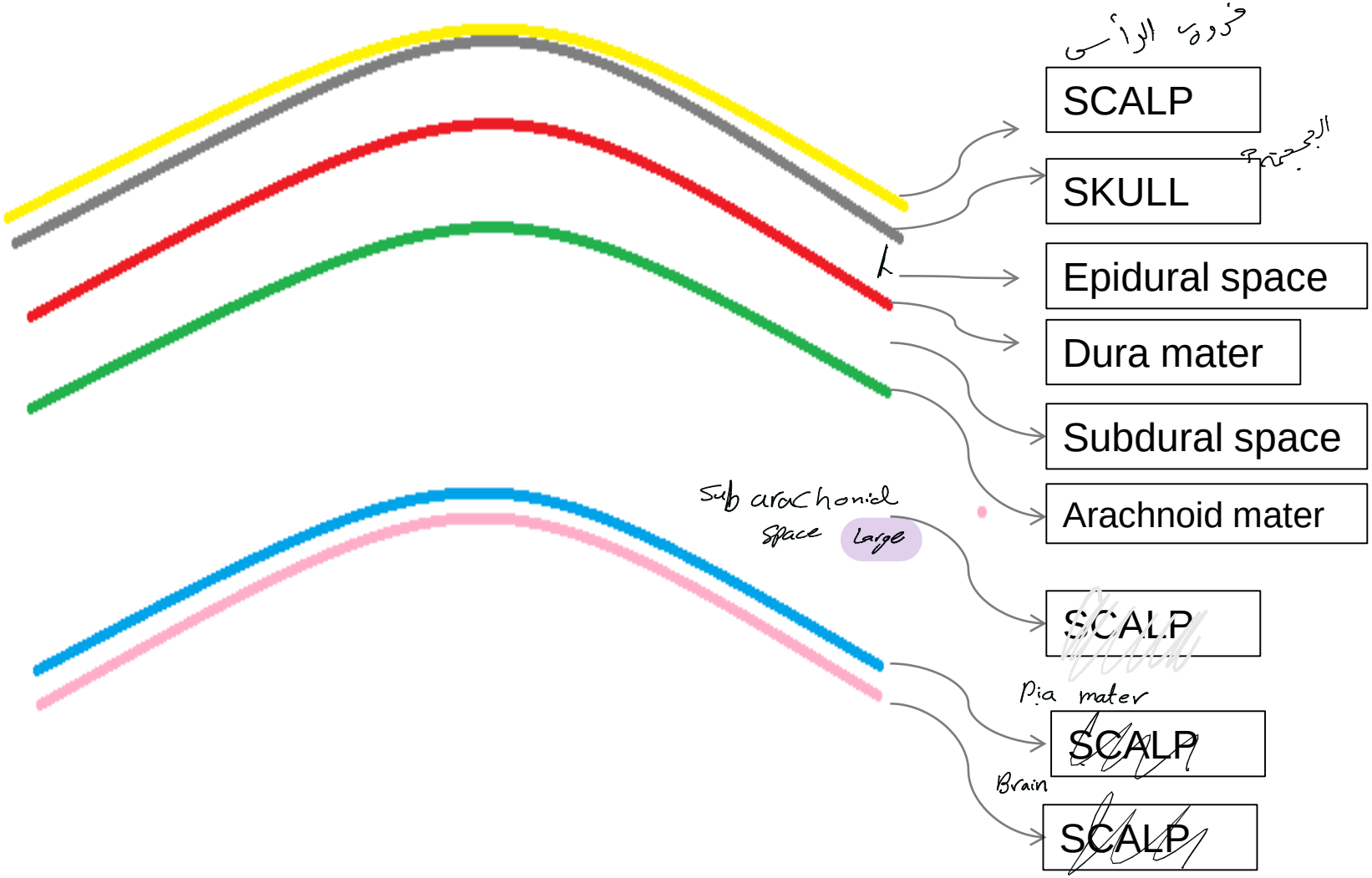



Fig.7: The cranial meninges.


فروة الرأس
SCALP
الجمجمة
SKULL
Epidural space
Dura mater
Subdural space
Arachnoid mater
Sub arachnoid space
Large
SCALP
Pia mater
SCALP
Brain
SCALP

# The Cerebrospinal Fluid (CSF)

- Clear fluid.
- Circulates through cavities in the brain (ventricles) and the spinal cord (central canal) and also in the subarachnoid space.
- ***Functions:***

1. ***Absorbs shock and protects the brain and the spinal cord.***
2. ***Helps transport nutrients and wastes between the blood and the nervous tissue.***

# The Blood-Brain Barrier

- This include a number of structures that control the passage of substances from blood to the nervous tissue to protect it against harmful agents.

- It's formed of:

1) Endothelium of capillaries
2) Pericytes: cells present around the capillaries beneath its basal lamina
3) Basal lamina
4) Processes of astrocytes

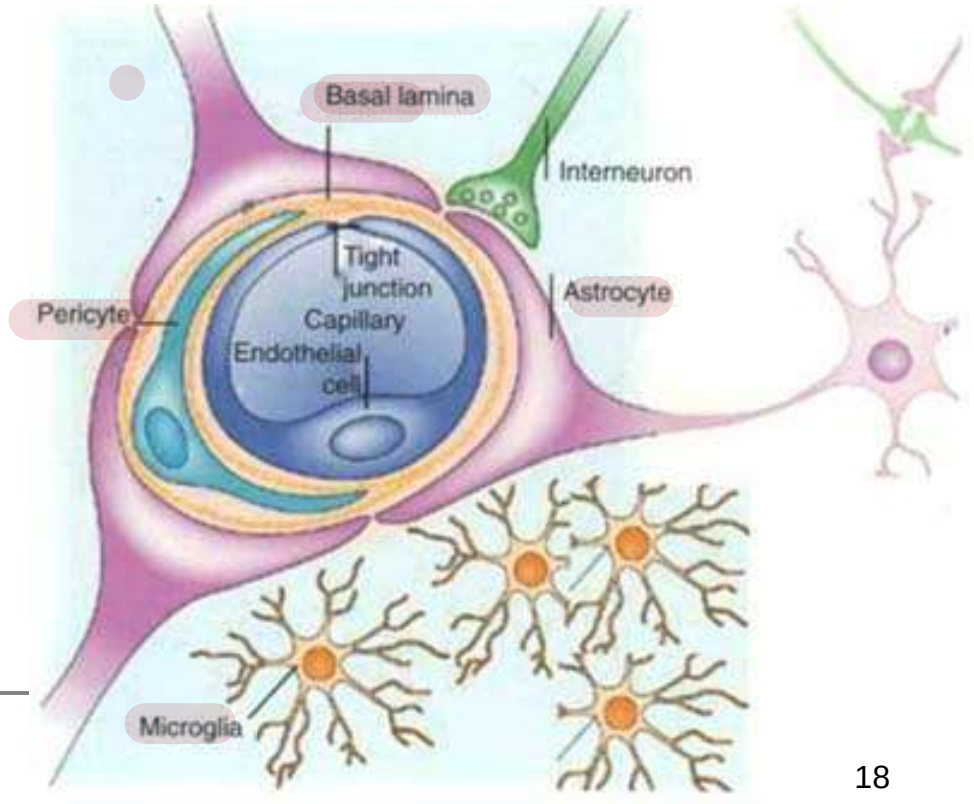
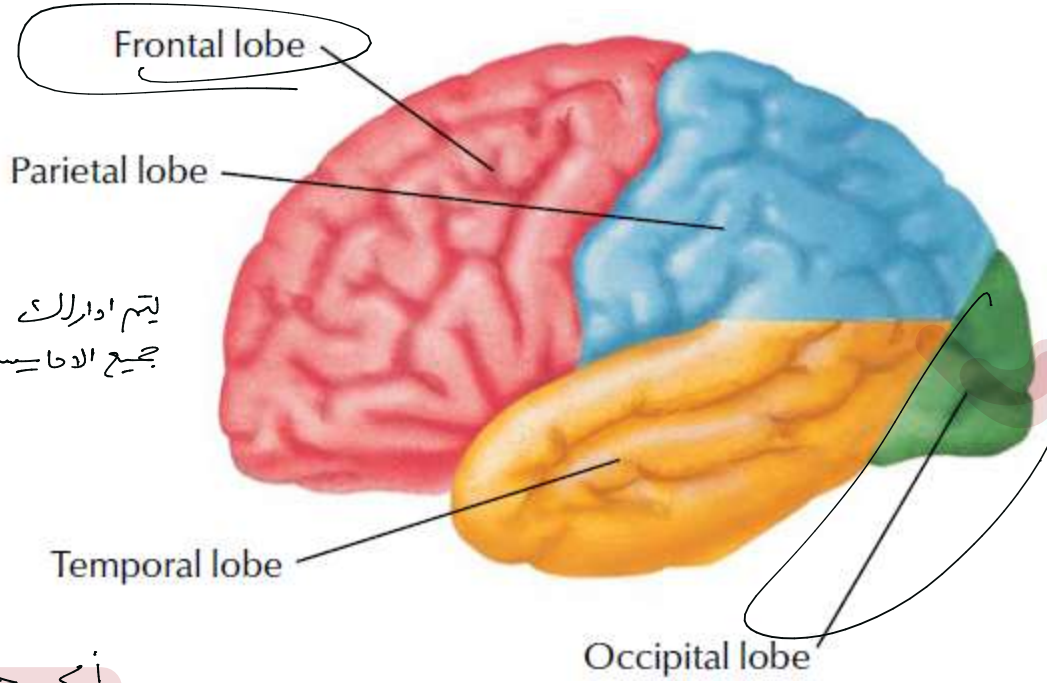



Fig.8: The blood-brain barrier.

# The Cerebrum

المخ

Fig.9: The Cerebrum (lateral view).




الأوامر الحركية

- All motor commands issue from the cerebrum. All sensations are perceived here. In addition, this part is responsible for emotions, behavior and memory.

يتم ادراك جميع الاحاسيس

العواطف والاحاسيس

التصرفات/السلوك

الذاكرة

أكبر جزء

- The cerebrum is the largest part of the brain. It's formed of two parts (called hemispheres) each of which is formed of four lobes: frontal lobe, parietal lobe, temporal lobe, and occipital lobe.

أربعة فصوص

- It's characterized by the presence of fissures called sulci and protrusions called gyri (Fig.11). The cavity within it is the lateral ventricle.

شقوق أو مثل الأخاديد

الالتفافات للداخل

نتوءات

الالتفافات الخارجة (تلافيف)

- The outer layer of the cerebrum is called the **cerebral cortex**. It's formed mainly of the body of neurons and therefore it's called the **gray matter**. Deep to it, we have the **white matter,** formed mainly of nerve fibers. = Axons
- In the spinal cord, the arrangement is reversed.

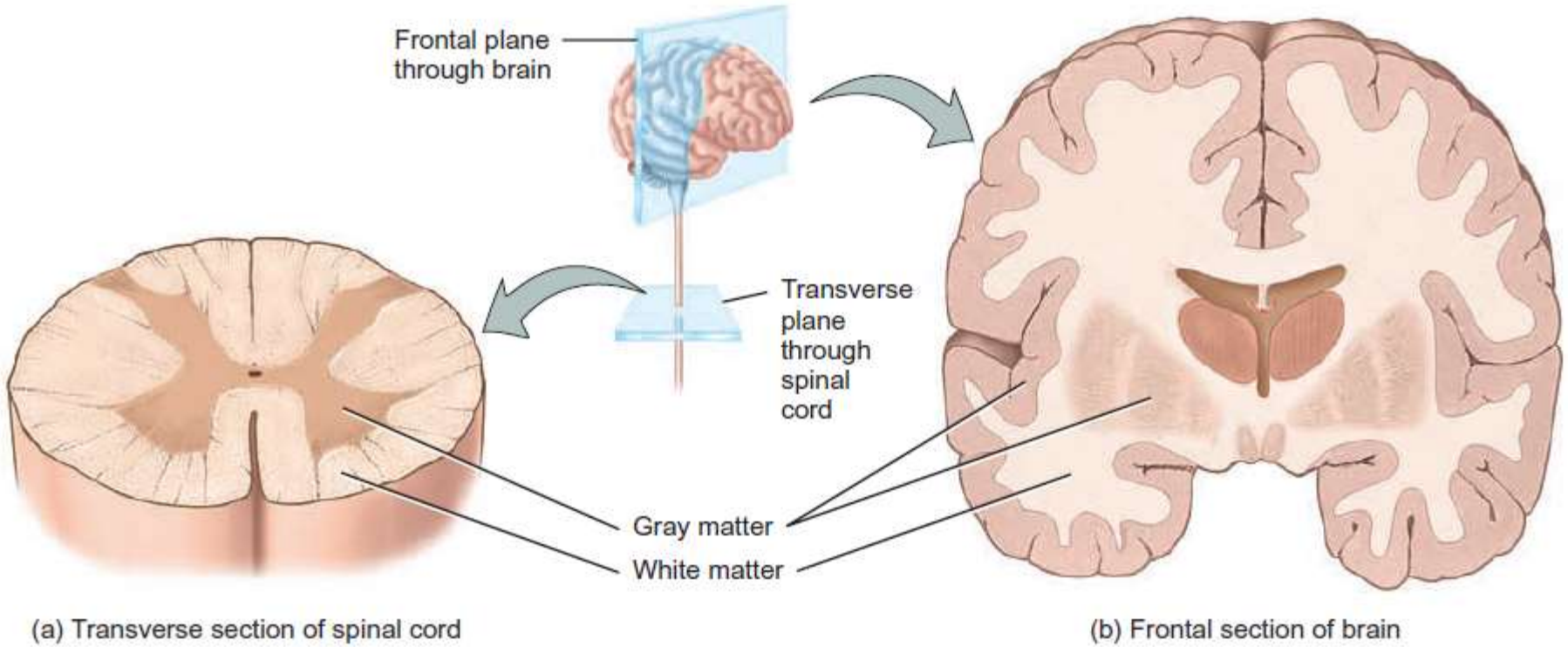
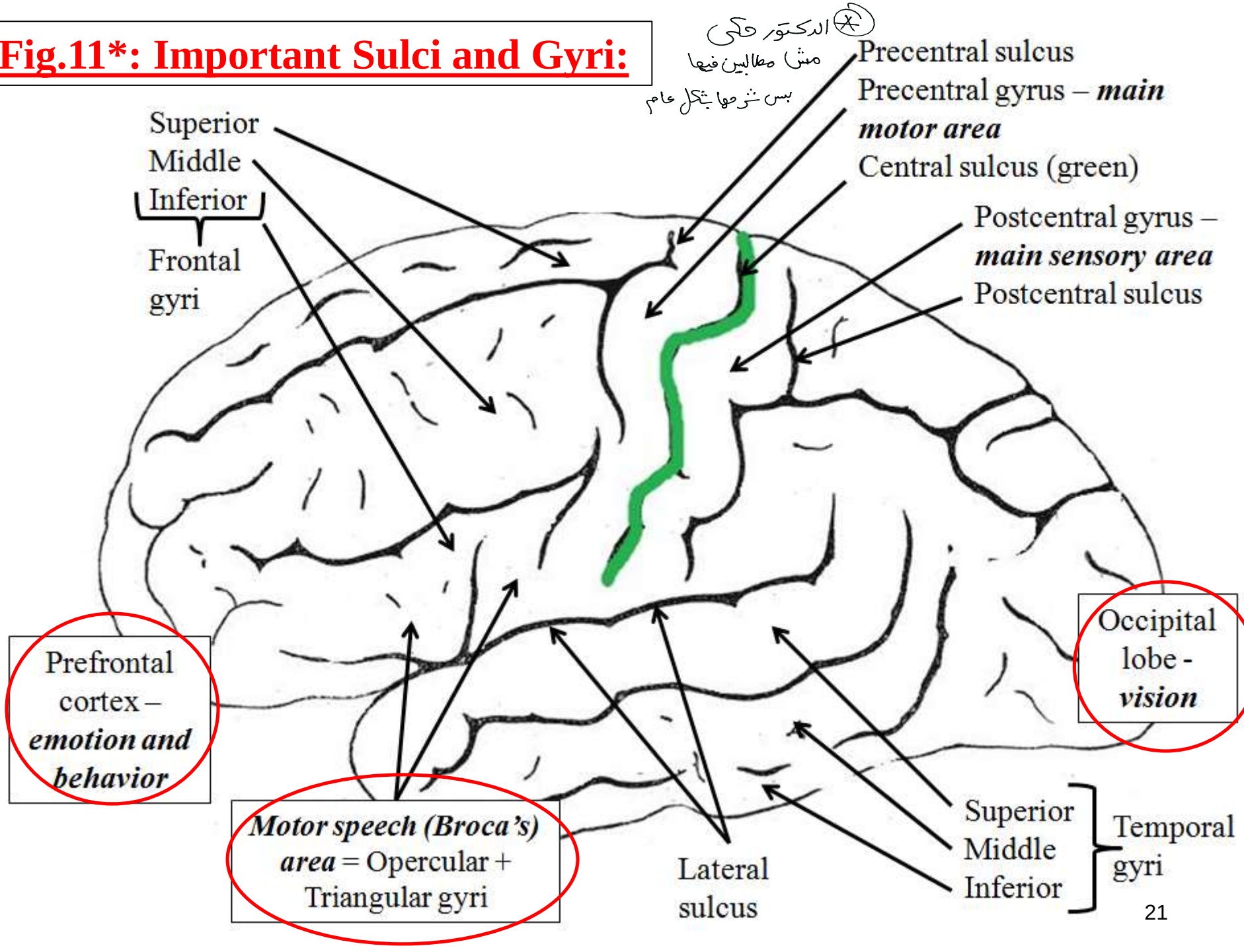



