PHYSIOLOGY

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LECTURE 7-PART (2)- SENSES

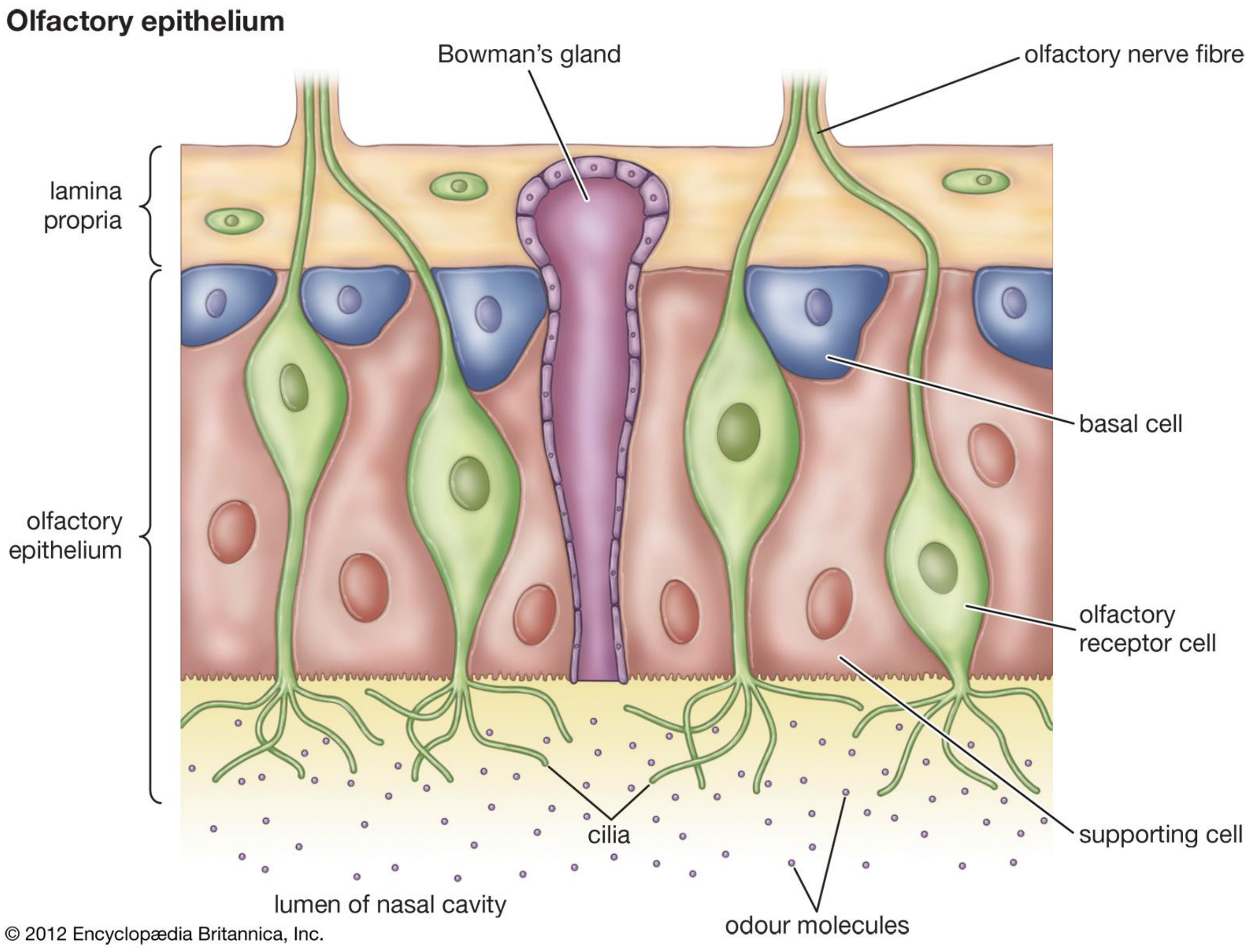
Objectives

1. Discuss **anatomy of olfactory receptors**.
2. Discuss **Gustation: Sense of Taste.**
3. Describe **Vision.**

(Pages 573-594 of the reference).

ANATOMY OF OLFACTORY RECEPTORS

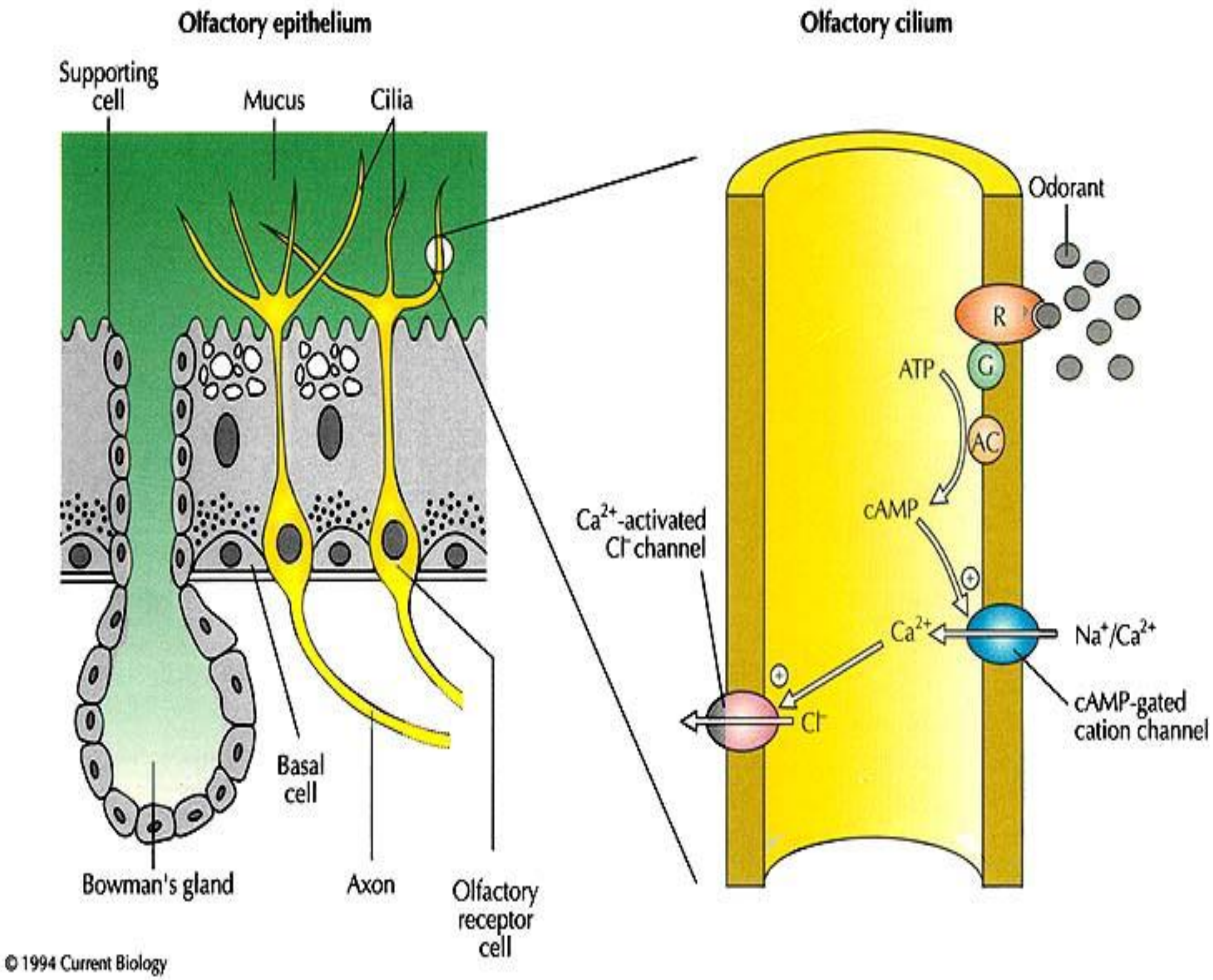
- the nose contains 10 million to 100 million **receptors** for the sense of smell or olfaction, contained within a region called the **olfactory epithelium**.
- The olfactory epithelium consists of three kinds of cells: **olfactory receptor cells, supporting cells, and basal cells.**
- Extending from the dendrite of an olfactory receptor cell are several **nonmotile olfactory cilia**, which are the sites of olfactory transduction. (Recall that transduction is the conversion of stimulus energy into a graded potential in a sensory receptor.)



OLFACTORY TRANSDUCTION

- Within the plasma membranes of the olfactory cilia are olfactory receptors that detect inhaled chemicals.
- **Occurs in the following way:**

1. Binding of an odorant to an olfactory receptor protein in an olfactory cilium stimulates a membrane protein called a G protein.
2. The G protein, in turn, activates the enzyme adenylate cyclase to produce a substance called cyclic adenosine monophosphate (cAMP).
3. The cAMP opens a sodium ion channel that allows Na ions to enter the cytosol, which causes a depolarizing generator potential to form in the membrane of the olfactory receptor cell.
4. If the depolarization reaches threshold, an action potential is generated along the axon of the olfactory receptor cell.



ODOR THRESHOLDS AND ADAPTATION

- **Olfaction**, like all the special senses, has **a low threshold**. Only a few molecules of certain substances (i.e., **chemical methyl mercaptan**) need to be present in air to be perceived as an odor.

- **A small amount of methyl mercaptan is added to natural gas to provide olfactory warning of gas leaks.**

- **Adaptation (decreasing sensitivity) to odors occurs rapidly. Still, complete insensitivity to certain strong odors occurs about a minute after exposure.**

THE OLFACTORY PATHWAY

- ✓ **On each side of the nose, about 40 bundles of unmyelinated axons of olfactory receptor cells.** These 40 or so bundles of axons collectively form the right and left olfactory (I) nerves.

