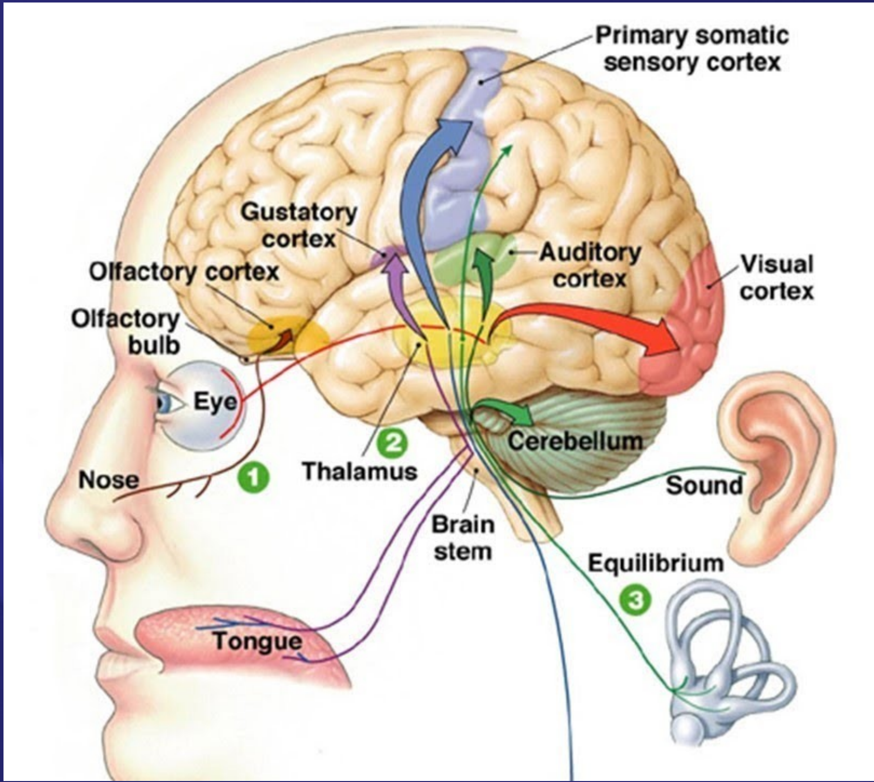
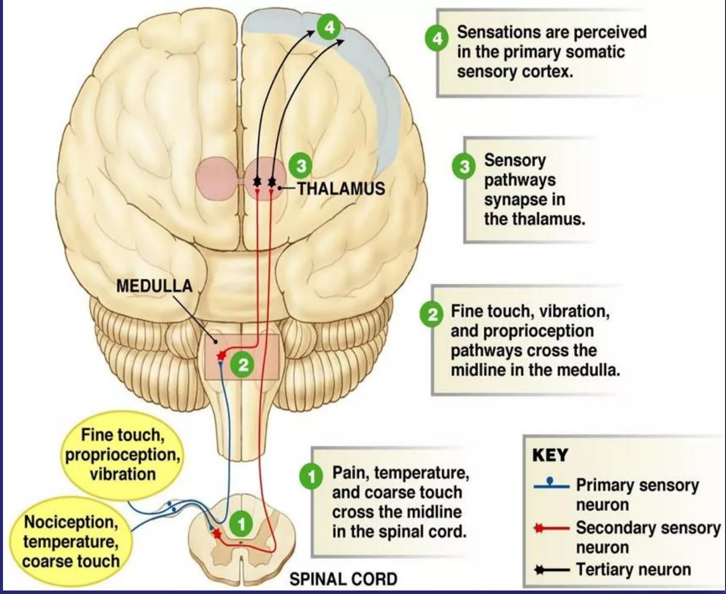
Volgograd State Medical University
Department of Normal Physiology

General and Special Physiology of Analyzers



General physiology of sensory systems



Analyser or sensory system is the part of the nervous system that consists of numerous perceiving devices or receptors and intermediate and central nerve cells connected by fibers.

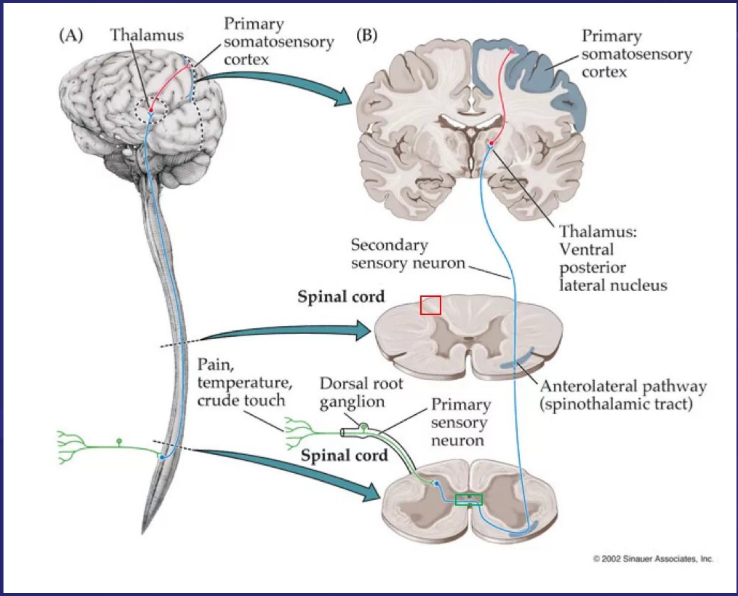
Analysers are the systems which ensure the input of information into the brain and its analysis.

Work of any analyser begins with reception by the specialized cells of physical and chemical energy supplied from the outside and transformation of this energy into neural signals that are transmitted to the brain via neuronal chains forming certain levels.

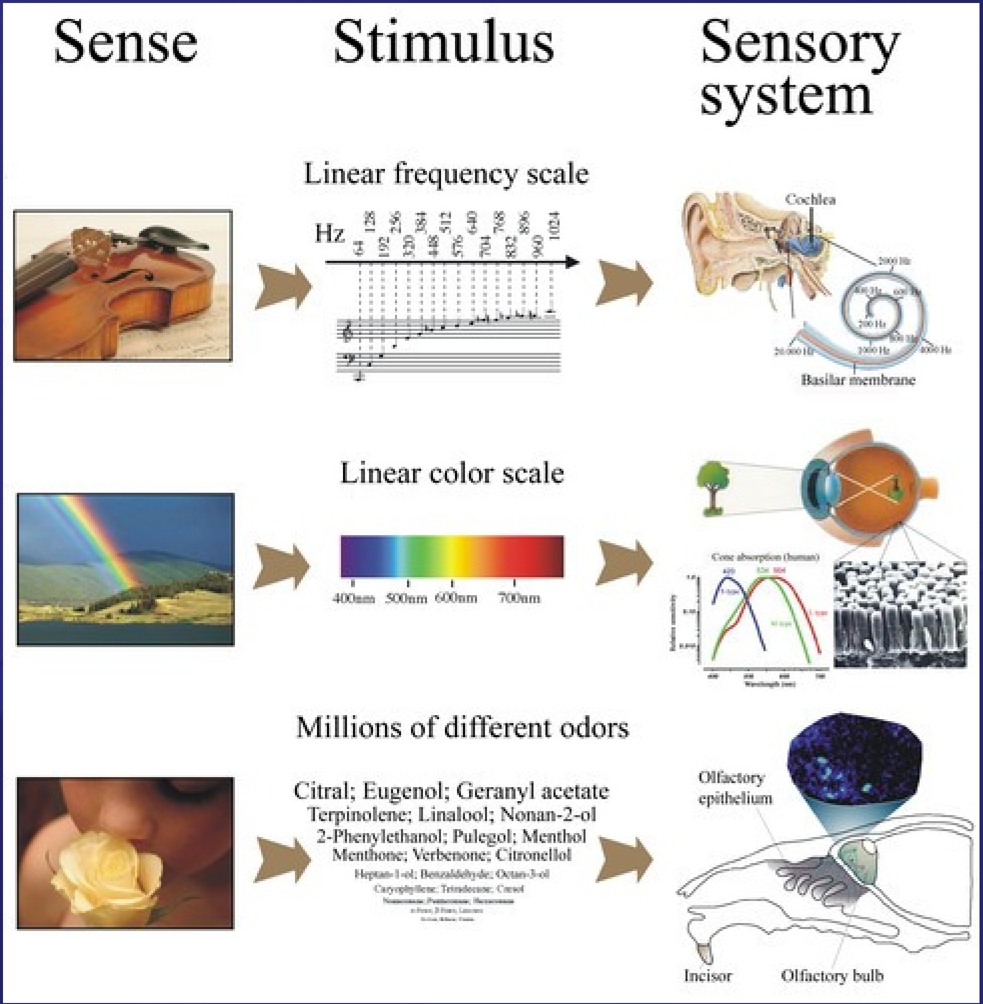
General physiology of sensory systems

The process of transmission of sensory signals is accompanied by their multi-stage transformations and storage and is completed by highest analysis and synthesis (recognition of an image). This is followed by the choice or elaboration of programme of the organism's response, but this is not the scope of analyser function.

All analyser systems of higher vertebrates and man are distinguished by the following principles of their structure.

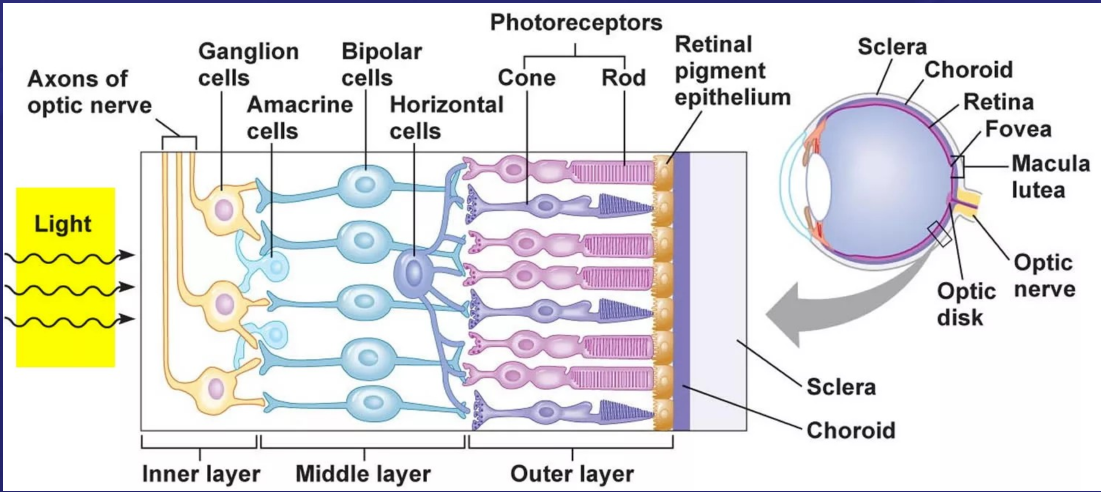


General physiology of sensory systems



General principles of structure of analysers

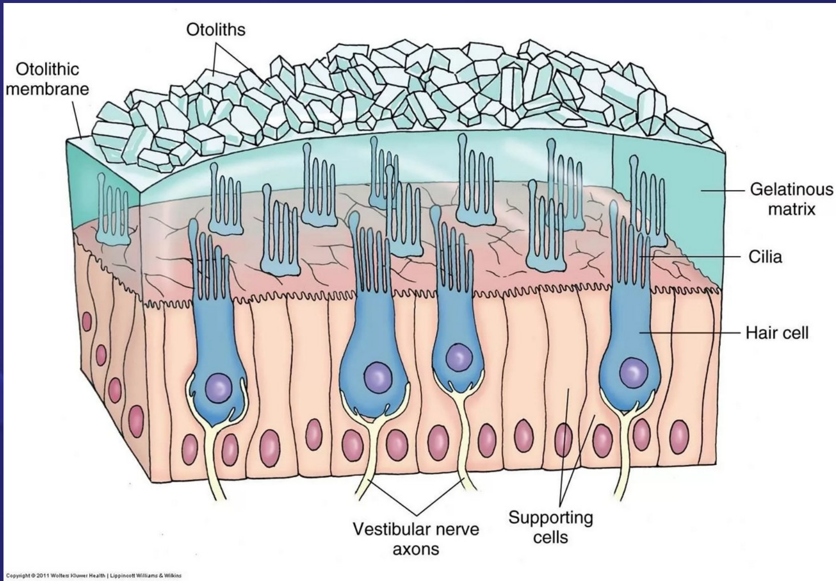
1. Analyser systems have the ***multi-layer composition***, i. e. the presence of several layers of nerve cells; the first layer is connected with receptor elements and the last one with neurons of association areas of the cerebral cortex. These layers are interconnected by conducting pathways made up of their neuron axons.



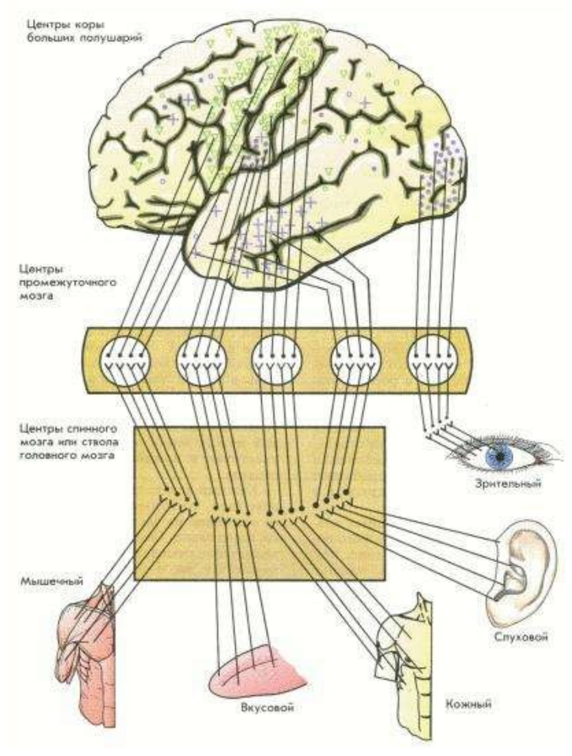
General principles of structure of analysers

This structure of analysers endows their various layers with a special function for processing separate types of information so that the organism can more rapidly respond to simple signals that are analysed already at the intermediate layers.

In addition, this provides conditions for fine regulation of these processes through the influences coming from higher levels of this system and other brain regions.

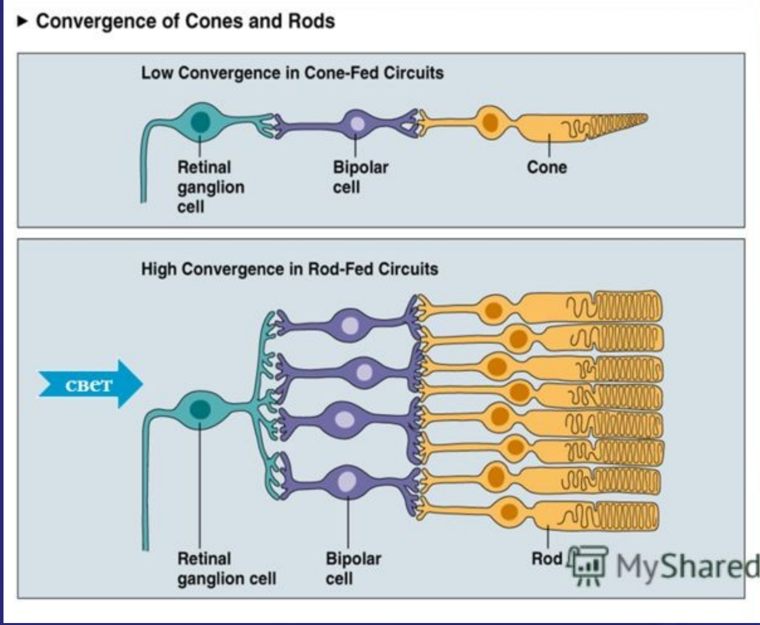


General principles of structure of analysers



2. The ***multi-channel structure*** of analysers means that each layer contains an enormous number of nerve elements (usually scores of thousands and sometimes up to millions) that are connected with a multitude of elements of the next layer; these, in their turn, send nerve impulses to the elements of higher level. Numerous channels ensure analysers of animals with highly reliable and fine analysis.

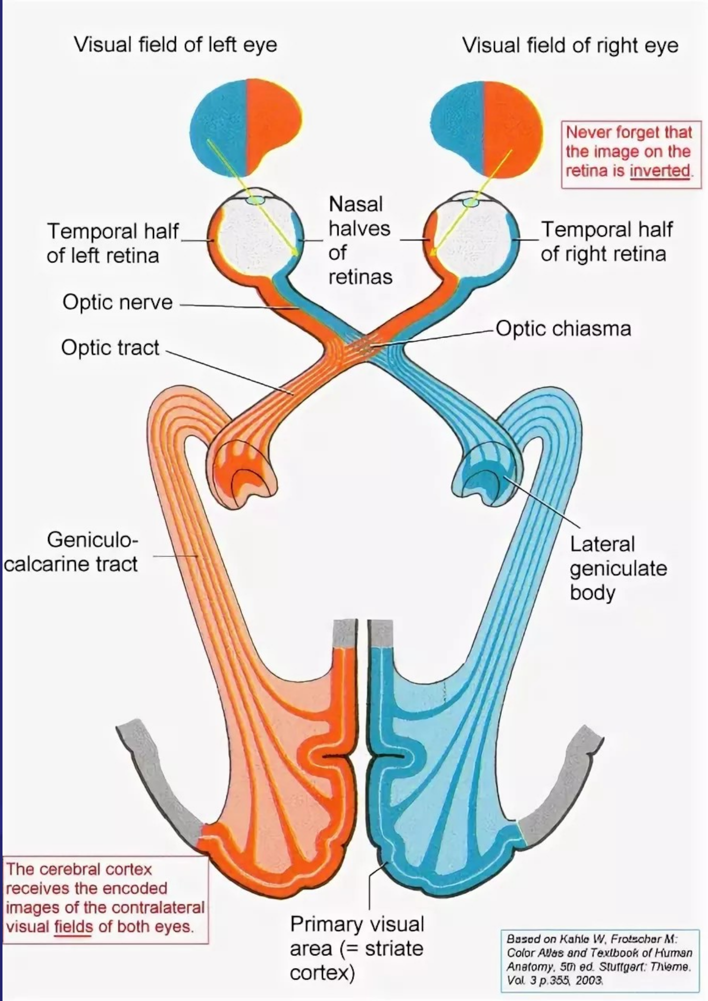
General principles of structure of analysers



3. Neighbouring layers have a dissimilar number of elements, the so-called *sensory '**funnels**'* as, for example, the visual system in which the photoreceptor layer in each retina of man has 130 000 000 elements and the layer of the output ganglion cells only 1 250 000 neurons. This is an example of a narrowing 'funnel'.