Fig.10: The arrangement of the gray and white matter in the cerebrum and spinal cord.

# Fig.11*: Important Sulci and Gyri:

الدكتور حكى
مش مطالبين فيها
بس شرحها بشكل عام



# The Diencephalon

الدماغ البيني

- This part of the brain is located on the medial aspect of the cerebrum. The cavity here is the 3rd ventricle.

- It's formed of the:

1. Thalamus (المهاد)
2. Hypothalamus (تحت المهاد)
3. Epithalamus

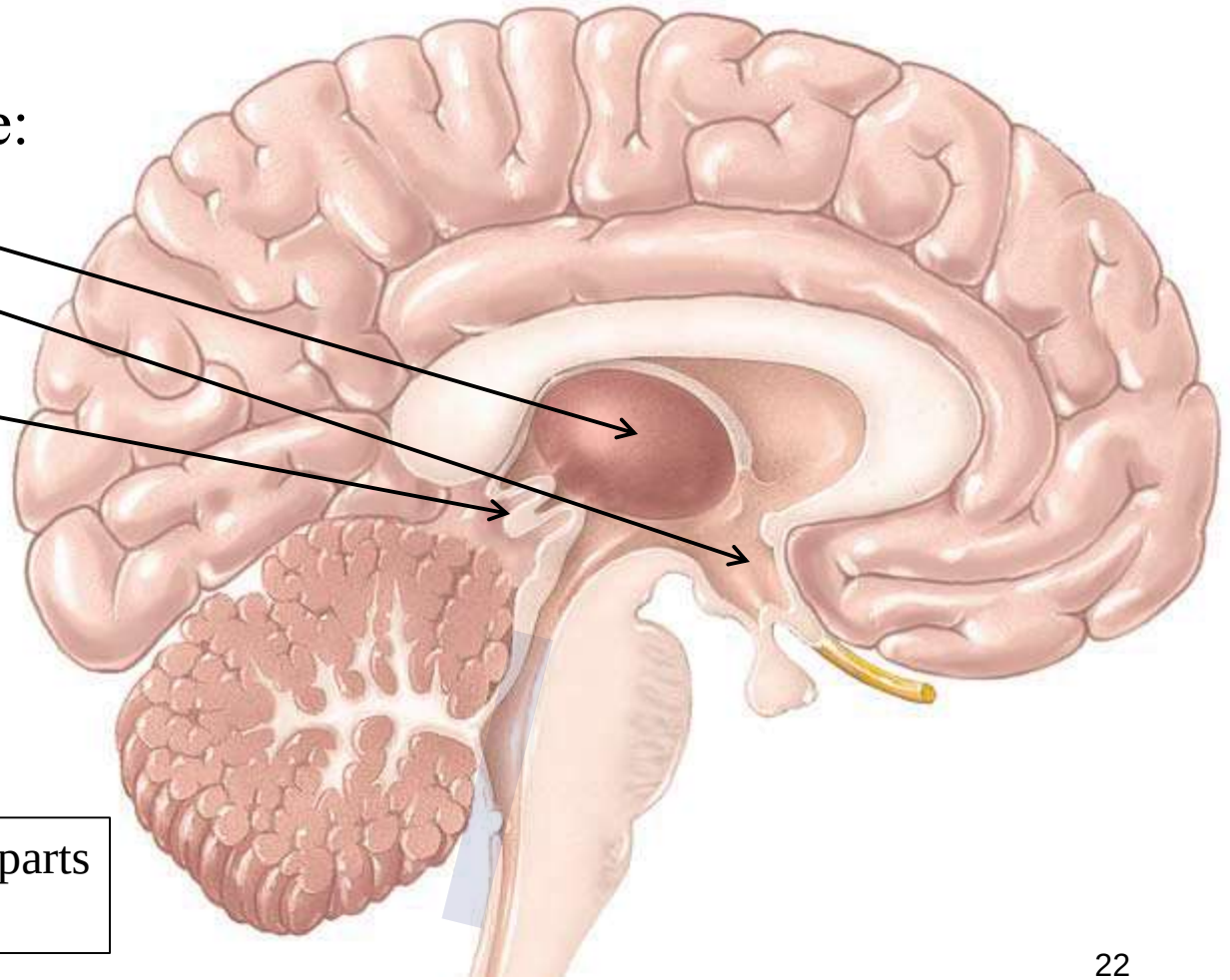
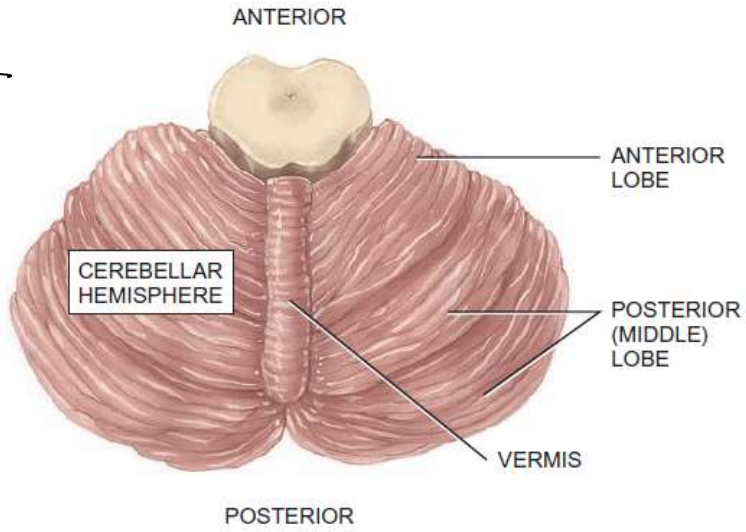


Fig.12: The location and parts of the diencephalon.

| Part | Main Function |
| --- | --- |
| Thalamus | Relay station for most sensation |
| Hypothalamus | 1. Controls hormone secretions of all endocrine glands in the body<br>2. Control body temperature<br>3. Control eating and drinking |
| Pineal gland of the epithalamus | Secrete melatonin hormone which regulates diurnal (day-night) cycles |

# The Cerebellum

- Second largest part of the brain.
- The central constricted area is the **vermis**. On each side of the vermis, we have the expanded **cerebellar hemispheres.**
- The cerebellum is located inferior to the occipital lobe and posterior to the brainstem. It's separated from the brainstem by the 4th ventricle.
- ***The function of the cerebellum is the coordination of movement and the maintaining of balance.***



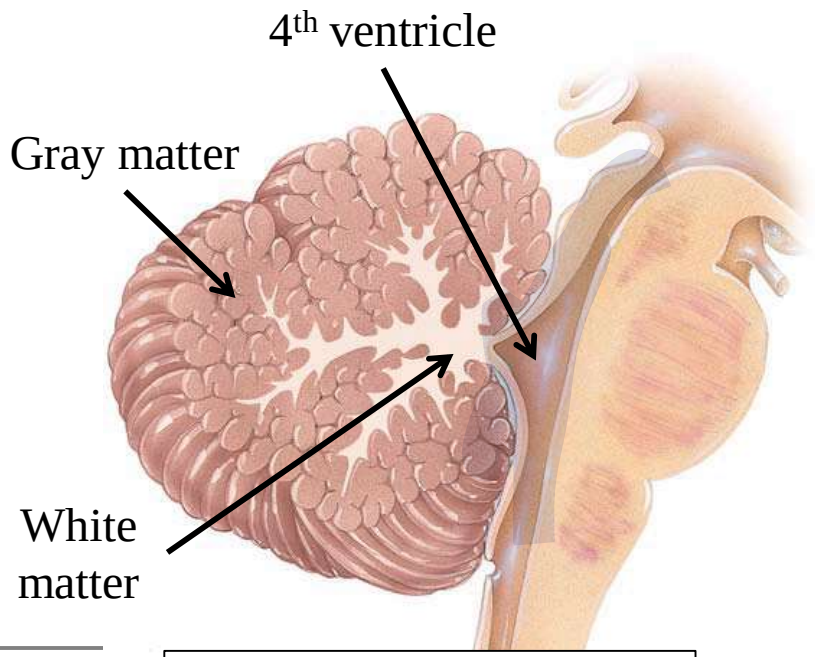




Fig.13: The cerebellum.

# The Brainstem

جذع الدماغ

- ✓ The part of the brain that connects the diencephalon with the spinal cord.
- ✓ Formed of 3 parts:
  - Midbrain (MB)
  - Pons – connect several parts of the CNS together. Contains respiratory centers.
  - Medulla oblongata
- ✓ The brainstem contains several important control centers and the attachment of several cranial nerves.
- ✓ Also in the brainstem is the ***Reticular Formation*** which is related to consciousness and muscle tone.

*الوعي

* قوة العضلات

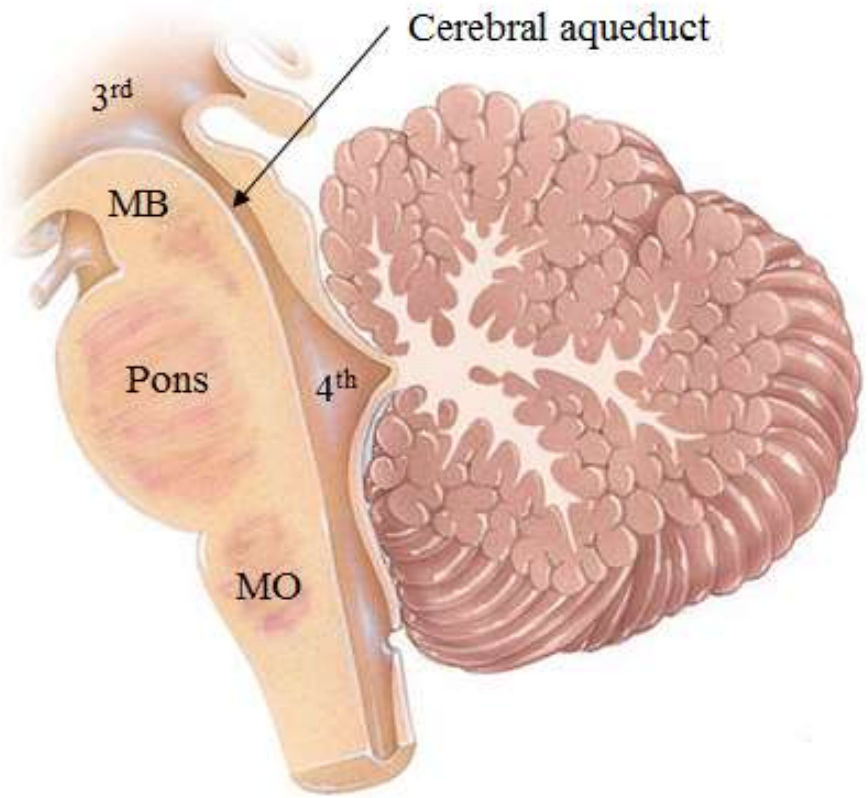
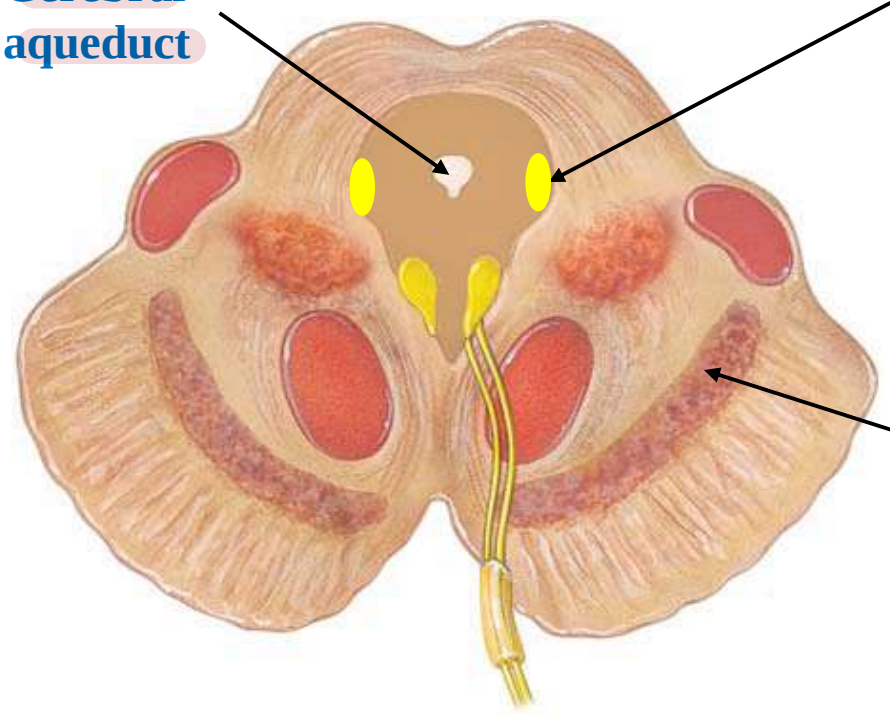



Fig.14: Location and parts of the brainstem.