- ✓ **The olfactory nerves terminate in the brain in paired masses of gray matter called the olfactory bulbs.**

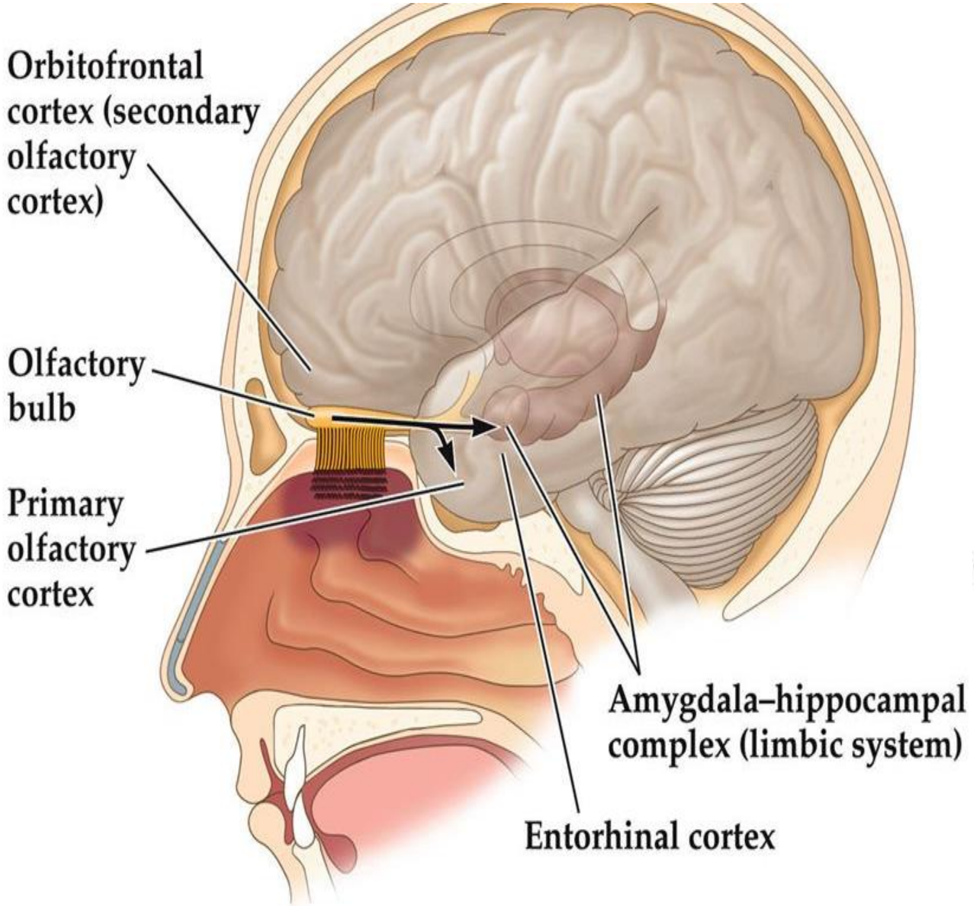
- ✓ **Within the olfactory bulbs, the axon terminals of olfactory receptor cells form synapses with the dendrites and cell bodies of olfactory bulb neurons in the olfactory pathway.**

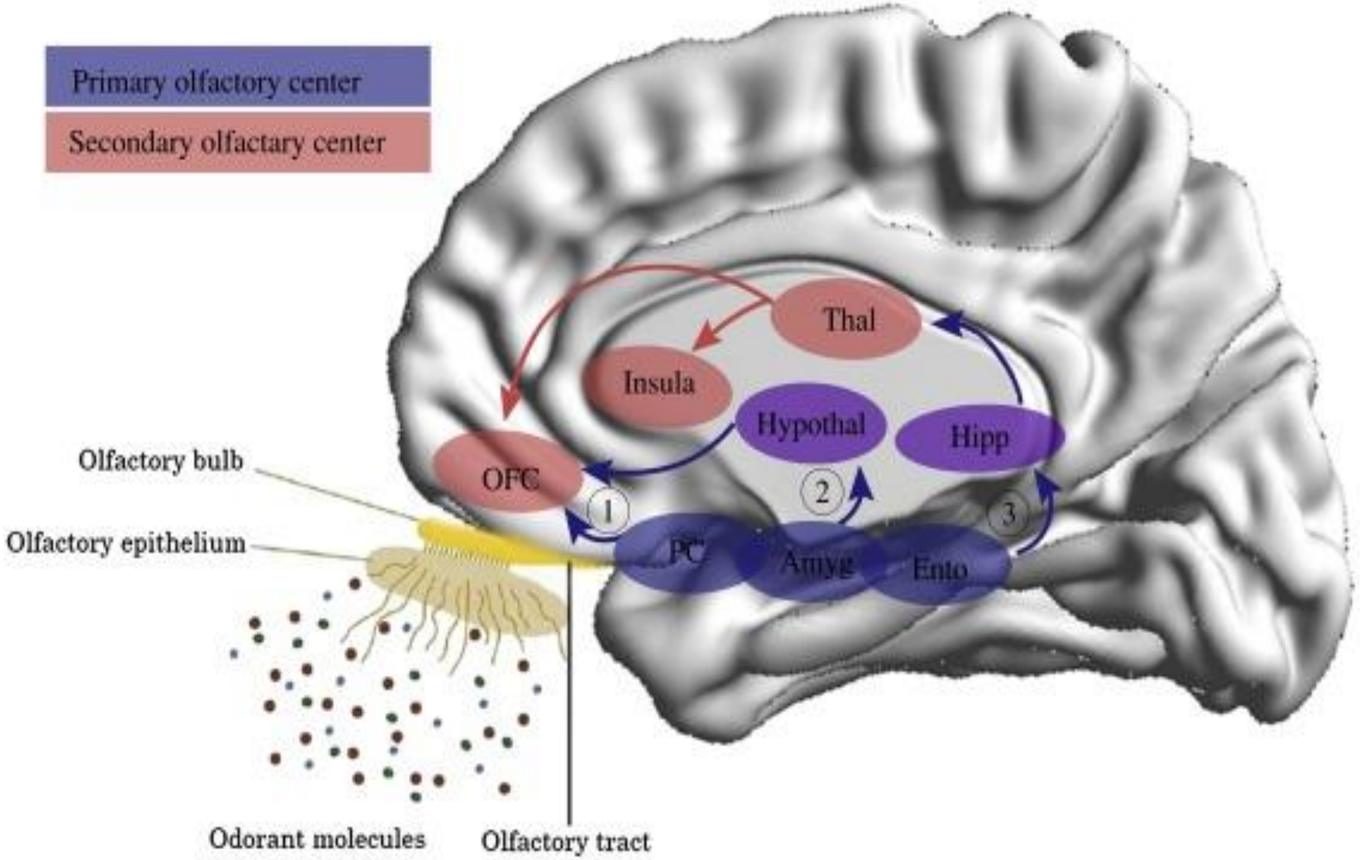
- ✓ **Axons of olfactory bulb neurons** extend posteriorly and **form the olfactory tract**.

- ✓ **Some of the axons of the olfactory tract project to the primary olfactory area of the cerebral cortex**, is where **conscious awareness of smell begins**.

- ✓ From the primary olfactory area, pathways also extend to the frontal lobe. An important region for **odor identification and discrimination is the orbitofrontal area.**

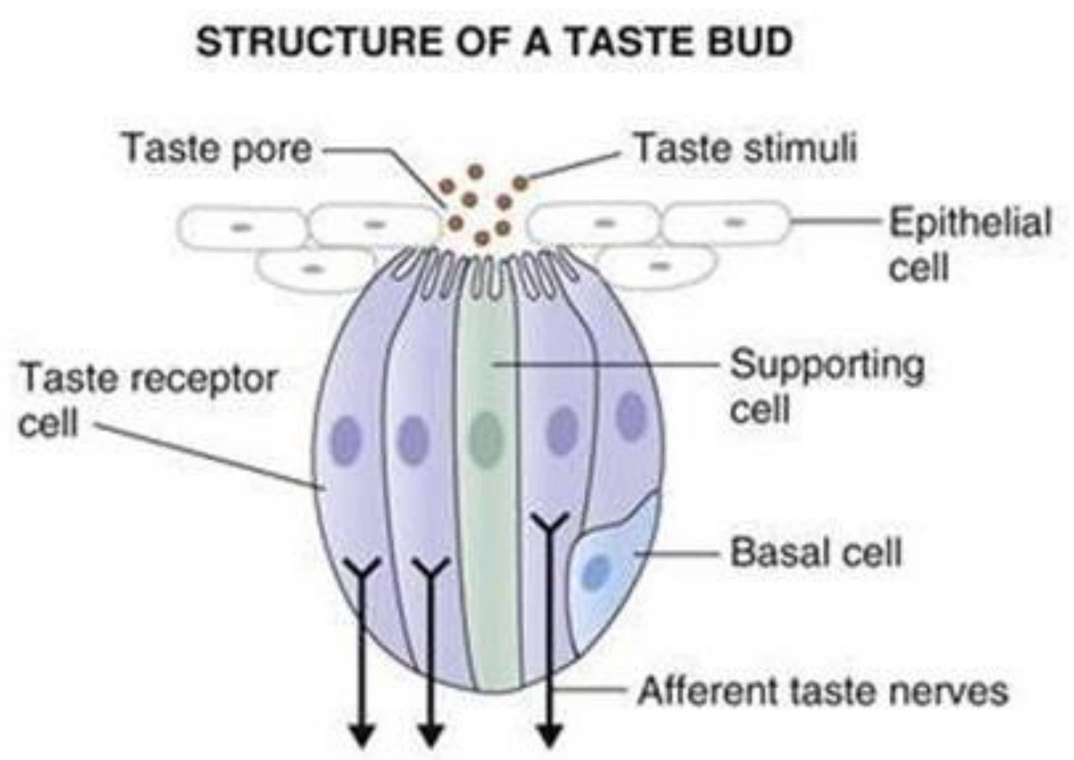
THE OLFACTORY PATHWAY





GUSTATION: SENSE OF TASTE

- Taste or gustation, like olfaction, is **a chemical sense**.
- The olfactory system thousands of times more strongly than it stimulates the gustatory system.
- **The receptors for sensations of taste are located in the taste buds**.
- Most of the nearly 10,000 taste buds of a young adult **are on the tongue**, but some are found on the soft palate (posterior portion of **the roof of the mouth**), **pharynx (throat)**, and **epiglottis** (**cartilage lid over voice box**).
- **Each taste bud** is an oval body consisting of three kinds of **epithelial cells: supporting cells, gustatory receptor cells, and basal cells**.

