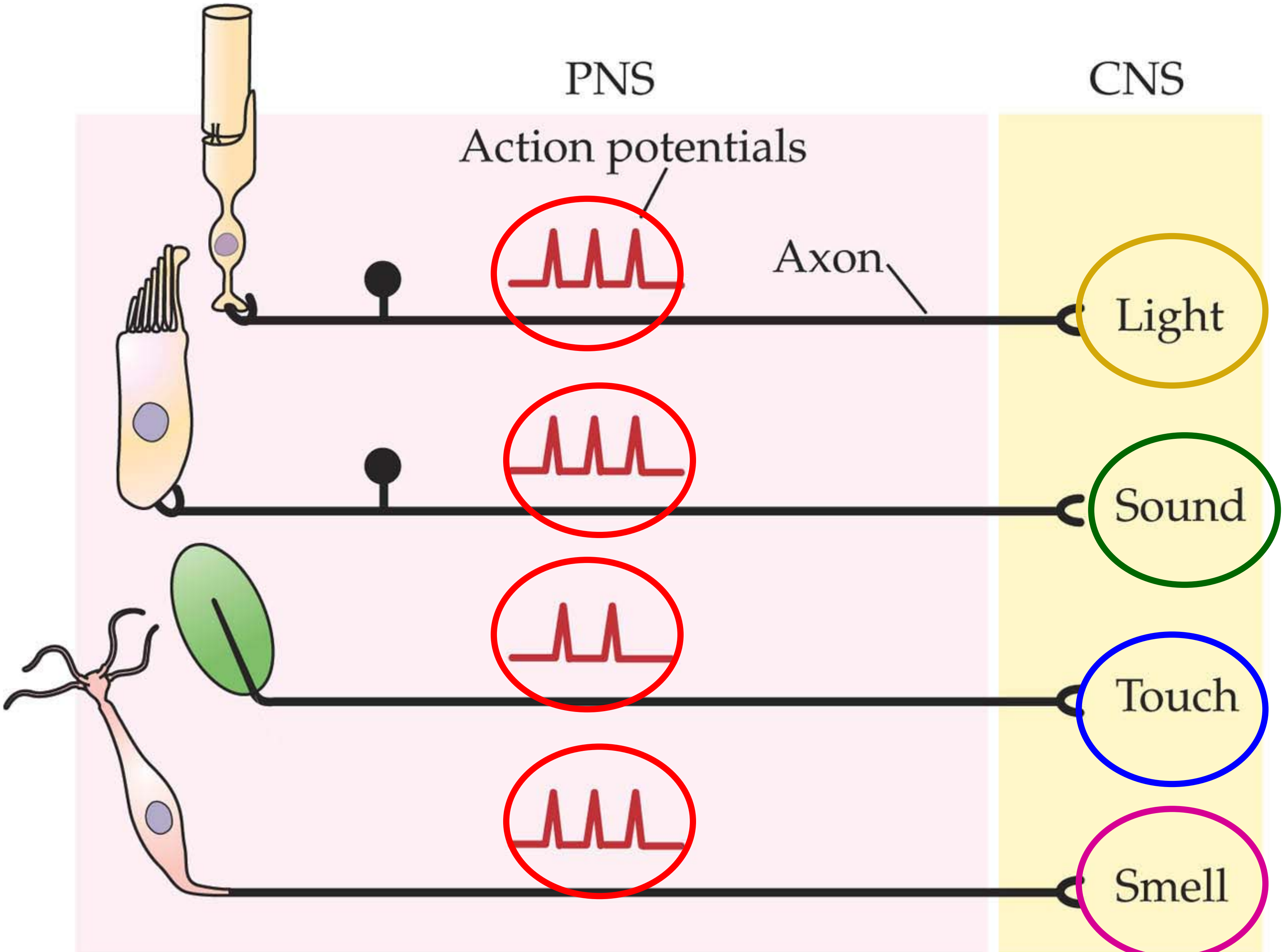
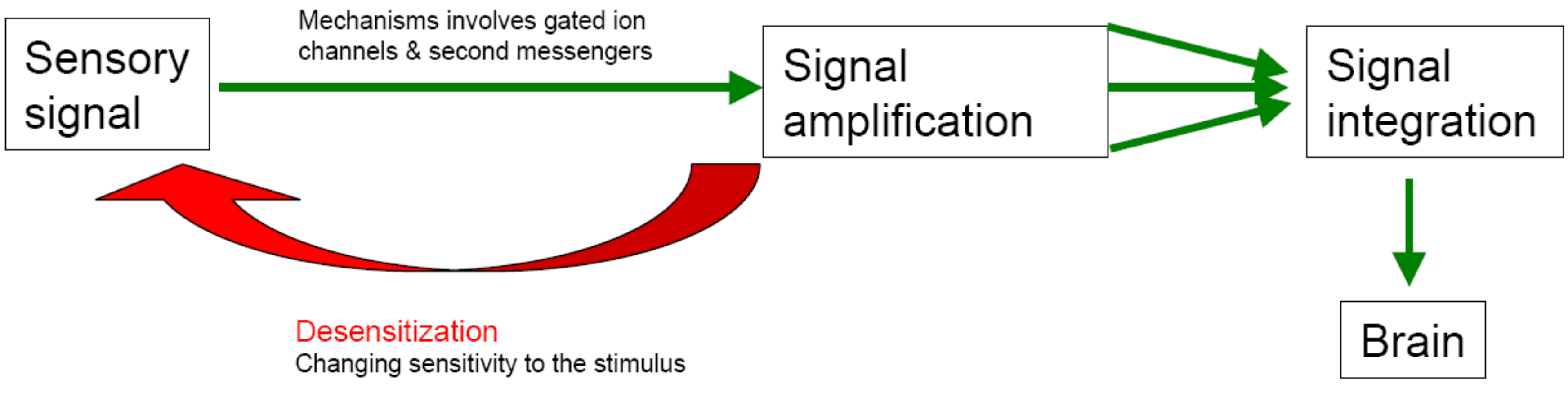
The principle of labeled lines in sensory systems



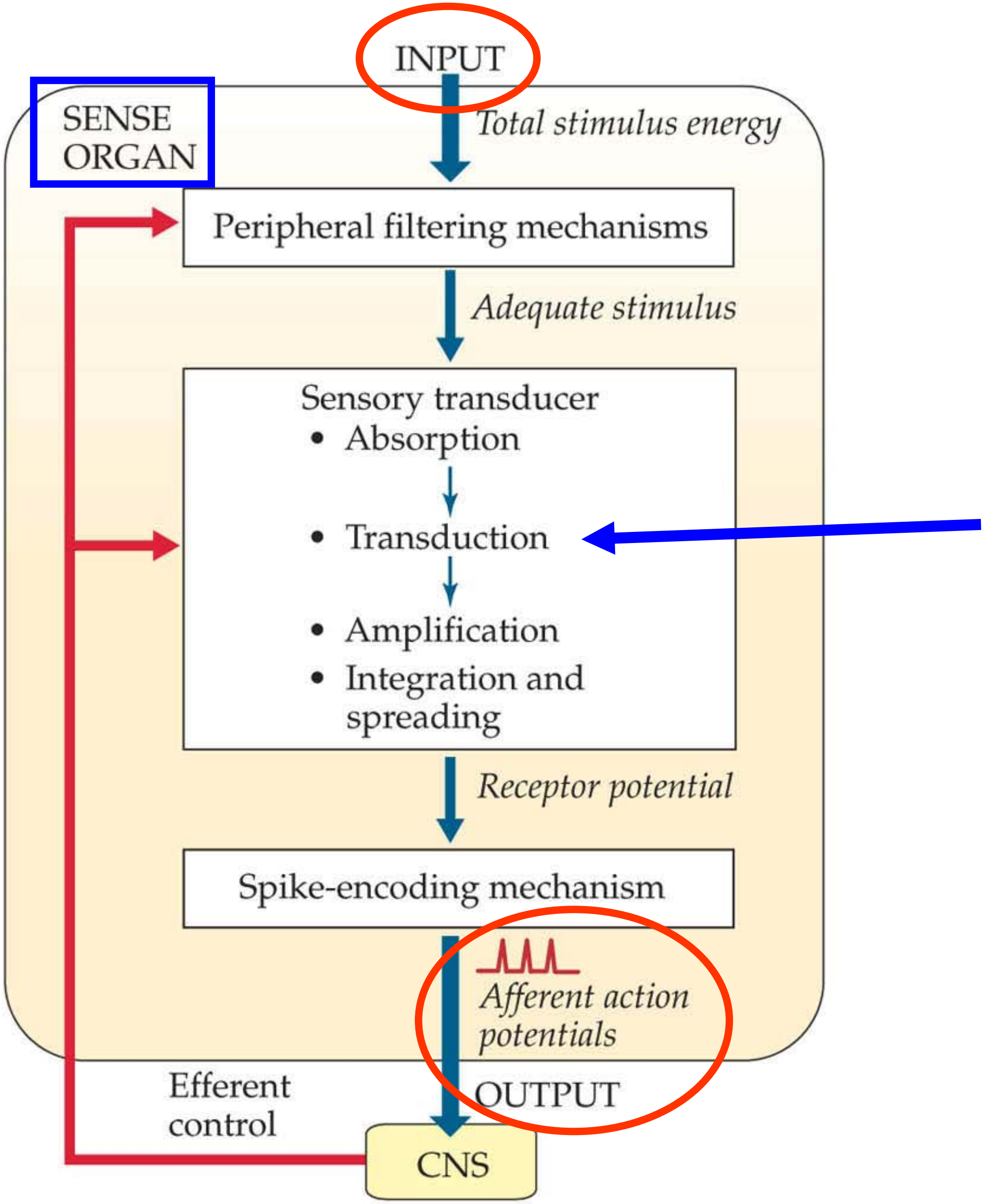
Sensory Transduction in Vision, Olfaction and Gustation