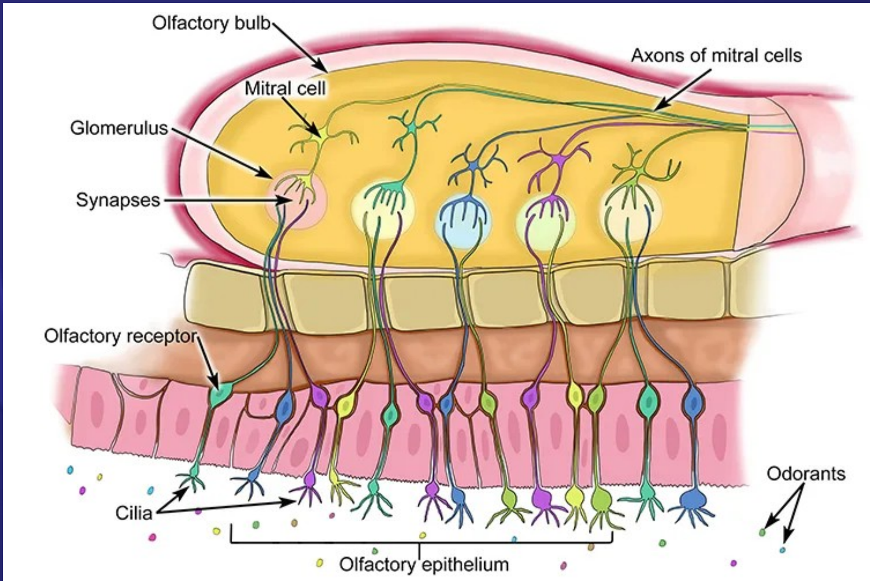
General principles of structure of analysers

However, at higher levels of the visual system a widening 'funnel' is formed: the number of neurons in the primary projection zone of the visual cortex is thousand times more that in the subcortical visual centre or at the exit from the retina. The auditory and certain other analysers have funnels widening in the direction from receptors to the cortex.



General principles of structure of analysers

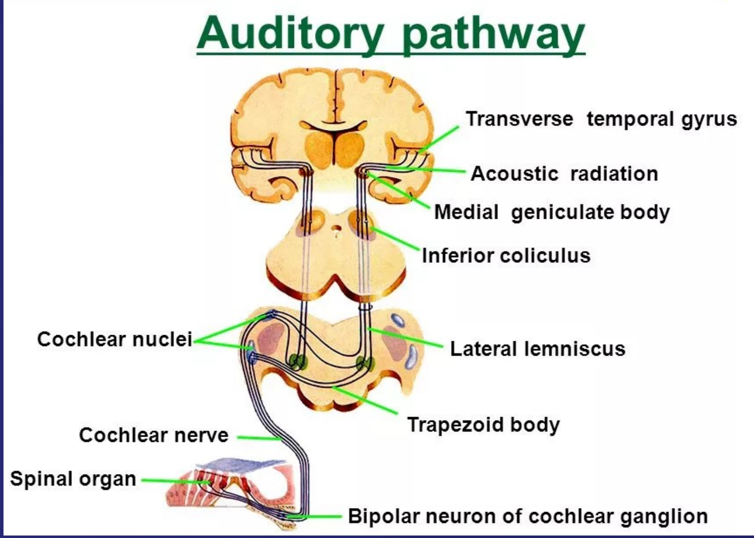
Physiologically, narrowing 'funnels' decrease the amount of information sent to the brain, while widening 'funnels' provide more differential and complex analysis of the different signal properties.



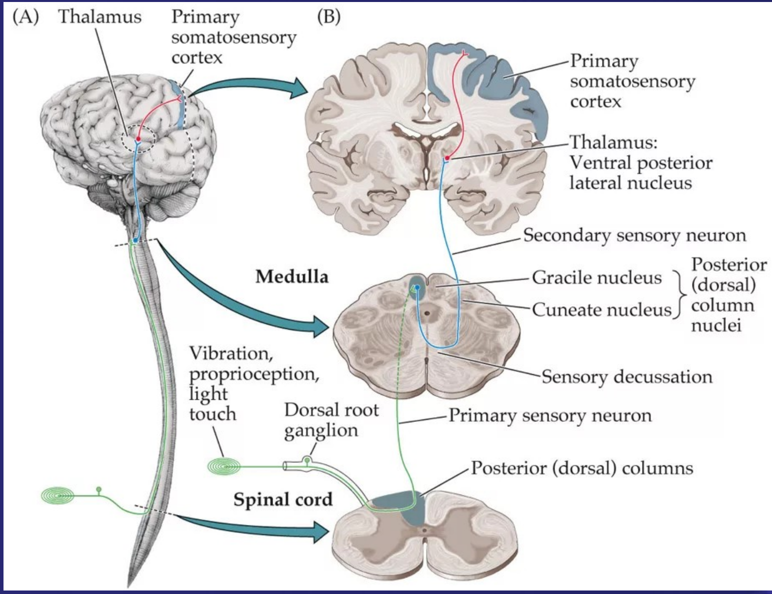
General principles of structure of analysers

4. ***Differentiation***

of analysers in the vertical and horizontal directions. Differentiation in the vertical direction consists in the formation of departments comprising a certain number of layers of nerve elements. A department is a larger morpho-functional unit than the layer of elements. Each department (e. g. the olfactory bulbs, cochlear nuclei or geniculate bodies) has a definite function.



General principles of structure of analysers



The receptor, or peripheral, department of the analyser system, one or, more often, several intermediate departments, and the cortical department of the analyser are commonly distinguished.

Differentiation of the analyser systems in the horizontal direction consists in various properties of the receptors, neurons and connections between them within each layer.

Basic functions of analysers

Analysers perform
a multitude of functions
or operations with signals.

The most important among them are:

I. Signal reception.

II. Differentiation of signals.

III. Transmission and transformation of neural signals.

IV. Coding of information.

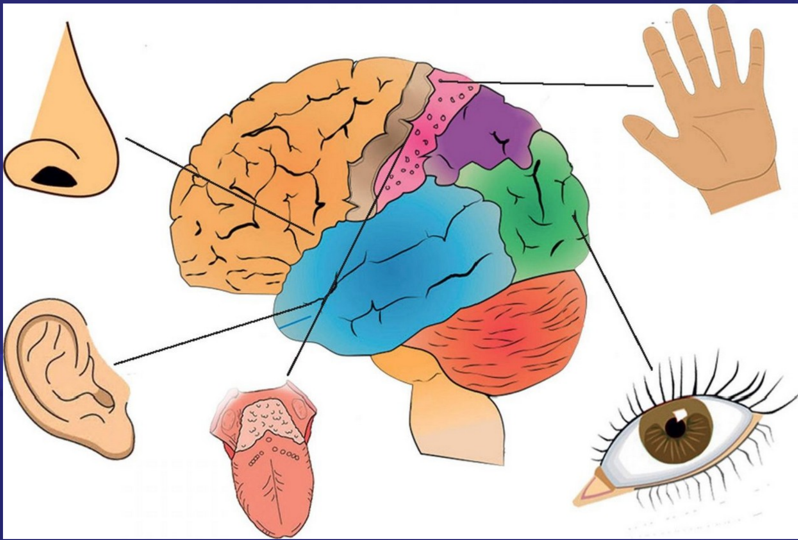
V. Detector processing of signals.

VI. Recognition or identification of images.

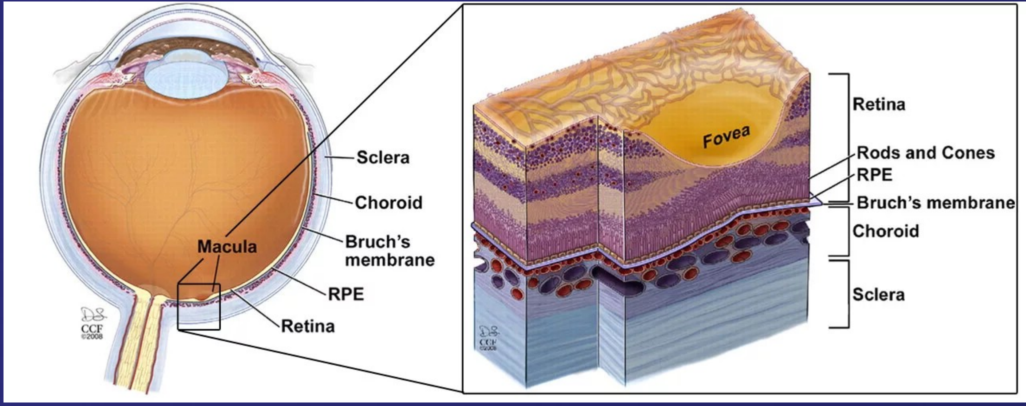
Basic functions of analysers

The reception and differentiation of signals (I, II) are ensured in the first place by receptors and their detection and recognition (V, VI) by highest cortical levels of analysers.

Transmission, transformation and coding of signals (III, IV) are pertinent to all analyser layers.

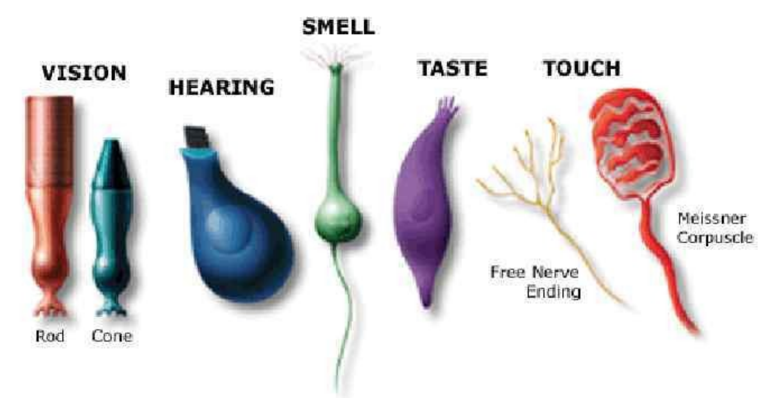


Reception of signals



I. The **reception of signals** begins in the receptors, the specialized cells, that are evolutionarily adapted for perception of a stimulus from the organism's external or internal environment and its transformation from the physical or chemical form into the form of nervous excitation.

Classification of receptors



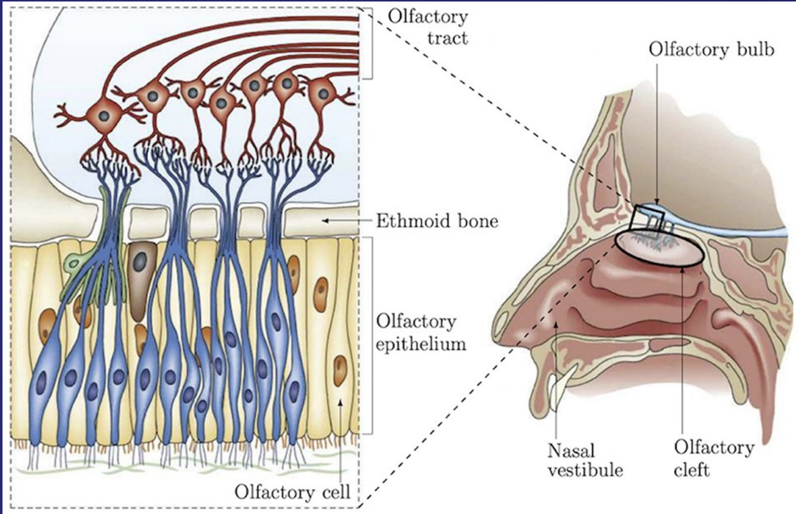
All receptors are divided into two large groups:

1) ***external*** or exteroceptors;
2) ***internal*** or interoceptors.

The exteroceptors include auditory, visual, olfactory, gustatory, and tactile receptors, and the interoceptors include visceroceptors that provide information on the state of the viscera, vestibule- and proprioceptors (receptors of the locomotor apparatus).

Classification of receptors

By the character of contact with the environment receptors are classified as:



1) ***distant***, which perceive information at a certain distance from the source of stimulation (visual, auditory and olfactory), and
2) ***contact***, i. e. those excited in a direct contact with a stimulus.

Classification of receptors

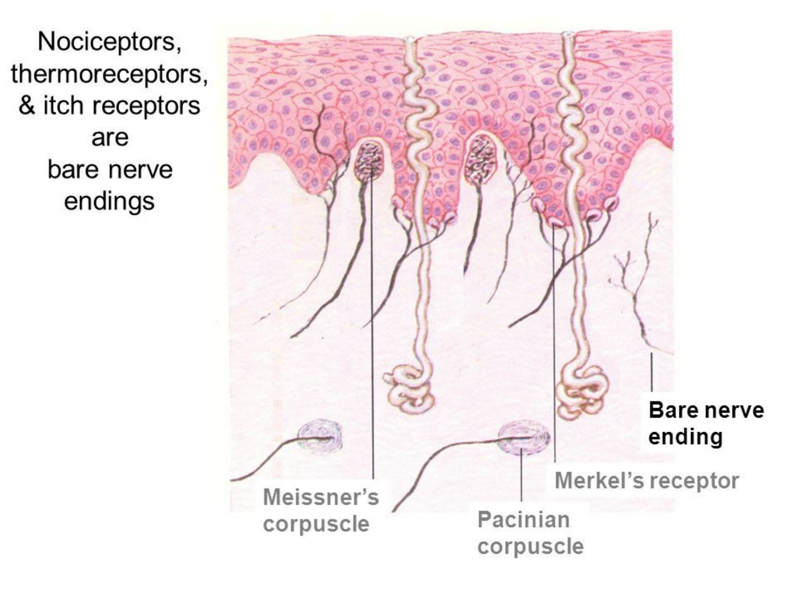
Depending on the nature of a stimulus to which the receptors in human subjects have optimal tuning, they can be classified as:

1) ***mechanoreceptors*** that include auditory, gravitational, vestibular, tactile cutaneous receptors, receptors of the locomotor apparatus, baroceptors of the cardiovascular system;
2) ***chemoreceptors*** that comprise gustatory and olfactory, vascular and tissue receptors;
3) ***photoreceptors***;

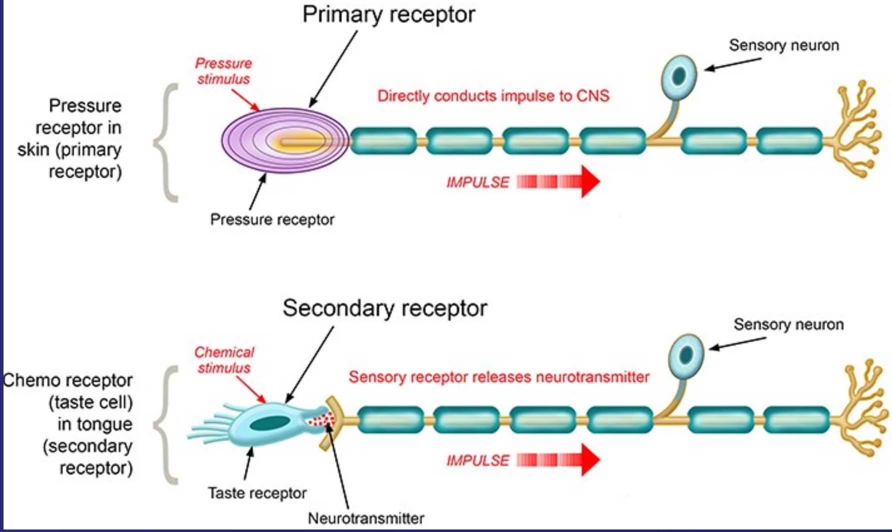
Classification of receptors

4) ***thermoreceptors*** (of the skin and viscera and also central thermosensitive neurons);

5) ***pain*** (nociceptive) ***receptors***; apart from them, painful stimulation can be perceived by other receptors.



Classification of receptors



All receptors are divided into:

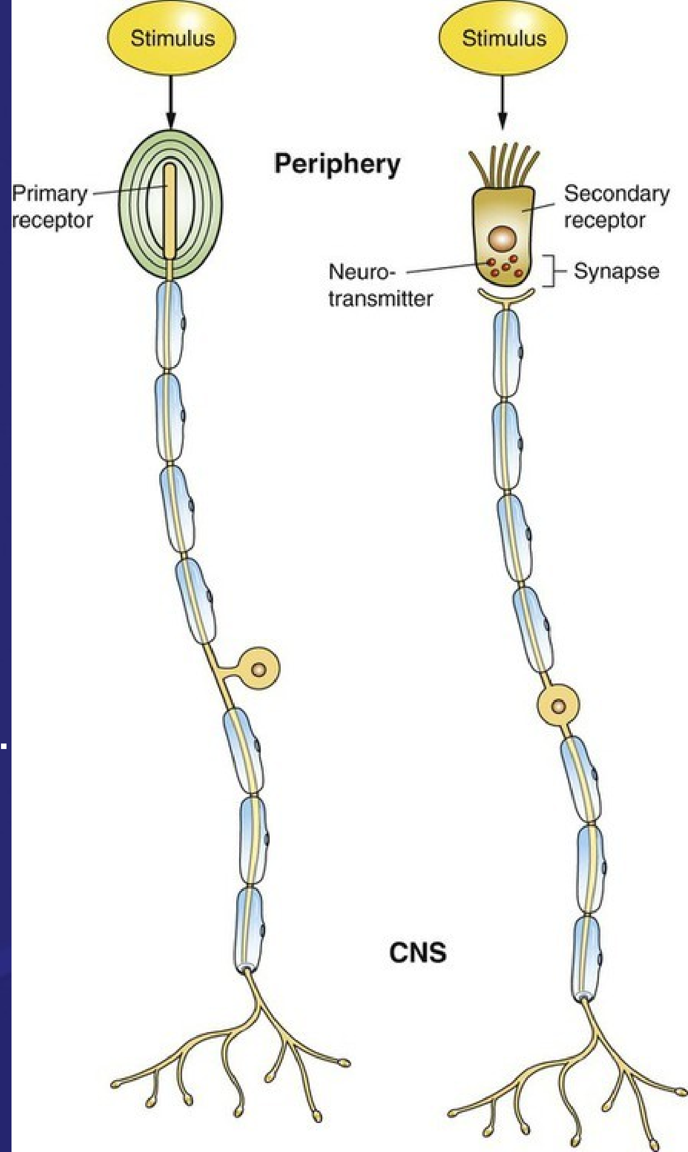
1) **primary** *(primary sensory)* and
2) **secondary** *(secondary sensory)* receptors.

The primary sensory receptors include olfactory, tactile receptors and proprioceptors. Their distinguishing feature is that perception and transformation of the energy of stimulation into the energy of nervous excitation occurs in the sensory neuron itself.

Classification of receptors

The secondary sensory receptors comprise gustatory, visual, auditory and vestibular receptors.

A structure that perceives stimulation is a highly specialized receptor cell, i. e. the primary sensory neuron is excited indirectly, through the receptor and not through the nerve cell.