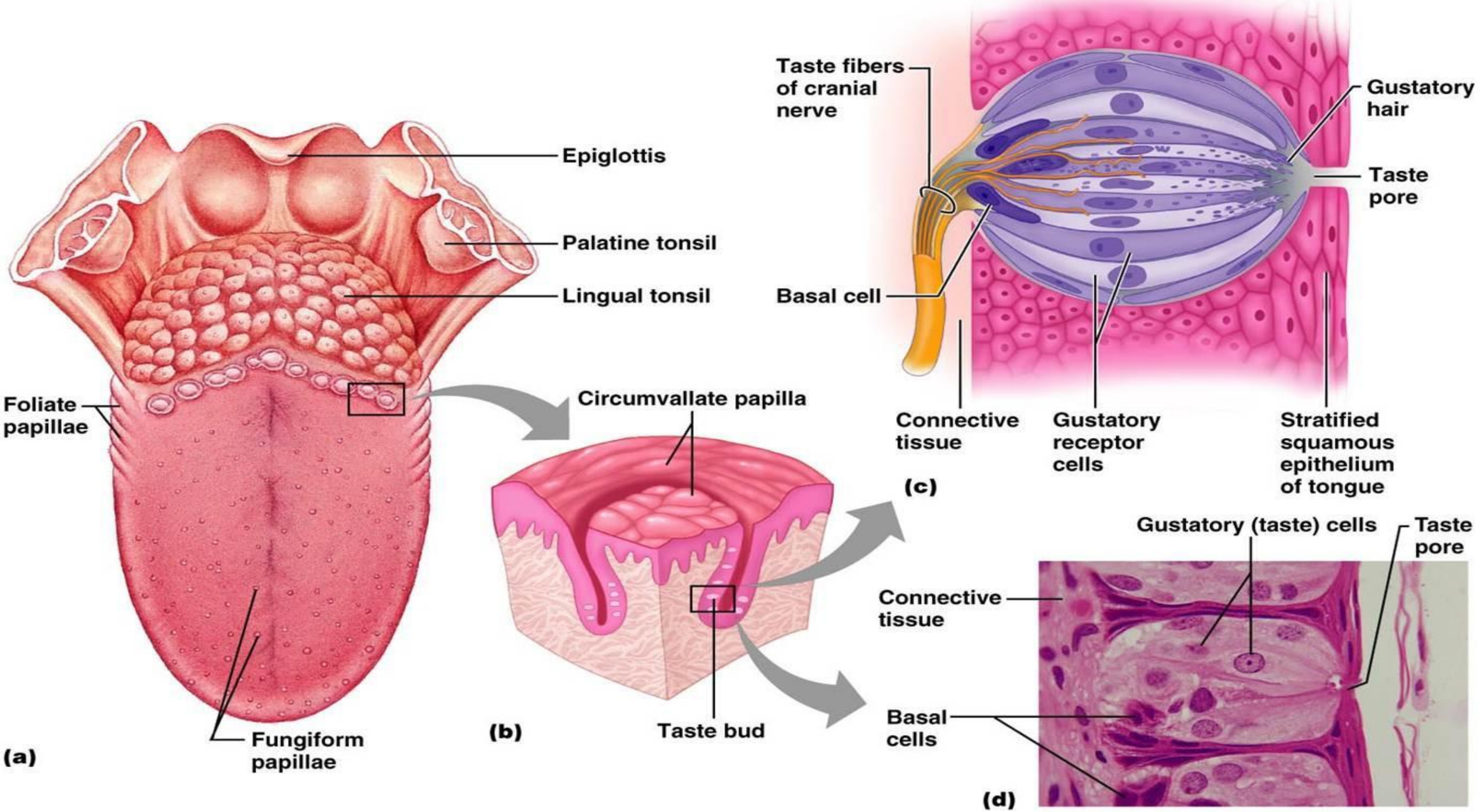


PHYSIOLOGY OF GUSTATION

- **Taste buds** are found in **elevations on the tongue called papillae**, which increase the surface area and provide a rough texture to the upper surface of the tongue.
- The entire surface of the tongue has **filiform papillae**, **increase friction between the tongue and food, making it easier for the tongue to move food in the oral cavity.**
- Chemicals that stimulate gustatory receptor cells are known as **tastants**.
- Once a **tastant is dissolved in saliva**, it can make **contact with** the plasma membranes of the **gustatory microvilli**, which are the **sites of taste transduction**.
- The result is a receptor potential that stimulates exocytosis of synaptic vesicles from the gustatory receptor cell. In turn, the liberated neurotransmitter molecules trigger nerve impulses in the first-order sensory neurons that synapse with gustatory receptor cells.

PHYSIOLOGY OF GUSTATION

- **The receptor potential arises differently for different tastants.**
- The **sodium ions** in a salty food enter gustatory receptor cells via Na ion channels in the plasma membrane.
- The **accumulation of Na ions inside the cell causes depolarization**, which leads to **release of neurotransmitter**.
- **Other tastants,** responsible for stimulating sweet, bitter, and umami tastes, **do not themselves enter gustatory receptor cells**. Rather, **they bind to receptors on the plasma membrane that are linked to G proteins. The G proteins then activate several different chemicals known as second messengers inside the gustatory receptor cell. Different second messengers cause depolarization in different ways, but the result is the same— release of neurotransmitter.**


Epiglottis
Palatine tonsil
Lingual tonsil
Foliate papillae
Fungiform papillae
(a)
Circumvallate papilla
Taste bud
(b)
Taste fibers of cranial nerve
Basal cell
Gustatory hair
Taste pore
Connective tissue
Gustatory receptor cells
Stratified squamous epithelium of tongue
(c)
Gustatory (taste) cells
Taste pore
Connective tissue
Basal cells
(d)

TASTE THRESHOLDS AND ADAPTATION

- **The threshold for taste varies for each of the primary tastes.**

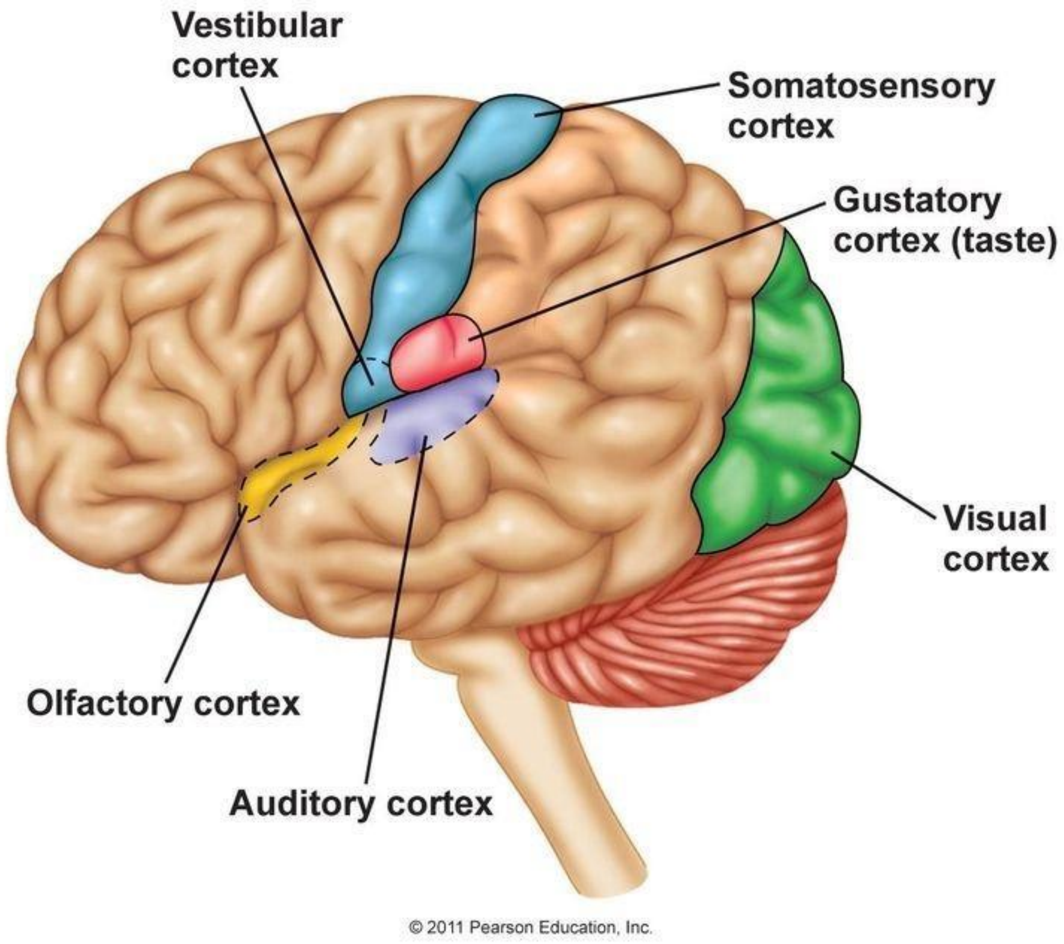
- Complete adaptation to a specific taste can occur in 1–5 minutes of continuous stimulation.

THE GUSTATORY PATHWAY

1. From the taste buds, nerve impulses propagate along these cranial nerves to the gustatory nucleus in the medulla oblongata.

2. From the medulla, some axons carrying taste signals project to the limbic system and the hypothalamus; others project to the thalamus.

3. Taste signals that project from the thalamus to the primary gustatory area in the parietal lobe of the cerebral cortex give rise to conscious perception of taste.



VISION

- Vision, the act of seeing, is extremely important to human survival.

- More than half the sensory receptors in the human body are located in the eyes, and a large part of the cerebral cortex is devoted to processing visual information.

ELECTROMAGNETIC RADIATION

- **Electromagnetic radiation** is energy in the form of waves that radiates from the sun.
- **There are many types of electromagnetic radiation, including gamma rays, x-rays, UV rays, visible light, infrared radiation, microwaves, and radio waves.**
- This **range of electromagnetic radiation** is known as the **electromagnetic spectrum**.
- The **distance between two consecutive peaks** of an electromagnetic wave is the **wavelength.**

ELECTROMAGNETIC RADIATION

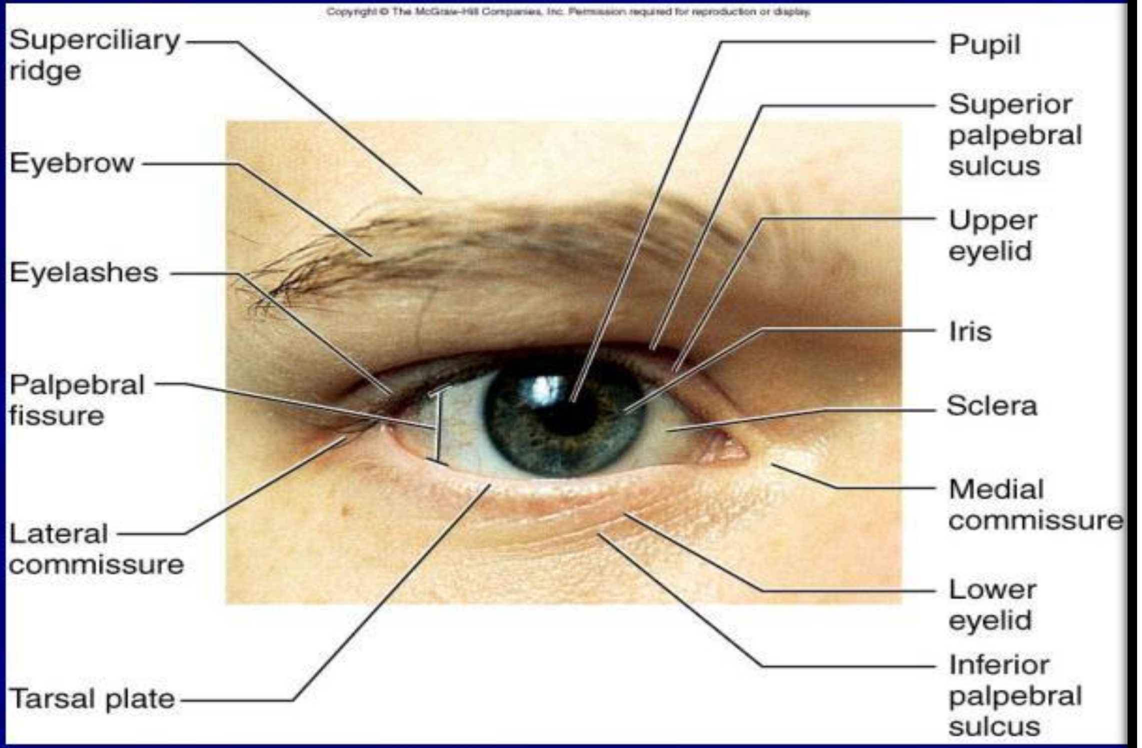
- **The eyes** are responsible for the **detection of visible light**, the part of the **electromagnetic spectrum with wavelengths ranging from about 400 to 700 nm.**