Detection of light, smells, and tastes

Specialized sensory neurons: uses signal transduction mechanism similar to those used to detect hormones, neurotransmitters and growth factors



Functional processes in a generalized sensory system



Classification of sensory receptors

TABLE 13.1 **Classification of sensory receptors, based primarily on the kind of stimulus energy that excites them** *(Part 1)*

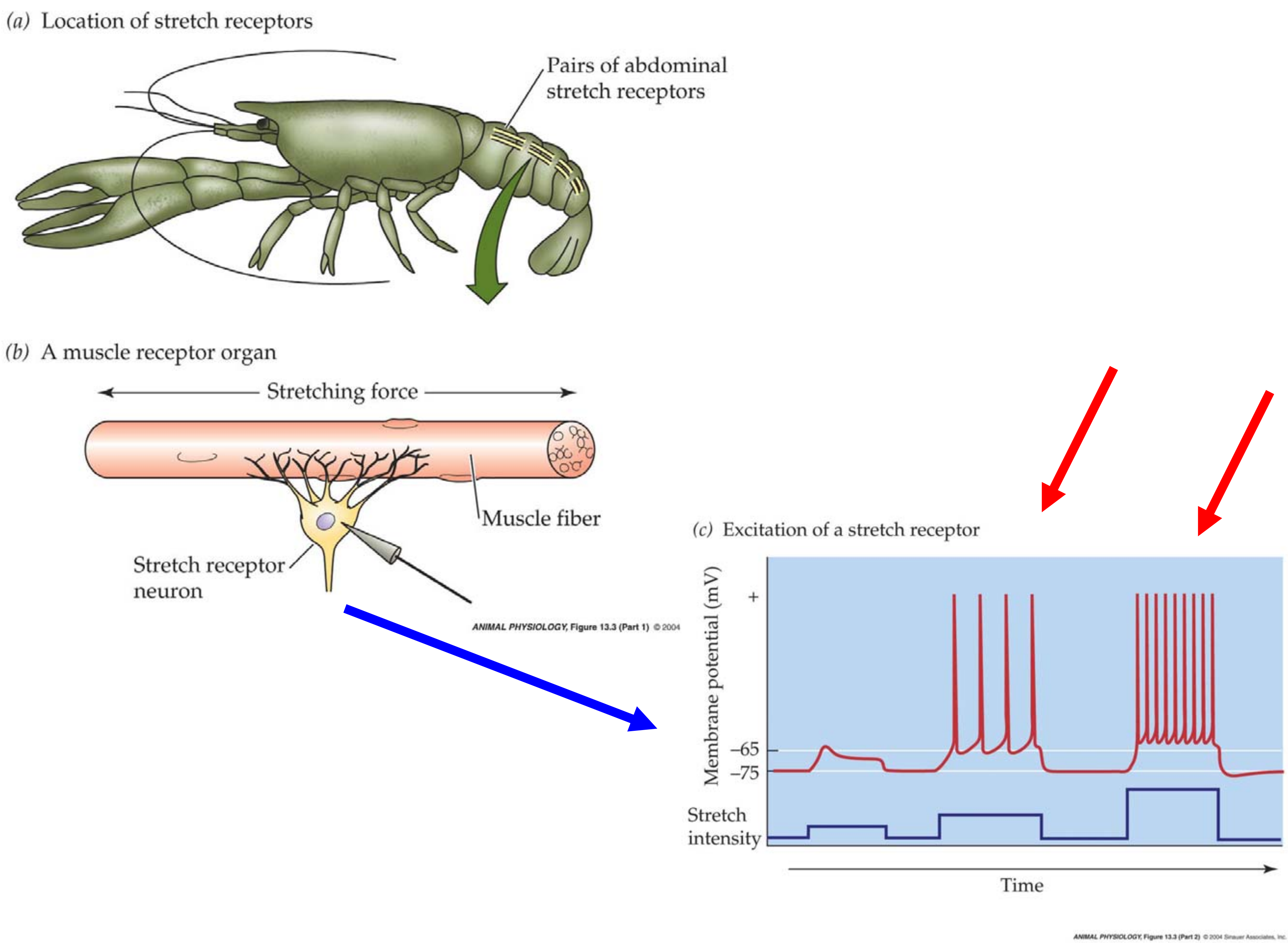
Stimulus energy	Receptor modality	Stimulus perceived
Electromagnetic energy	Photoreceptors **EYES**	Visible light Ultraviolet light Infrared radiation?
	Electroreceptors	Electrical field or charge movement
	Magnetoreceptors	Earth's magnetic field
Thermal energy	Thermoreceptors	Hot Cold

Classification of sensory receptors

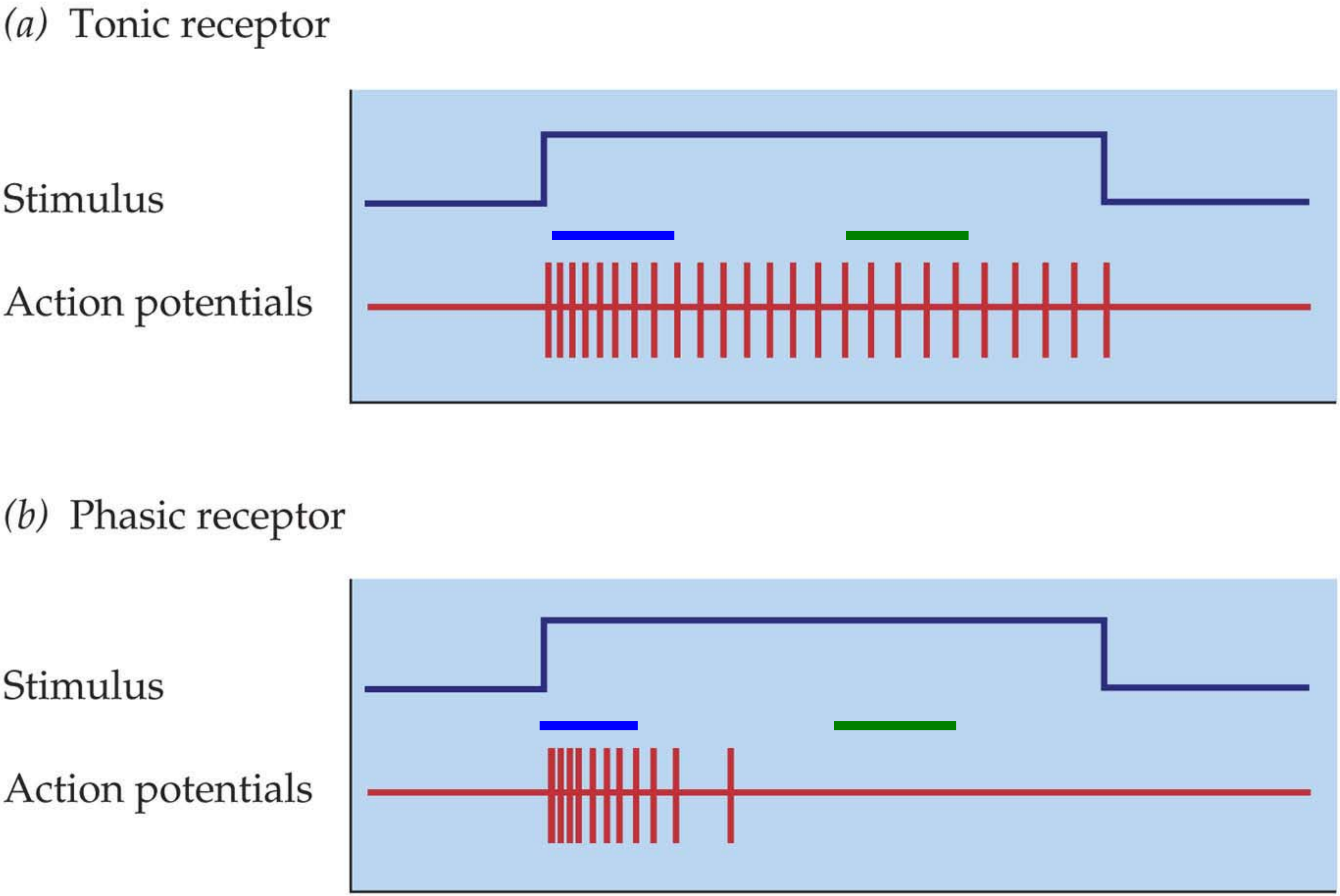
TABLE 13.1 Classification of sensory receptors, based primarily on the kind of stimulus energy that excites them *(Part 2)*