# The Midbrain




**Mesencephalic nucleus** – contains pseudounipolar neurons that carry sensations from the face. The only place in the CNS with such neurons; all other pseudounipolar neurons are located in peripheral ganglia.

**Substantia nigra** – neurons here release Dopmaine and is involved in muscular activity. Lesion in this area is associated with Parkinson's disease.

Fig.15: Section through the midbrain.

# The Medulla Oblongata

- ✓ Contains important control centers:
  - Cardiovascular center مركز القلب والأوعية الدموية
  - Respiratory center مركز الجهاز التنفسي
- ✓ Anteriorly, near the midline, are ***the pyramids*** which are formed by the descending motor tracts (group of nerve fibers in the CNS).
- ✓ At a certain point in the medulla, the majority of the fibers in these tracts will cross to the opposite side forming the ***decussation of the pyramid***. تقاطع
- ✓ This is why each half of the brain controls the opposite side of the body.

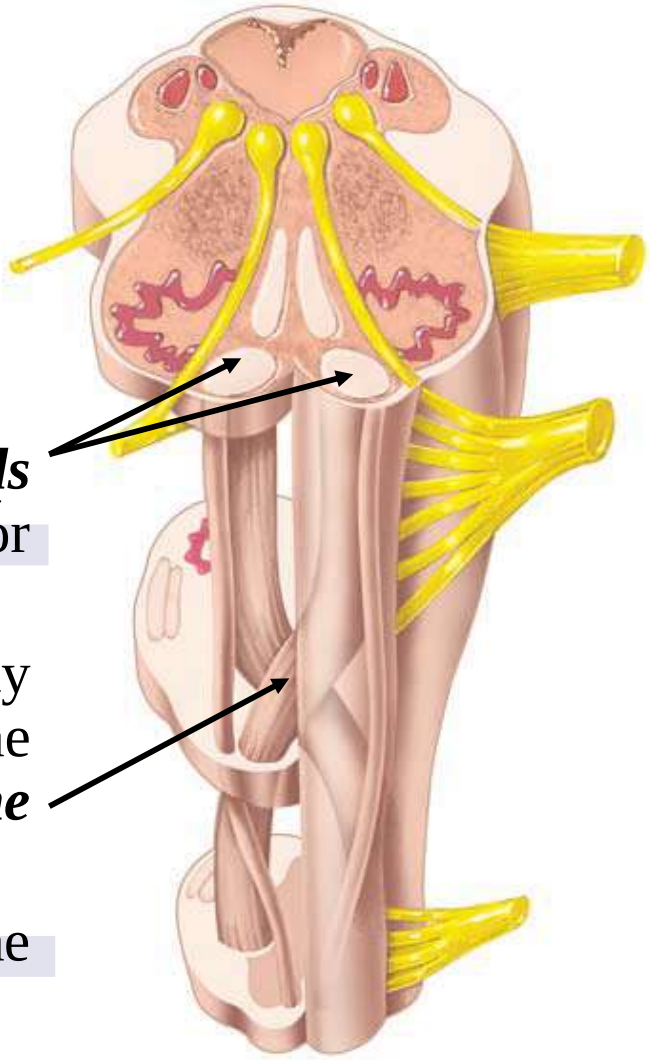


Fig.16: The medulla oblongata.

# The Central Nervous System - The Spinal Cord

- A grayish-white cylindrical structure.
- Starts at the foramen magnum and ends at lower border of L1 in adults. In children, it ends at L3.
- Protected by the vertebral column and the three layers of meninges.
- The pia matter will continue after the termination of the spinal cord as a thin thread called the filum terminale.

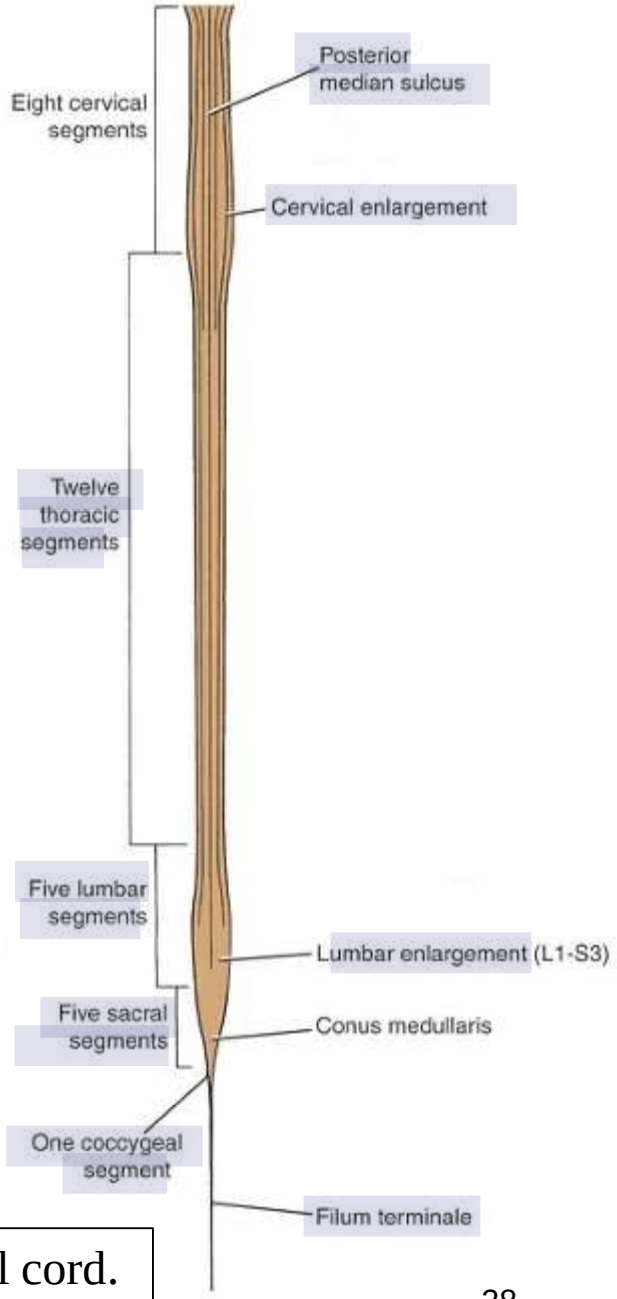



Fig.17: The spinal cord.

# External features of the spinal cord

- It has two enlargements: cervical and lumbar. The cervical enlargement is the origin of the cervical and brachial plexuses. The lumbar enlargement is the origin of the lumbar and sacral plexuses.

- The terminal part of the spinal cord is cone shaped and called the **Conus medullaris.**

Fig.18: The conus medullaris.

- The spinal cord is divided into segments: 8 Cervical, 12 Thoracic, 5 Lumbar, 5 Sacral and 1 Coccygeal. From each segment arises a pair of spinal nerves. Thus, we have a total of 31 pairs of spinal nerves.

- The nerves pass laterally to exit the vertebral column. The spinal cord is shorter than the spine. Therefore the lower nerves must pass down for a distance before exiting. These will form a structure like a wisp of hair around the filum terminale called the **Cauda Equina.**

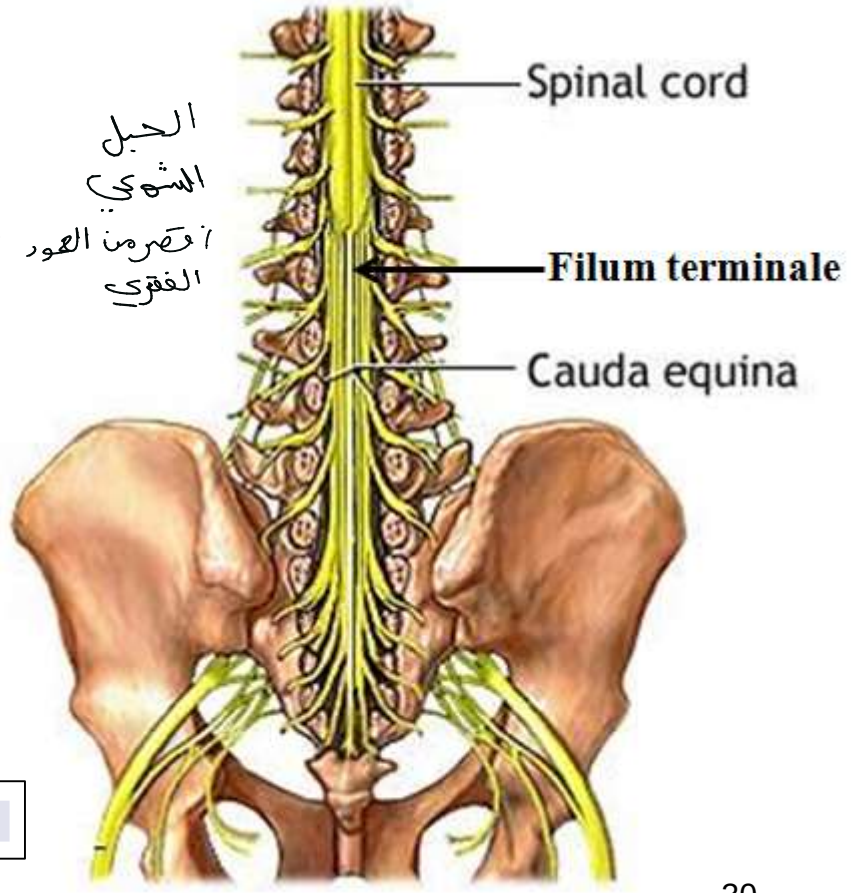



Fig.19: The cauda equina.

# Internal features of the spinal cord

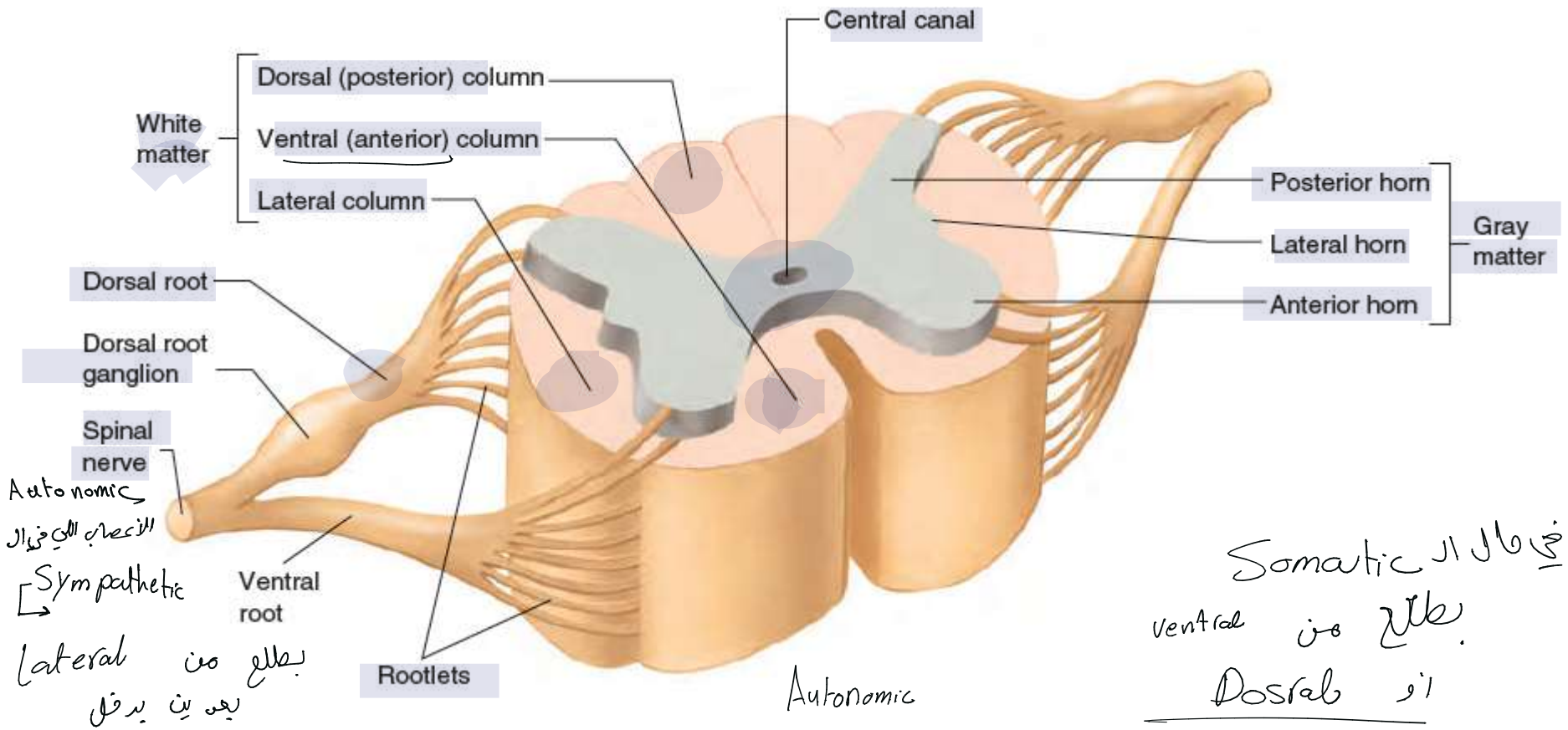


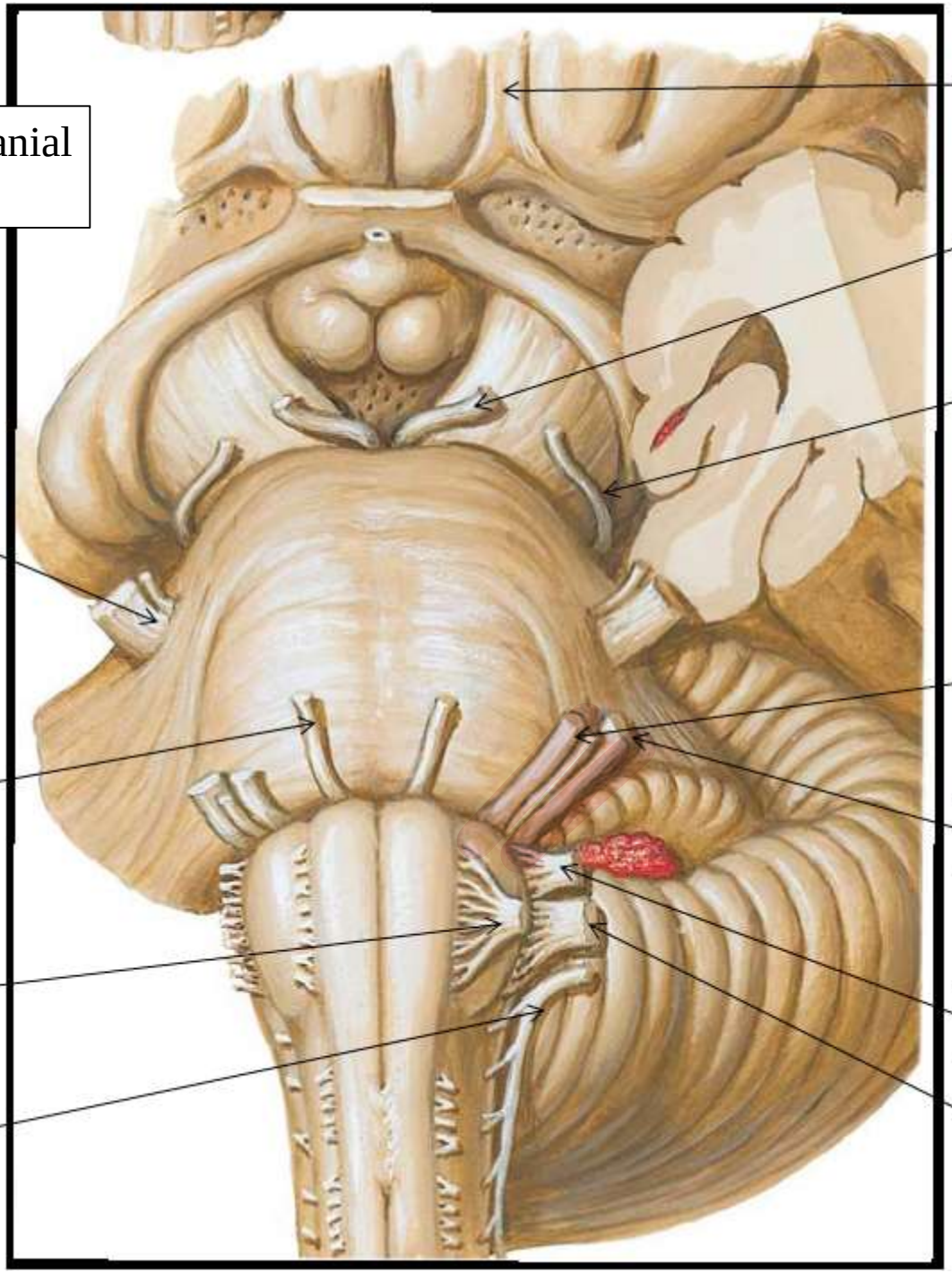

Fig.20*: Cross section through the spinal cord showing important internal features.