ACCESSORY STRUCTURES OF THE EYE

- **The accessory structures of the eye include the eyelids, eyelashes, eyebrows, the lacrimal (tear-producing) apparatus, and extrinsic eye muscles.**

Surface Anatomy and Accessory Structures of the Eye

1. eyelids
2. eyelashes
3. eyebrows
4. extrinsic eye muscles
5. lacrimal apparatus

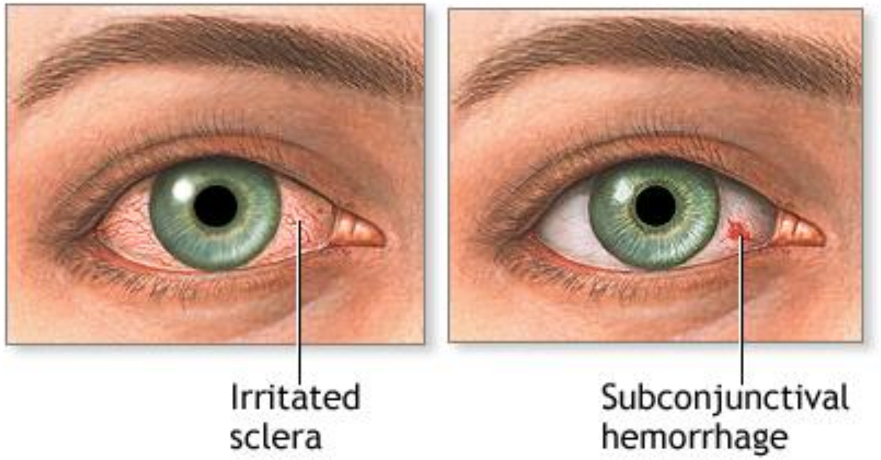


EYELIDS

- The upper and lower eyelids, **shade the eyes during sleep**, **protect the eyes from excessive light and foreign objects**, and spread lubricating secretions over the eyeballs.

- The **conjunctiva** is a thin, protective mucous membrane composed of nonkeratinized stratified squamous epithelium with numerous goblet cells that is supported by areolar connective tissue.

- **Dilation and congestion of the blood vessels of the bulbar conjunctiva, which lines the inner aspect of the eyelids, ,** due to local irritation or infection are the cause of **bloodshot eyes**.



EYELASHES AND EYEBROWS

- **The eyelashes**, which project from the border of each eyelid.
- **Sebaceous glands at the base of the hair follicles of the eyelashes,** called **sebaceous ciliary glands**. **Infection of these glands, usually by bacteria, causes a painful, pus-filled swelling called a sty.**

- **The eyebrows,** which arch transversely above the upper eyelids, help protect the eyeballs from foreign objects, perspiration, and the direct rays of the sun.

THE LACRIMAL APPARATUS

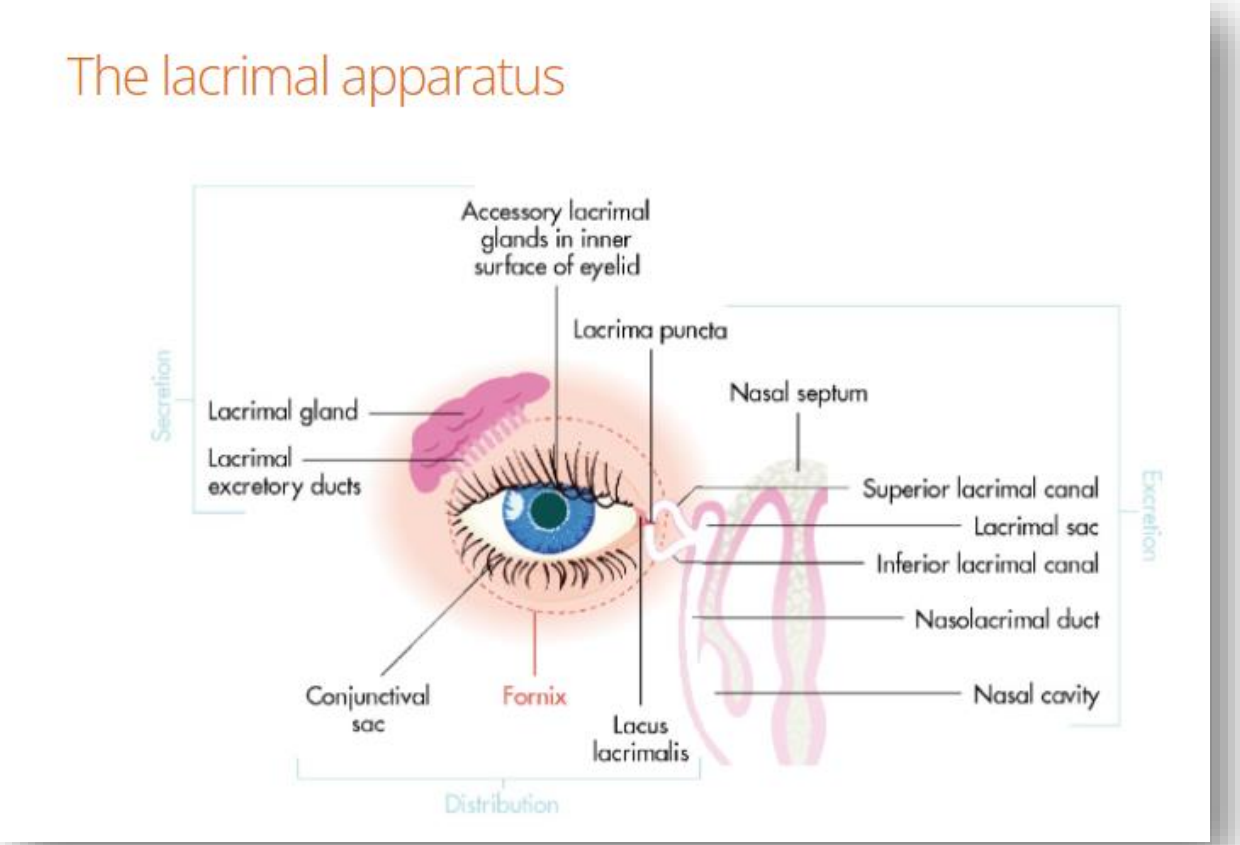
- The lacrimal apparatus is **a group of structures that produces and drains lacrimal fluid or tears** in a process called lacrimation.

- The **lacrimal glands**, **secrete lacrimal fluid**, **which drains into 6–12 lacrimal ducts** that **empty tears onto the surface of the conjunctiva of the upper lid**.

THE LACRIMAL APPARATUS

- **The lacrimal glands are supplied by parasympathetic fibers of the facial (VII) nerves.** After being secreted from the <u>lacrimal gland</u>, lacrimal fluid is spread medially over the surface of the eyeball by the blinking of the eyelids.

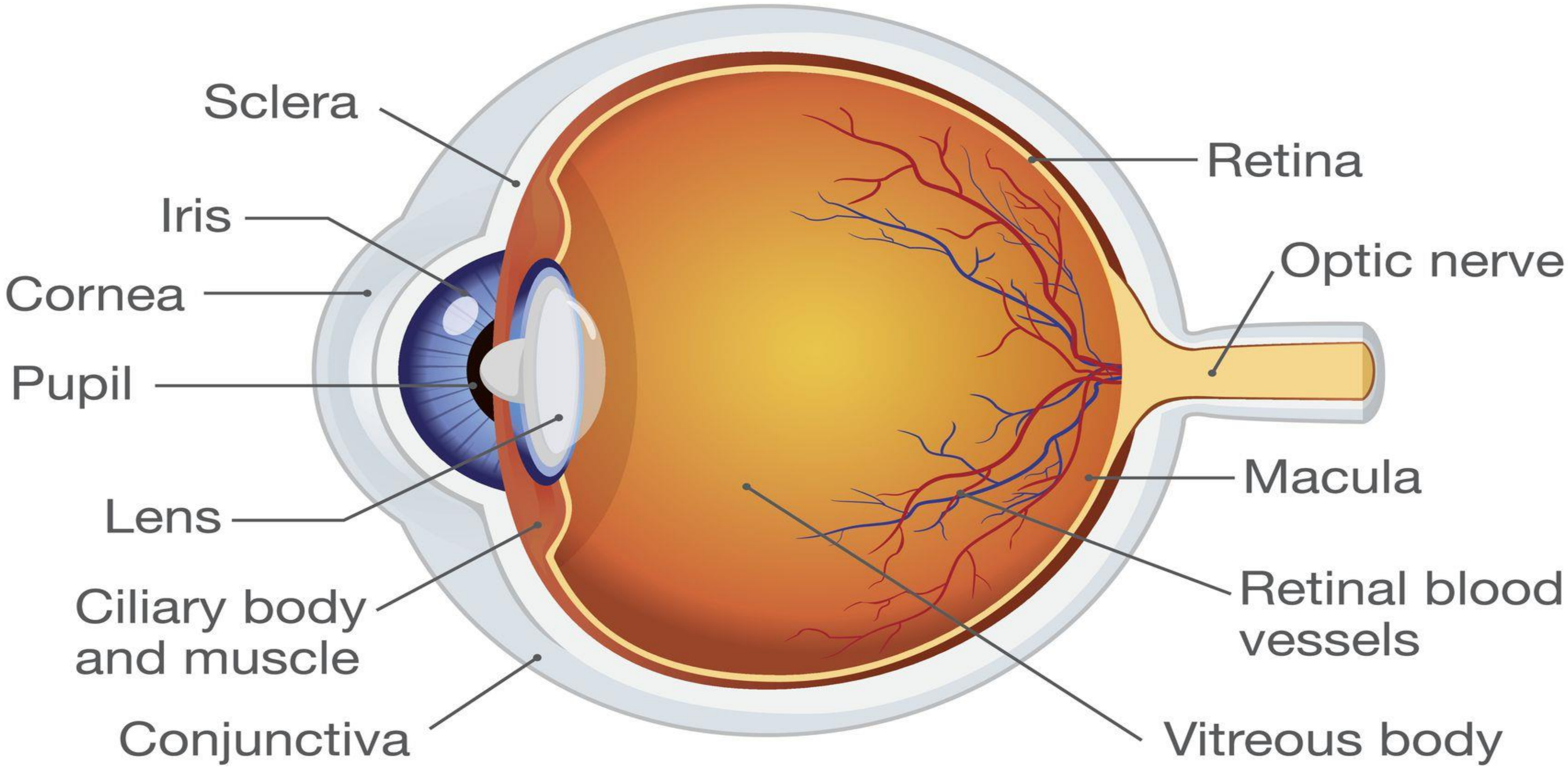
- From here the tears pass medially over the anterior surface of the eyeball to **enter two small openings called <u>lacrimal puncta</u>** (singular is punctum). Tears then **pass into two ducts**, the superior and inferior lacrimal canaliculi, which lead into the **<u>lacrimal sac</u> <u>(within the lacrimal fossa</u>) and then into the <u>nasolacrimal duct.</u>**



EXTRINSIC EYE MUSCLES

- Muscles that produce their essential movements, move the eyeball laterally, medially, superiorly, and inferiorly.
- These muscles are capable of moving the eye in almost any direction.
- **Six extrinsic eye muscles move each eye: the superior rectus, inferior rectus, lateral rectus, medial rectus, superior oblique, and inferior oblique.**
- Neural circuits in the brain stem and cerebellum coordinate and synchronize the movements of the eyes.