Stimulus energy	Receptor modality	Stimulus perceived
Chemical energy	Chemoreceptors **Noses**	Olfactory stimuli (distance chemoreceptors) Taste (contact chemoreceptors) Internal chemoreceptors
Mechanical energy	Mechanoreceptors **Tongue** **Ears**	Touch, pressure Muscle length Muscle tension Joint position and movement Sound (auditory stimuli) Balance and acceleration
	Osmoreceptors	Osmotic pressure

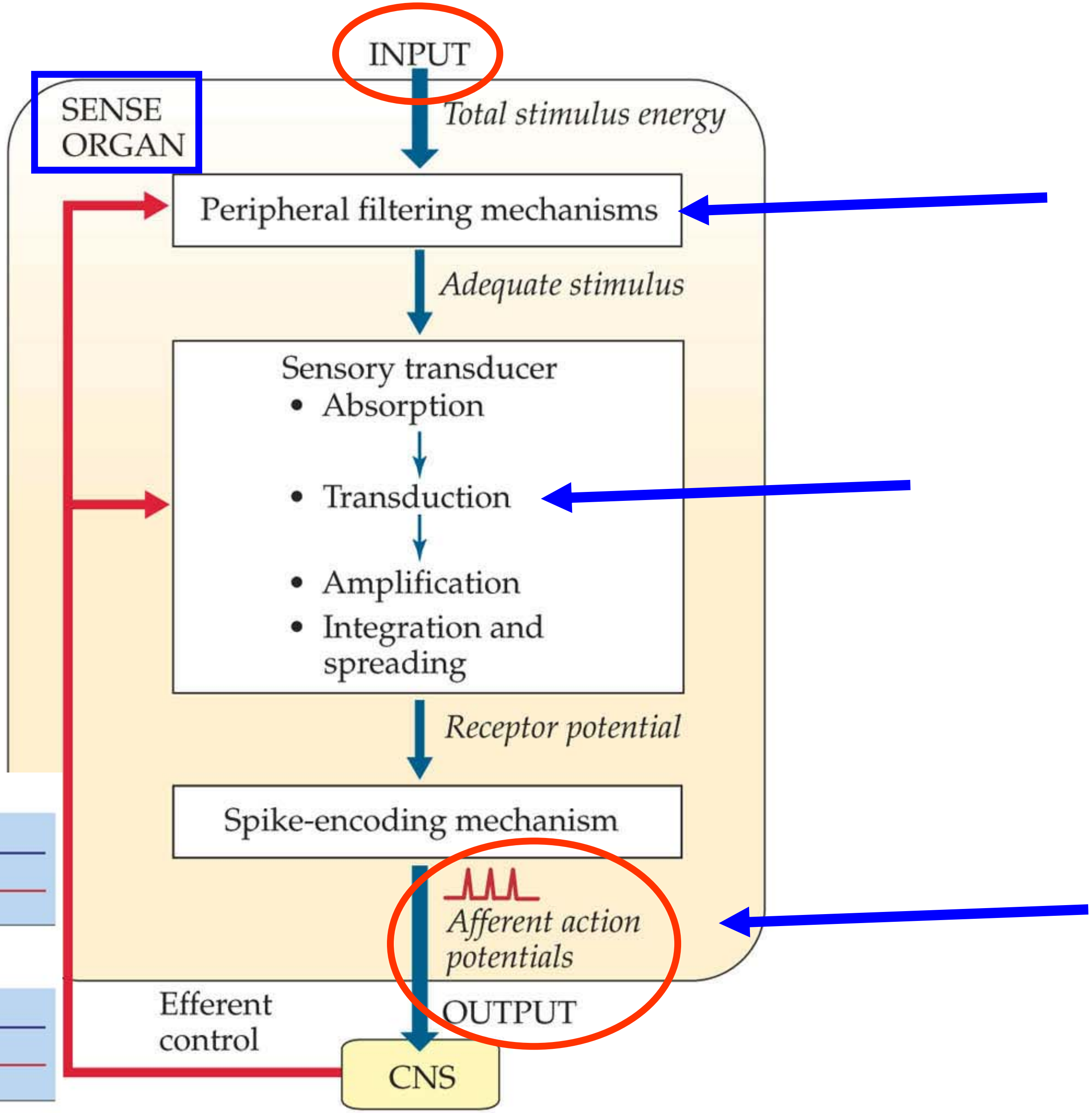
Crayfish stretch receptors exemplify sensory processes