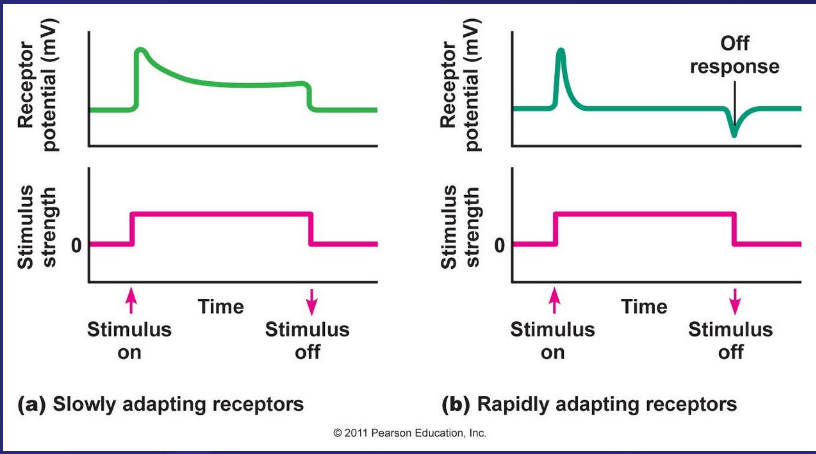
Classification of receptors

According to their main properties, receptors are also classified into:

1) ***rapidly*** and
2) ***slowly*** adapting,

1) ***low-threshold*** and
2) ***high-threshold***,

1) ***monomodal*** and
2) ***polymodal*** receptors.

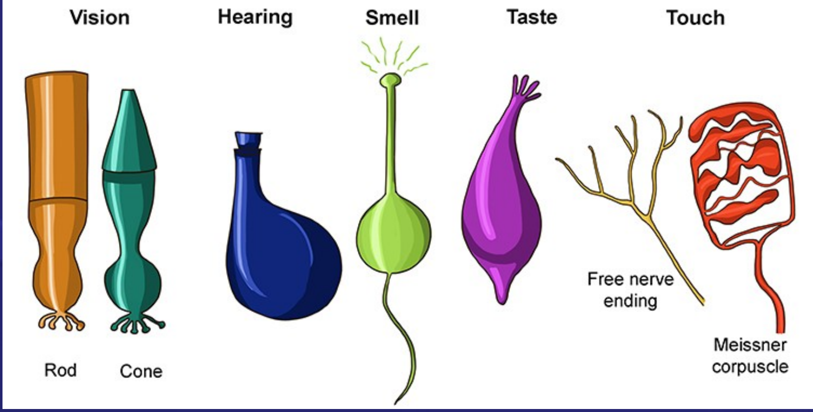


Classification of receptors

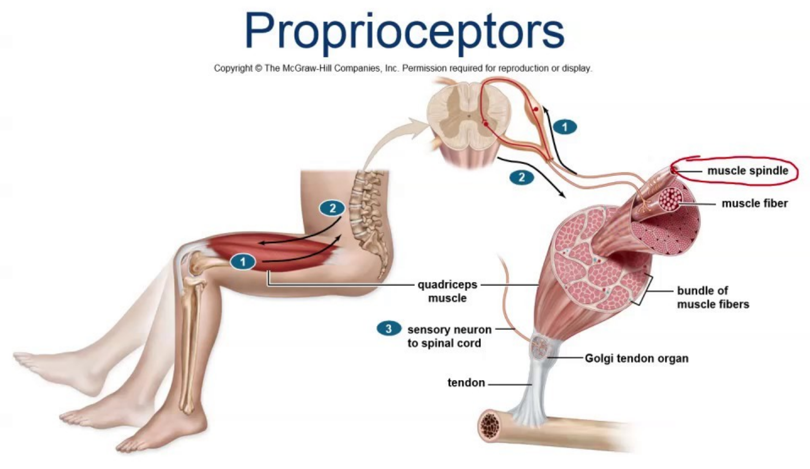
A psychophysiological classification of receptors based on the character of sensation arising on their stimulation is most important practically.

According to it, the following receptors are distinguished in man:

1) ***visual***,
2) ***auditory***,
3) ***olfactory***,
4) ***gustatory***,
5) ***tactile***,
6) ***thermoreceptors***.



Classification of receptors



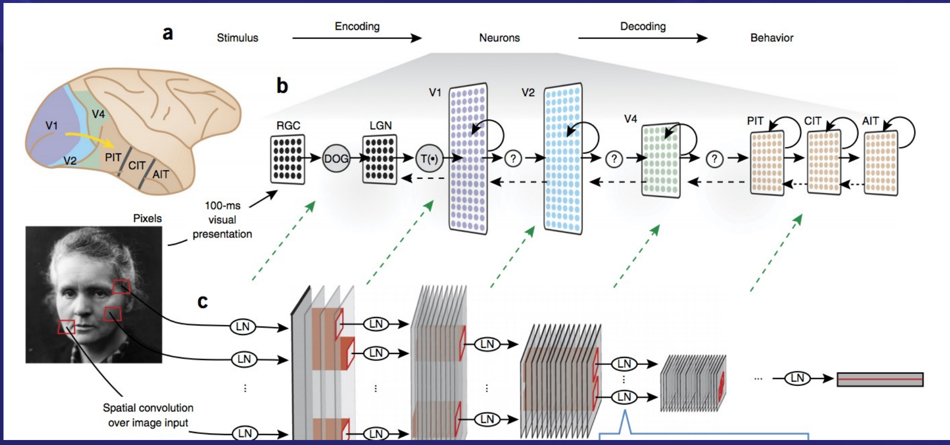
Those for position of the body and its parts in space there are:

1) ***proprioceptors***,
2) ***vestibuloceptors*** and
3) ***receptors for pain***.

Differentiation of signals

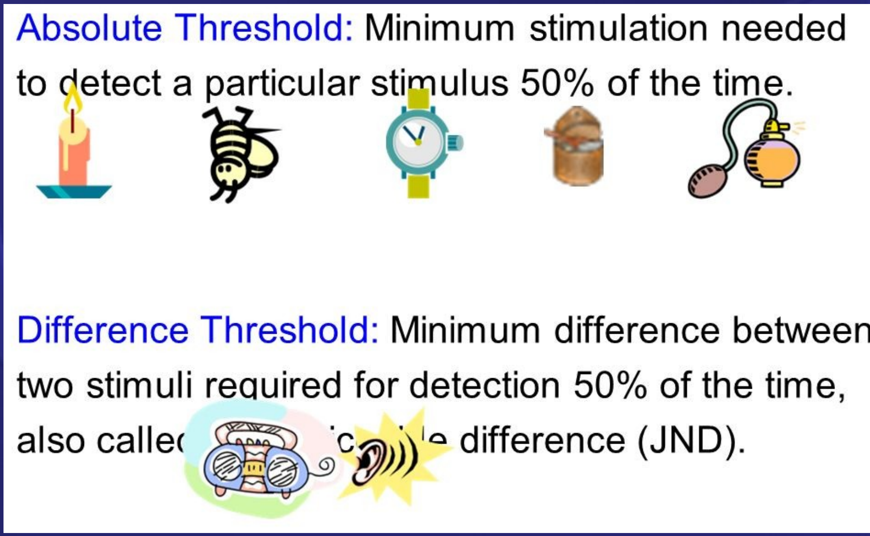
II. **Differentiation of signals**. An important feature of analysers is their ability to detect changes in intensity, temporal parameters or spatial qualities of a stimulus.

These operations of analysers related to signal discrimination begin already in the receptors and then other elements of an analyser take part in it.



Differentiation of signals

Analysers have to respond to the minimal differences between stimuli. This minimal difference is the differential threshold (the threshold of difference as related to the comparison of intensities).

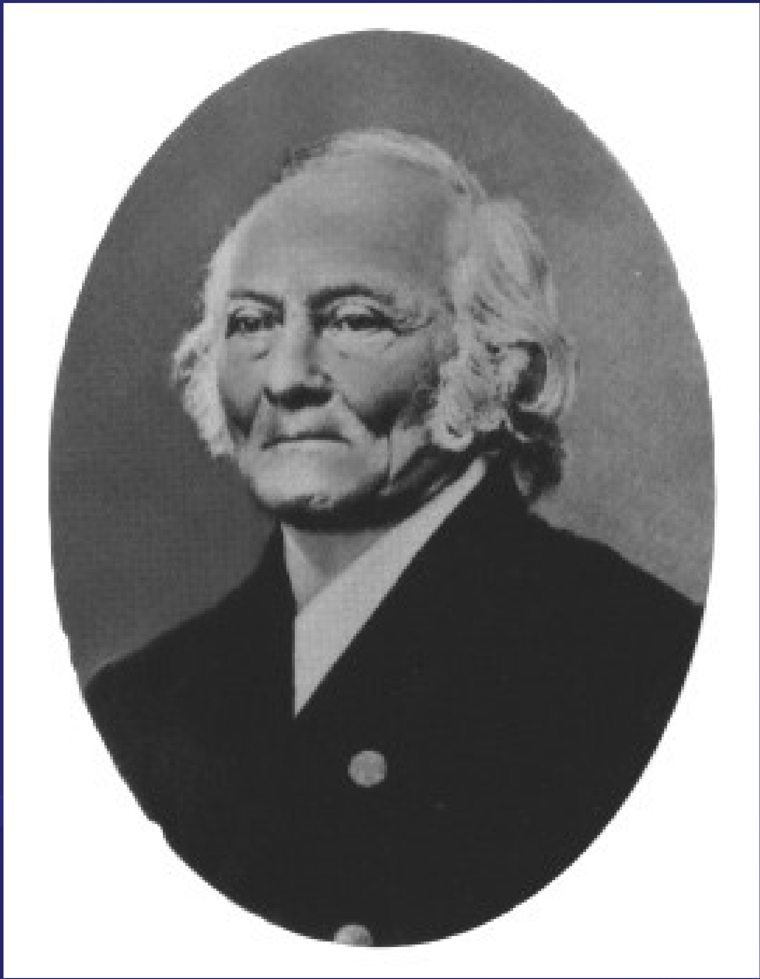


Differentiation of signals

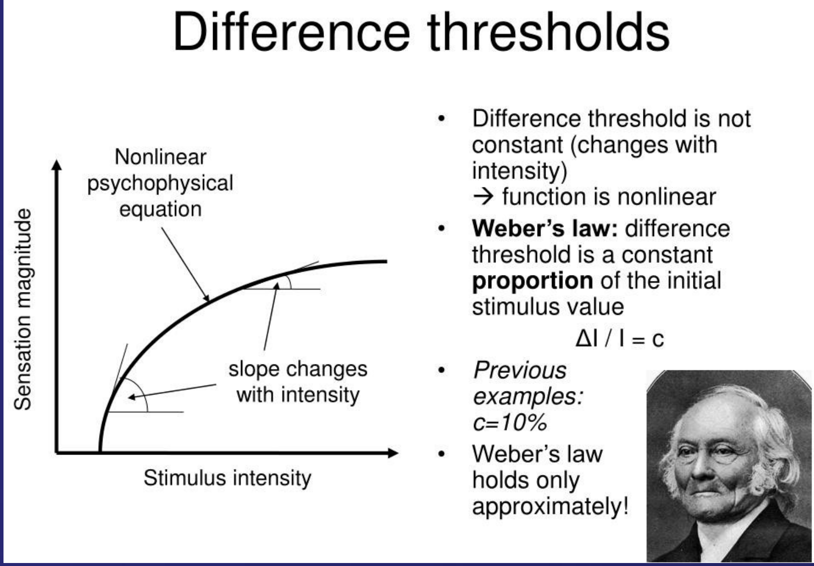
In 1834 ***Weber*** formulated the ***law*** which states that the ***increase of stimulus in order to be perceptible*** (differential threshold) ***must exceed the stimulus already acting by a definite proportion***. An increase in the sensation of pressure exerted on the skin of a hand was only felt when the original load was increased by a definite amount.

Differentiation of signals

Ernst Weber (1795-1878): German anatomist and physiologist who first introduced the concept of the "just-noticeable difference" (or JND). The JND is the smallest difference between two stimuli which can just be detected. He showed that the JND was not a constant increment, but was proportional to the base intensity on top of which it must be detected. Weber's empirical observations were later formulated mathematically by Gustav Theodor Fechner, who called his formulation Weber's law.



Differentiation of signals

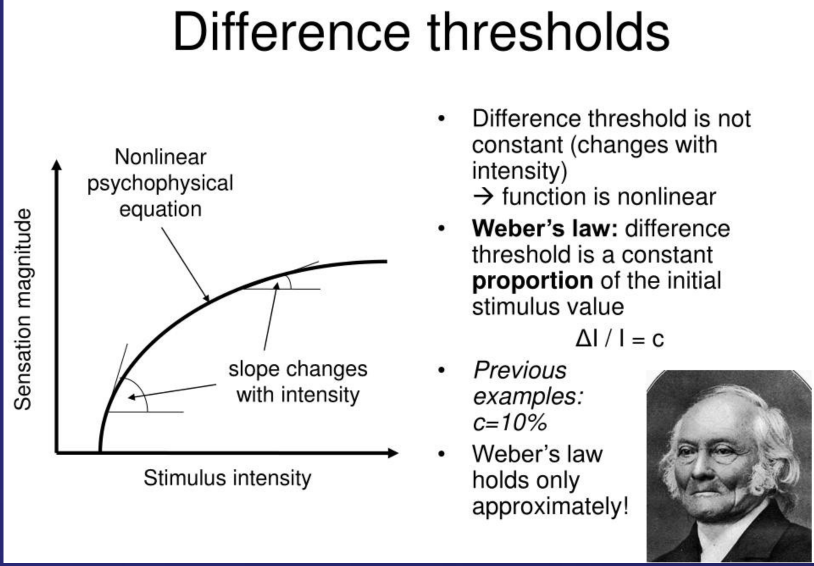


For instance, when a weight of 100 g was applied, an additional 3 g had to be added to increase the sensation of pressure, and with a weight of 200 g 6 g had to be added to produce the smallest perceptible increase in pressure. This dependence is expressed by the formula

A I / I = const,

where ***I*** is the stimulus, ***A I*** – Its perceptible increment (differential threshold), and ***const*** is a constant.

Differentiation of signals



The following formula was deduced, which expressed the dependence of sensation on a stimulus intensity:

$E = a \log I + b$,

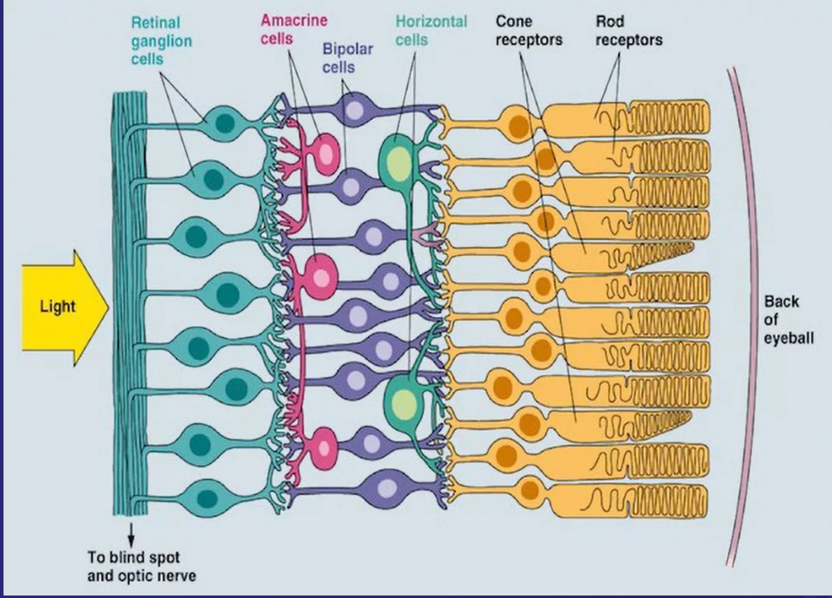
where ***E*** is the intensity of sensation, ***I*** is the stimulus intensity, and ***a*** and ***b*** are constants that differ for different signals. According to this formula, a sensation increases in proportion to the logarithm of stimulus intensity. This generalized expression is known as the ***Weber-Fechner law*** and was confirmed in many various investigations.

Differentiation of signals

Gustav Fechner (1801-1887): German physicist and philosopher. Fechner's Elements of Psychophysics (1860) established his lasting importance in psychology. His most important contribution was his derivation of an equation, now known as Fechner's Law, which relates the magnitude of sensory experience to stimulus intensity.

Gustav Theodor Fechner (1801–1887).

Differentiation of signals



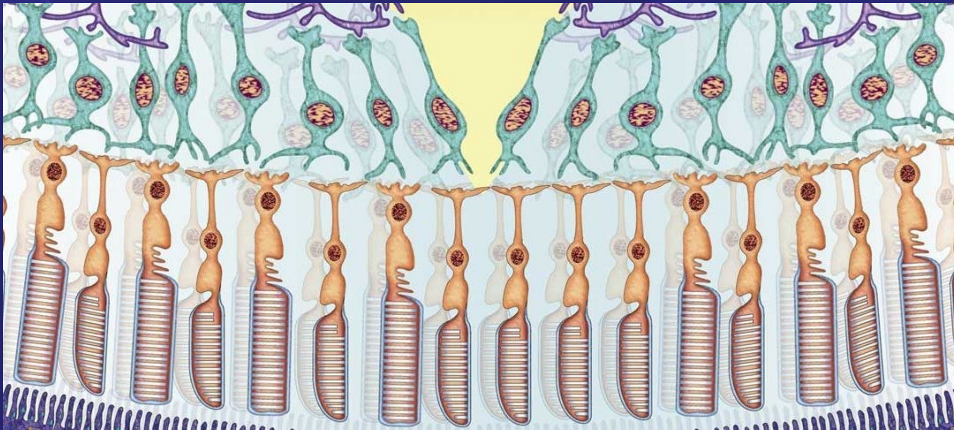
Spatial differentiation of signals is based on the difference in spatial distribution of excitation in the receptor and neural layers.

For instance, if certain two stimuli excited the two, neighbouring, receptors, the discrimination between these two stimuli would be impossible, and they would be perceived as a single whole.

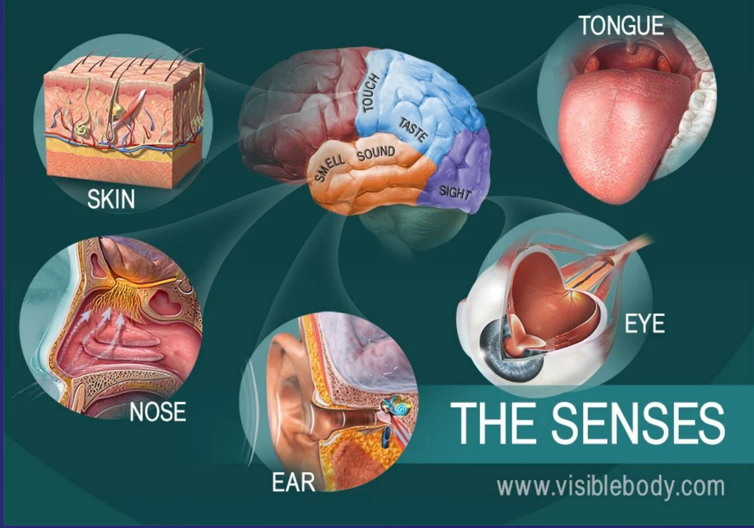
Differentiation of signals

For the spatial discrimination between these two stimuli to be possible, it is necessary that even one unexcited receptor element be present between these excited receptors.