Human Eye Anatomy



SUMMARY OF THE STRUCTURES OF THE EYEBALL

1. **Fibrous tunic : Cornea:** Admits and refracts (bends) light. **Sclera:** Provides shape and protects inner parts.
2. **Vascular tunic: Iris:** Regulates amount of light that enters eyeball. **Ciliary body:** alters shape of lens for near or far vision (accommodation). **Choroid:** Provides blood supply and absorbs scattered light.
3. **Retina:** Receives light and converts it into receptor potentials and nerve impulses. Output to brain via axons of ganglion cells, which form optic (II) nerve.
4. **Lens:** Refracts light.

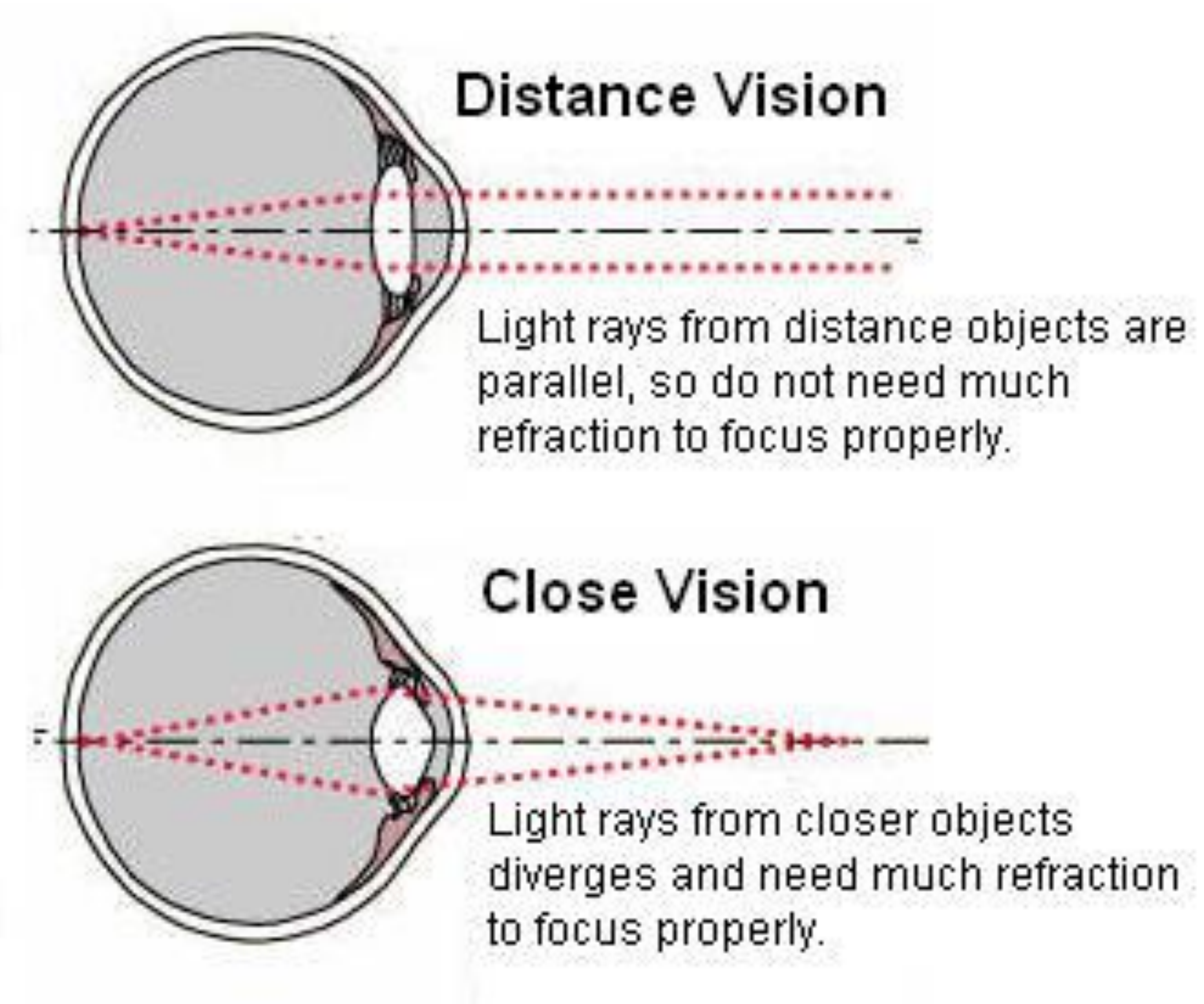
IMAGE FORMATION

- To understand how the eye forms clear images of objects on the retina, we must examine three processes:

- **(1) the refraction or bending of light by the lens and cornea;**
- **(2) accommodation, the change in shape of the lens;**
- **(3) constriction or narrowing of the pupil.**

REFRACTION OF LIGHT RAYS

- **As light rays enter the eye, they are refracted at the anterior and posterior surfaces of the cornea.**
- Both surfaces of the lens of the eye further refract the light rays so they come into exact focus on the retina.
- **Images focused on the retina are inverted (upside down).**
- About 75% of the total refraction of light occurs at the cornea.
- The lens provides the remaining 25% of focusing power and also changes the focus to view near or distant objects.


Distance Vision
Light rays from distance objects are parallel, so do not need much refraction to focus properly.
Close Vision
Light rays from closer objects diverges and need much refraction to focus properly.

ACCOMMODATION AND THE NEAR POINT OF VISION

- When the eye is focusing on a close object, the lens becomes more curved, causing greater refraction of the light rays.

- This increase in the curvature of the lens for near vision is called accommodation. The near point of vision is the minimum distance from the eye that an object can be clearly focused with maximum accommodation.

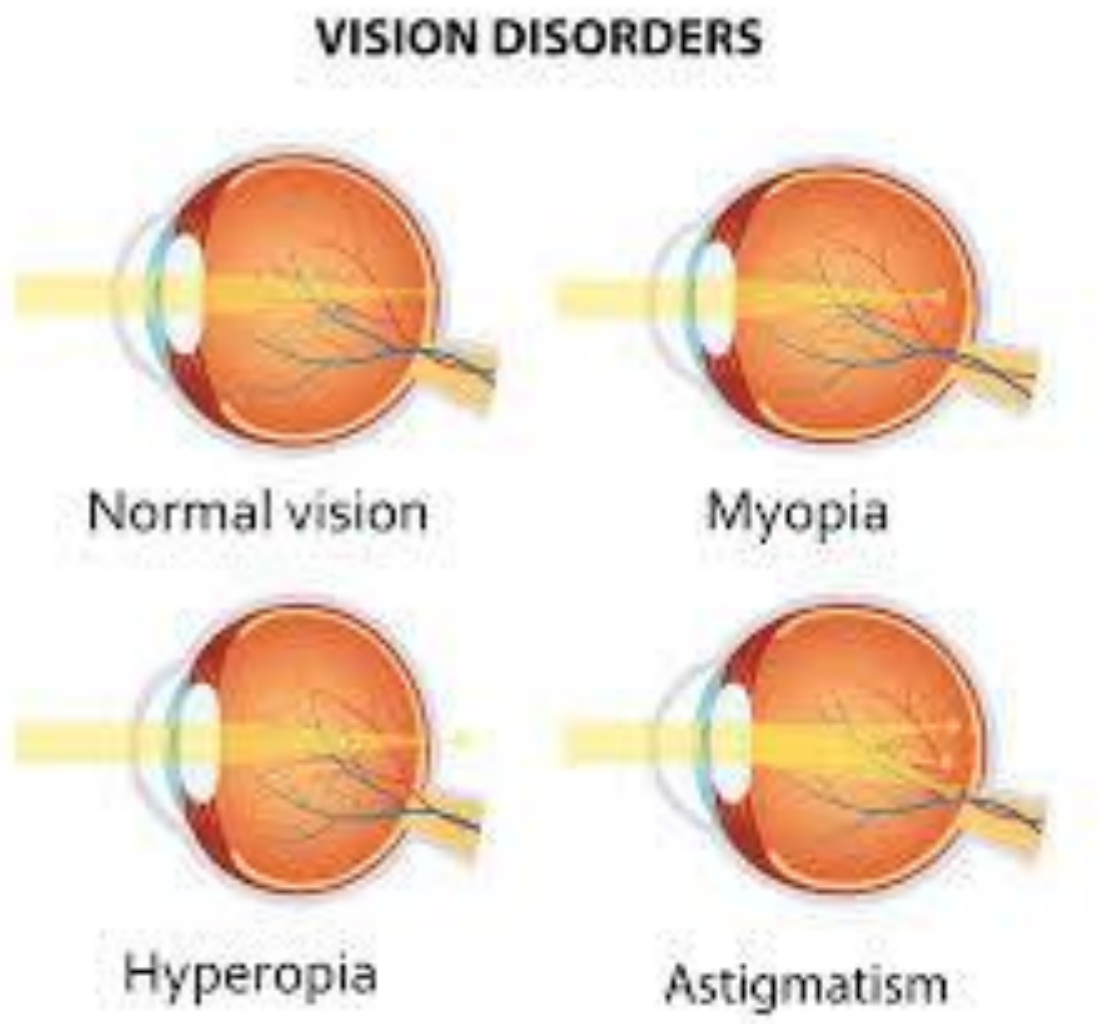
- the lens becomes more spherical, which increases the refraction of light.