# The Peripheral Nervous System - The Cranial Nerves

| | Cranial Nerve | Main Functions |
|---|---|---|
| 1 | I – Olfactory | Olfaction (Smelling) |
| 2 | II – Optic | Vision |
| 3 | III – Oculomotor | Supplies extrinsic muscles of eye |
| 4 | IV - Trochlear | |
| 5 | V – Trigeminal | 1. Carries sensation from face<br>2. Supplies muscles of mastication |
| 6 | VI – Abducent | Supplies extrinsic muscles of eye |

| Cranial Nerve | Main Functions |
|---|---|
| VII – Facial | 1. Supplies muscles of facial expression<br>2. Carries taste sensations from anterior 2/3 of tongue |
| VIII - Vestibulocochlear | Hearing and equilibrium |
| IX - Glossopharyngeal | 1. Supplies some muscles<br>2. Carries taste sensation from posterior 1/3 of tongue |
| X – Vagus | 1. Supplies various muscles<br>2. Carries various sensation<br>3. Supplies internal organs |
| XI – Accessory | Supplies the sternocleidomastoid and trapezius muscles |
| XII – Hypoglossal | Supplies all muscles of the tongue (except palatoglossus) |

Fig.21: The cranial nerves.



# The Peripheral Nervous System - The Spinal Nerves

- 31 pairs of mixed nerves (sensory and motor): Cervical (C1-C8), thoracic (T1-T12), lumbar (L1-L5), sacral (S1-S5) and coccygeal (Co).
- A spinal nerve gives off two main branches: anterior ramus and posteior ramus. Anterior rami of spinal nerves are usually arranged in groups called plexuses.

collection of nerves عبارة عن plexus

| Plexus | Main Branches |
|---|---|
| **Cervical** | Phrenic |
| **Brachial** | Axillary, Musculocutaneous, Radial, Median, Ulnar |
| **Lumbar** | Obturator, Femoral |
| **Sacral** | Sciatic (Largest nerve in the body) |

# The Autonomic Nervous system

- The autonomic nervous system (ANS) is part of the peripheral nervous system. It operates unconsciously to control involuntary muscles (cardiac and smooth) and glands. It's formed of two divisions: The Sympathetic and Parasympathetic.
- The ANS is formed of Preganglionic and Postganglionic fibers. The preganglionic fibers arise from autonomic centers in the CNS and pass through cranial and spinal nerves to autonomic ganglia outside the CNS. The postganglionic fibers arise from the autonomic ganglia to supply the involuntary muscles and glands.
- The autonomic centers are controlled by the ***Hypothalamus.***

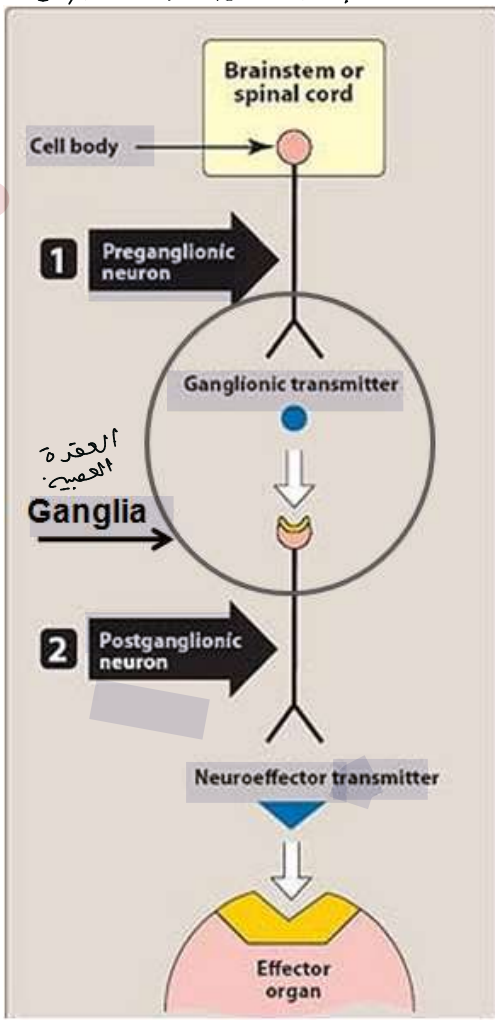



Fig.22: The two-neuron pathway of the ANS.

# The Sympathetic (Thoracolumbar) Division

- The gray matter of the ***T1-L2 segments*** of the spinal cord possess a ***lateral horn*** in which are located the cell bodies of the sympathetic preganglionic neurons.
- The myelinated axons of these neurons leave the spinal cord through the anterior root of the spinal nerves.
- They pass through the white ramus to enter the sympathetic trunk.
  - *Sympathetic trunk* is a chain of ganglia located on each side of the vertebral column.

- In the sympathetic trunk, the preganglionic neuron may either:
  1. *Synapse* with the postganglionic neurons in the ganglia at the *same level* on the same side. In this case, the unmyelinated postganglionic fibers exit the trunk through the gray ramus to re-enter the spinal nerves where they pass to supply the smooth muscles of blood vessels, sweat glands, and the arrector pili muscles of the skin.
  2. Pass up/down in the sympathetic trunk to *synapse* with postganglionic neurons at a *different level* to supply skin. Some postganglionic fibers will supply various organs in the head, chest, abdomen and pelvis.
  3. *Leave* the trunk *without synapsing*. Here preganglionic fibers will form the Splanchnic nerves and they will eventually synapse with postganglionic neurons in the preaortic ganglia (celiac, superior mesenteric, inferior mesenteric and renal). The postganglinic fibers will then pass to supply the viscera.

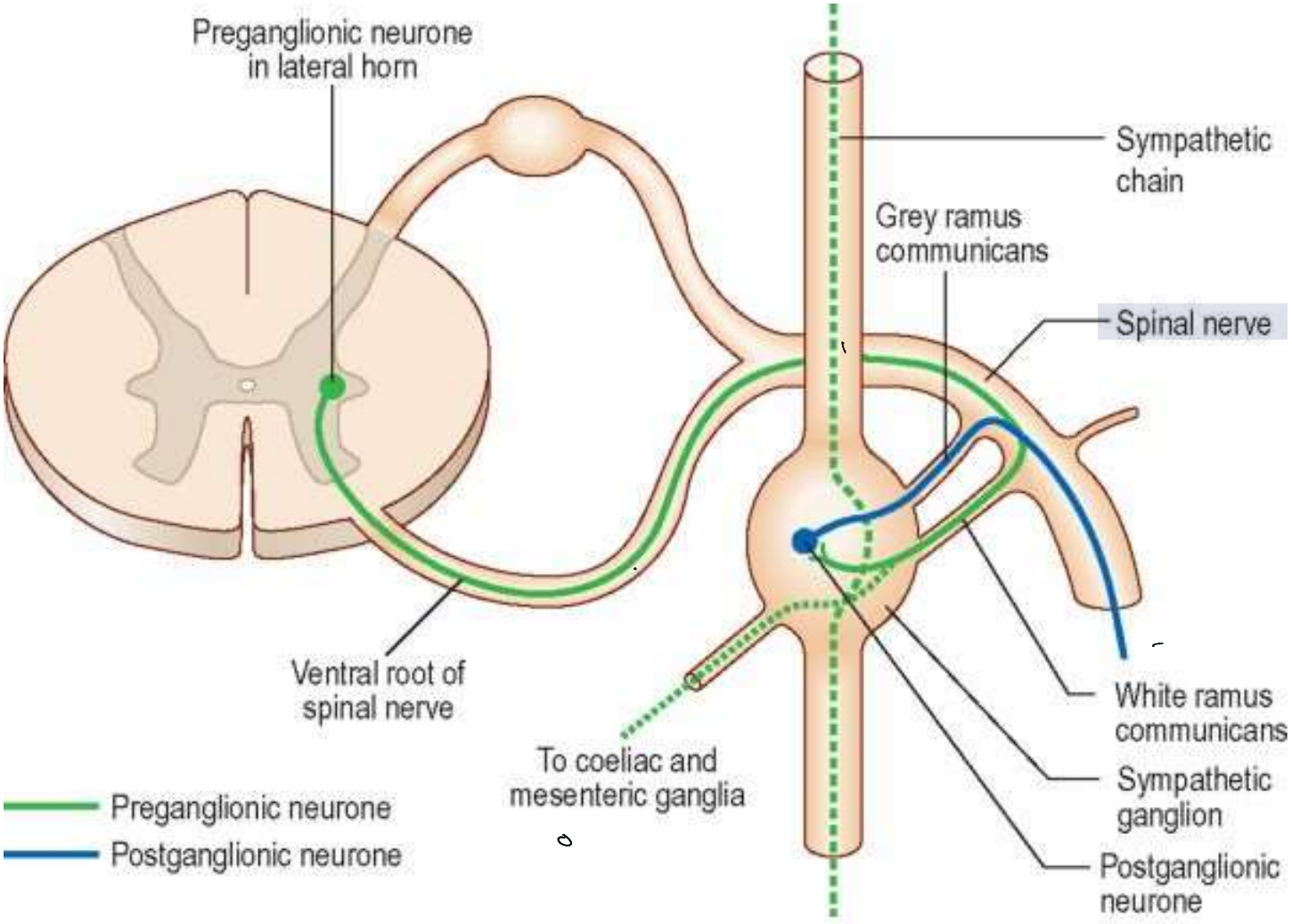



Fig.23: The pathway of the sympathetic neurons.

- The sympathetic splanchnic nerves are the greater, lesser, least (lowest), and lumbar splanchnic nerves.
- ***Some preganglionic fibers will pass, without synapsing, in the sympathetic chain, the greater splanchnic nerves, and the celiac ganglia to end in the Adrenal Medulla where they stimulate the release of hormones***.

- A single sympathetic preganglionic fiber has many axon collaterals and may synapse with 20 or more postganglionic neurons. The postganglionic axons typically terminate in several visceral effectors.
- Therefore the effects of sympathetic stimulation are more widespread than the effects of parasympathetic stimulation.

# The Parasympathetic Division

- Also called Craniosacral division.
- Preganglionic neurons pass through:
  - The cranial nerves III, VII, IX and X
  - Sacral spinal nerves S2-S4 (form the Pelvic Splanchnic nerves)
- Parasympathetic ganglia: terminal ganglia (close to or within effector organs).
- A preganglionic neuron usually synapses with 4-5 postganglionic neurons all of which supply a single visceral effector. So the effect is limited.

# General and Special Sensations

# General and Special Senses

## General Senses

- Include:
  - Somatic sensations (tactile, thermal, pain, and proprioceptive –> sense of position) from body and joints
  - Visceral sensations from the organs.
- Scattered throughout the body.
- Simple structures.

## Special Senses

- Include
  - Smell
  - Taste
  - Vision
  - Hearing and equilibrium.
- Concentrated in specific locations in the head.
- Anatomically distinct structures.
- Complex neural pathway.

# The General Sensory Structures

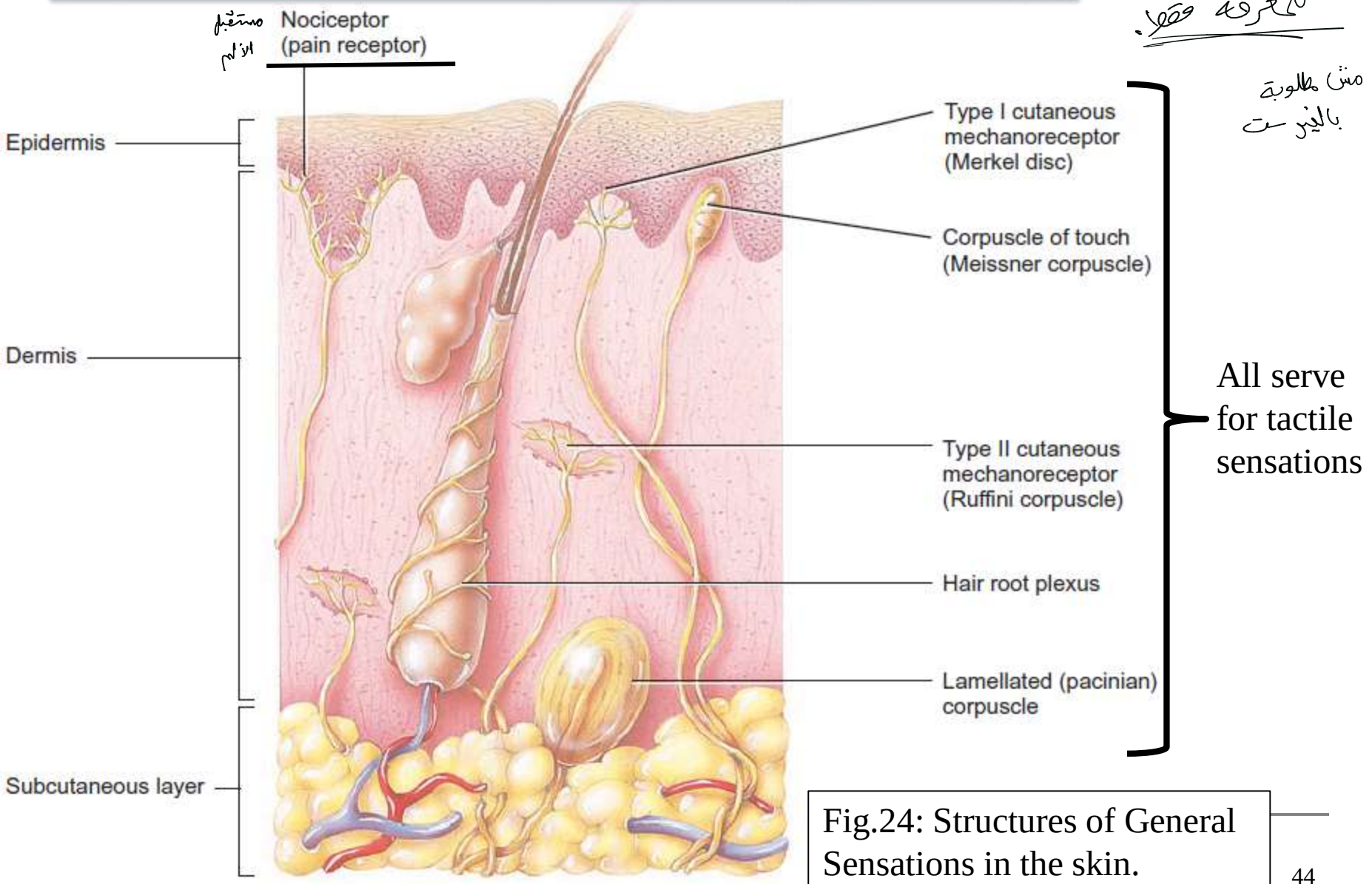



Fig.24: Structures of General Sensations in the skin.