Temporal discrimination between two stimulations would be possible if the nervous processes elicited by them are not fused in time, and the neural signal caused by the next stimulus would not fall in the refractory period of the preceding stimulation.



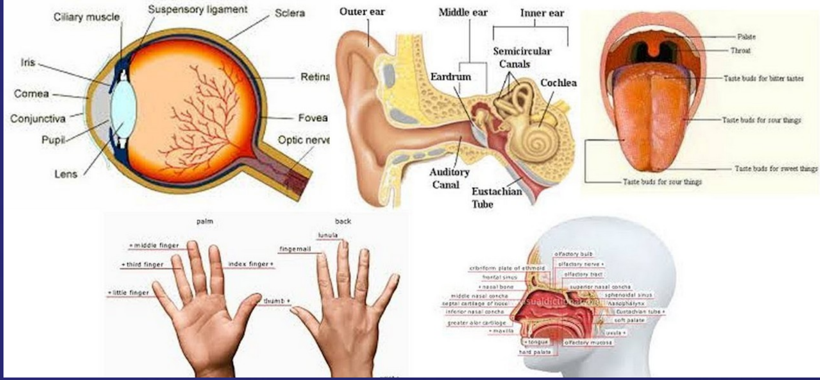
Differentiation of signals



In the psychophysiology of sense organs a stimulus threshold is that value of the stimulus the probability of whose perception is 0.75 (correct response to the presence of a stimulus in 75 per cent of cases of its action).

Naturally, lower values of intensity are considered subthreshold and higher ones suprathreshold.

Differentiation of signals



It turned out, however, that a distinct differentiated reaction to the superlow (or supershort) stimuli does exist also in the sub-threshold range.

For example, if the intensity of light is decreased so that a person under study cannot determine whether he saw the flash of light, then the objectively registered skin-galvanic reaction reveals the exact response of the organism to a given signal. The perception of such superlow stimuli proves to occur at the subthreshold level.

Transmission and transformation of neural signals

III. Transmission and transformation of neural signals. Transformation of the energy of a physical or chemical stimulus in receptors into nervous excitation is followed by a chain of processes involved in the transformation and transmission of the obtained signal.

Their aim is to supply the highest levels of the brain with the most essential information about a stimulus in the form most convenient for its reliable and quick analysis.

Transmission and transformation of neural signals

Transformation of signals can be conventionally divided into ***spatial*** and ***temporal***. Among spatial transformations are changes in their scale on the whole or distortion of the correlation between various spatial parts.

For instance, a significant distortion in geometric proportions of the representation of separate body parts or parts of the visual field occurs in the visual and somatosensory systems at a cortical level. The visual cortex has sharply increased representation of the fovea centralis of the retina with a relative reduction of periphery of the visual field ('Cyclopean eye').

Transmission and transformation of neural signals

Temporal transformations of information are mainly reduced to its compression into separate impulse packages or bursts with pauses and intervals between them.

Typical for all analysers is the transition from tonic impulsation of neurons to phasic bursts of neuron discharges.

Coding of information

IV. **Coding of information.** Coding is the process of transformation of information into a conventional form or code, which is performed according to definite rules.

Signals from the analyser systems of vertebrates are coded by a binary code, i. e. by the presence or absence of a burst of impulses at a certain moment of time in a specific neuron.

Coding of information

This type of coding is not the sole one and is not most advantageous. It is distinguished by stability and simplicity: really, what could be more simple and reliable than to work only in the two extreme and standard states, i. e. in the presence or absence of an impulse.

This is important when impulses are transmitted to great distances (to scores and hundreds of centimetres) via the conductors (nerve cell axons) with rather poor parameters (internal impedance, the quality of isolation, capacity parameters).

Coding of information

At the same time, in connection with a limited frequency range of nerve cell discharges (frequencies up to only several hundreds per second) the number of possible gradations of message and the velocity of information conduction are significantly reduced.

This is a sound example of the 'evolutionary compromise' in which a gain in some qualities of a system is accompanied by loss of other qualities and possibilities.

Coding of information

It should be noted that it is only in rare cases, when signals are transmitted between neighboring cells, that no generation of impulses occurs or they are reduced (i. e. impulseless transmission of signals in the retina of vertebrates between photoreceptors and bipolar neurons and between bipolar and ganglion cells).

Coding of information

Information on stimuli and their parameters in vertebrate animals is transmitted in the form of separate groups or bursts of impulses (impulse bursts). As was pointed out above, all parameters of an individual impulse have standard characteristics (the same amplitude, duration and shape), while the number of impulses in a burst, their frequency, the duration of bursts and the intervals between them, as well as the temporal pattern of a burst, i. e. distribution of separate impulses in it, usually differ and are determined by stimulus characteristics.

Coding of information

The information may be coded also through changes in the number of fibers along which it is simultaneously transmitted and through the point of excitation in a neuron layer.

Detector processing of signals

V. **Detector processing of signals** is a special type of selective analysis of individual stimulus characteristics and their actual biological significance.

Special *neurons-detectors* perform this analysis which, owing to the properties of their connections, can respond only to strictly defined parameters of a stimulus.

Detector processing of signals

One cortical visual detector responds only to one among the multitude of positions or orientations of the light or dark slit or edge located in a definite part of the visual field. Other neurons will respond when the position and/or orientation of this slit is changed.

The totality of neurons, which estimate different aspects of one and the same characteristic (i. e. all possible orientations of image borders), constitute the system of detection of this characteristic.

Detector processing of signals

Hierarchical gradation is the general principle of distribution of detectors, according to which detectors of more simple characteristics that ensure simple analysis are located at lower levels.

Detectors of more complex characteristics are concentrated at the highest levels of analysers, as a rule.

Recognition or identification of images

VI. Recognition or identification of images is the ultimate and most intricate operation of analysers. It is concerned with classifying images and attributing them to one or another class of objects met by the organism in its previous experience.

This is done on the basis of all the previous processing of the afferent signal, its decomposition into separate elements by neurons-detectors and their parallel analysis.

Recognition or identification of images

The task of recognition can be described as the building up by the brain of a 'stimulus model' and its separation from the multitude of similar other models.

Recognition is completed by the act of decision making on the object or situation the organism has come across.

Recognition or identification of images

It is supposed that specific spatially connected neuron sets exist for the purpose (neuron ensembles—highest detectors) whose excitation means for the brain the appearance of a specific image.

It is exactly owing to this recognition or identification that we are fully aware of a man we see, or the voice we hear, or the smell we feel, etc.

Recognition or identification of images

Recognition occurs independently of the changes suffered by a signal. Recognition of visual objects is quite reliable, for example, in their different illumination, color, size, orientation, and the position in the visual field.

In the same way, a familiar voice is recognized at its various intensity and in the presence of acoustic background, and the meaning of speech when the voice timbre and tempo undergo significant changes.

Recognition or identification of images

Hence, the reflection of a signal, sensory image, is formed at some highest levels of the analyser and does not depend on some changes in signal characteristics.

This is the totality of signals reflected in a similar spatial-temporal distribution of the excitation and inhibition processes at the highest level of analyser.

Recognition or identification of images

Interaction between the analyser neurons is accomplished with the help of two main mechanisms, i. e. ***excitatory*** and ***inhibitory***.

The excitatory interaction occurs primarily between the elements of successively located neural layers, while the inhibitory interaction occurs mainly between the neurons of one and the same layer.

Recognition or identification of images

The *excitatory interaction* is effected in the following manner. First, the axon of each neuron on entering the above-lying layer is divided into a greater or lesser number of ramifications that establish synaptic contacts not with one, but with several neurons.

Second, the 'dendrite tree', i. e. the neuron inputs, commonly have synaptic contacts with axons of not one, but several cells of the preceding layer.

Recognition or identification of images

That is why practically all the neurons of an analyser have projection fields, i. e. the totality of neurons at the next and higher levels of the analyser with which they interact.

The totality of receptors whose impulses arrive at a given neuron is called its ***receptive field***.

Recognition or identification of images

It should be borne in mind that receptive and projection fields exist simultaneously in all the neurons of the system. Moreover, they partly overlap.

Such 'shifted lateral overlapping' of connections consists in the fact that part of the receptors making up the receptive field of a given neuron also forms the receptive field of the neighboring cell, and some of the neurons entering the projection field of any receptor may also enter the projection field of the neighboring receptor.

Recognition or identification of images

This intricate interaction of cells leads to the formation of the so-called ***nervous network*** in the analyser. It contributes to an increase in sensitivity of an analyser to weak signals.

In addition, a diversity of connections between the cells of analysers provides them with high adaptability to changing environmental conditions.

Recognition or identification of images

The ***inhibitory interaction*** in analysers is effected with the help of inhibitory neurons (interneurons).

Most commonly inhibition consists in the following: each excited neuron activates the inhibitory interneuron, which, in its turn, causes suppression and inhibition of impulsation both of the neuron by which it was excited and its neighboring neurons in the layer.

Recognition or identification of images

The intensity of this inhibition is the greater, the stronger is excitation of the neuron and the closer it lies to the neighboring cell.

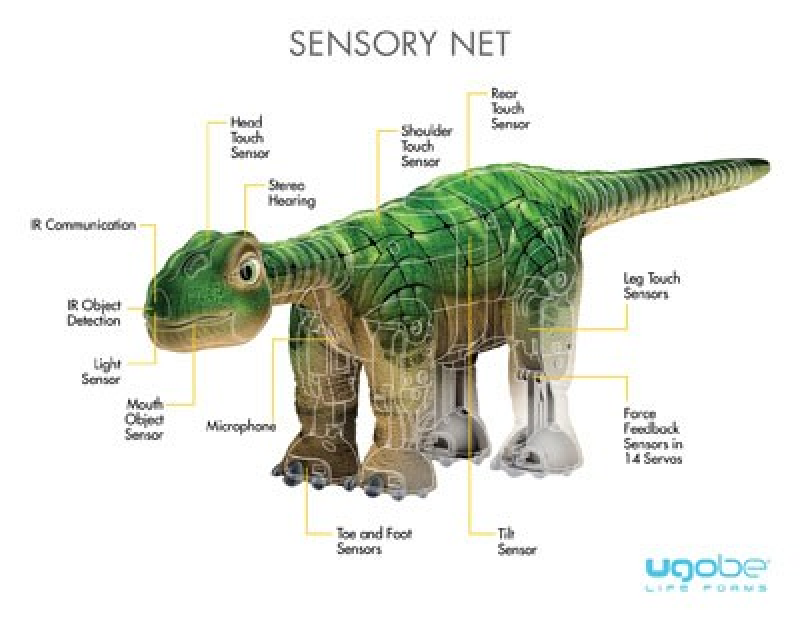
This universal mechanism of inhibition in the analyser systems serves for accomplishing part of the operations concerned with reduction of the excess information arriving from the receptors and with revealing information on the spatial and temporal characteristics of stimuli.

Recognition or identification of images

Inhibition is of major importance also in temporal processing of signals since its action begins, as a rule, with a certain delay after excitation and it predominantly suppresses delayed (relative to the beginning of stimulation) neuron responses.

As a result, they adequately respond only to stimulus changes in time, in particular to the beginning and cessation of stimulus action.

Thanks for your attention!



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Physiology Of Vision

Rodion A. Kudrin

The plan

- Anatomy of the eye.
- Optics: formation of the retinal image.
- Accommodation of the eye for objects at different distances.
- Optic defects and abnormalities.
- Optical defects in the ametropic eye.
- Visual acuity.
- Photoreceptors.
- Visual pathways.

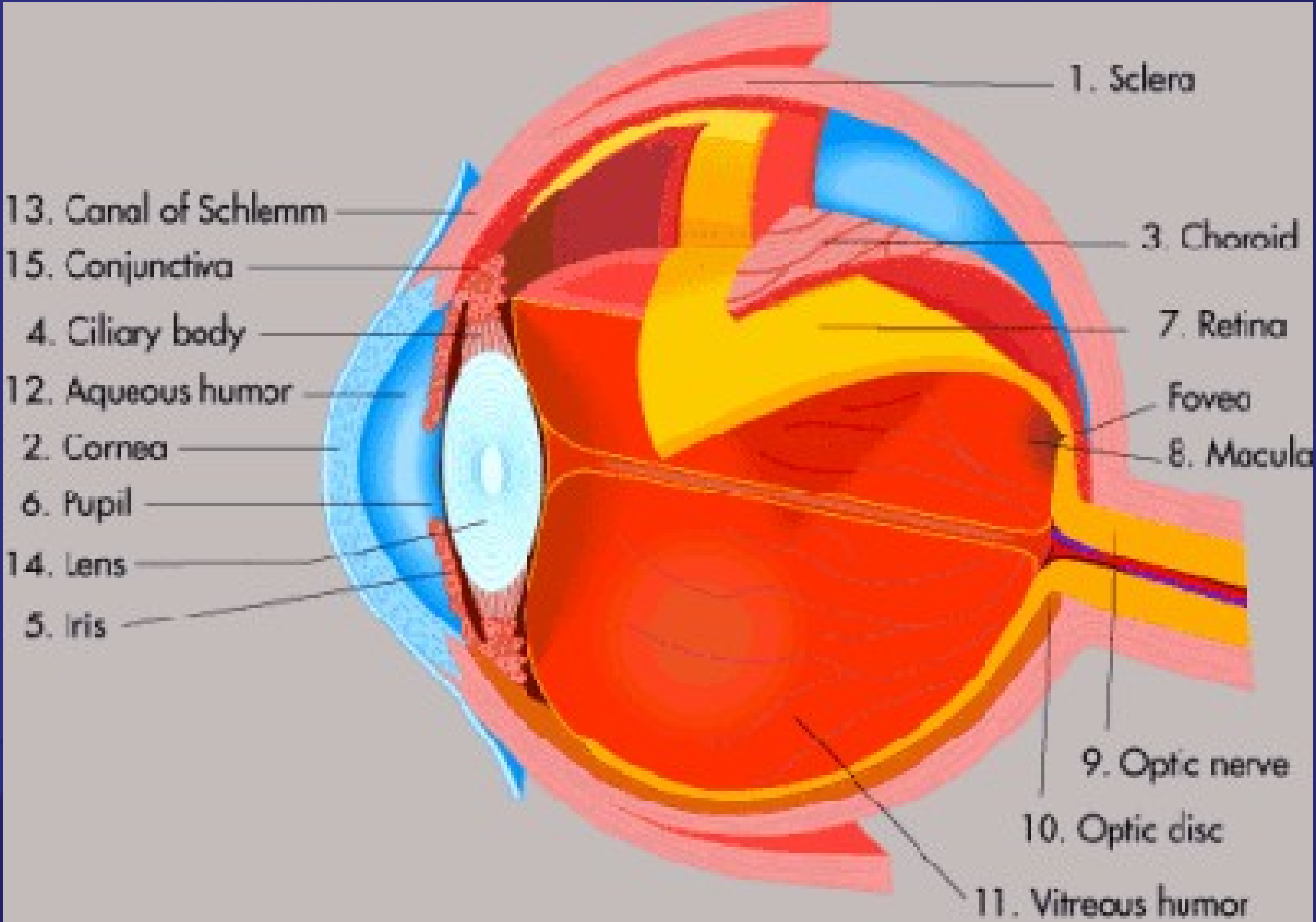
Introduction

Eyes are complex sense organs that evolved from primitive light-sensitive spot on the surfaces of invertebrates.

Each eye has a layer of receptors, a lens that focuses light on these receptors, and a system of nerves that conducts impulses from receptor to brain.

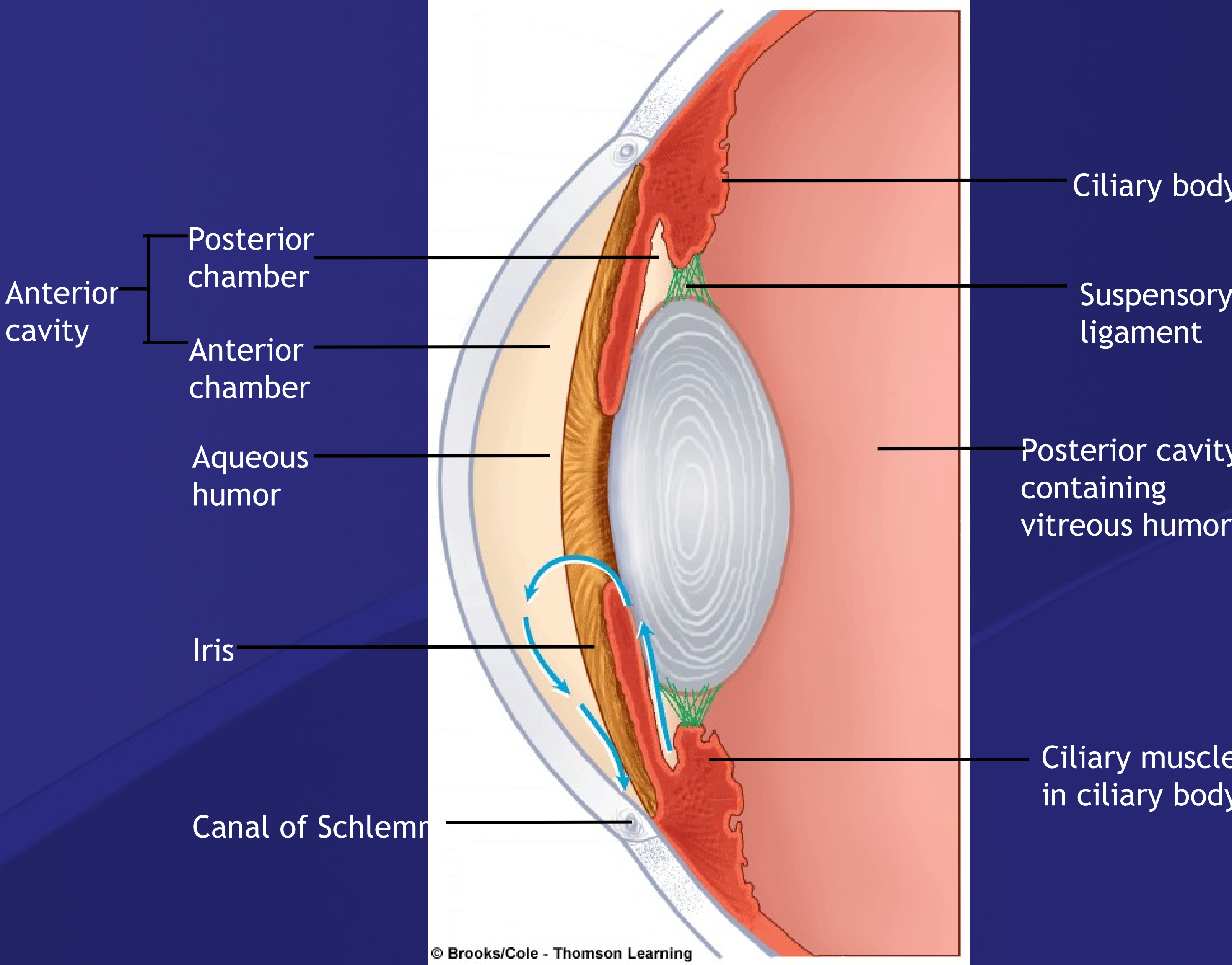
Of all sensory receptors in the body, 70 % are in the eye.