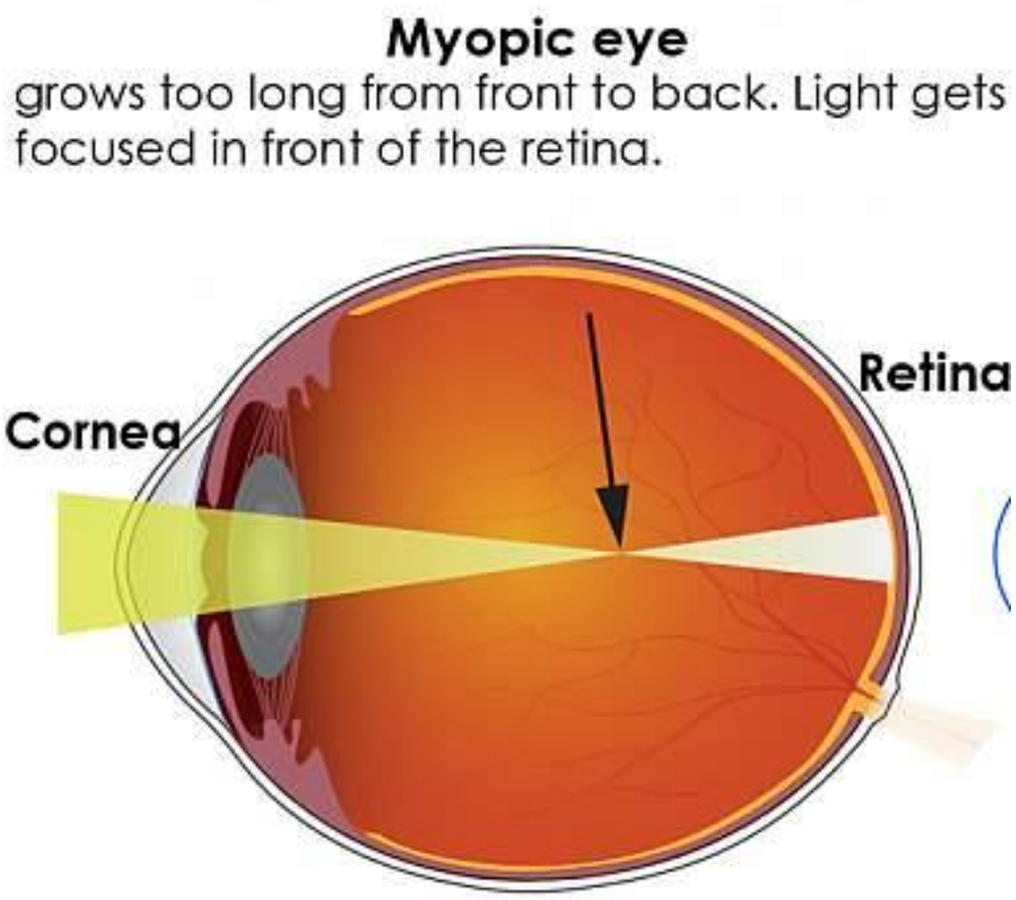
REFRACTION ABNORMALITIES

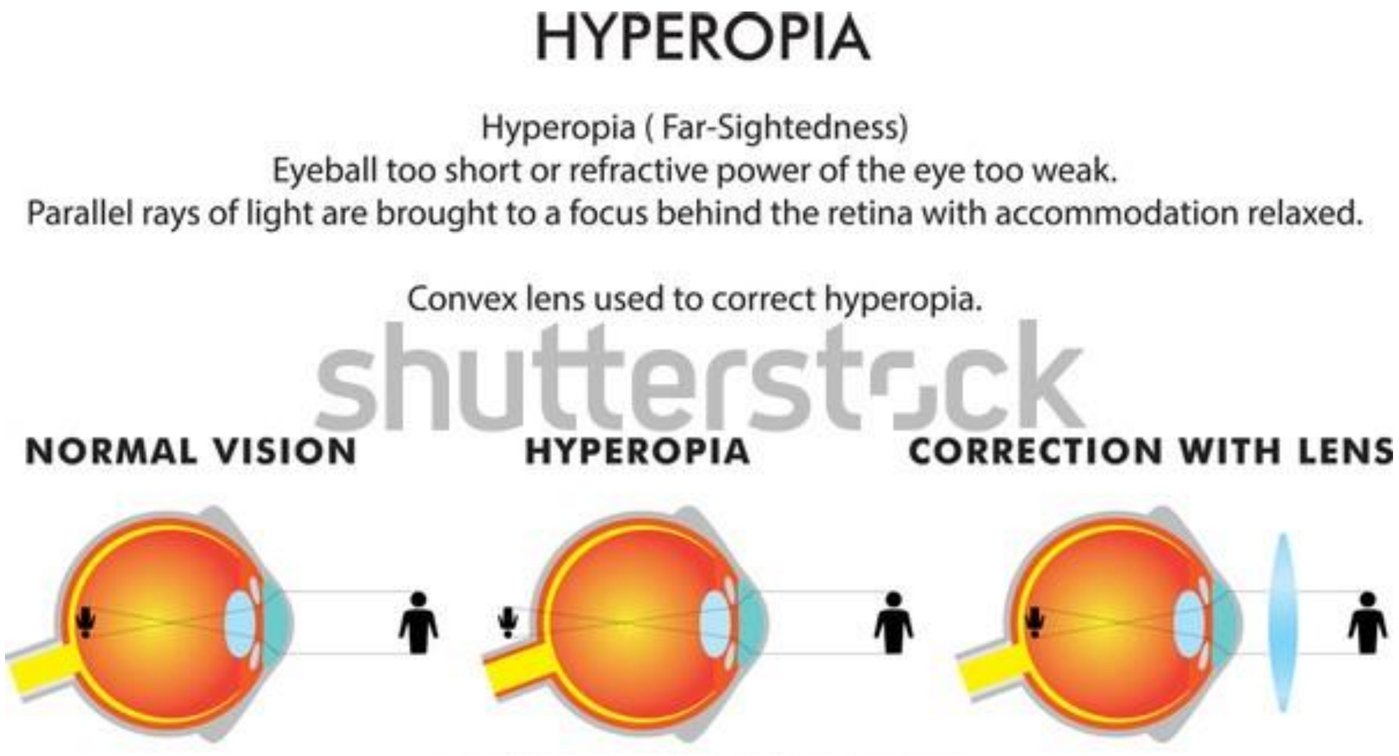
- Among these abnormalities are **myopia**, which occurs when the eyeball is too long relative to the focusing power of the cornea and lens, or when the lens is thicker than normal, so an image converges in front of the retina. **Myopic individuals can see close objects clearly, but not distant objects.**

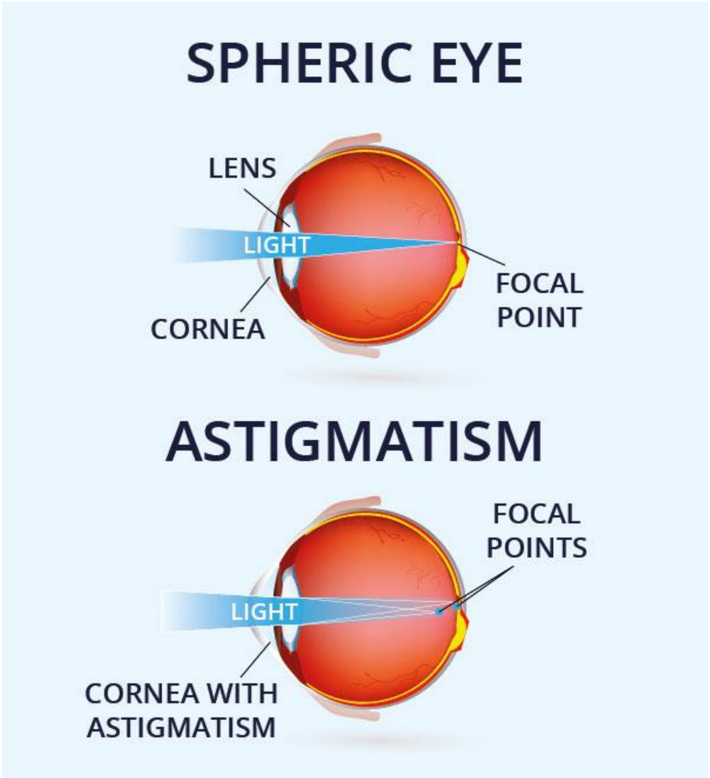
- **Hyperopic individuals can see distant objects clearly, but not close ones.**

- Another refraction abnormality is **astigmatism**, in which either the cornea or the lens has an irregular curvature. As a result, parts of the image are out of focus, and thus vision is blurred or distorted.


VISION DISORDERS
Normal vision
Myopia
Hyperopia
Astigmatism


Myopic eye
grows too long from front to back. Light gets focused in front of the retina.
Cornea
Retina


HYPEROPIA
Hyperopia (Far-Sightedness)
Eyeball too short or refractive power of the eye too weak.
Parallel rays of light are brought to a focus behind the retina with accommodation relaxed.
Convex lens used to correct hyperopia.
shutterstock
NORMAL VISION
HYPEROPIA
CORRECTION WITH LENS


SPHERIC EYE
LENS
LIGHT
FOCAL POINT
CORNEA
ASTIGMATISM
FOCAL POINTS
LIGHT
CORNEA WITH ASTIGMATISM

CONSTRICTION OF THE PUPIL

- The circular muscle fibers of the iris also have a role in the formation of clear retinal images.

- The constriction of the pupil is a **narrowing of the diameter of the hole through which light enters the eye** due to the **contraction of the circular muscles of the iris.**