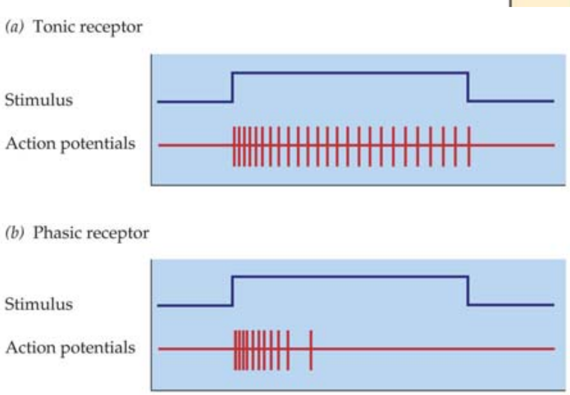


Slowly adapting and rapidly adapting receptors

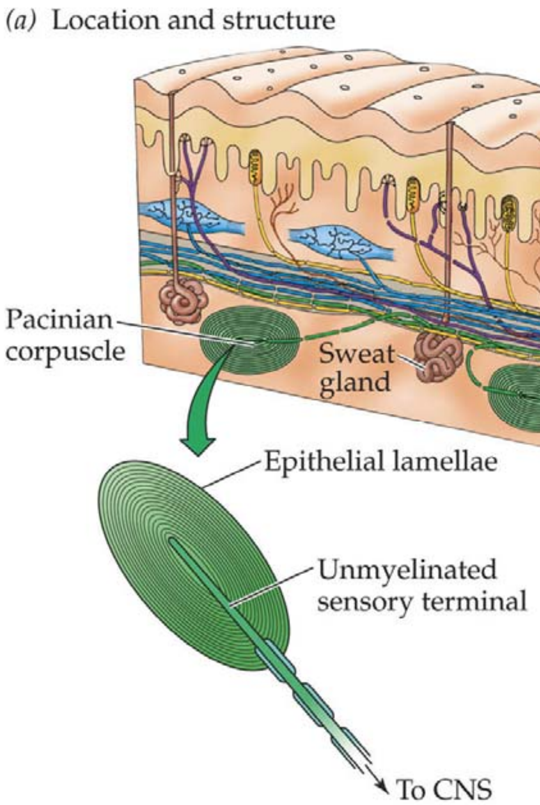


Receptor ADAPTATION can occurr at 3 sites

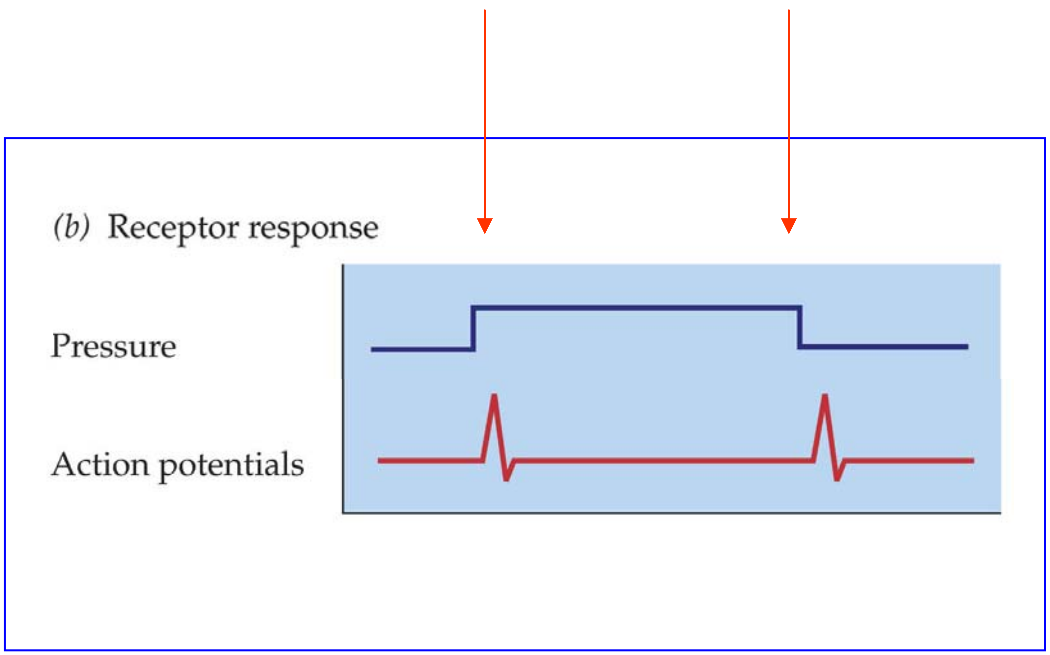




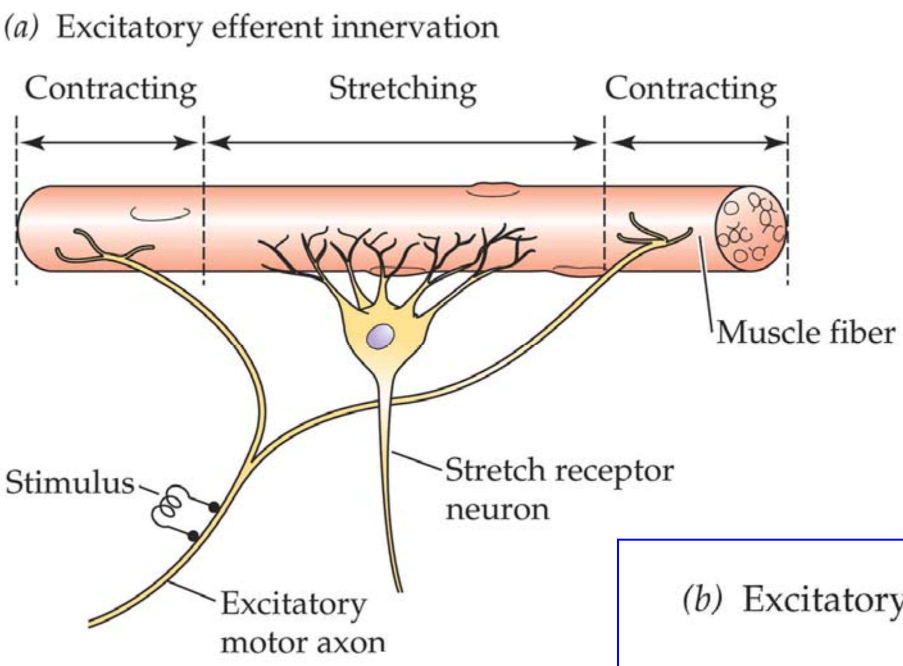
The Pacinian corpuscle is a rapidly adapting mechanoreceptor



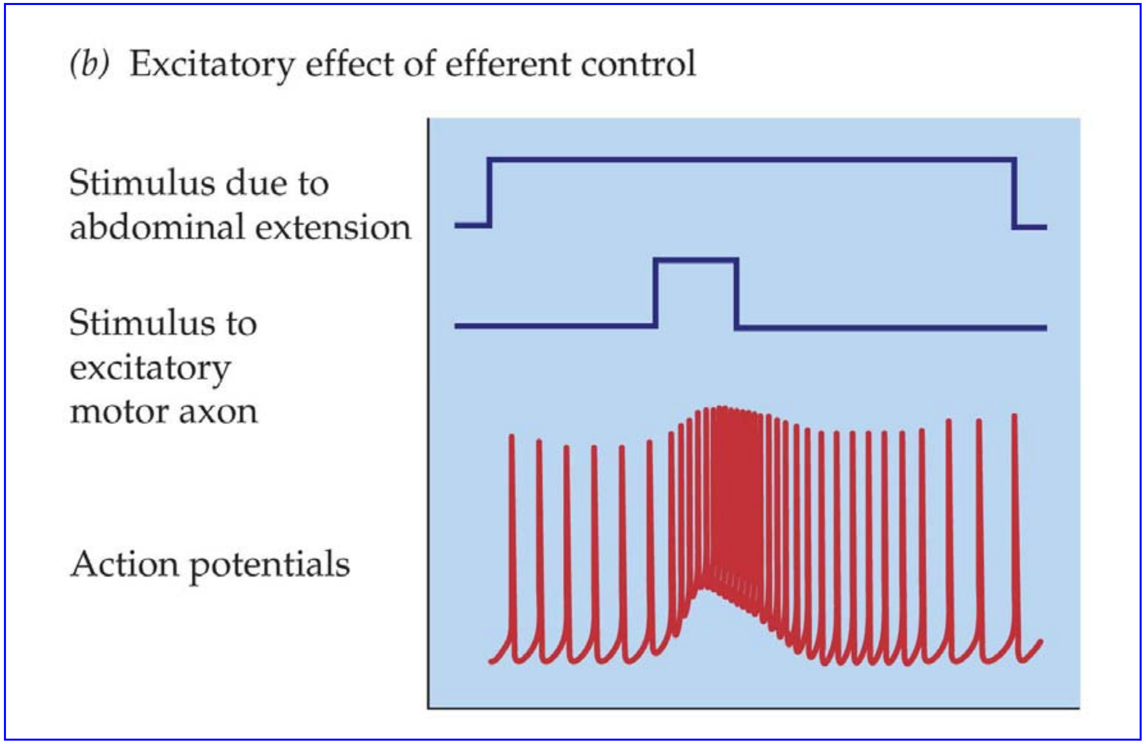
Start **End stimulus**



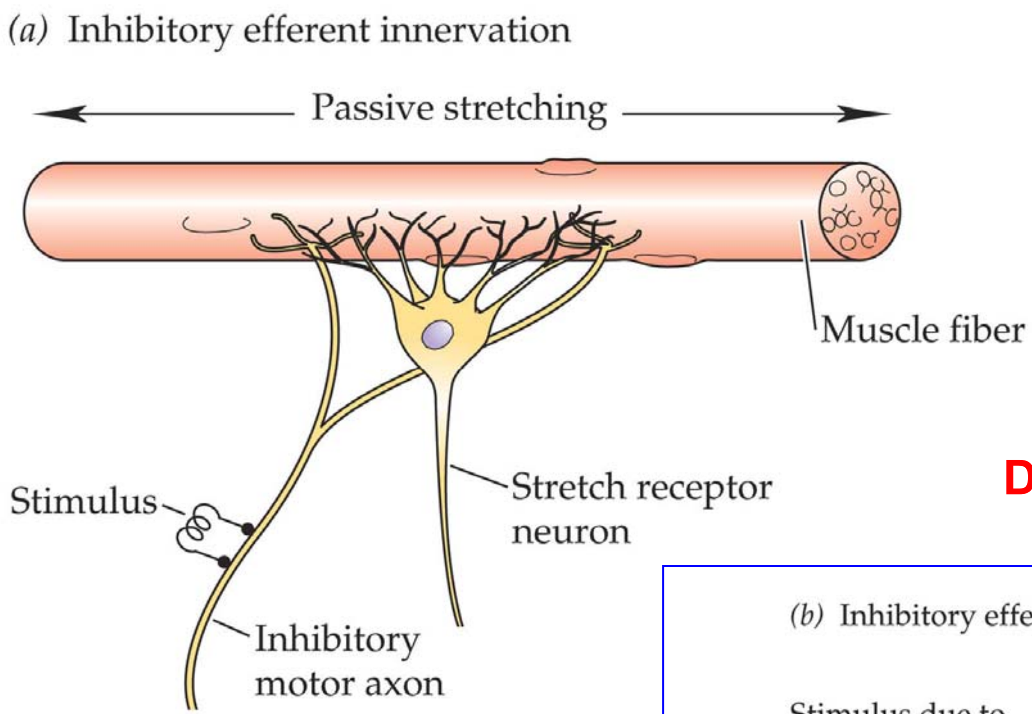
Sensory receptors are subject to excitatory efferent control from the CNS