1. Anatomy of the eye



1. Anatomy of the eye

- spherical in shape
- 24 mm in diameter
- in orbital cavity
- loosely embedded in fatty tissue
- protected by the eyelids


Ciliary body
Posterior chamber
Anterior cavity
Anterior chamber
Suspensory ligament
Aqueous humor
Posterior cavity containing vitreous humor
Iris
Ciliary muscle in ciliary body
Canal of Schlemm
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1. Anatomy of the eye

Layers of the eyeball

- Sclera – External, fibrous tunic
- Choroid – Intermediate, vascular tunic
  - ✓ iris
  - ✓ ciliary body
- Retina – Internal tunic

1. Anatomy of the eye

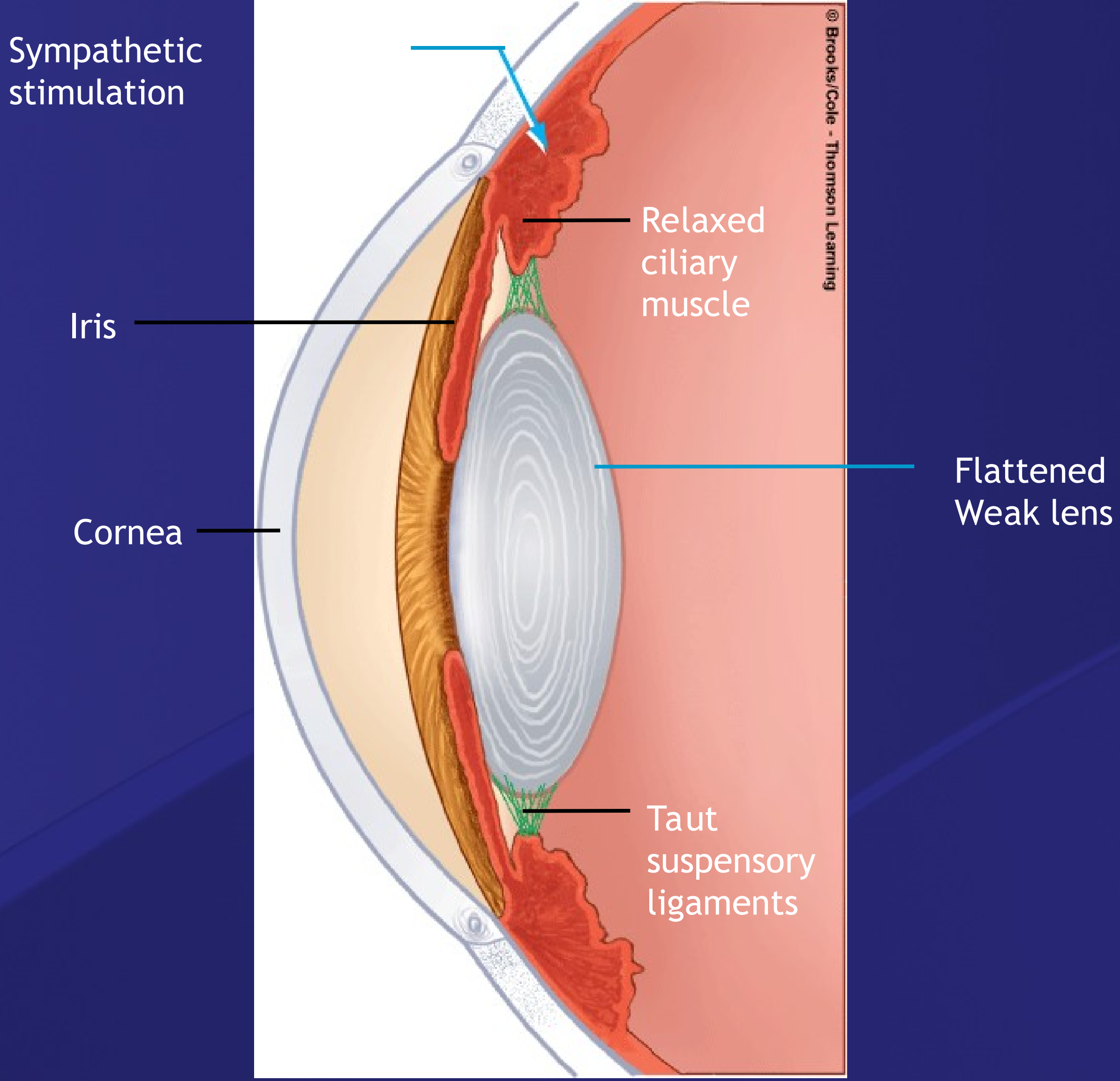
Sclera

- Greater part of the external surface
- White of the eye
- Anteriorly cornea transparent greater curvature than the rest of the eye

1. Anatomy of the eye

Choroid

- Middle layer
- Vascular and pigmented
- Anteriorly, the choroid becomes modified into the:
  - ✓ Iris
  - ✓ ciliary body



Sympathetic stimulation
Relaxed ciliary muscle
Iris
Flattened Weak lens
Cornea
Taut suspensory ligaments
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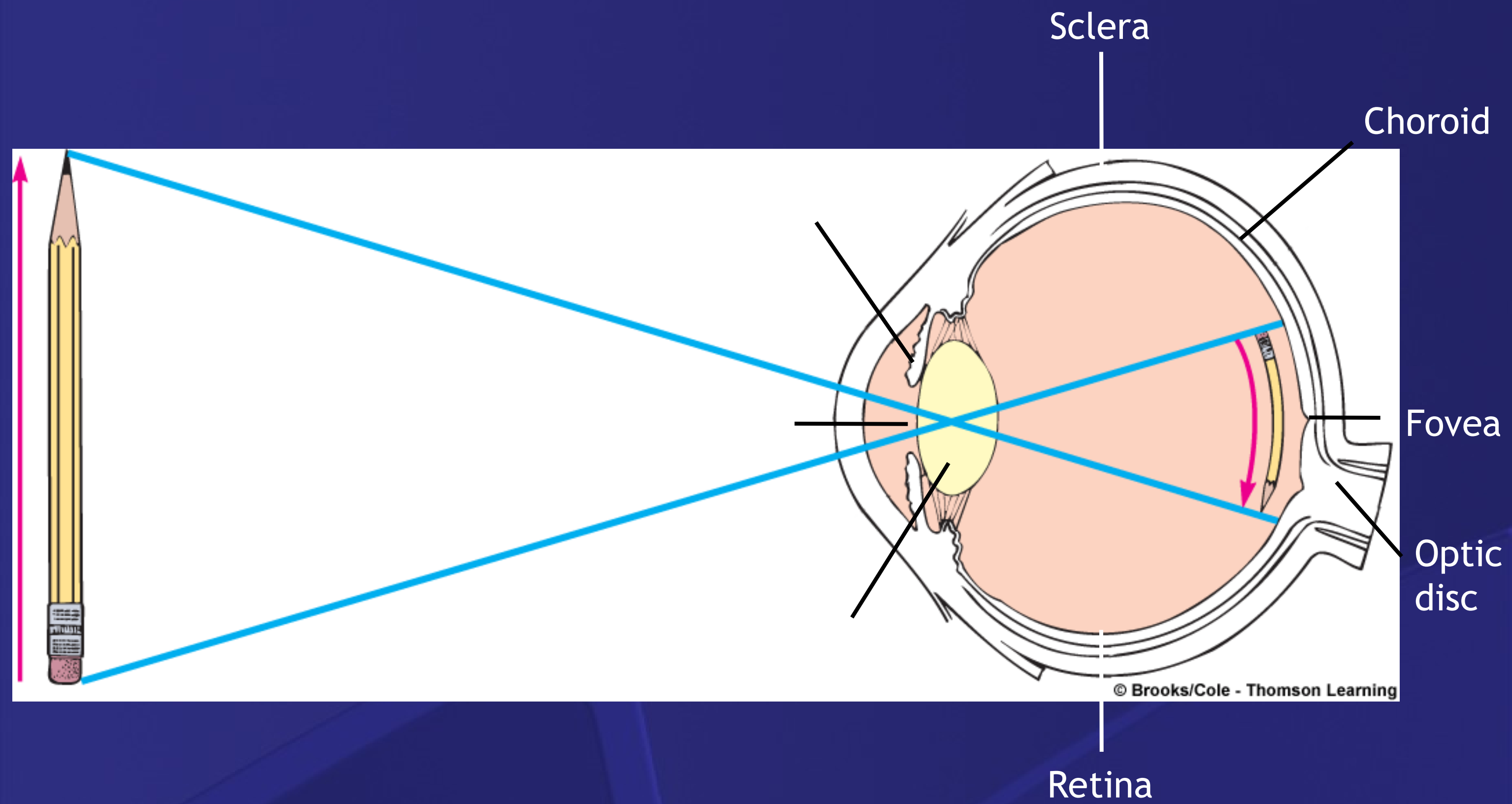
1. Anatomy of the eye

Retina

- The innermost layer
  - Pigmented Layer
  - Nervous Layer
- Macula lutea
- Fovea Centralis
- Optic nerve
  - Optic disc
    - area surrounding optic nerve
  - Optic cup
    - small depression at the center of the optic disc


Sclera
Choroid
Fovea
Optic disc
Retina
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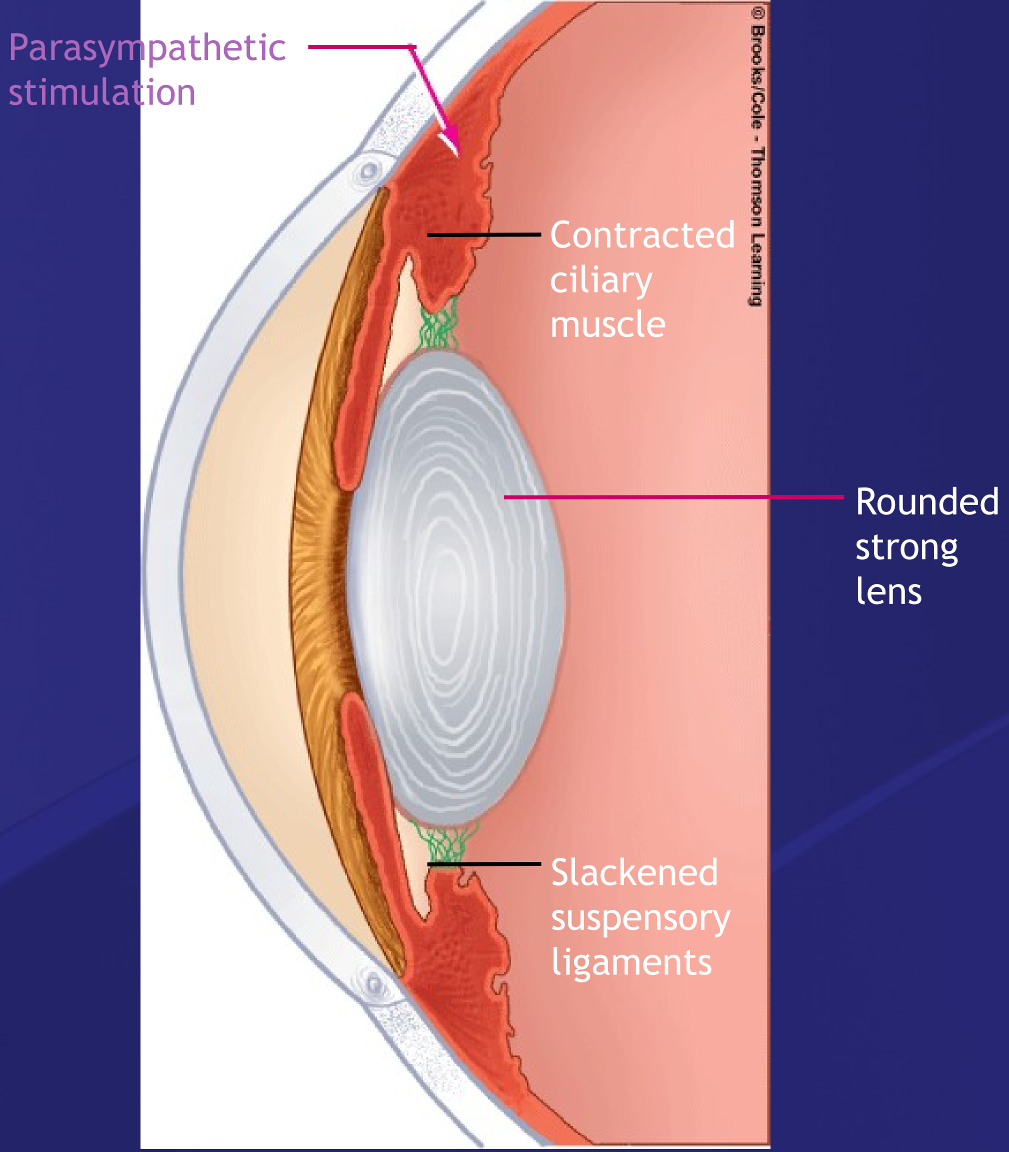
1. Anatomy of the eye

Lens

- Transparent, colorless body
- Biconvex lens

- **IRIS**
- **PUPIL**


Parasympathetic stimulation
Contracted ciliary muscle
Rounded strong lens
Slackened suspensory ligaments
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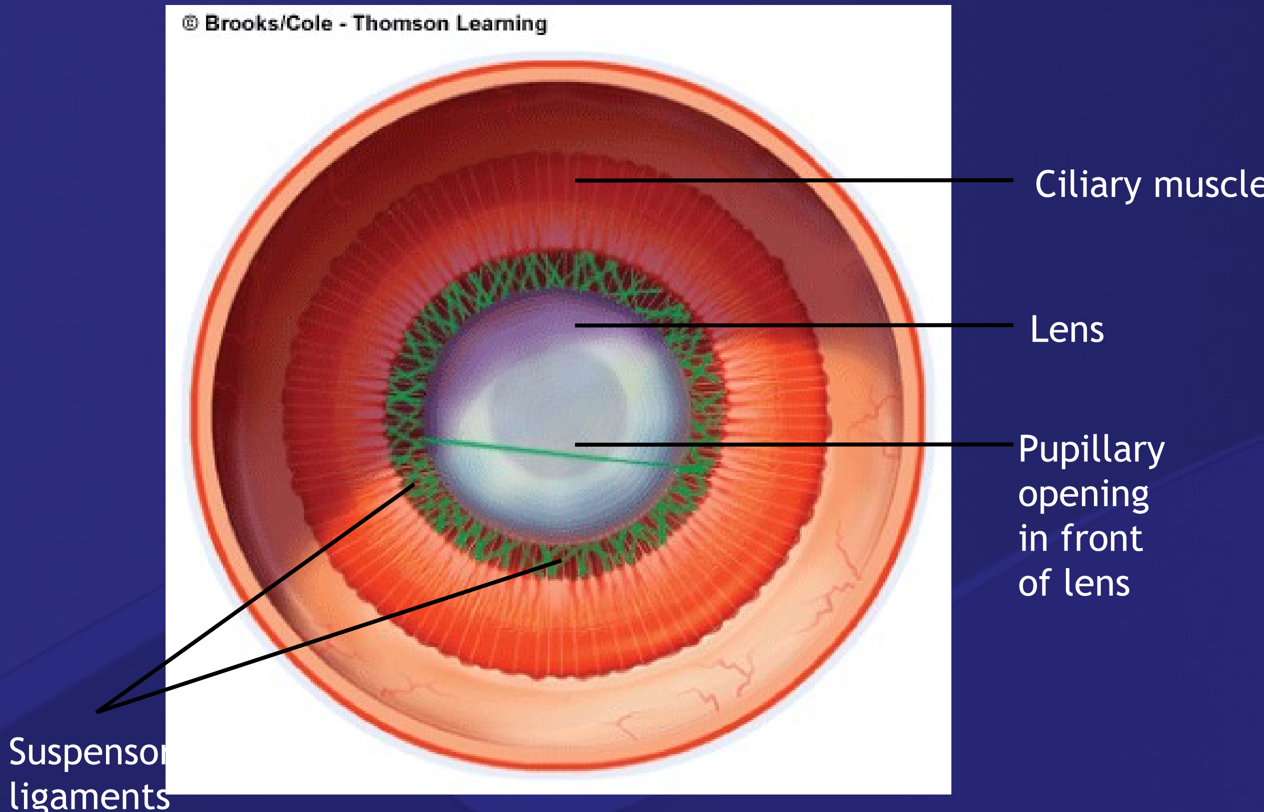
The iris is circular and pigmented. It is two layers of smooth muscle that control the amount of light passing through the pupil and into the eye.