CONVERGENCE

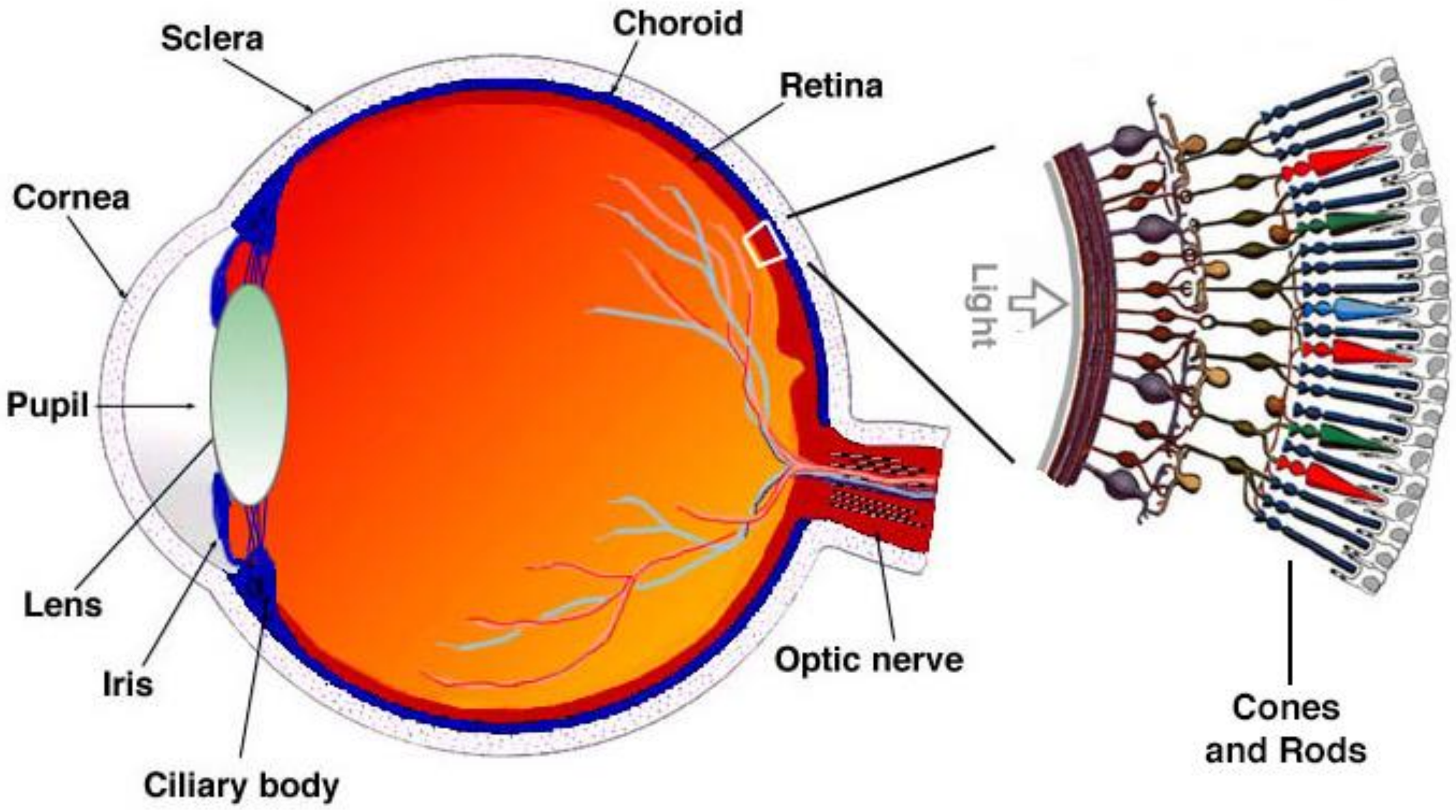
- In humans, both eyes focus on only one set of objects—a characteristic called **binocular vision**.
- The term convergence refers to a medial movement of the two eyeballs so that both are directed toward the object being viewed, for example, tracking a pencil moving toward your eyes.
- The nearer the object, the greater the degree of convergence needed to maintain binocular vision.

PHYSIOLOGY OF VISION

❖ Photoreceptors and Photopigments:

- **Types of photoreceptors are rods and cones.**
- The outer segments of rods are cylindrical or rod-shaped; those of cones are tapered or cone-shaped.
- **Transduction of light energy into a receptor potential occurs in the outer segment of both rods and cones.**
- **The photopigments are integral proteins in the plasma membrane of the outer segment.**
- **The inner segment of photoreceptors contains the cell nucleus, Golgi complex, and many mitochondria. At its proximal end, the photoreceptor expands into bulblike synaptic terminals filled with synaptic vesicles.**

PHOTORECEPTORS AND PHOTOPIGMENTS:



VISUAL TRANSDUCTION

- 1- The first step in visual transduction is **absorption of light by a photopigment**, a colored protein that undergoes structural changes when it absorbs light, in the outer segment of a photoreceptor.

- 2- Light absorption initiates the events that lead to the production of a receptor potential.

- ***Note 1:*** The single type of photopigment in rods is rhodopsin. However, three different cone photopigments are present in the retina, one in each of the three types of cones. Thus, color vision results from different colors of light selectively activating the different cone photopigments.

VISUAL TRANSDUCTION

- ***Note 2:*** All photopigments associated with vision contain two parts: a glycoprotein known as opsin and a derivative of vitamin A called retinal. Retinal is the light-absorbing part of all visual photopigments.

- ***Note 3***: In the human retina, there are four different opsins, three in the cones and one in the rods (rhodopsin). **Small variations in the amino acid sequences of the different opsins permit the rods and cones to absorb different colors (wavelengths) of incoming light**.

VISUAL TRANSDUCTION

- 1- In darkness, retinal has a bent shape, called cis-retinal, fits into the opsin portion of the photopigment. When cis-retinal absorbs a photon of light, it straightens out to a shape called trans-retinal. This cis-to-trans conversion is called **isomerization** and is the **first step in visual transduction**.

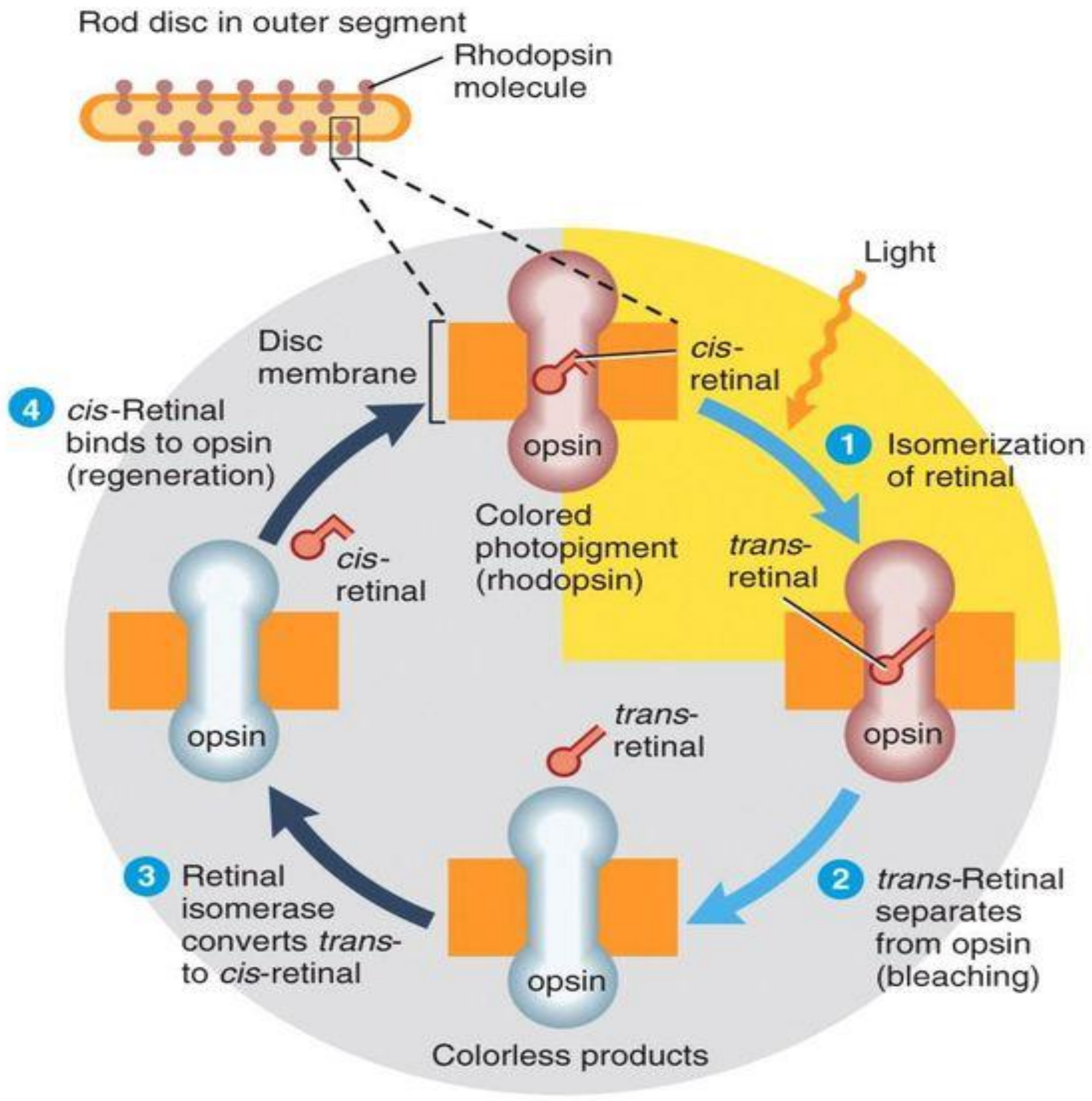
- 2- After retinal isomerizes, several unstable chemical intermediates form and disappear. These **chemical changes lead to production of a receptor potential.**

- 3- In about a minute, **trans-retinal completely separates from opsin**. The final products look colorless, so this part of the cycle is termed **bleaching of photopigment**.

VISUAL TRANSDUCTION

4- An enzyme called **retinal isomerase** converts trans-retinal back to cis-retinal.

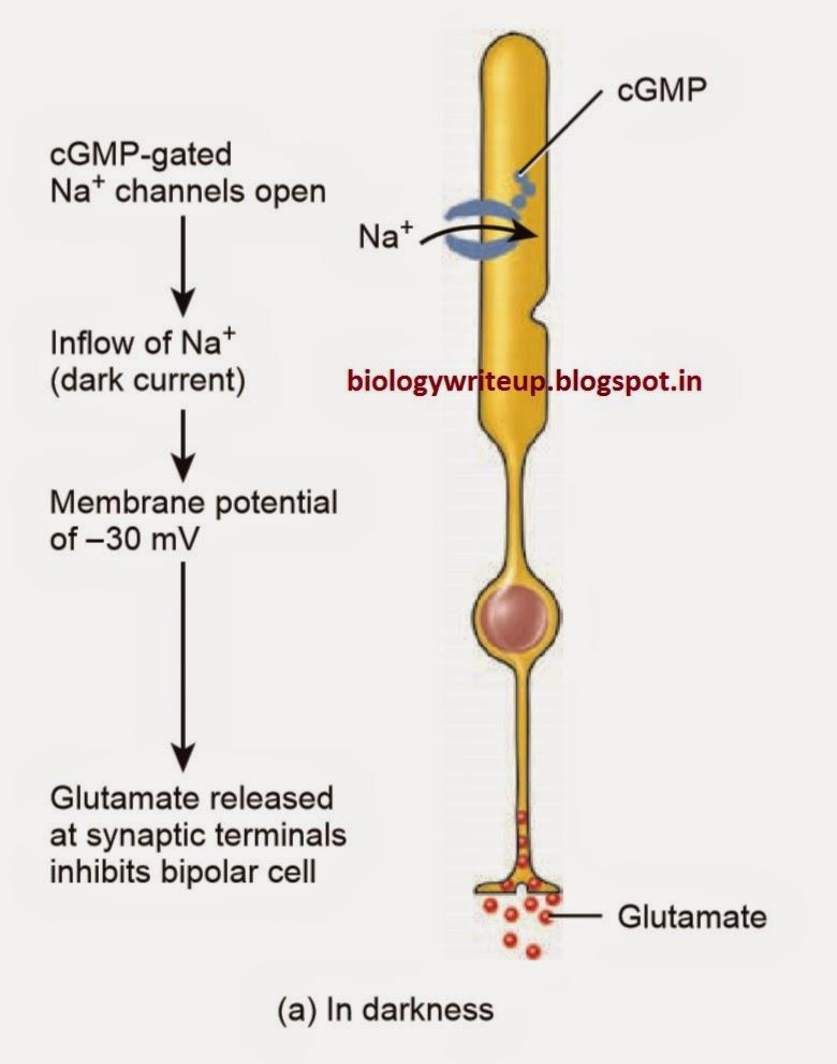
5- The cis-retinal then can bind to opsin, reforming a functional photopigment. **This part of the cycle—resynthesis of a photopigment—is called regeneration**. Cone photopigments regenerate much more quickly than the rhodopsin in rods.