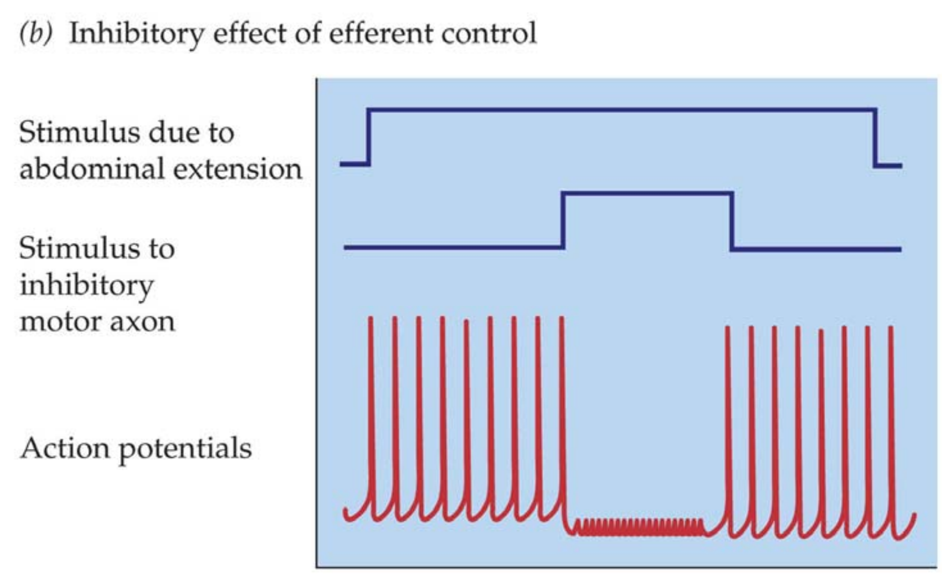
INCREASE sensitivity receptor



Receptors may also receive inhibitory efferent control



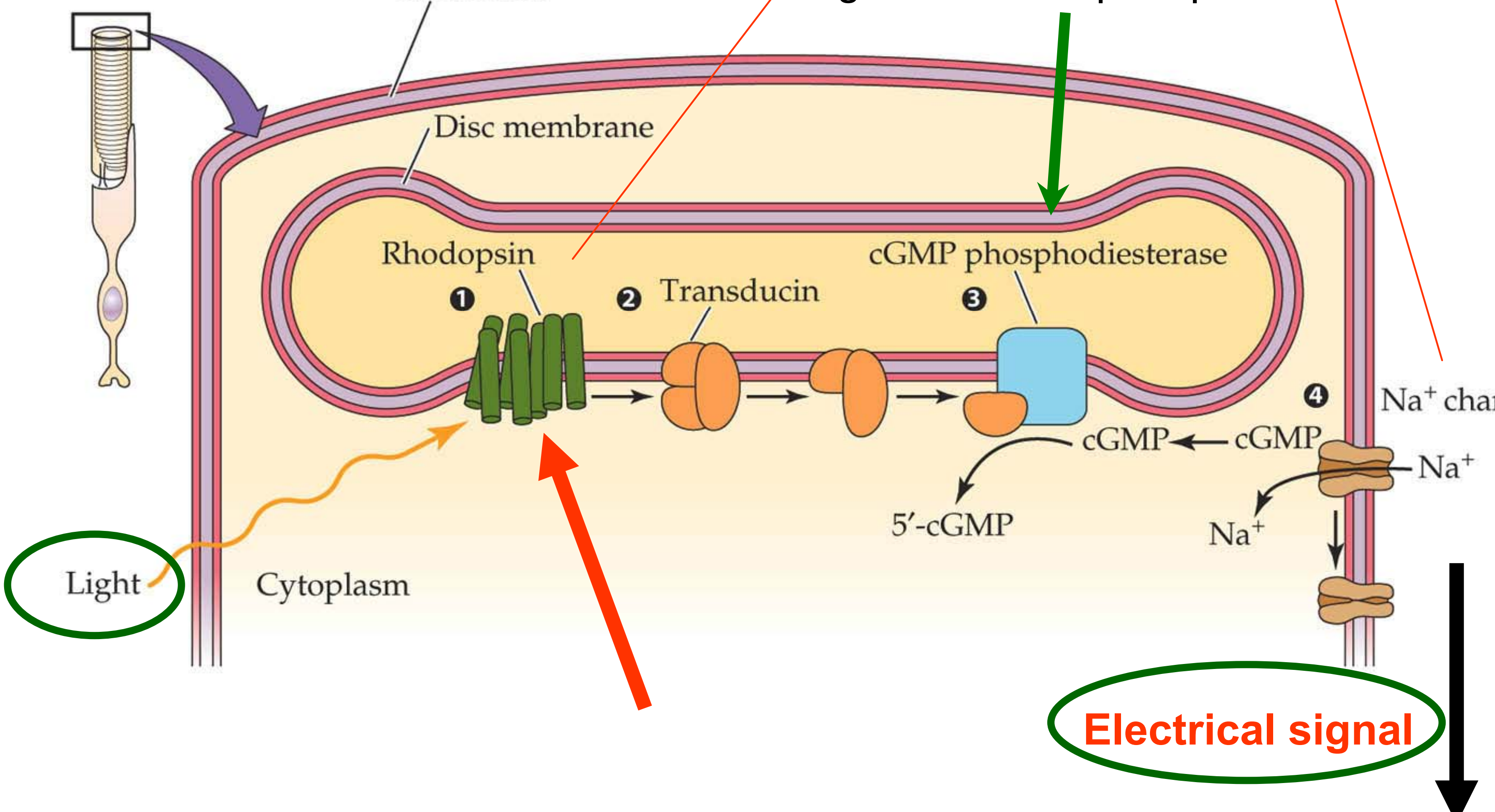
DECREASE sensitivity receptor



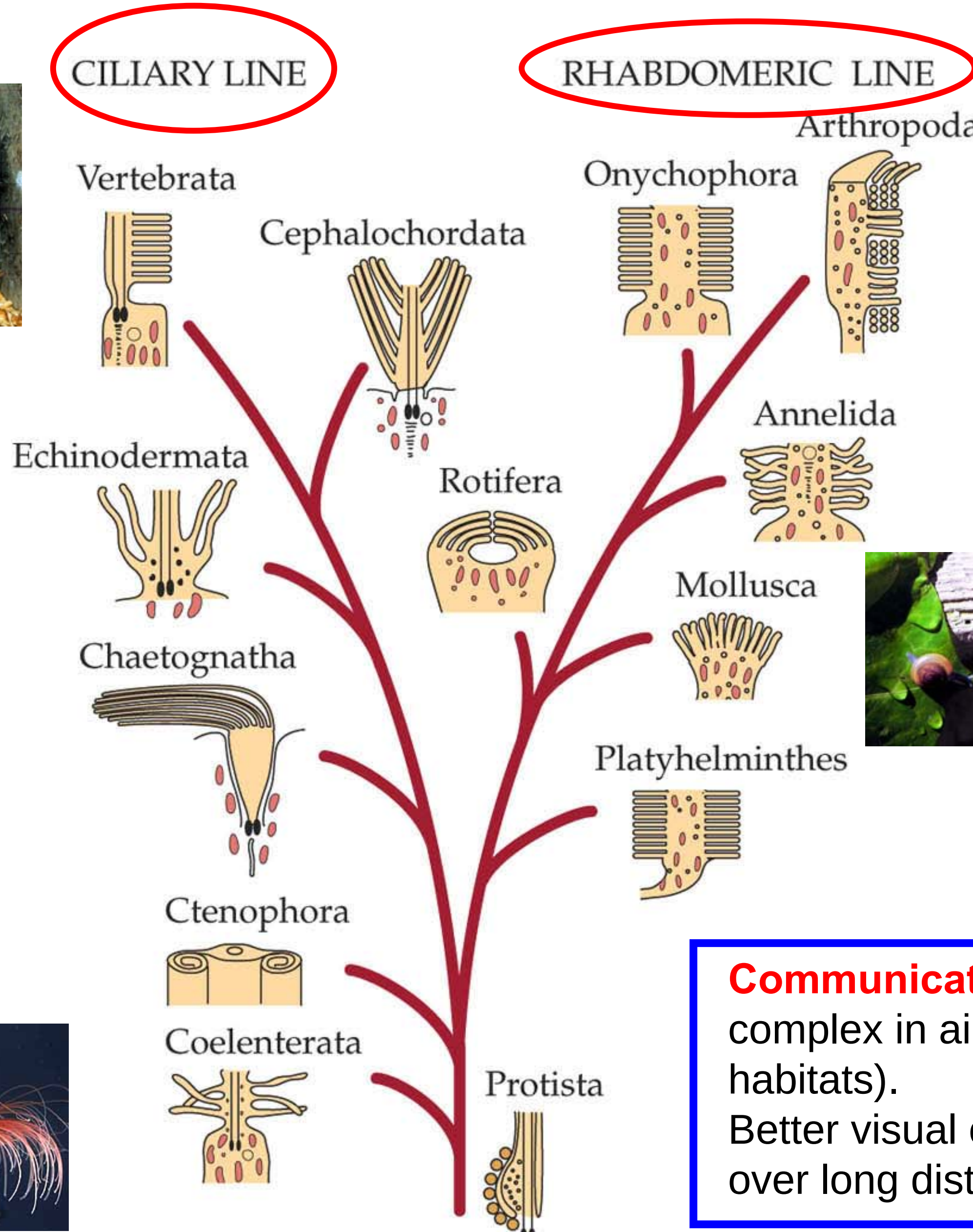
Photoreceptors contain photo pigments

Photo pigments are molecules that absorb and transduce light into an electrical signal

Catalysis of the reaction: guanosine 3',5'-cyclic phosphate + H2O = guanosine 5'-phosphate



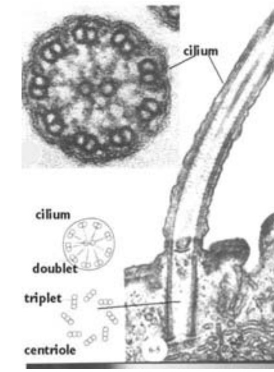
A simplified evolutionary relation of photoreceptive structures