# Special Senses – Olfaction = Smell

- The olfactory epithelium is located in the roof of the nasal cavity.

- The olfactory epithelium is formed of:

1. ***Olfactory receptors*** - bipolar neurons with cilia called olfactory hairs.
2. ***Supporting cells***- provide support and nourishment.
3. ***Basal cells***- replace olfactory receptors.

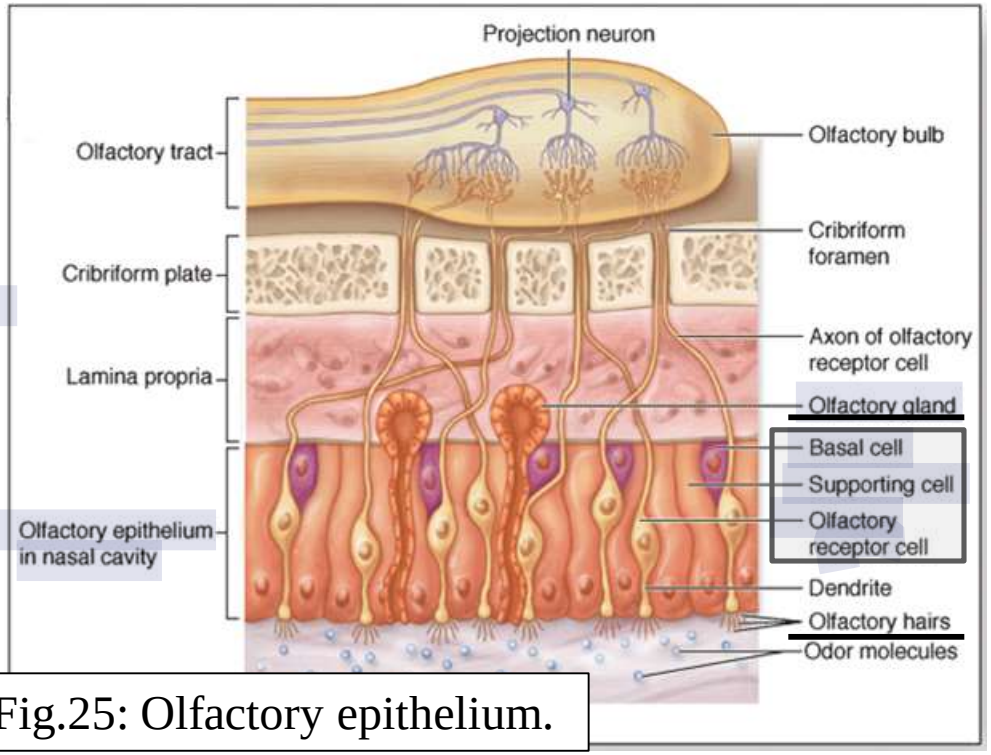



Fig.25: Olfactory epithelium.

- Olfactory glands produce a secretion that helps in moistening the surface of the epithelium

# Special Senses – Gustation = Taste

حاسة التذوق

- Gustation is performed by specialized structures called ***Taste Buds*** that are mainly present in the papillae of the tongue.

الأعصاب اللي بتتحكم هم السابع والتاسع.

- Taste buds are oval structures formed of:

1. ***Gustatory cells***- Each one has a gustatory hair (a long microvillus) that projects through an opening in the bud called the taste pore.
2. ***Supporting cells***- provide support and nourishment.
3. ***Basal cells***- replace the other cells.

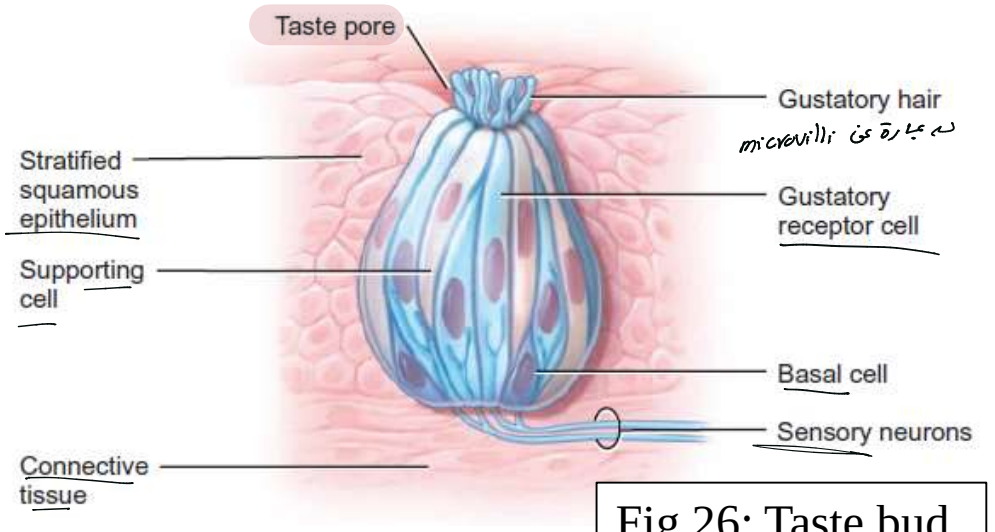


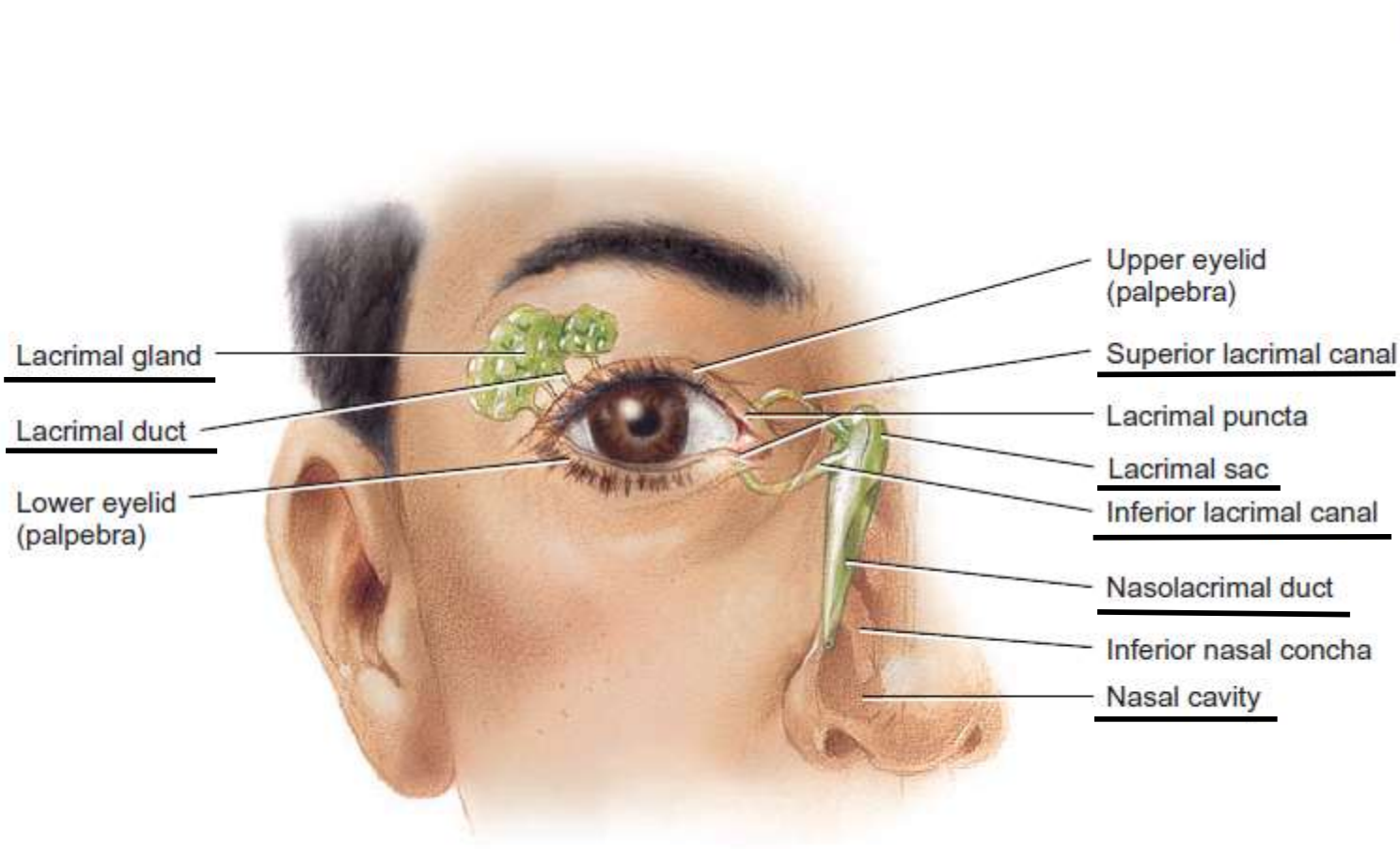

Fig.26: Taste bud.

# Special Senses – Vision

- Vision is the function of the eye.
- The eyeball is located in the orbital cavity of the skull.
- Accessory structures of the eye include:
  1. The eyelids ← الجفون
  2. The lacrimal apparatus → الجهاز الدمعي
  3. The extrinsic muscles of the eye ← عضلات + بتتحكم فيهم 3 nerves

- The two eyelids (palpebrae) (1)protect eye from light, (2)shade eye during sleep, and (3)spread tear.
- The space between the eyelids that exposes the eyeball is called the ***palpebral fissure***. ← المكان اللي بتبين منه العين
- The ***levator palpebrae superioris*** muscle raises the upper eyelid.
  ← مسؤولة عن رفع الجفن الاعلى

# The Lacrimal Apparatus




FLOW OF TEARS

Lacrimal gland

↓

Lacrimal ducts

↓

Superior or inferior lacrimal canal

↓

Lacrimal sac

↓

Nasolacrimal duct

↓

Nasal cavity

Fig.27*: Components of the lacrimal apparatus.

# Extrinsic Eye Muscles

- Six **extrinsic** eye muscles control movements of each eyeball. They are called extrinsic because they originate outside the eyeball in the bony orbit and insert on the outer surface of the sclera. These muscles are supplied by cranial nerve III, IV, and VI.

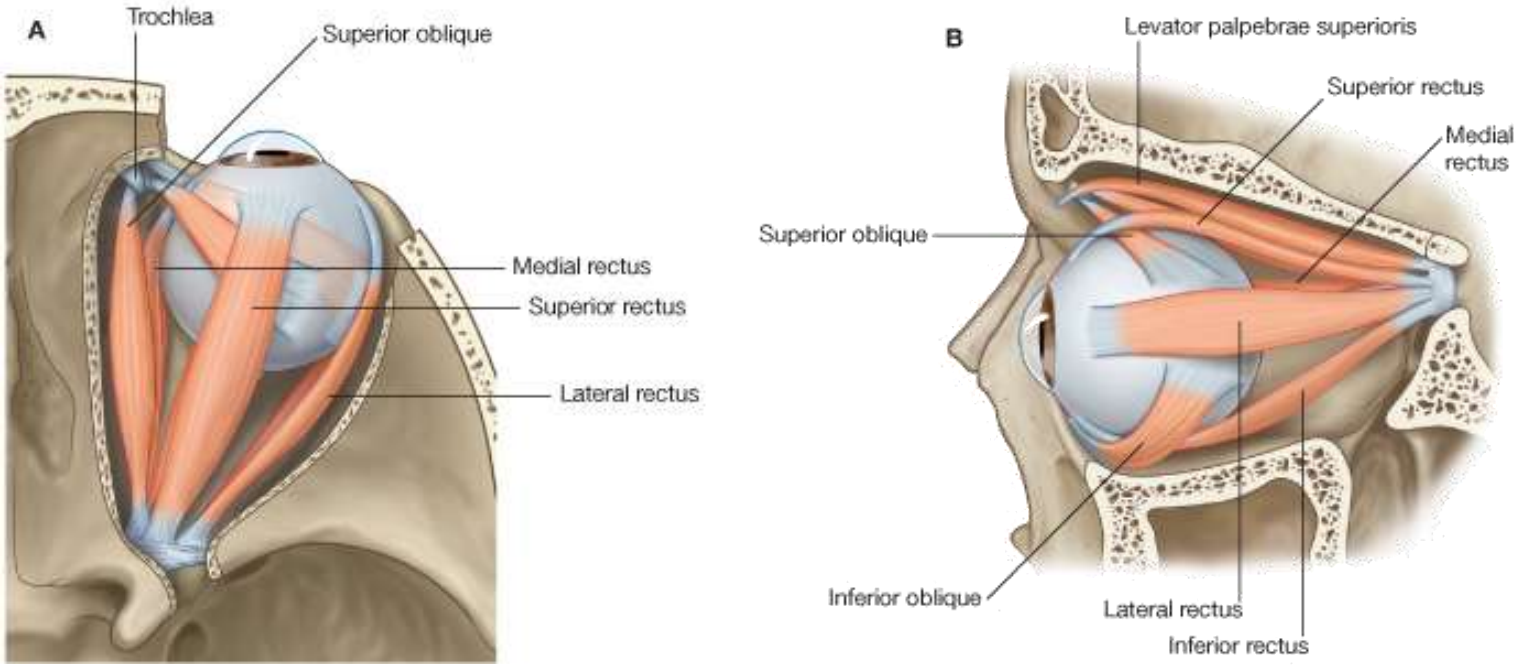



Fig.28: Extrinsic muscles of the eye. (A) superior view. (B) lateral view.