Rod disc in outer segment
Rhodopsin molecule
Light
Disc membrane
cis-retinal
opsin
4 cis-Retinal binds to opsin (regeneration)
1 Isomerization of retinal
Colored photopigment (rhodopsin)
trans-retinal
cis-retinal
opsin
opsin
trans-retinal
3 Retinal isomerase converts trans- to cis-retinal
2 trans-Retinal separates from opsin (bleaching)
opsin
Colorless products

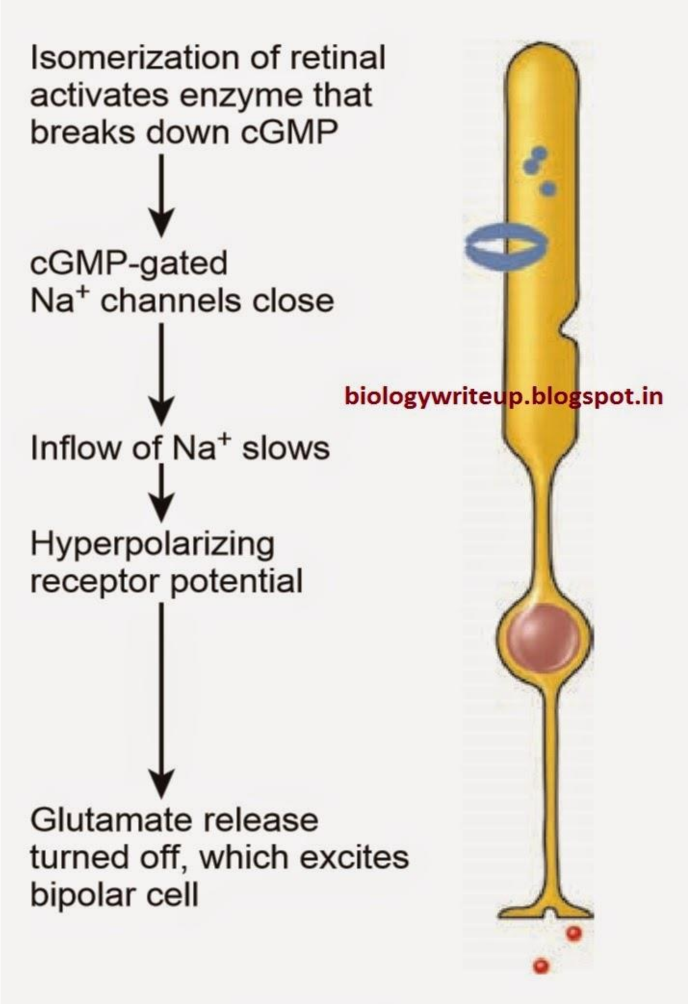
RELEASE OF NEUROTRANSMITTER BY PHOTORECEPTORS

- As mentioned previously, the absorption of light and isomerization of retinal initiates chemical changes in the photoreceptor outer segment that lead to production of a receptor potential.
- **cyclic guanosine monophosphate (cyclic GMP) or cGMP.**
- **glutamate is an inhibitory neurotransmitter: It triggers inhibitory postsynaptic potentials (IPSPs) that hyperpolarize the bipolar cells and prevent them from transmitting signals to the ganglion cells.**



RELEASE OF NEUROTRANSMITTER BY PHOTORECEPTORS

- When light strikes the retina and cis-retinal undergoes isomerization, enzymes are activated that break down cGMP.
- **This sequence of events produces a hyperpolarizing receptor potential that decreases the release of glutamate.**
- **Thus, light excites the bipolar cells that synapse with rods by turning off the release of an inhibitory neurotransmitter. The excited bipolar cells subsequently stimulate the ganglion cells to form action potentials in their axons.**



(b) In light

THE VISUAL PATHWAY

The axons of retinal ganglion cells provide output from the retina to the brain, exiting the eyeball as the optic (II) nerve.

PROCESSING OF VISUAL INPUT IN THE RETINA

- Input from several cells may either converge on a smaller number of postsynaptic neurons **(convergence)** or diverge to a large number **(divergence).**
- Once receptor potentials arise in the outer segments of rods and cones, they spread through the inner segments to the synaptic terminals.
- Neurotransmitter molecules released by rods and cones induce local graded potentials in cells.

BRAIN PATHWAY AND VISUAL FIELDS

- The axons within the optic (II) nerve pass through the optic chiasm, a crossing point of the optic nerves.

- Some axons cross to the opposite side, but others remain uncrossed.

- **After passing through the optic chiasm, the axons, now part of the optic tract, enter the brain and most of them terminate in the lateral geniculate nucleus of the thalamus. Here they synapse with neurons whose axons form the optic radiations, which project to the primary visual areas in the occipital lobes of the cerebral cortex, and visual perception begins.**

BRAIN PATHWAY AND VISUAL FIELDS

- ✓ **Everything that can be seen by one eye is that eye's visual field.**
- ✓ Because our eyes are located anteriorly in our heads, the visual fields overlap considerably.
- ✓ **The visual field of each eye is divided into two regions: the nasal or central half and the temporal or peripheral half.**
- ✓ For each eye, light rays from an object in the nasal half of the visual field fall on the temporal half of the retina, and light rays from an object in the temporal half of the visual field fall on the nasal half of the retina.

BRAIN PATHWAY AND VISUAL FIELDS

1. The axons of all retinal ganglion cells in one eye exit the eyeball at the optic disc and form the optic nerve on that side.

2. At the optic chiasm, axons from the temporal half of each retina do not cross but continue directly to the lateral geniculate nucleus of the thalamus on the same side.

BRAIN PATHWAY AND VISUAL FIELDS

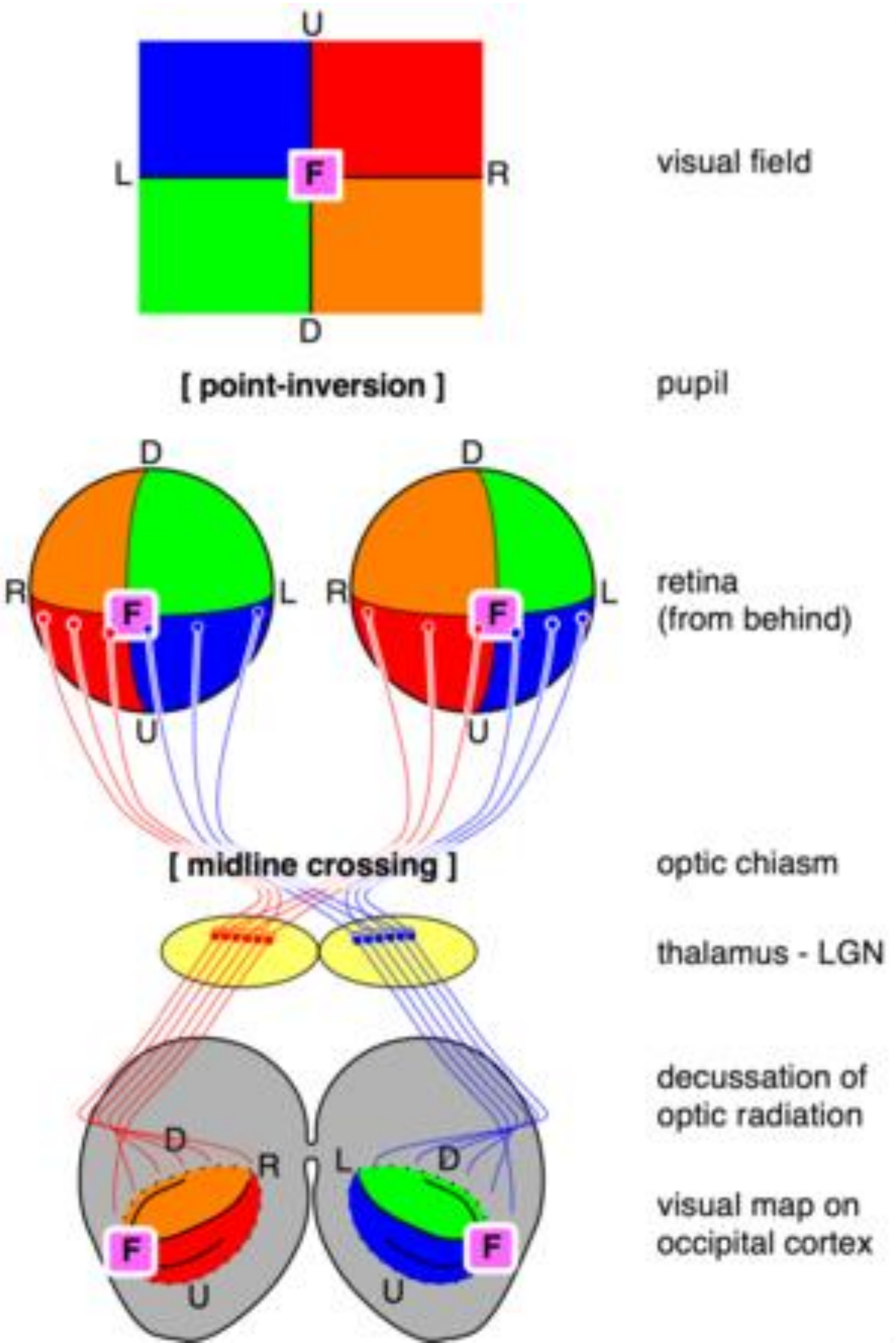
3. In contrast, axons from the nasal half of each retina cross the optic chiasm and continue to the opposite thalamus.

4. Each optic tract consists of crossed and uncrossed axons that project from the optic chiasm to the thalamus on one side.

BRAIN PATHWAY AND VISUAL FIELDS

5. Axon collaterals (branches) of the retinal ganglion cells project to the midbrain, where they participate in neural circuits that govern constriction of the pupils in response to light and coordination of head and eye movements.

6. The axons of thalamic neurons form the optic radiations as they project from the thalamus to the primary visual area of the cortex on the same side.


U
L
F
R
D
visual field
[point-inversion]
pupil
D
R
F
L
U
D
R
F
L
U
retina
(from behind)
[midline crossing]
optic chiasm
thalamus - LGN
decussation of
optic radiation
D
R
F
U
L
D
F
U
visual map on
occipital cortex

THANK YOU

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