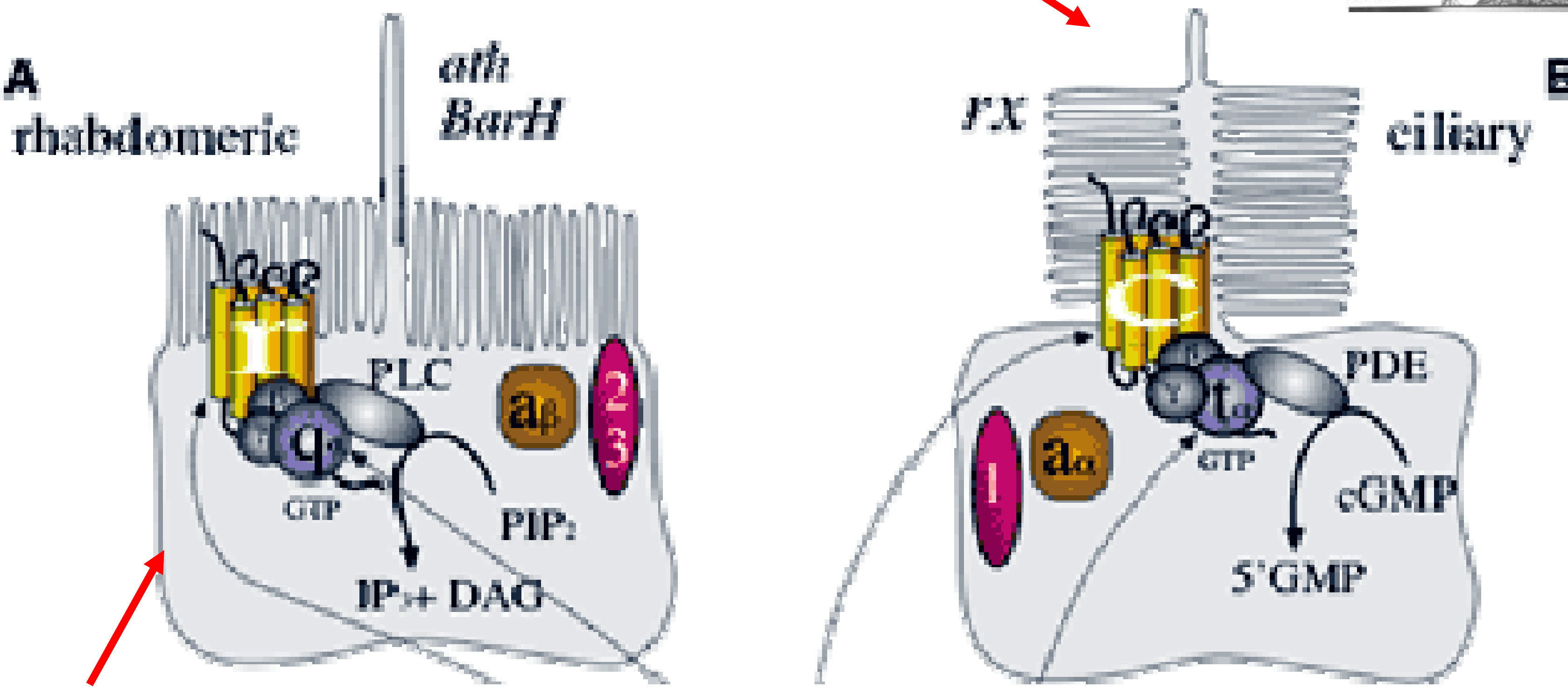


Communications are more complex in air (terrestrial habitats).
Better visual communication over long distances

A simplified evolutionary relation of photoreceptive structures

Ciliary: cilia modification (organelle) (phosphodiesterase and cGMP)