# Anatomy of the Eyeball

## The Wall of the eyeball

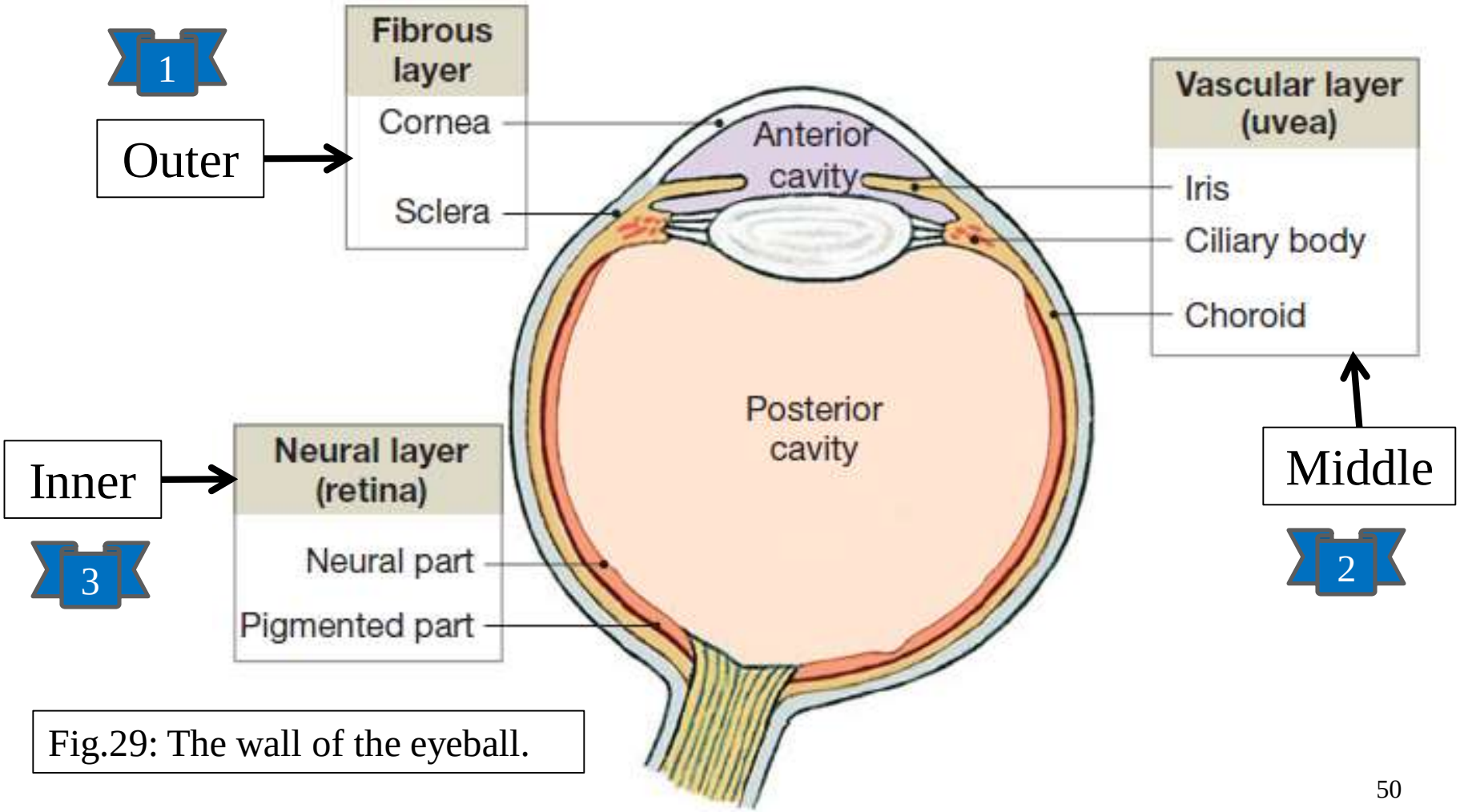



Fig.29: The wall of the eyeball.

## 1. *Fibrous tunic (layer)*

### a) **Sclera** "white" of the eye

- The larger posterior part.
- A strong fibrous layer.
- Functions:
  1. Protect the eye.
  2. Help maintain shape of the eye.
  3. Site of attachment of extrinsic eye muscles.

### b) **Cornea**

- The smaller anterior part. Located in front of the iris.
- Transparent.
- Function: it allows light to enter the eye and it's the major refractory structure in the eye.

## 2. *Vascular tunic*

### a) Choroid

- The large posterior part. It's highly vascular layer with numerous melanin-producing melanocytes.
- Functions: (1)supply nutrients to the retina, (2)melanin pigment absorbs any stray lights, thus, making the image sharp.

### b) Ciliary body

- The middle part of the vascular tunic.
- Located just posterior to the junction of the cornea and sclera.
- Has numerous protrusions called the ***ciliary processess***. These produce the aqueous humor. From them extend the ***zonular fibers*** (suspensory ligaments) that are attached to the lens.
- The ***ciliary muscle*** is a smooth muscle within the ciliary body. It's responsible for changing the shape of the lens.

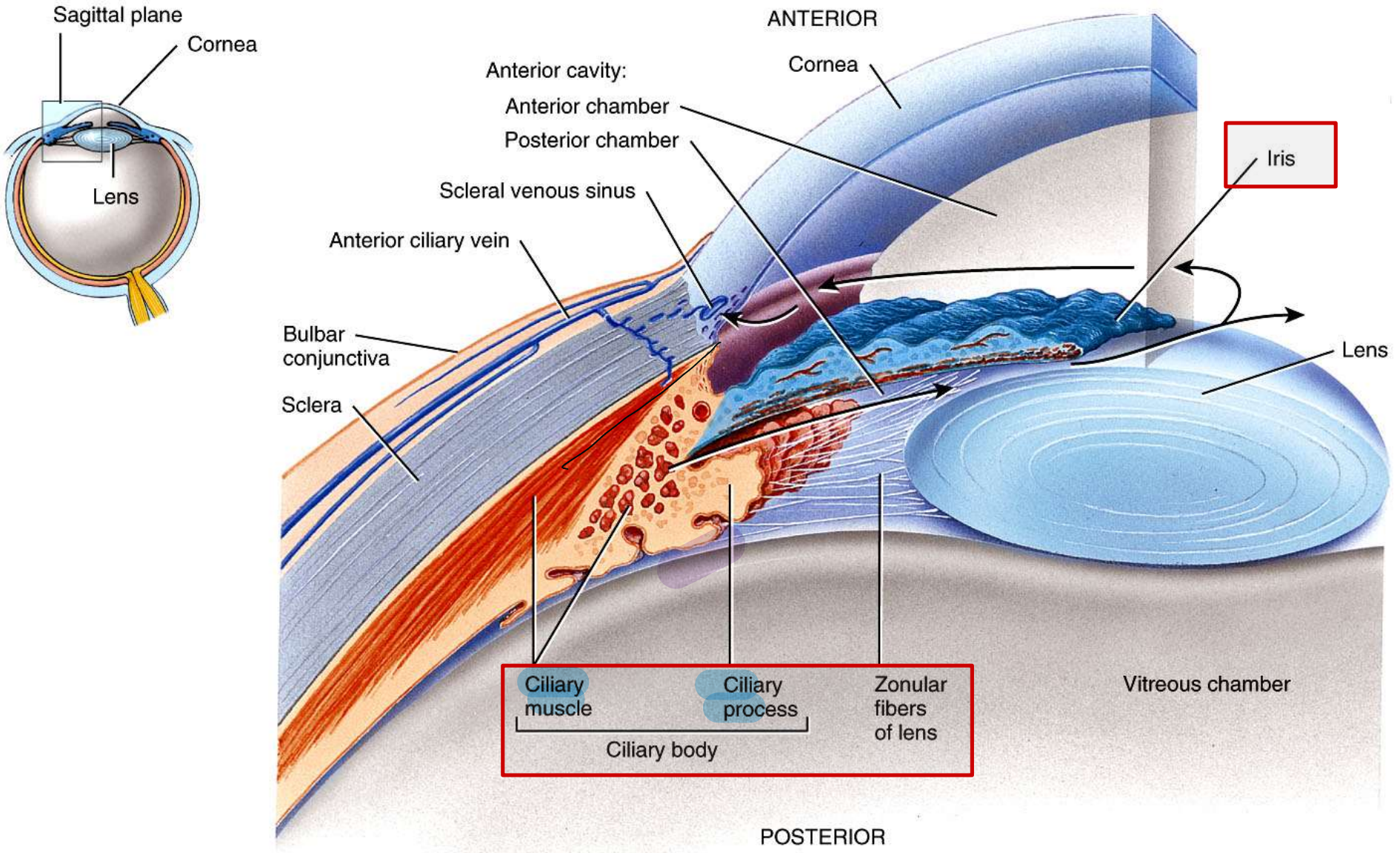



Fig.30: The ciliary body and the iris.

## c) The Iris

- The anterior colored portion of the vascular tunic.
- The opening in the middle of the iris is called the ***pupil***. Through this pupil light can pass to the lens.

- The iris contains the circular ***sphincter pupillae muscle*** and the radial ***dilator pupillae muscle***. These muscles change the diameter of the pupil regulating the amount of light passing through it.

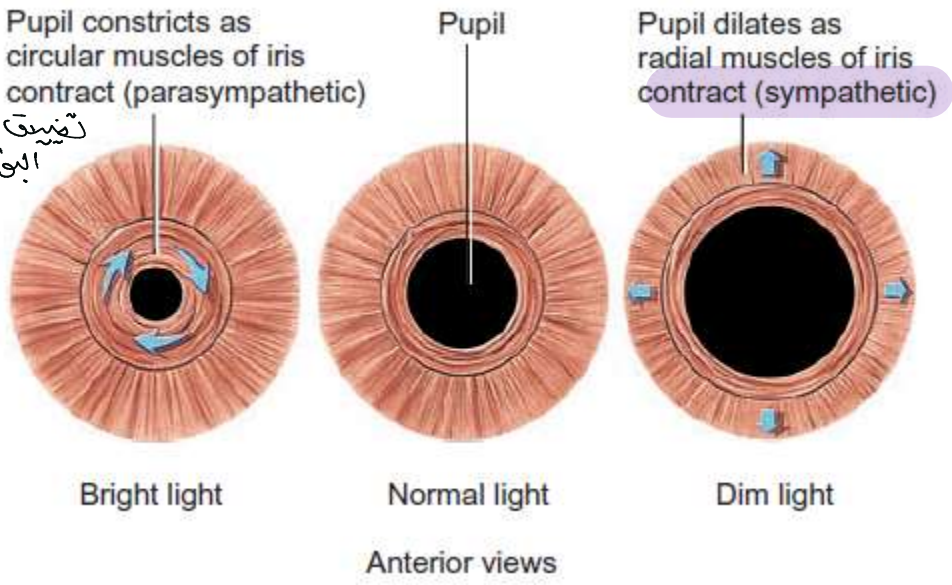



Fig.31*: The muscles of the iris. Note the effect of the two divisions of the ANS on them.

## 3. *The Retina*

آخر جزء من الجزء الأمامي للعين

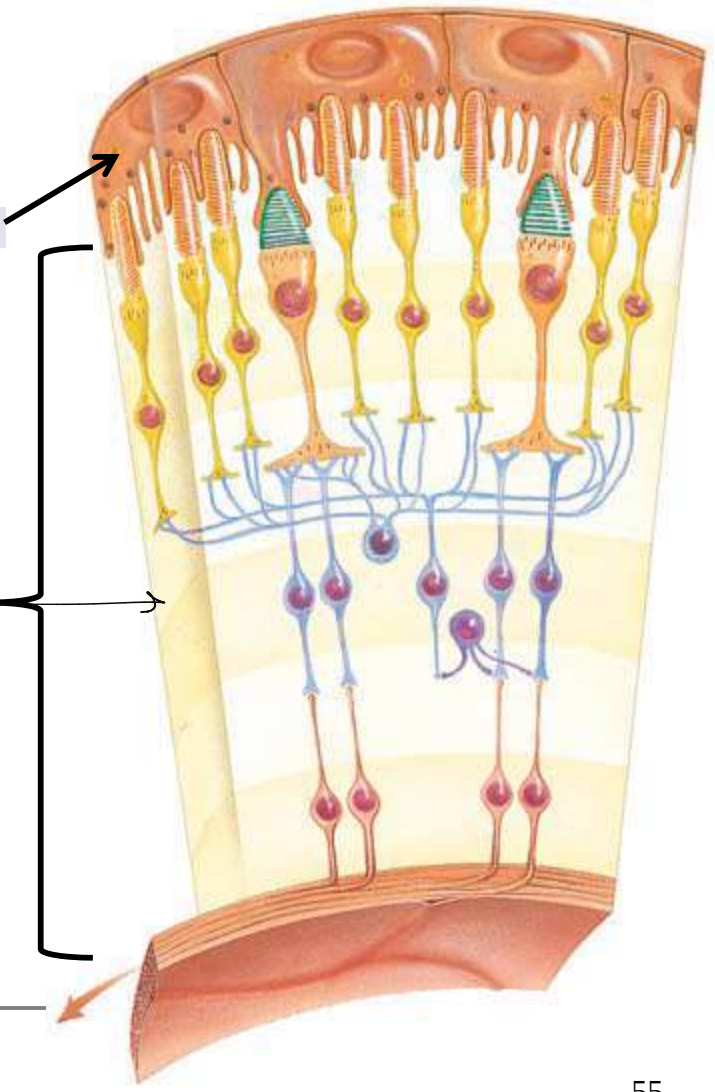
- Located in the posterior 2/3 of the eyeball
- Formed of two layers:
  a) An outer ***Pigmented layer*** which contains melanin that absorbs any stray light

  b) An inner ***Neural layer*** formed of several types of cells including the photoreceptors

- Axons from the neural layer will come together to form the Optic nerve (CN II)

العصب رقم 2 المسؤول عن الرؤية

Fig.32: The retina.