1. Anatomy of the eye

Humors

- The lens divide the eye cavity into an
  - Anterior space
  - Posterior space

2. Optics: formation of the retinal image

Refraction of Light

- Light rays, on passing obliquely from one transparent medium to another of a different optical density, are deflected from their path

- rarer to denser medium
- denser to rarer medium

2. Optics: formation of the retinal image

Image Formation by a Convex Lens

- Artificial lens
  - Converging lens
  - Diverging lens

- The principal axis of a lens with two spherical surfaces is a line passing through the centers of curvature

2. Optics: formation of the retinal image

Focal points

- Light from a point on the principal axis so distant that the rays are parallel when they strike the lens, will converge at a point

Focal length

- which is a measure of the refractive power of “strength” of the lens

Diopter

- The unit for the refractive power of a lens which is the reciprocal of the focal length expressed in meters

Refractive power

- depends upon the curvature of the lens surface and the refractive index depends on the material of the lens

2. Optics: formation of the retinal image

Image Formation of the Eye

- Refracting media
- Reduced Eye
- Index of refraction (IOR)=1.333
- Optical center
  - ✓ 5 mm behind the cornea
  - ✓ the retina is 15 mm behind the optical center
- Cornea to the retina is 20 mm
- The total refractive power is 59 D

2. Optics: formation of the retinal image

A real, inverted image, smaller than the object

$$\frac{\text{size (object)}}{\text{size (image)}} = \frac{\text{Distance from object to optical center}}{\text{Distance from image to optical center}}$$

2. Optics: formation of the retinal image

- The visual angle is formed at the optical center by the limiting rays from the object
- This angle increases as the object is placed closer to the eye

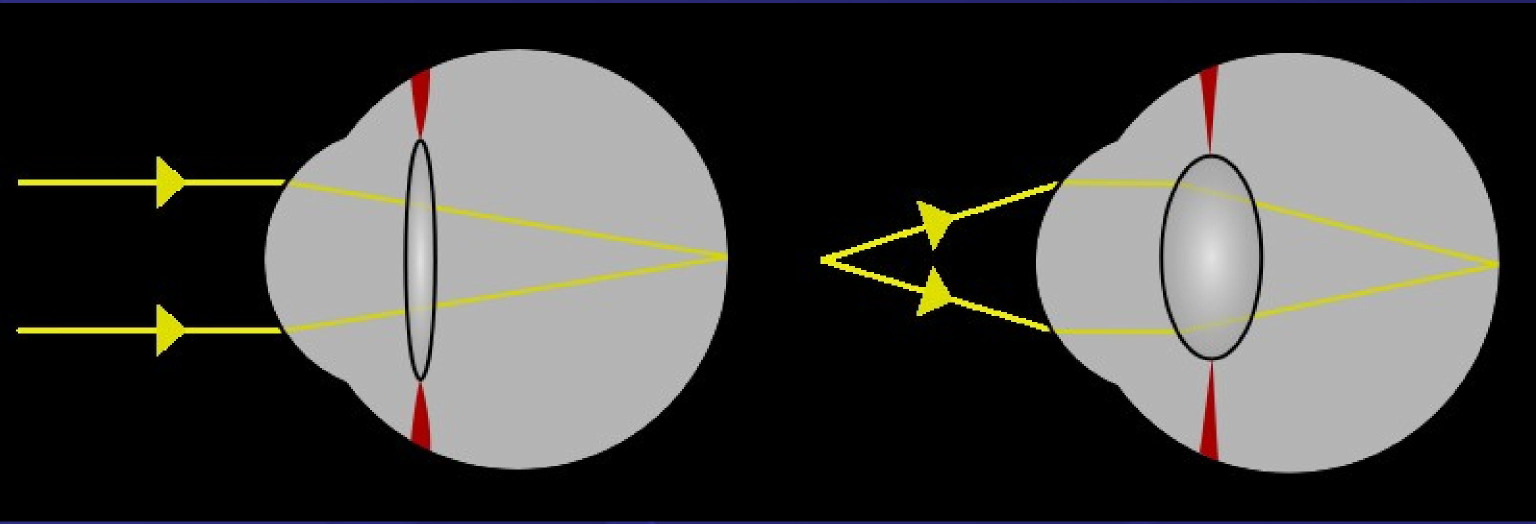
2. Optics: formation of the retinal image

- Retinal images are inverted – they are perceived as “erect” (in the correct position) and “projected”
- The “righting” of the image

3. Accommodation of the eye for objects at different distances

- The lens is suspended by the zonula
- Ciliary muscle is relaxed → zonule is under tension and pulls on the equator of the lens so that the lens is flattened
  - ✓ Refractive power of the lens is decreased.
- Ciliary muscle contracts → pulls the ciliary body towards the lens, relaxing the zonula.
  - ✓ The tension which held the lens in its flattened shape having been reduced or abolished
  - ✓ Refractive power of the lens is increased.

3. Accommodation of the eye for objects at different distances



This diagram shows how light from afar is bent by the stretched lens to strike the retina, and how light from a closer source is bent even more sharply by the relaxed lens to strike the retina

3. Accommodation of the eye for objects at different distances

Constriction of the Pupils

By constricting, the iris

- excludes the periphery of the lens
- increases the depths of focus
- diminishes the quantity of light entering the eye

3. Accommodation of the eye for objects at different distances

Convergence of the Eyeball

Visual axis are so directed that the images will be formed on the corresponding points of the retina

3. Accommodation of the eye for objects at different distances

Near and Far points of Distinct Vision

- **<u>Near Point</u>**
  - ✓ the nearest point at which an object can be distinctly seen, with full accommodation.
- The distance increases with age
  - ✓ slowly in early life (7 cm in children)
  - ✓ In 20 years – 10 cm
  - ✓ In 30 years – 14 cm
  - ✓ most rapidly in the early 40's (22 cm)
  - ✓ very slowly after 50 (40 cm).
    - ➢ progressive loss of the plasticity of the lens.
- **<u>Presbyopia</u>**

3. Accommodation of the eye for objects at different distances

- In the normal eye, parallel rays are brought to focus on the retina from infinity.

- Object at distances greater than 20 ft (6 m).

are seen distinctly without accommodation, that is, with the eye at rest.

- Distance of 6 meters or 20 ft. is the Far Point of the normal eye.

3. Accommodation of the eye for objects at different distances

Refractive Power and Amplitude of Accommodation

- The refractive power of a lens is usually expressed in terms of its principal focal distance or focal length.
- A lens with a focal distance of 1 meter is taken as a unit and is designated as having a refractive power of 1 diopter (D).
- The refractive power of the lens is expressed in terms of the reciprocal of their focal distances measured in meters
  - ✓ lens with a principal focal distance of 0.10 meter is a lens of 10D, and one with a focal distance of 0.2 meters is a lens of 5D

4. Optic Defects and Abnormalities

Optic Defects of the Emmetropic (Normal Eye)

- Spherical Aberration
- Chromatic Aberration
- Blind Spot

4. Optic Defects and Abnormalities

Spherical Aberration

- In the optical lens, the marginal rays are focused in front of the focus of the central rays: thus blurring the image
- Corrected:
  - ✓ Constriction of the iris
  - ✓ Greater optical density of the nucleus of the lens with respect to the cortex

4. Optic defects and abnormalities

Chromatic Aberration

- This is due to
  - ✓ different dispersion of the light rays by the lens, according to their wavelength
- Chromatic aberration is most marked to wavelengths at the end of the spectrum

4. Optic defects and abnormalities

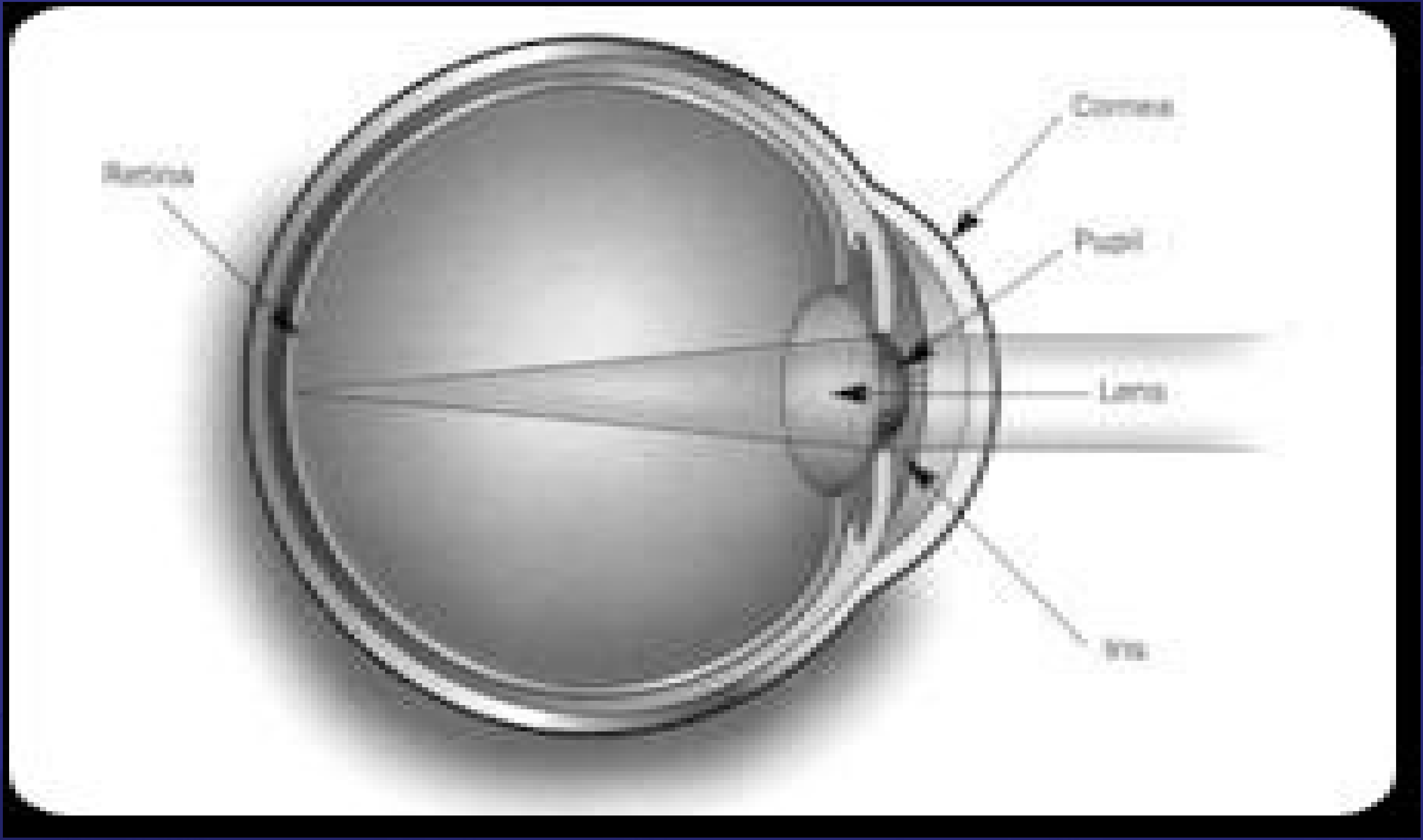
Blind Spot

- Optic nerve enters the eye has no cones and no rods
- This produces a blind spot in the visual field
- The blind spot is 15 degrees to the temporal side of the visual field

5. Optical defects in the ametropic eye

- Emmetropia
- Ametropia

Normal vision



5. Optical defects in the ametropic eye

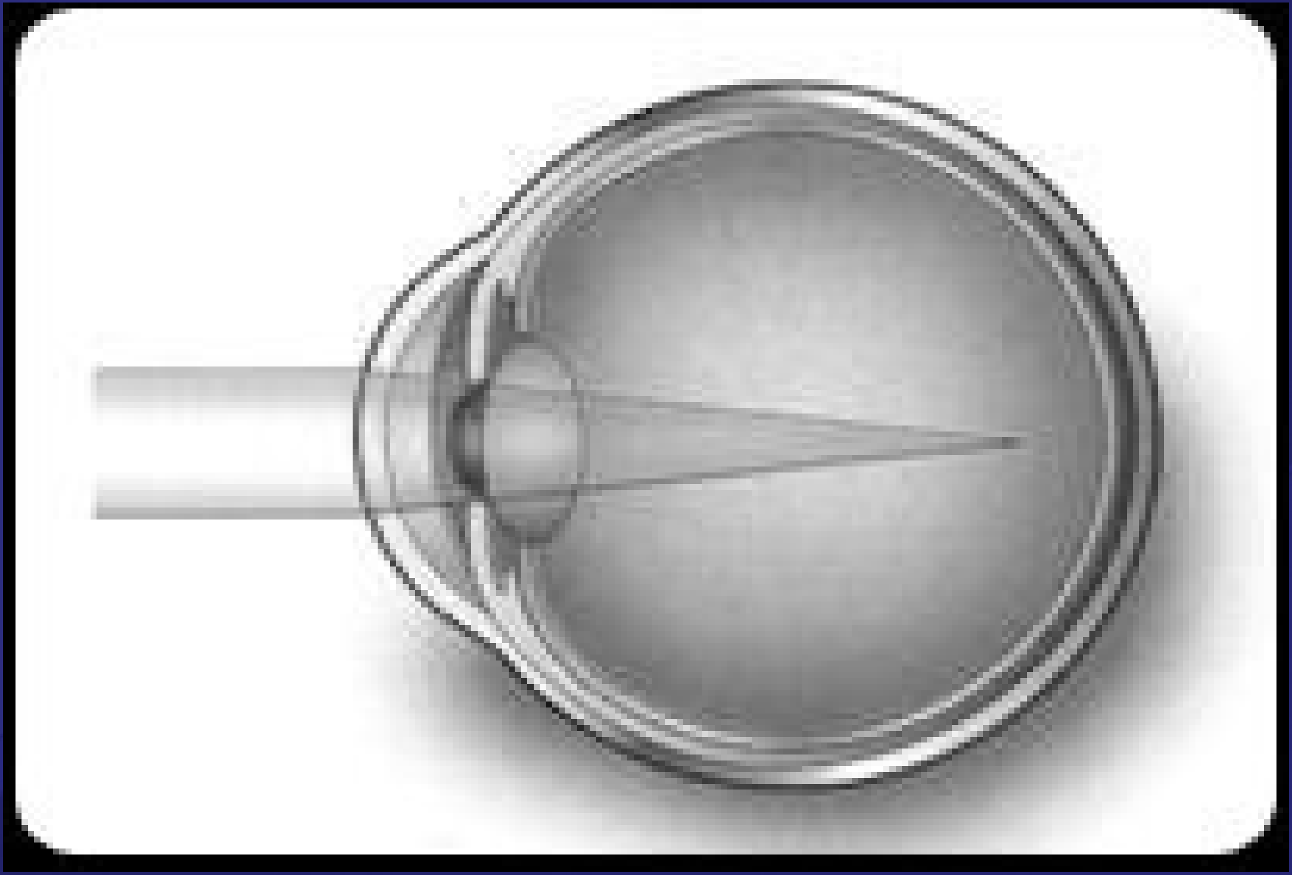
- Myopia
- Hyperopia or Hypermetropia
- Presbyopia or “Old-Sightedness”
- Astigmatism

5. Optical defects in the ametropic eye

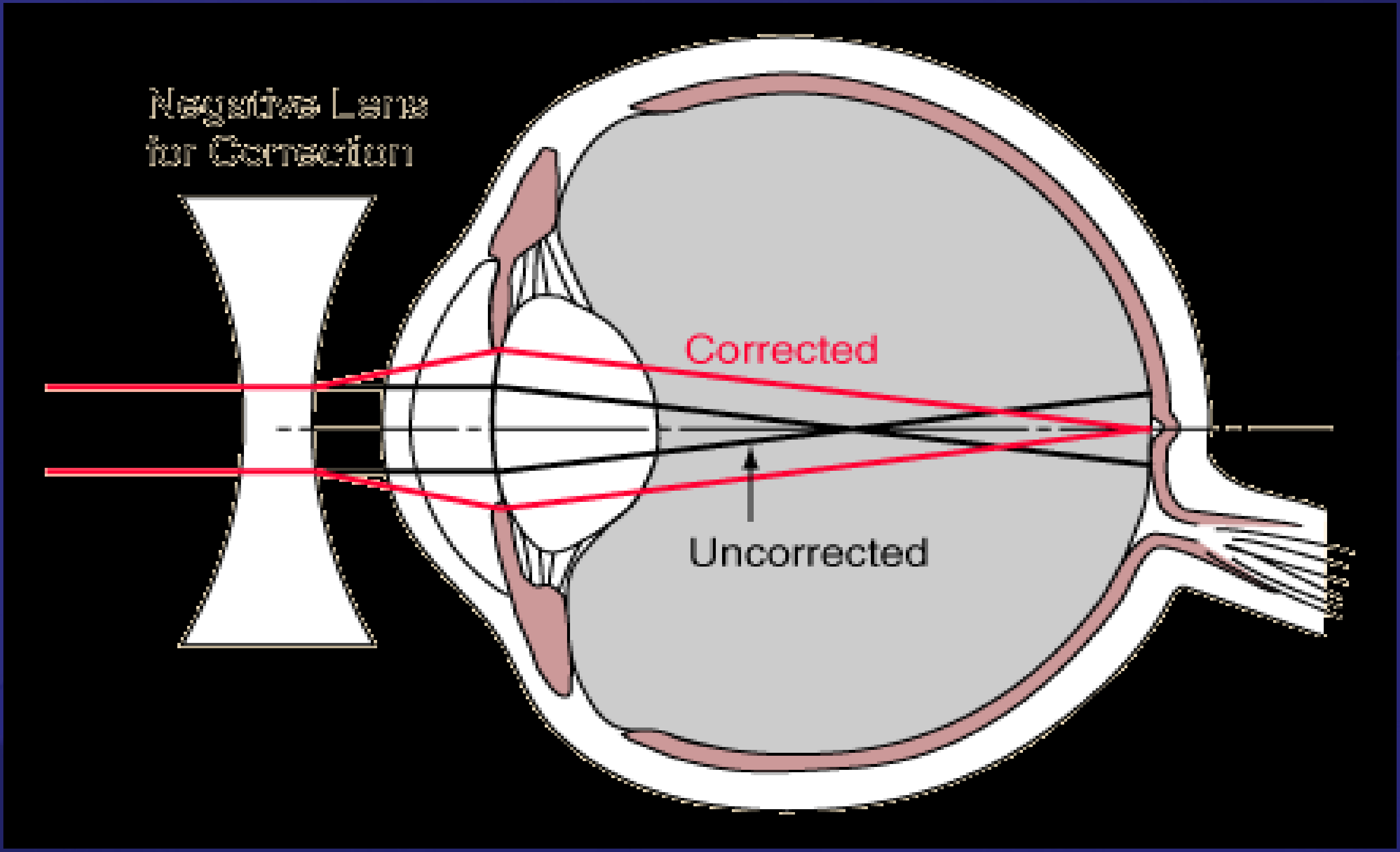
Myopia

- Without accommodation come to a focus in front of the retina due
  - the eyeball is too long
  - the lens is too thick
- The far point is nearer than infinity
- All distant objects appear blurred
- Its near point is nearer than that of an emmetropic eye with equal amplitude of accommodation. Thus the term “nearsightedness”
- For distant vision, the remedy is the use of concave lenses