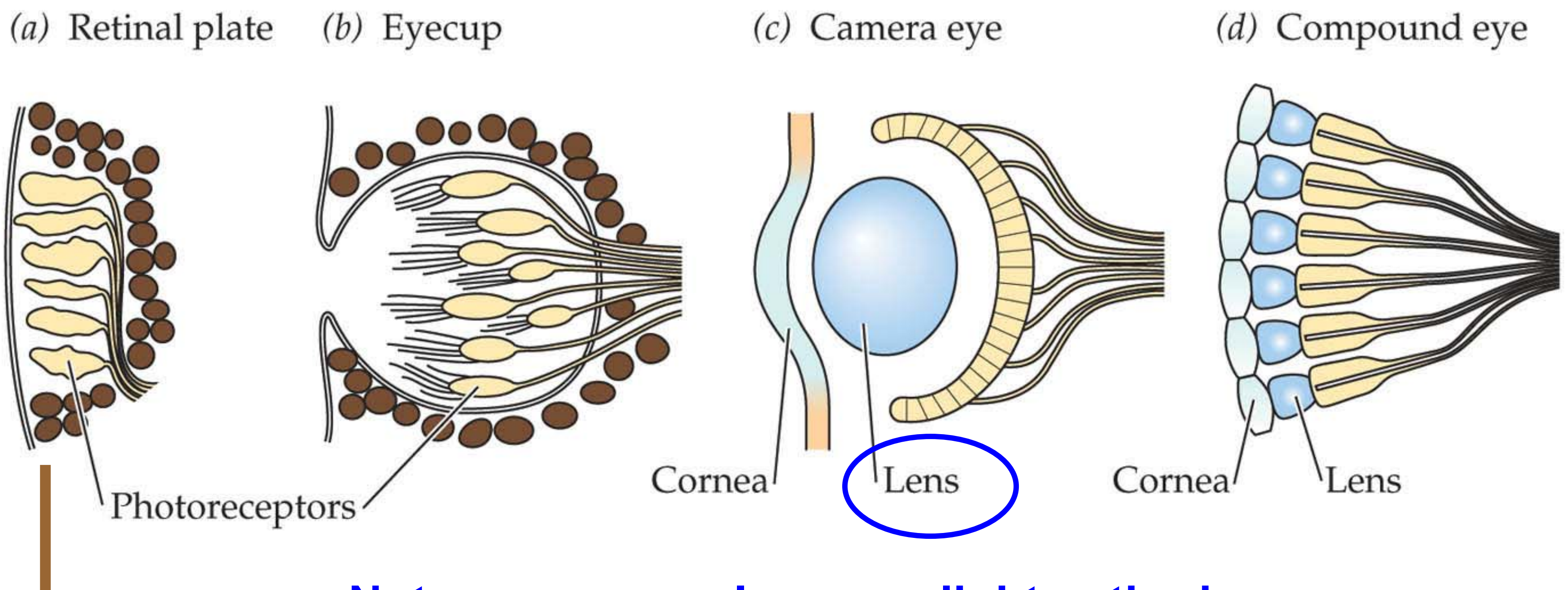




Rhabdomeric: cell membrane extensions (phospholipase C and inositol phosphate

Four patterns of organization of eyes

Pigments: shield the photoreceptor from light, allow the animal to orient

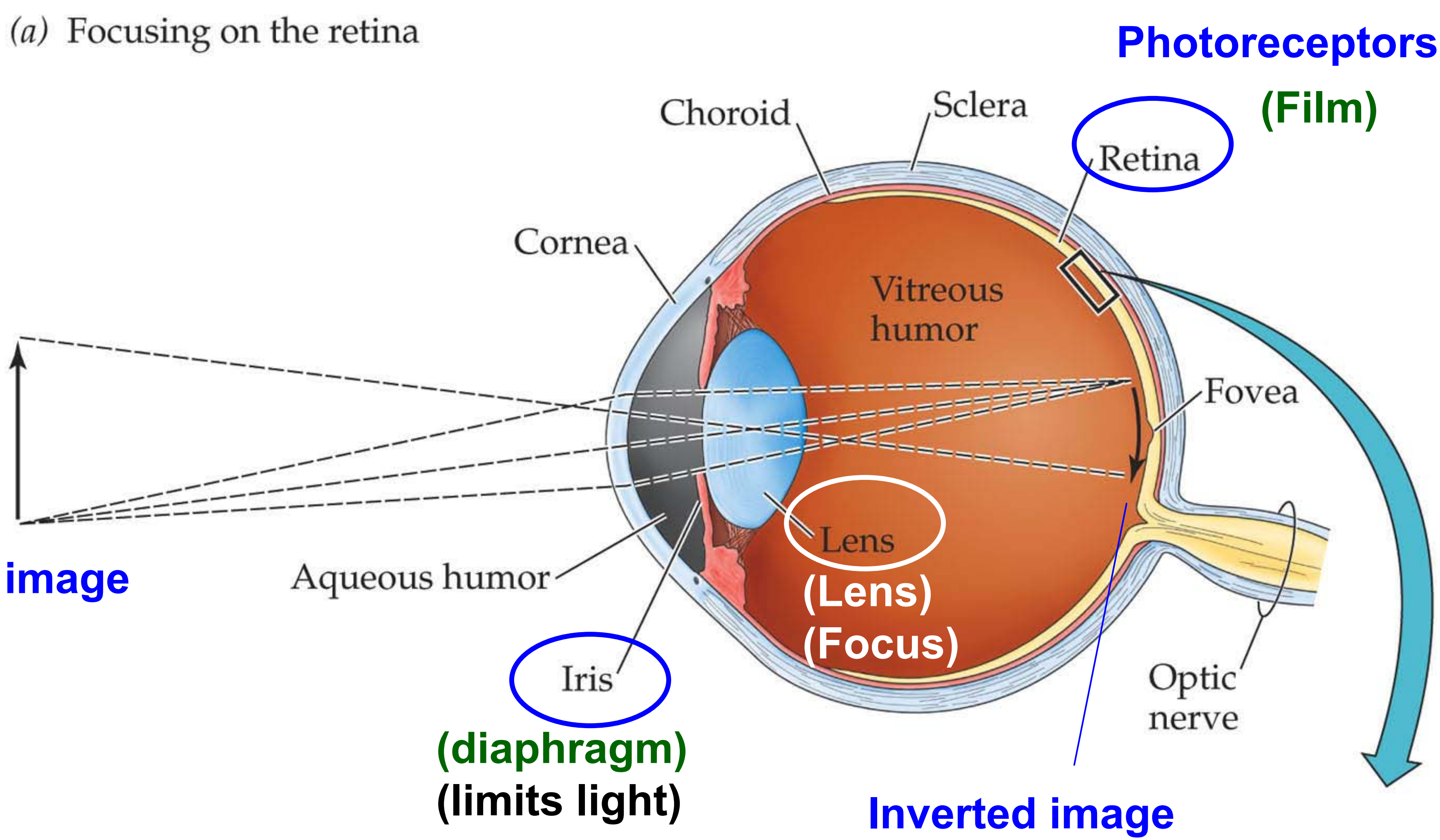


Pigment

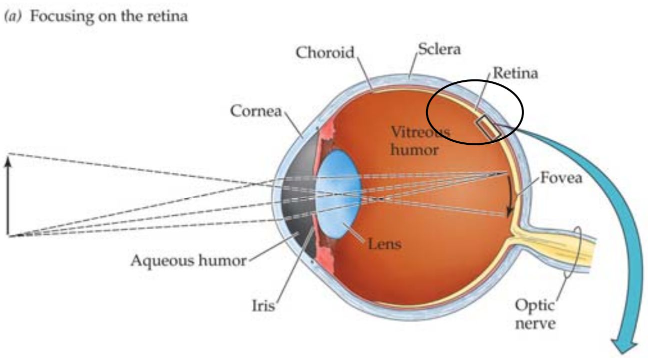
Not very sensitive

Increase light gathering

Structure of the mammalian eye and retina