# The Photoreceptors of the retina – Rods and Cones

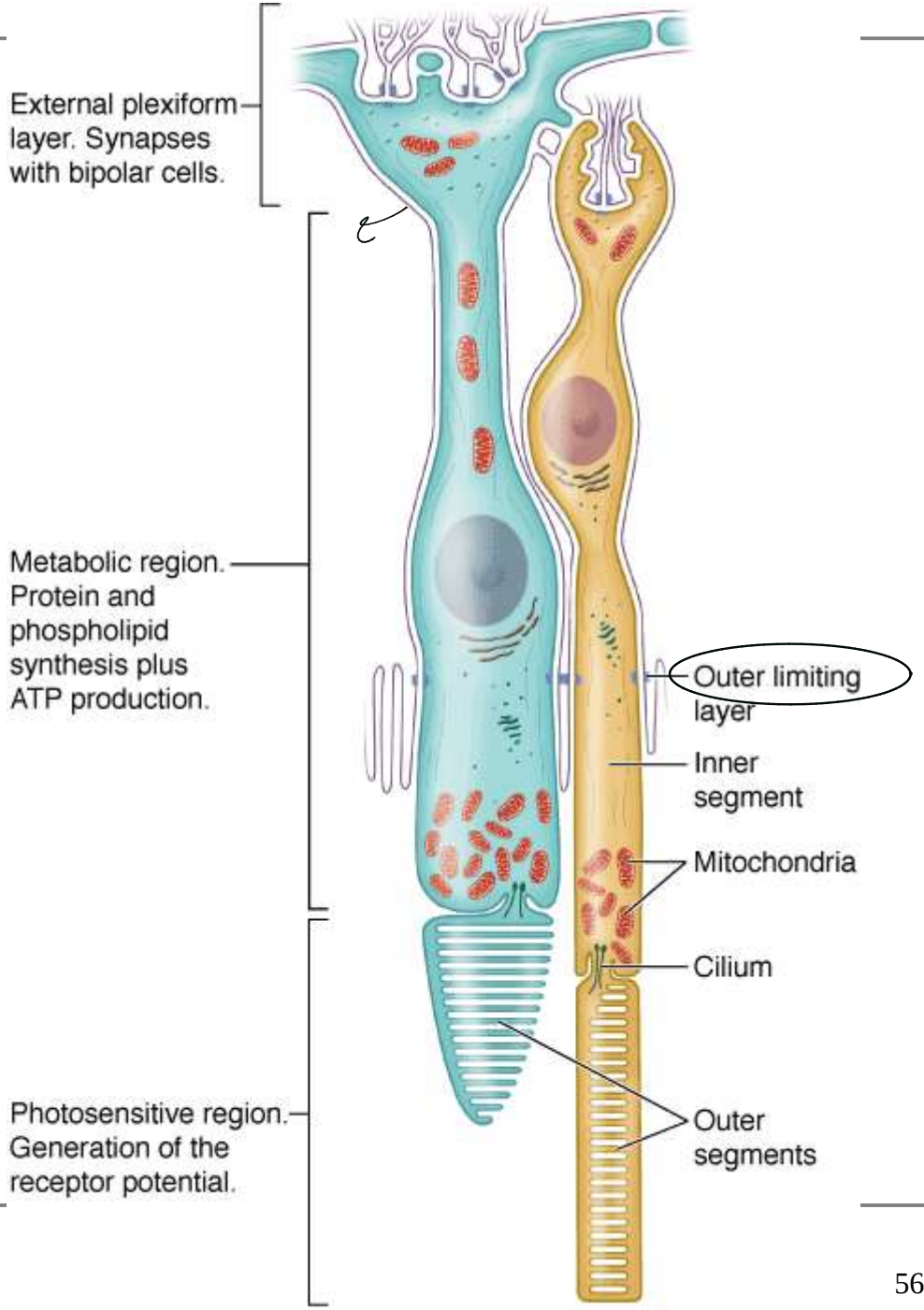



Fig.33: The rods and cones.

| Cones | Feature | Rods |
|---|---|---|
| Cone-shaped | **Outer segment** | Rod-shaped |
| Continuous with the cell membrane | **Membranous discs** | Stacked on each other and separated from the cell membrane |
| Contains the nucleus, mitochondria, Golgi and polyribosomes | **Inner segment** | Contains the nucleus, mitochondria, Golgi and polyribosomes |
| Modified cilium | **2 segments connected by** | Modified cilium |
| Less | **Sensitivity to light** | More |
| Color vision | **Specialized in** | Dark vision يساعد الرؤية المعتمة. |
| Mostly in the center | **Location in Retina** | Mostly on the periphery |

- **Macula lutea** is in the exact center of the posterior portion of the retina, at the visual axis of the eye.
- **Fovea centralis** a small depression in the center of the macula lutea, contains only cones. Thus, any image falling on this spot will have a high resolution.
- **Optic disc** is the area in the retina at which the optic nerve exits the eyeball. This area has no cones or rods and, therefore, it's called the ***blind spot***.

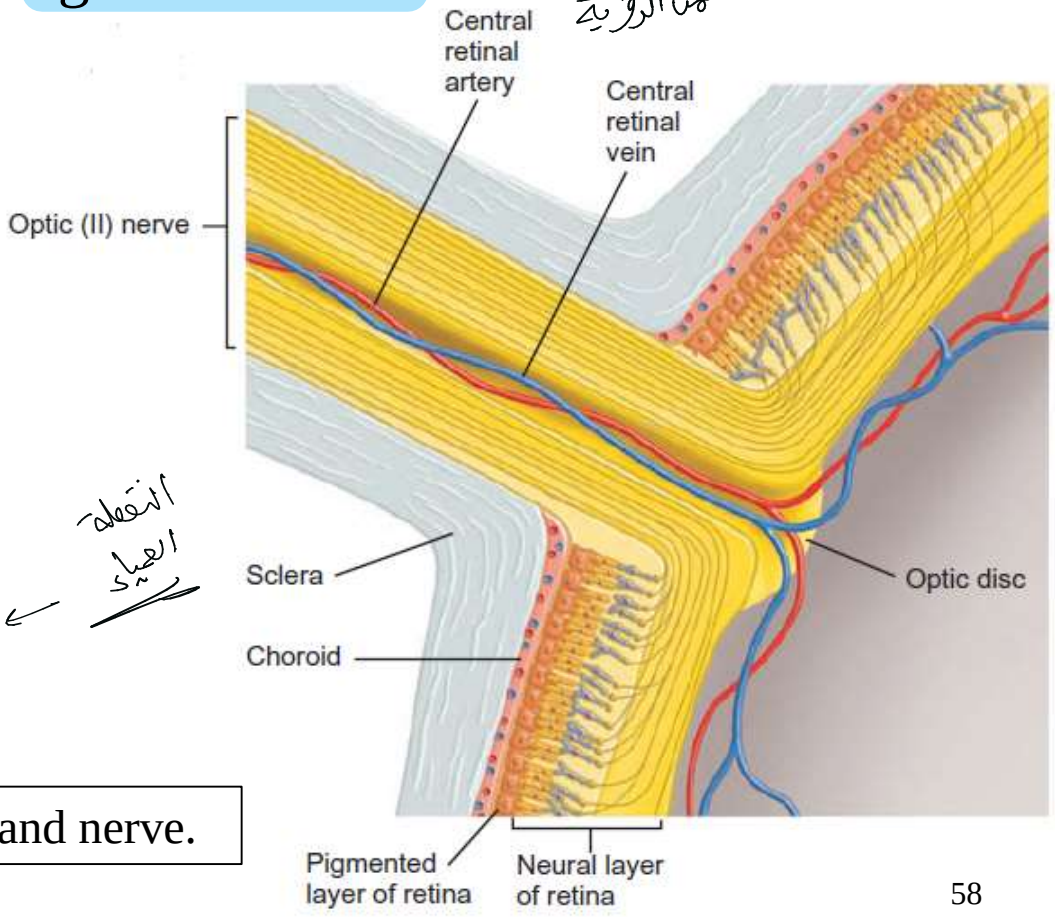



Fig.34: The optic disc and nerve.

# The Interior of the eyeball

- ***Lens***
  - Transparent structure.
  - Lacks blood vessels.
  - Divides the eyeball into two cavities: anterior and posterior.
- ***Anterior cavity***
  - Between the cornea and the lens.
  - Contains *aqueous humor* which helps provide nutrients for the lens and cornea.
  - Further divided into:
    1. Anterior chamber: between cornea and iris
    2. Posterior chamber: between iris and lens
- ***Posterior cavity***
  - Posterior to the lens.
  - Filled with the gelatinous *vitreous humor* which maintains the shape of the eye.

# ***Glaucoma*** ← مرض الجلوكوما

- The aqueous humor is a fluid present inside a closed space (the anterior cavity); therefor, a pressure is formed in this space called '*the intraocular pressure*'.

- The aqueous humor is produced by the ciliary processes and circulates in the posterior chamber. After passing through the pupil, it enters and circulates in the anterior chamber. In the angle between the iris and the cornea, there are several channels through which this humor passes to enter the systemic venous circulation.

- There is a balance between the rate of production and removal of the aqueous humor. Any problem that leads to accumulation of this humor will lead to increased intraocular pressure; and this is a serious condition known as '***Glaucoma***'.

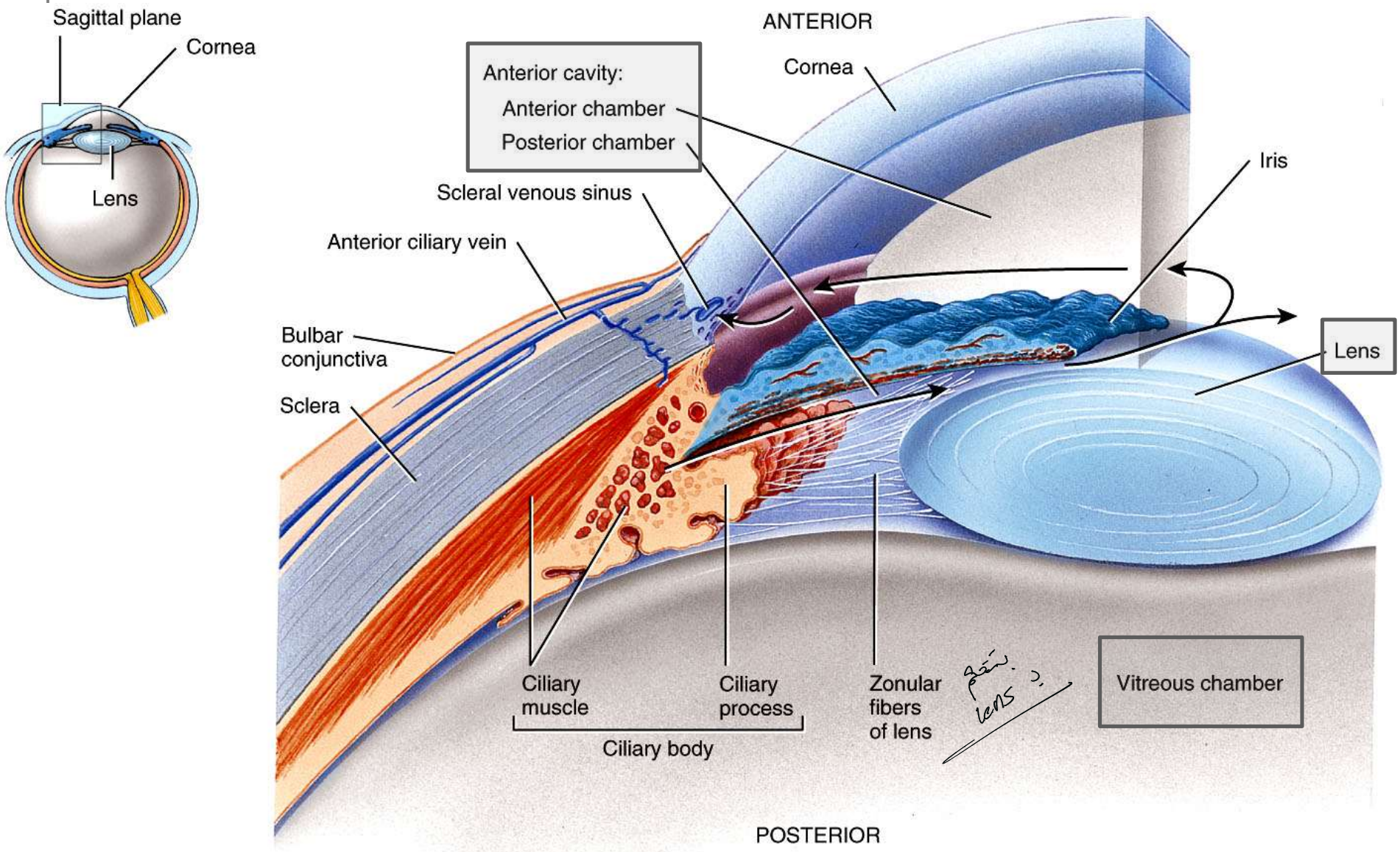



Fig.35: The cavities and chambers of the eye.

# Special Senses – Hearing

- Hearing (and equilibrium) is the function of the ear.
- The ear is formed of 3 parts:

1. The ***external ear***, which collects sound waves and channels them inward.
2. The ***middle ear***, which conveys sound vibrations to the oval window.
3. The ***internal (inner) ear***, which houses the receptors for hearing and equilibrium.

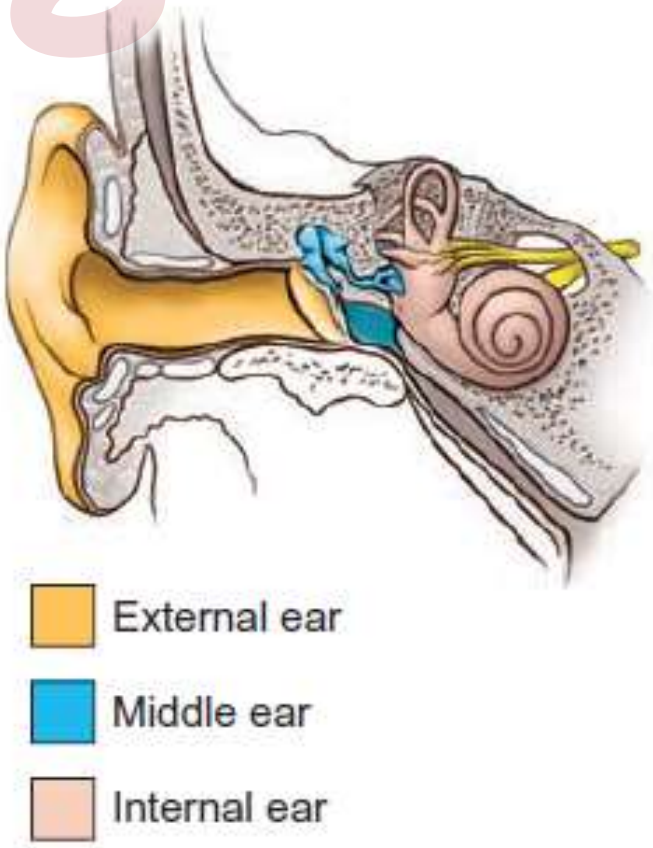



Fig.36: The three parts of the ear.

# The External Ear

الصيوان

- Formed of the auricle, the external auditory canal and the tympanic membrane (eardrum).
- The ***auricle*** (pinna) of the ear is formed of elastic cartilage covered by skin. Its shape allows it to act as an antenna. The ***external auditory canal**** conveys sounds from the auricle to the eardrum.
- The ***eardrum*** is a thin semitransparent partition between the external and middle ears. It's convex towards the middle ear. To it is attached the malleus bone. It transmits sound to the middle ear.