Myopia



Myopia

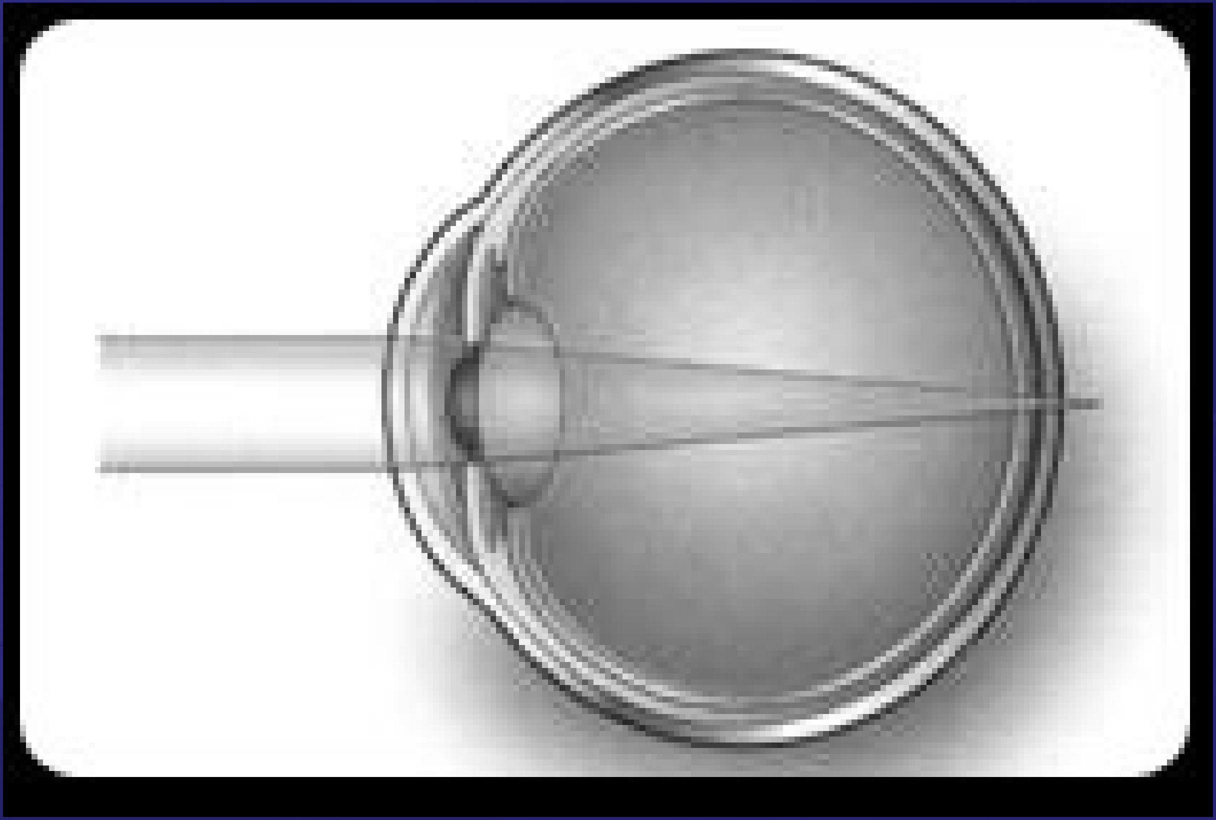


5. Optical defects in the ametropic eye

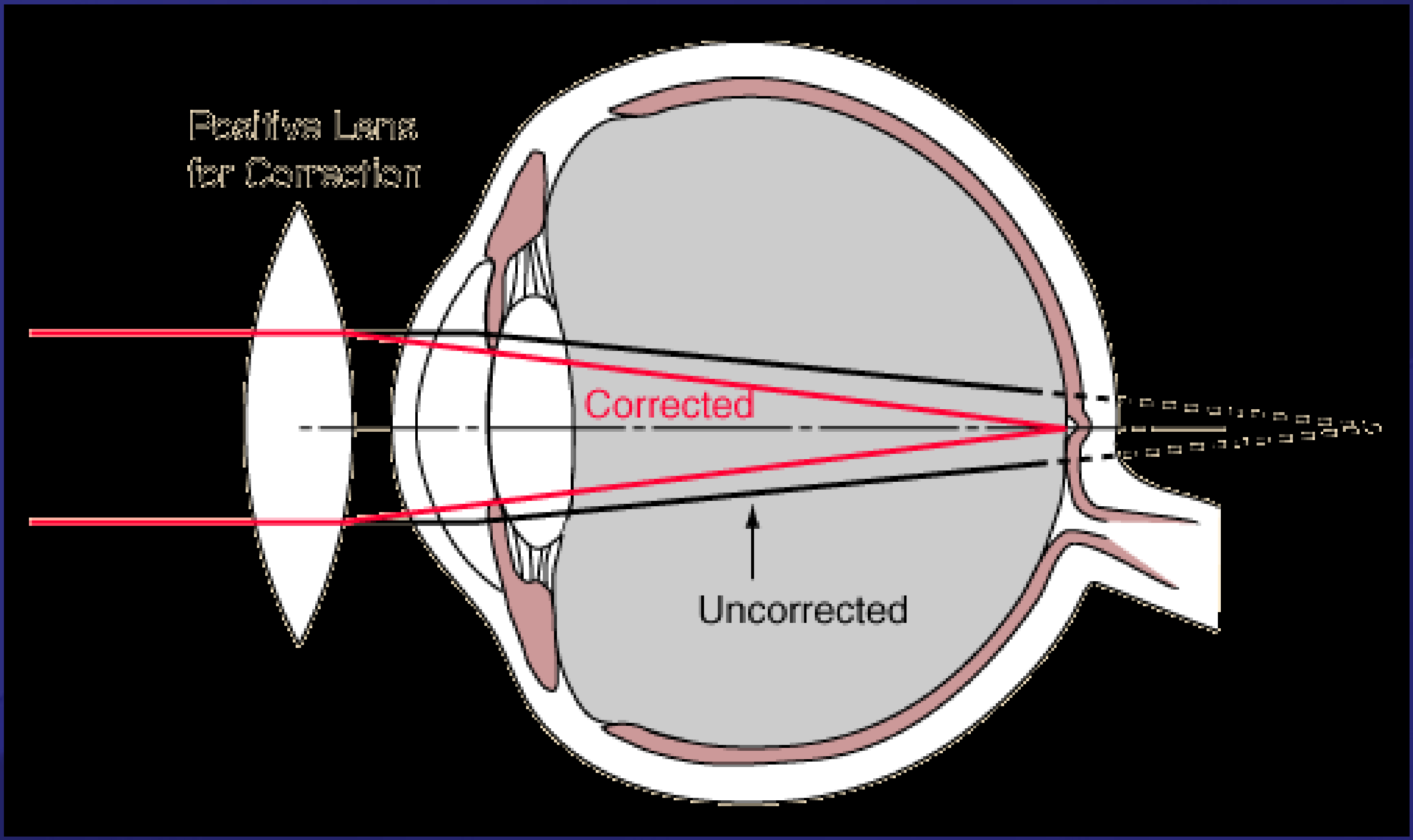
Hyperopia or Hypermetropia

- Parallel rays of light without accommodation are focused behind the retina, that is, the retina is reached by the rays before they come to focus
- The uncorrected hyperope may see distant objects clearly only by the use of his accommodation
- The near point is greater than 10 cm
- The term "far-sightedness" refers mainly to the excessive distance of the near point
- Correction is by the use of convex lenses

Hypermetropia



Hypermetropia



5. Optical defects in the ametropic eye

Presbyopia or “Old-Sightedness”

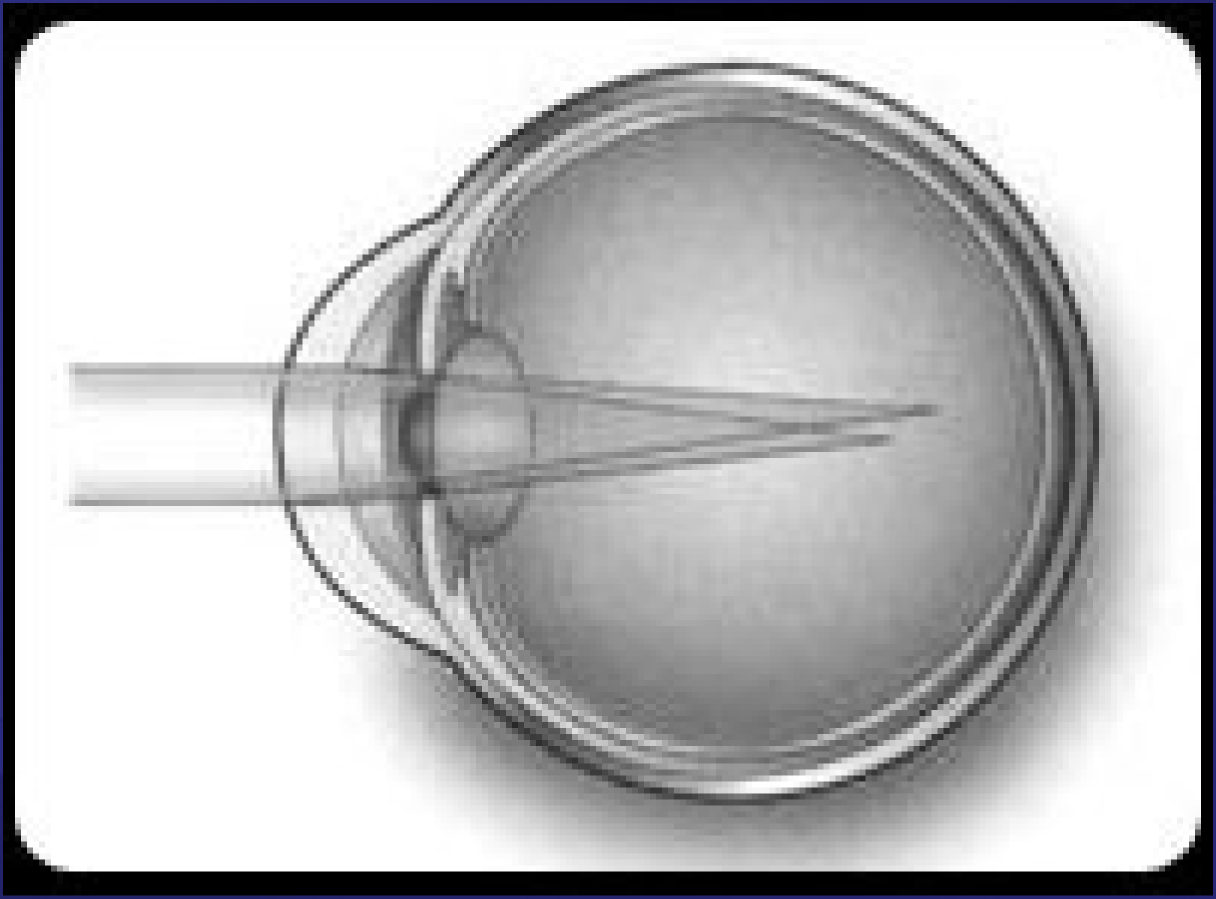
- A decrease in the amplitude of accommodation as a consequence of aging
- The near point of distinct vision recedes farther and farther from the eye until near is difficult or impossible
- All properly corrected eyes will become presbyopic at about the same time, at an age approximately 45

5. Optical defects in the ametropic eye

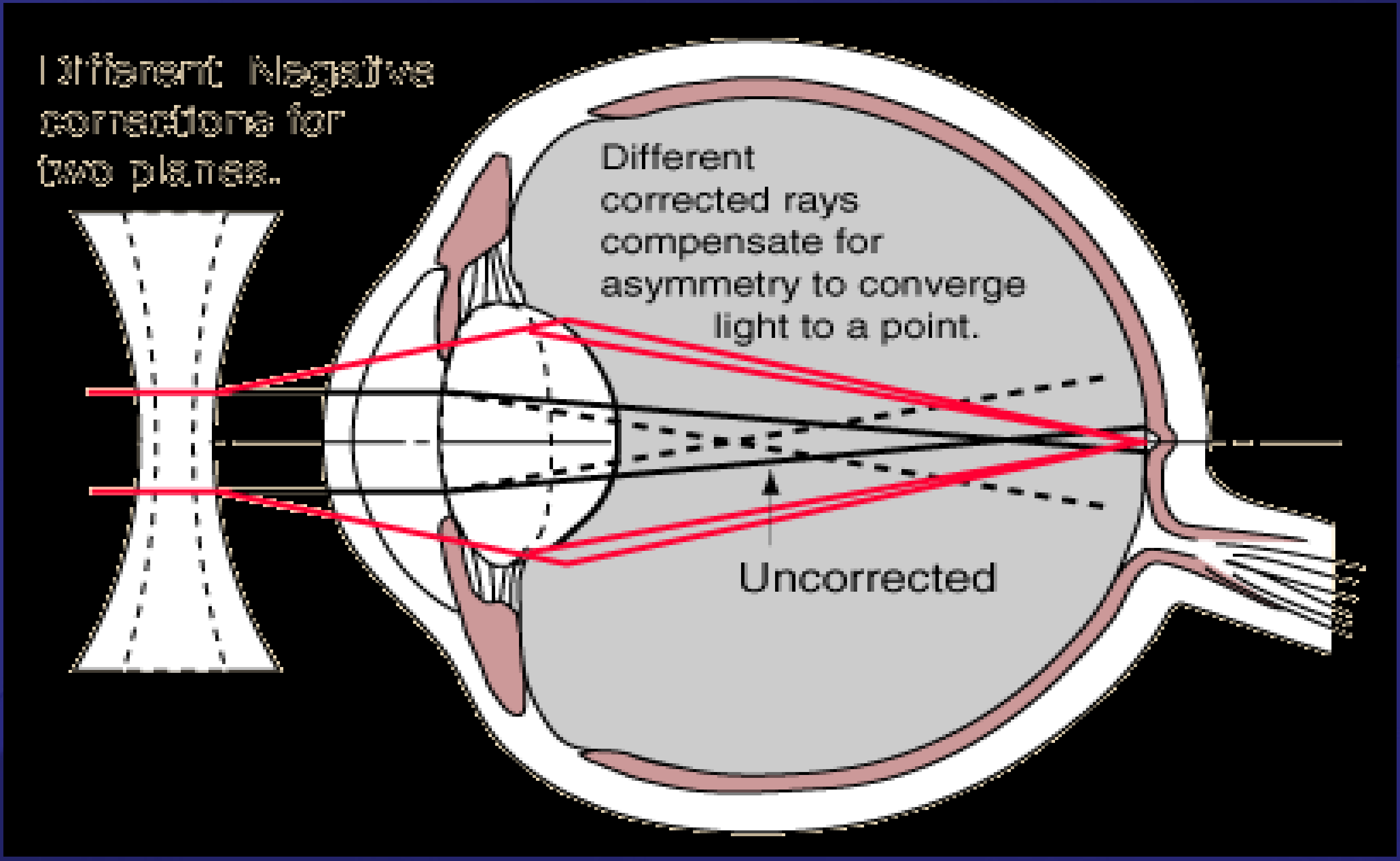
Astigmatism

- An error of refraction due to the uneven curvature of the cornea
- The corneal surface is not spherical, so there is a meridian of least curvature and meridian of greatest curvature at right angle to the first
- Rays falling on the greatest curvature are focused earlier than those falling on the least curvature
- Correction is by the use of cylindrical lenses

Astigmatism



Astigmatism



6. Visual acuity

- Visual acuity is the sharpness with which details and contours of objects are perceived and constitutes the basis for form or object vision
- The zone immediately surrounding the fovea possesses the next greater capacity for detailed vision
- Visual acuity diminishes further towards the periphery
- The fovea is specialized for detailed vision in four ways:
  - the cones are more slender and densely packed
  - it is rod free
  - blood vessels and nerves detour around it, and the cellular layers are deflected to the side, removing the scattering of light
  - each cone is connected to one ganglion cell

6. Visual acuity

Measurement of Visual Acuity

- Visual acuity is usually expressed in terms of **minimum separable** the smallest distance by which two lines may be separated without appearing as a single line.
- The angle that these two lines subtend at the eye is called the **visual angle**, which is **one minute** for the normal eye.
- Visual acuity can also be expressed in terms of **minimum visible**, the narrowest line or the finest thread that can be discriminated from a homogenous background.

6. Visual acuity

Factors Modifying Visual Acuity

- Dependent upon Stimulus
  - ✓ Brightness of object in contrast with dark background
  - ✓ Intensity of illumination
  - ✓ Size of object
- Dioptric Factors
  - ✓ Spherical aberration
  - ✓ Chromatic aberration
  - ✓ Error of refraction
  - ✓ Composition of light (monochromatic light improves visual acuity by decreasing chromatic aberration)
- Retinal Factors. The fovea centralis is adapted for acutest vision

6. Visual acuity

Snellen's Test Chart:

- Consists of 9 lines of letters in which the letters in each line are smaller than those in the previous line.
- The chart is viewed at a distance of 20 ft., or 6 m
- If at 20 ft. the individual reads the letters of the line marked 20, visual acuity is 20/20 which is considered normal
- If the individual can read only the line marked 100 (which a normal individual can read at 100 ft), his visual acuity is 20/100

7. Photoreceptors

Signal transduction pathway is by which the energy of a photon signals a mechanism in the cell that leads to its electrical polarization.

This polarization ultimately leads to either the transmittance or inhibition of a neural signal that will be fed to the brain via the optic nerve.

7. Photoreceptors

In humans, the visual system uses millions of photoreceptors to view, perceive, and analyze the visual world.

Moreover, the photoreceptor is the only neuron in humans capable of phototransduction (with an exception being the recently discovered photosensitive ganglion cell).

All photoreceptors in humans are found in the outer nuclear layer in the retina at the back of each eye, while the bipolar and ganglion cells that transmit information from photoreceptors to the brain are in front of them.

7. Photoreceptors

This arrangement requires two specializations: a fovea in each retina (for high visual acuity) and a blind spot in each eye, where axons from the ganglion cells can go back through the retina to the brain.

Humans have two types of photoreceptors: rods and cones. Both are neurons that transduce light into a change in membrane potential through the same signal transduction pathway.

7. Photoreceptors

Rods and cones differ in a number of ways.

The most important difference is in their relative sensitivity: rods are sensitive to very dim light, cones require much brighter light. The most notable being the absence of rods in the fovea.

They differ in shape: rods are long and slender; cones are short and tapered.