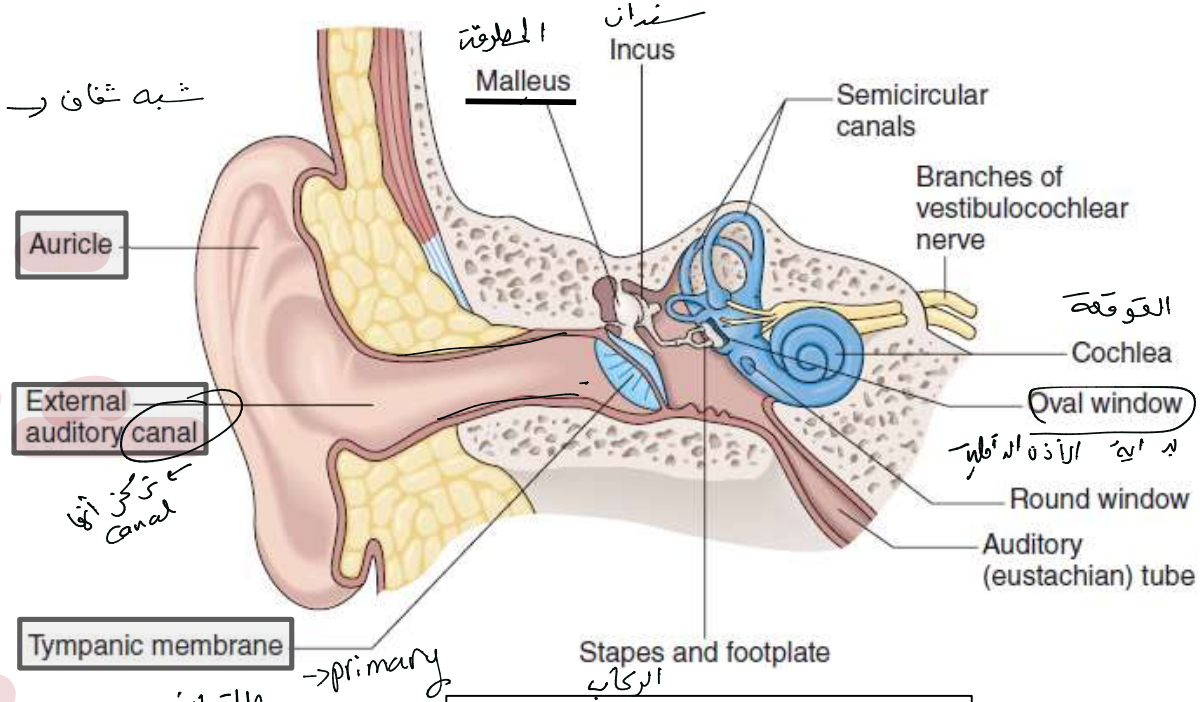



Fig.37: The external ear.

# The Middle Ear

- A small, air-filled, epithelium-lined cavity in the petrous part of the temporal bone.
- It contains 3 very small bones (ear ossicles): the ***malleus***, ***incus***, and ***stapes***. These bones articulate with each other by synovial joints.
- The stapes fits into an opening called the ***oval windows***. Below this is another opening called the ***round window*** which is closed by a membrane called the ***secondary tympanic membrane***.
- ***Tensor tympani*** muscle increases tension in the eardrum. The ***stapedius*** muscle (the smallest skeletal muscle in the body) dampens vibrations of the stapes. These skeletal muscles protect the inner ear from loud noises.
- The ***auditory tube*** connects the middle ear with the pharynx. This helps equalize air-pressure around the eardrum.

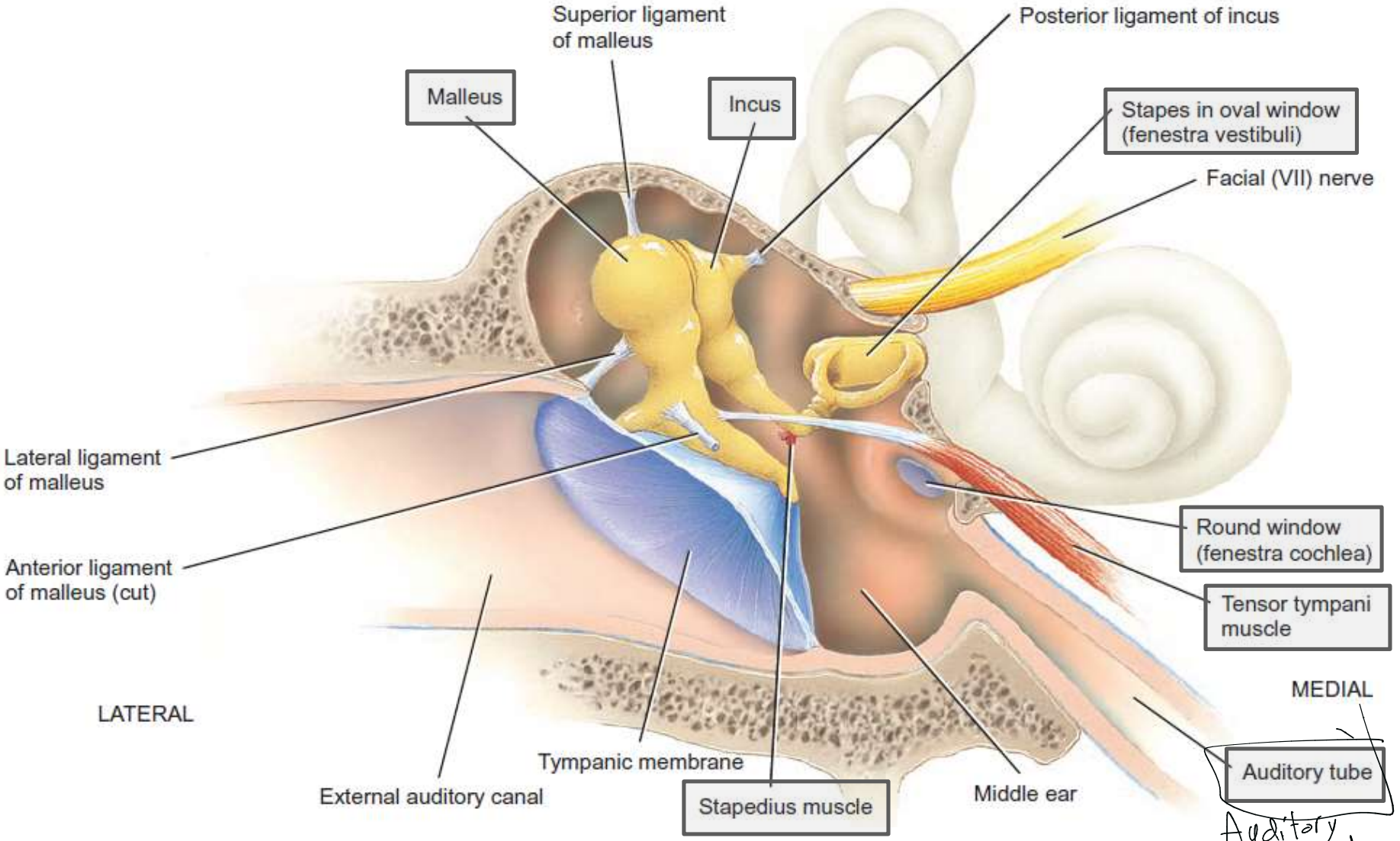



Fig.38: The middle ear.

# The Inner Ear (The Labyrinth)

- Formed of the vestibule, cochlea and semicircular canals.
- These structures are bony cavities that lie within the petrous part of the temporal bone. Inside them is another set of membranous structures that have the same shape (the membranous labyrinth).
- Between the bony and membranous labyrinths, we have a fluid called ***perilymph***. Inside the membranous labyrinth, we have another fluid called ***endolymph***.
- The ***vestibule*** is the central portion of the bony labyrinth.
- There are three ***semicircular canals***. The membranous *semicircular ducts* are present inside the canals.

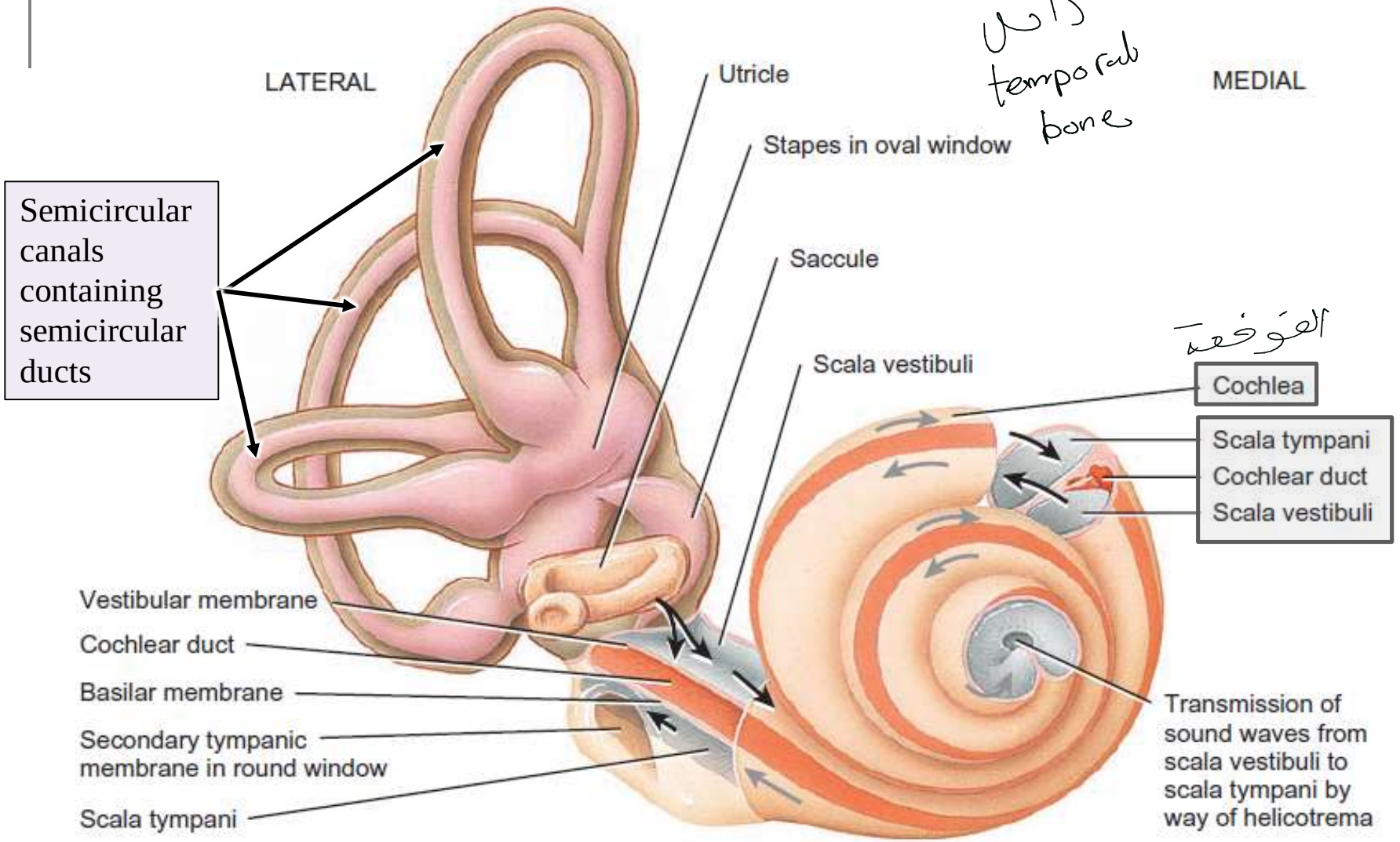



Fig.39: Parts of the inner ear.

## ➢ *The cochlea*

- A snail-shaped structure.
- It spirals for almost 3 turns.
- Formed of 3 channels:
  - *a)* ***The cochlear duct*** – continuation of the membranous labyrinth.
  - *b)* ***The scala vestibuli*** – opens at the oval window.
  - *c)* ***The scala tympani*** – opens at the round window.
- The scala vestibuli and scala tympani are completely separated from each other by the cochlear duct until they reach the apex of the cochlea where they'll meet at the ***helicotrema.***
- The spiral organ (of Corti) lies within the cochlea and spirals with it. It contains hair cells that are responsible for the sensation of sound.

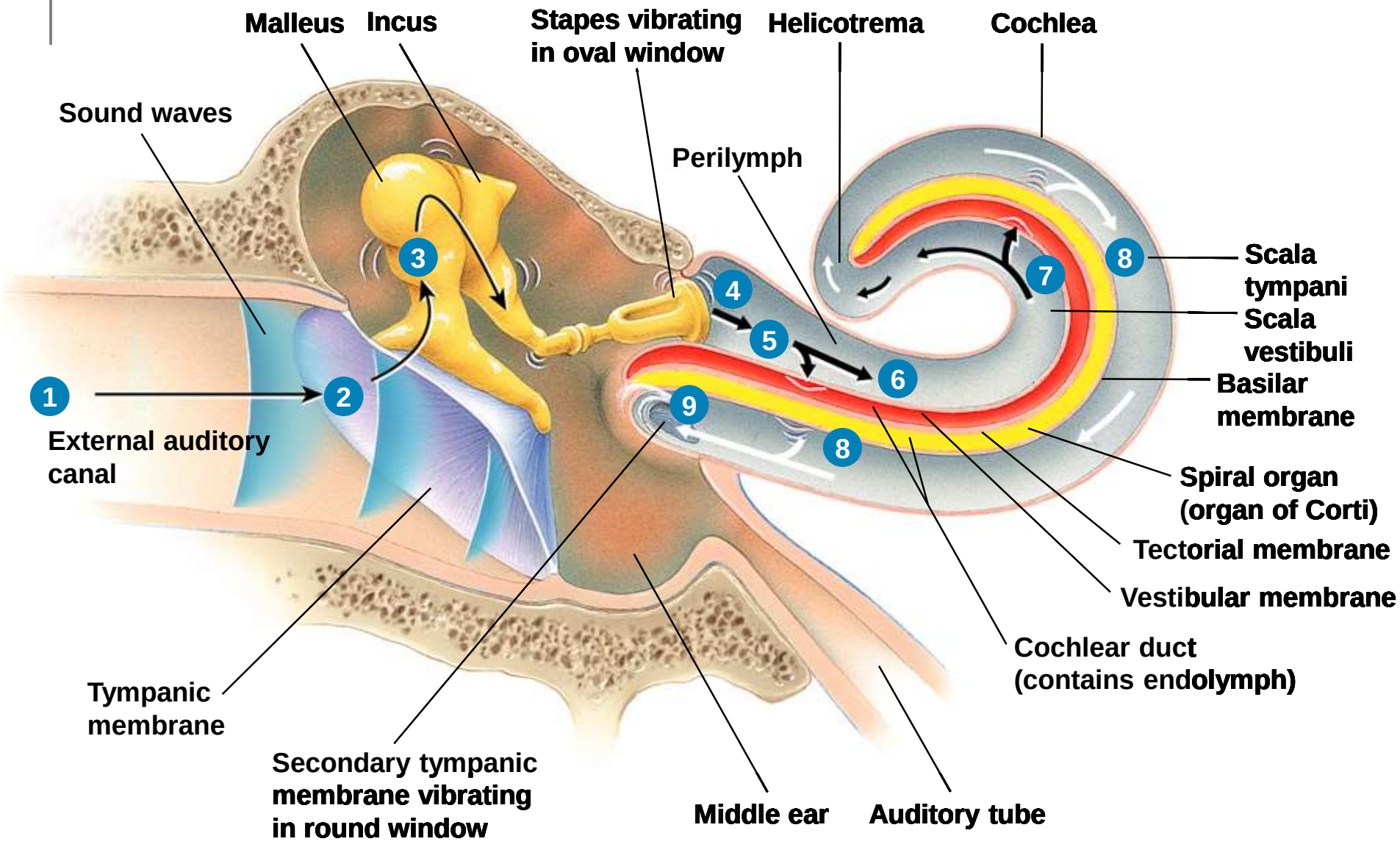



Fig.40: How sound is transmitted in the ear.