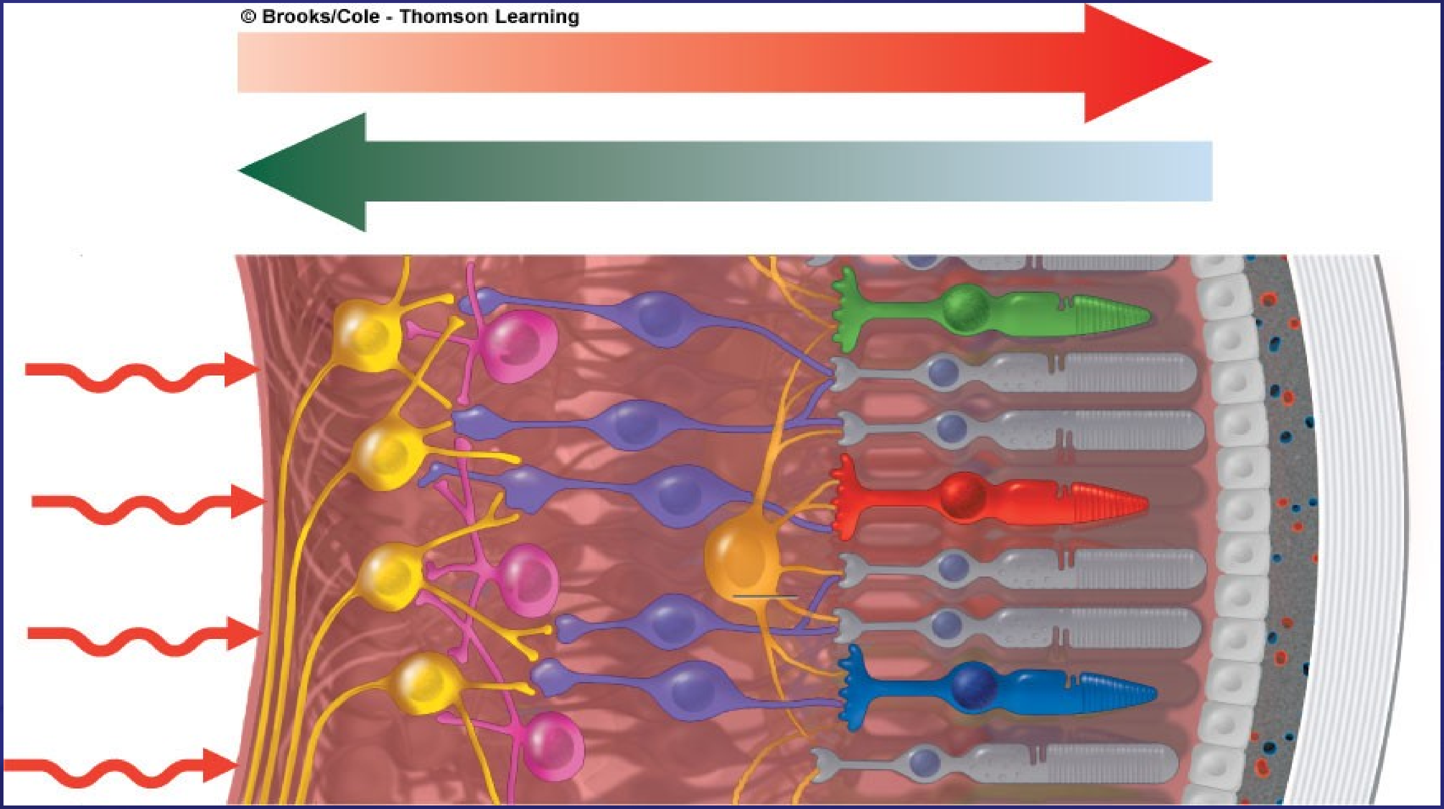
Both rods and cones contain light-sensitive pigments. All rods have the same pigment; cones are of three types, each type containing a different visual pigment. The four pigments are sensitive to different wavelengths of light, and in the case of the cones these differences form the basis of our color vision.

7. Photoreceptors

The receptors respond to light through a process called bleaching. In this process a molecule of visual pigment absorbs a photon, or single package, of visible light and is thereby chemically changed into another compound that absorbs light less well, or perhaps differs in its wavelength sensitivity.

In virtually all animals, from insects to humans and even in some bacteria, this receptor pigment consists of a protein coupled to a small molecule related to vitamin A, which is the part that is chemically transformed by light.

7. Photoreceptors



7. Photoreceptors

Sequence of events during photoreception

1. Incident light
2. Structural change in the retinine of photopigment
3. Conformational change of photopigment
4. Activation of transduction
5. Activation of phosphodiestrase
6. Decreased intracellular cGMP
7. Closure of Na+ channels
8. Hyperpolarization
9. Decreased release of synaptic transmitter (glutamate)
10. Response in bipolar cells and other neural elements

8. Visual pathways

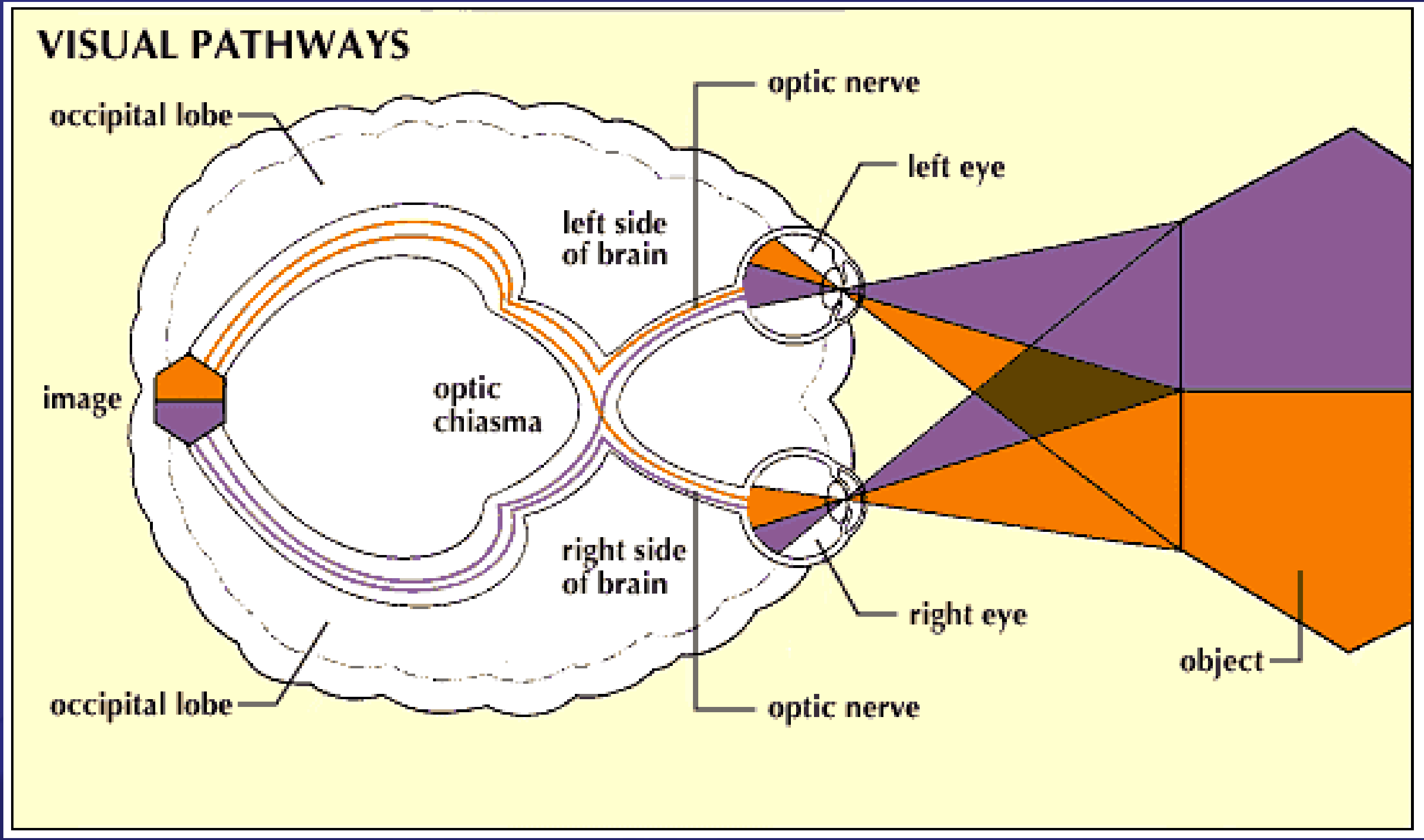
There are three main visual pathways in the central nervous system of vertebrates.

The most commonly discussed pathway is the Thalamofugal Pathway, necessary for visual distinction of form and color, as well as visual motion perception.

The Tectofugal Pathway, on the other hand, is primarily involved in the processes necessary for visual orientation and spatial attention, and neurons within this neural circuit are frequently found to be sensitive to visual motion stimuli.

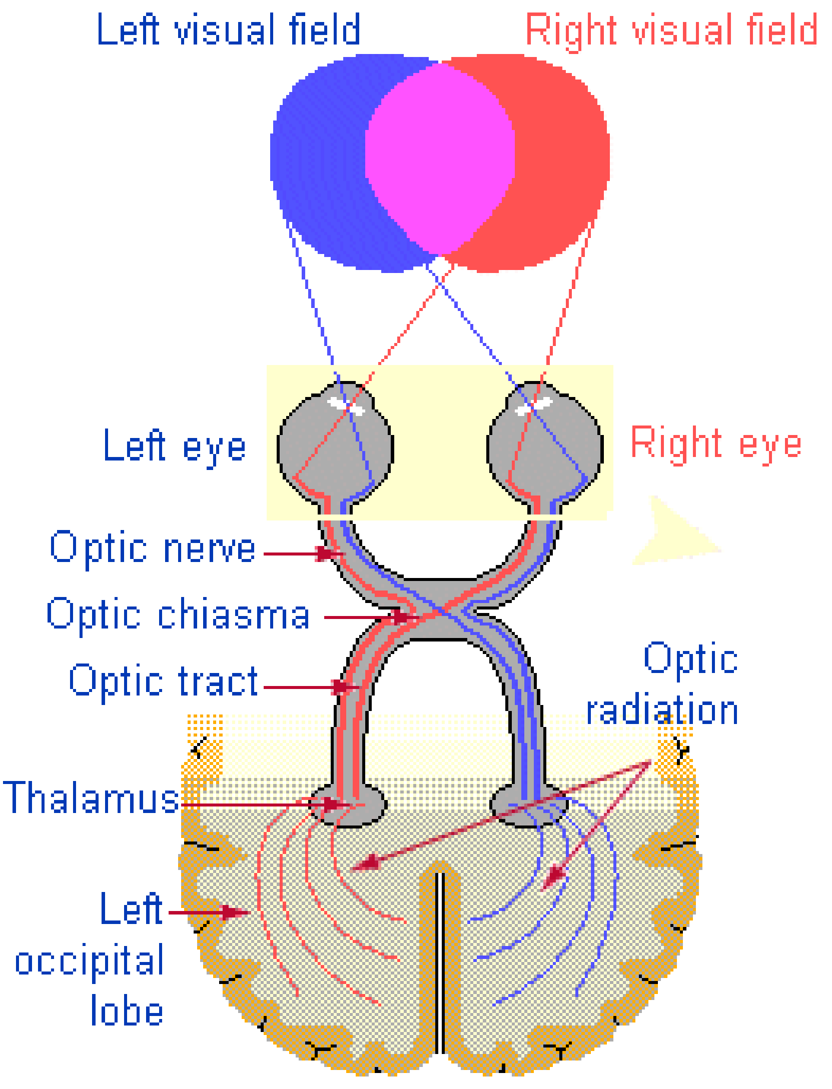
The final pathway, the Accessory Optic System, is a subcortical pathway necessary for the perception of self-motion and gaze stabilization.

8. Visual pathways



8. Visual pathways

This scheme shows the flow of information from the eyes to the central connections of the optic nerves and optic tracts, to the visual cortex. Area **V1** is the region of the brain which is engaged in **vision**.



Responses in the visual pathways and cortex

The lateral geniculate nucleus:

"Geniculate" means knee-shaped, and it is a pretty accurate description of the LGN. The stripes are actually layers, and there should be six of them in most parts of the LGN. Each layer receives inputs from a different eye: 3 layers for the left eye and 3 layers for the right.

There is a second aspect of organization in the LGN. The outer 4 layers are composed of small cells, and correspondingly, receive inputs from the small ganglion cells of the retina. These layers are called the **parvocellular layers**.

The **magnocellular layers**, on the other hand, are composed of large cells and receive their input from large ganglion cells.

Responses in the visual pathways and cortex

On to cortex:

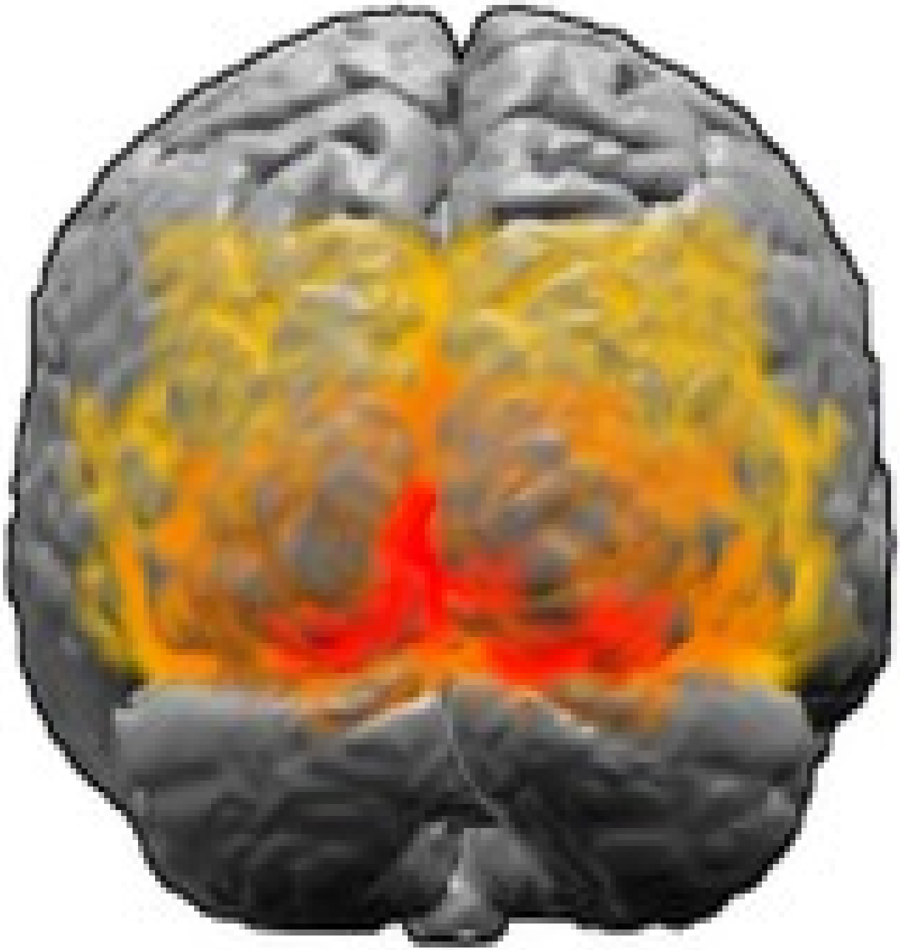
The neurons in the LGN send their axons directly to **V1** (primary visual cortex, striate cortex, area 17) via the **optic radiations**.

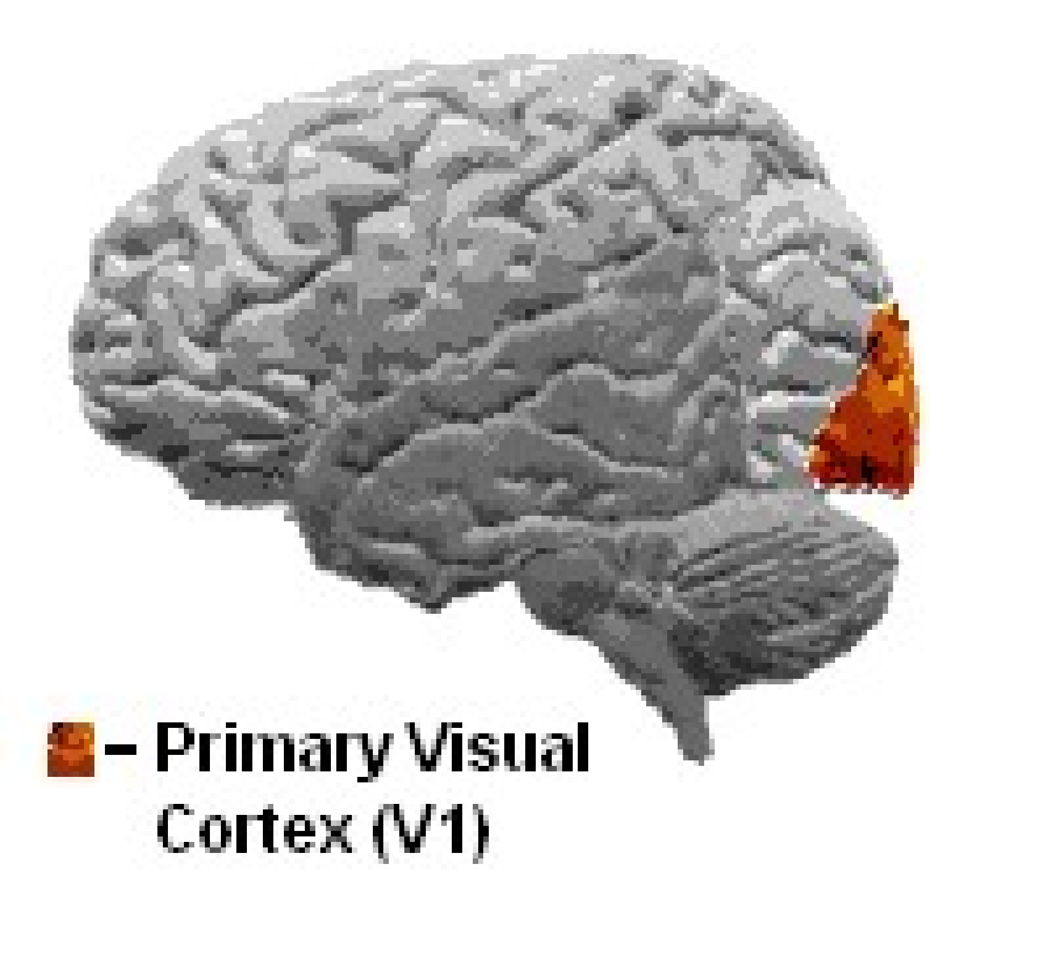
This highway of visual information courses through the white matter of the temporal and parietal lobes.

Once the axons reach V1, they terminate primarily in a single sub-layer of cortex.

Brodmann first subdivided the cortex into over 50 areas.

These areas are known today to correspond to functionally distinct areas - area 17 is primary visual cortex, for example.




– Primary Visual
Cortex (V1)

Primary visual cortex

The koniocortex (sensory type)

- located in and around the calcarine fissure in the occipital lobe.
- receives information directly from the lateral geniculate nucleus.
- highly specialized for processing information about static and moving objects and is excellent in pattern recognition.
- divided into six functionally distinct layers
- Layer 4, which receives most visual input from the lateral geniculate nucleus (LGN), is further divided into 4 layers(4A, 4B, 4Cα, and 4Cβ).

Sublamina 4Cα receives most magnocellular input from the LGN,

layer 4Cβ receives input from parvocellular pathways.

Axons from the interlaminar region end in layers 2 and 3.

Primary visual cortex

Simple cells-respond only when the bar of light have a particular orientation.

Complex cells-respond maximally when a linear stimulus is moved laterally without a change in its orientation.

Simple and complex cells are called feature detectors due to their functions.

So, primary visual cortex segregates information about color from that concerned with the form and movement, combines the input from two eyes and converts the visual world into short line segments of various orientation.

Other cortical areas

V2, V3, VP-larger visual fields

V3A-motion

V5/MT-motion; put to control of movement

V8-concerned with color vision in human.

LO-recognition of large objects.

Thanks for your attention!