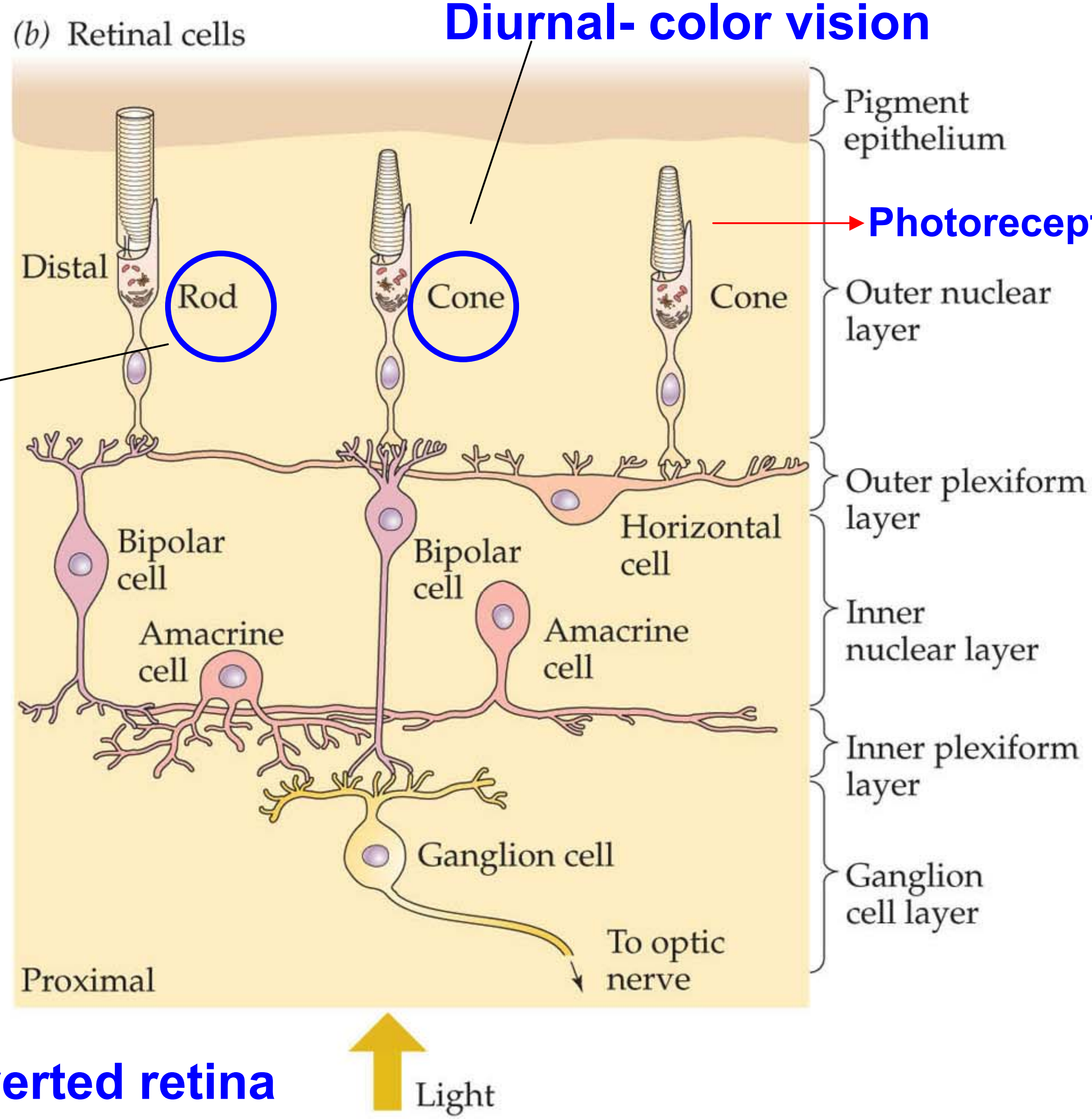


Structure of the mammalian eye and retina



Diurnal- color vision

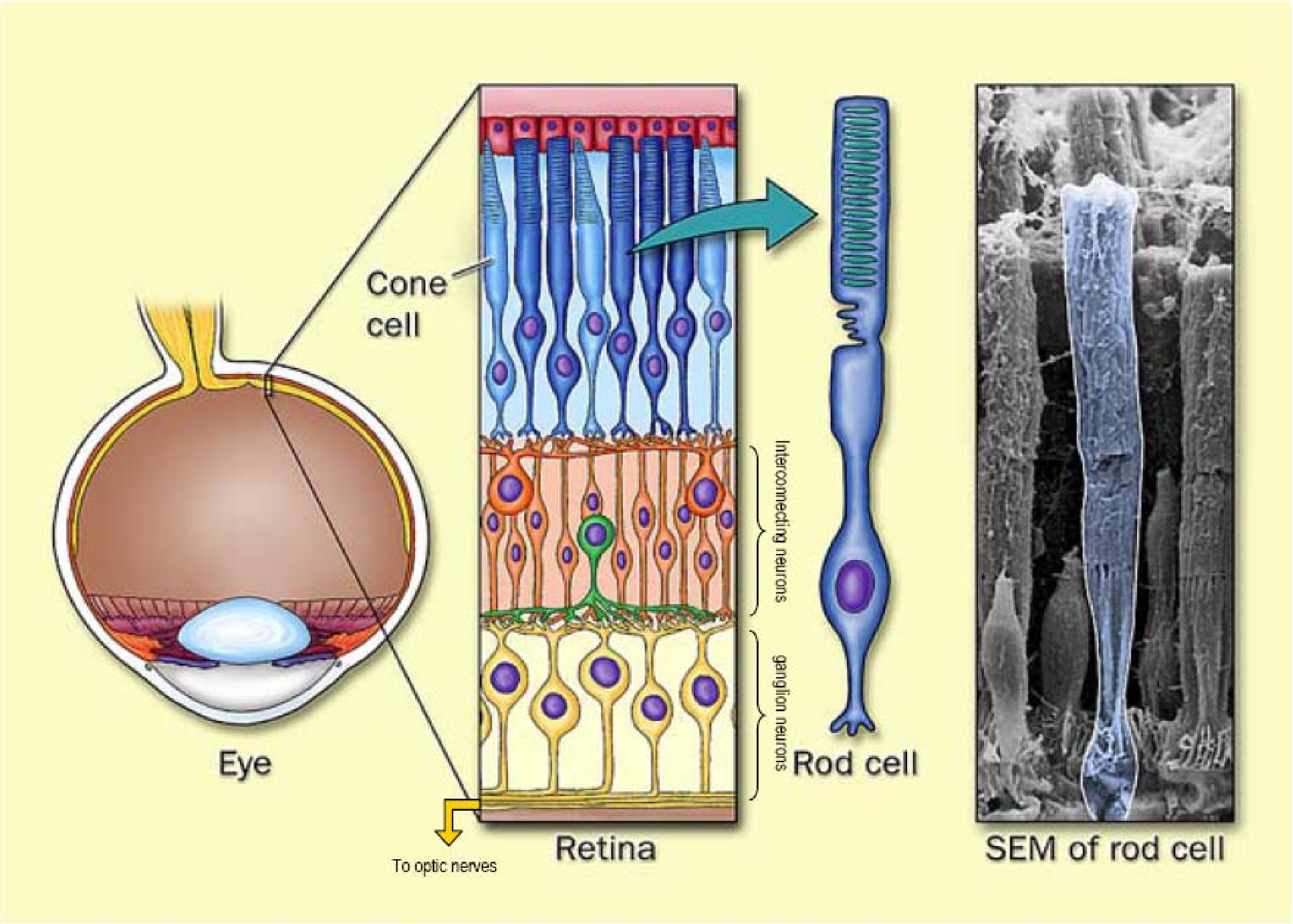
Photoreceptors



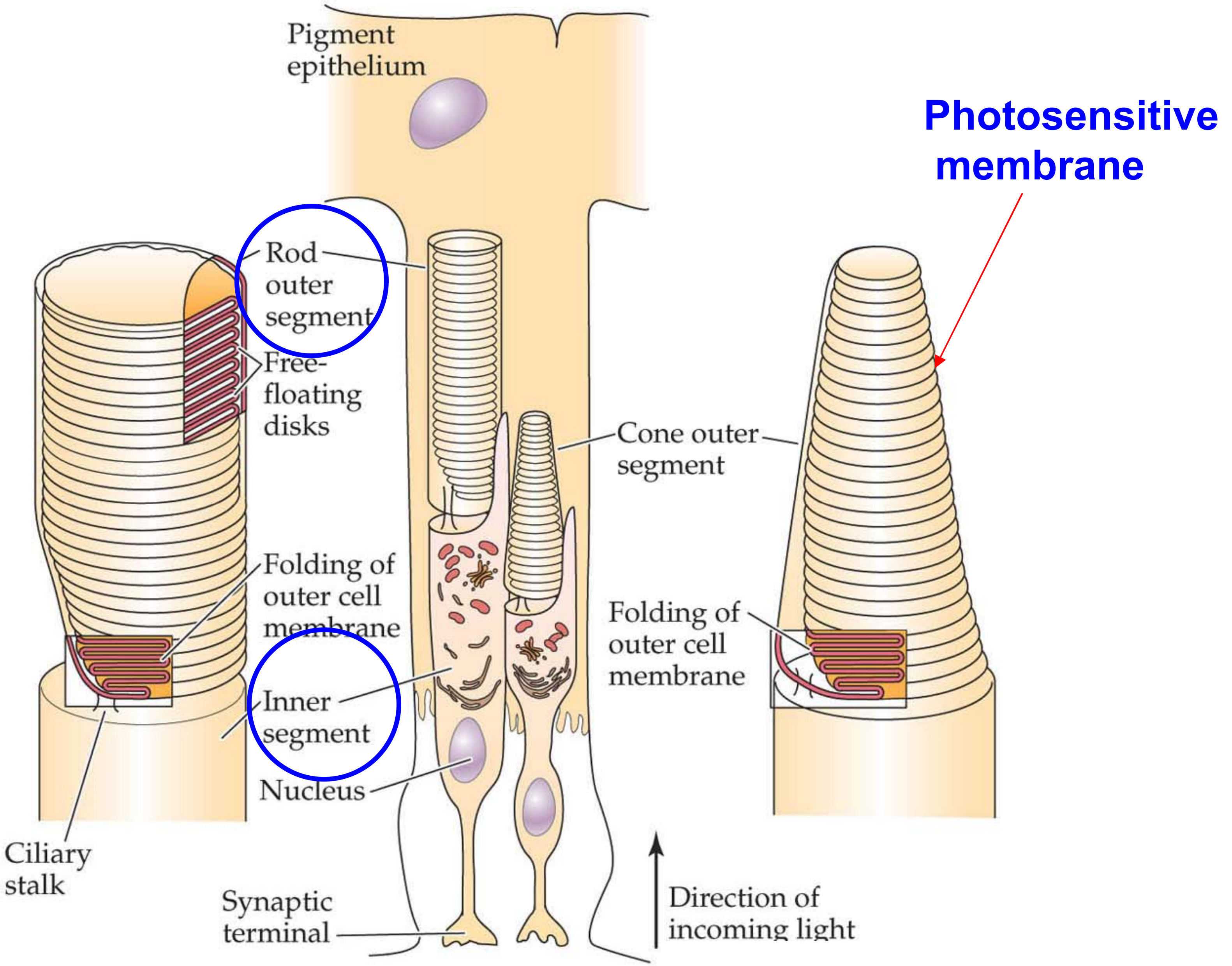
Nocturnal
High resolution

Inverted retina

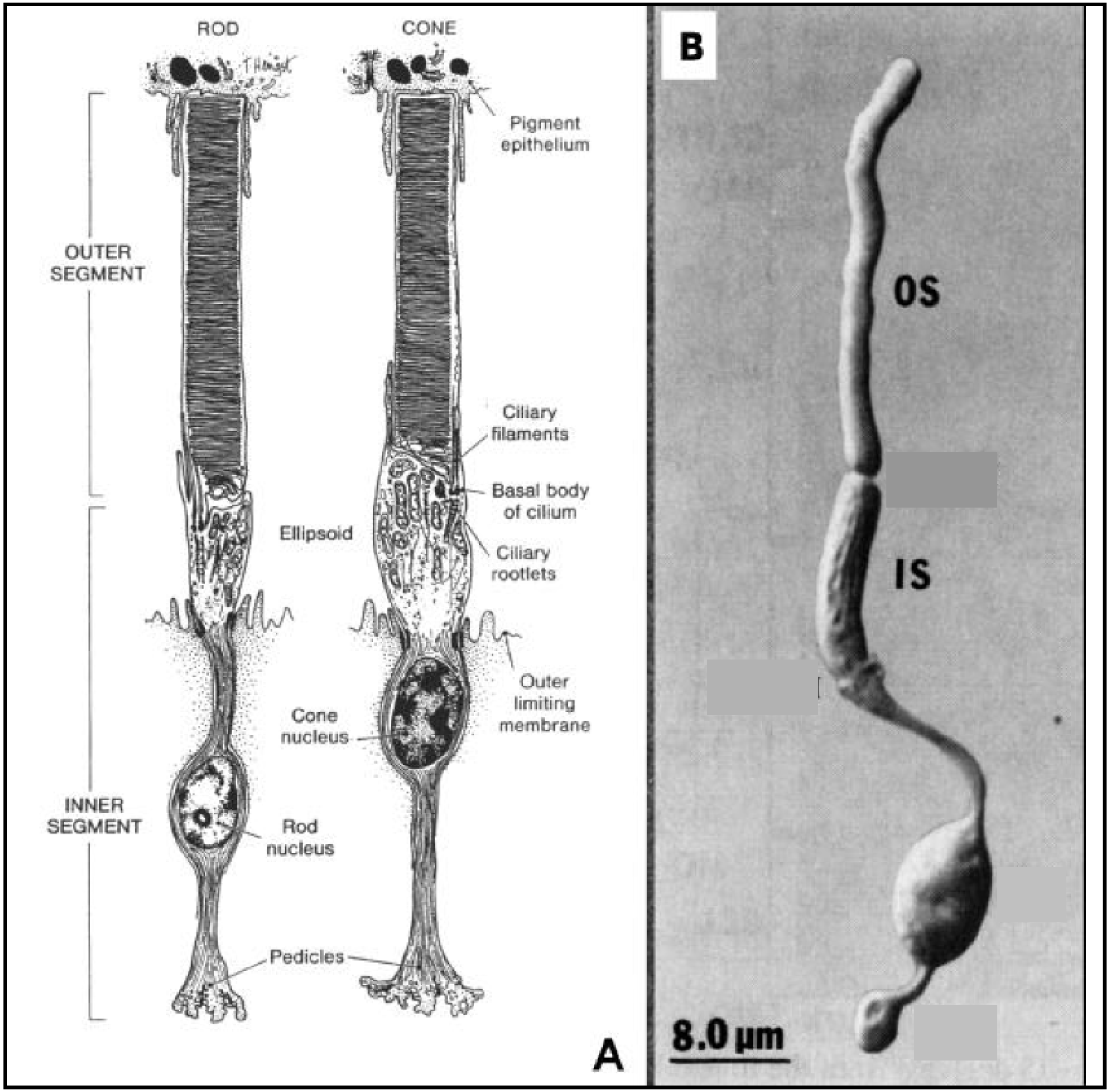
Structure of the mammalian eye and retina



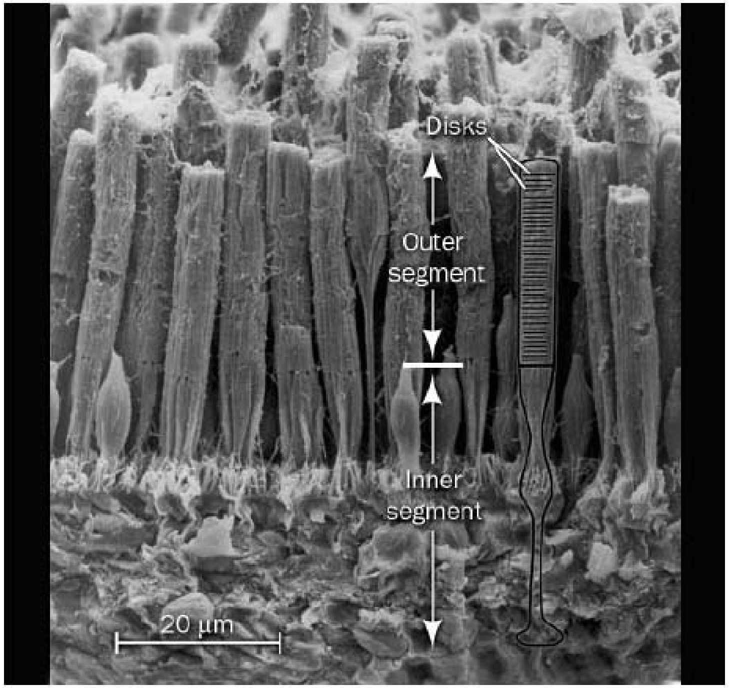
Vertebrate photoreceptors

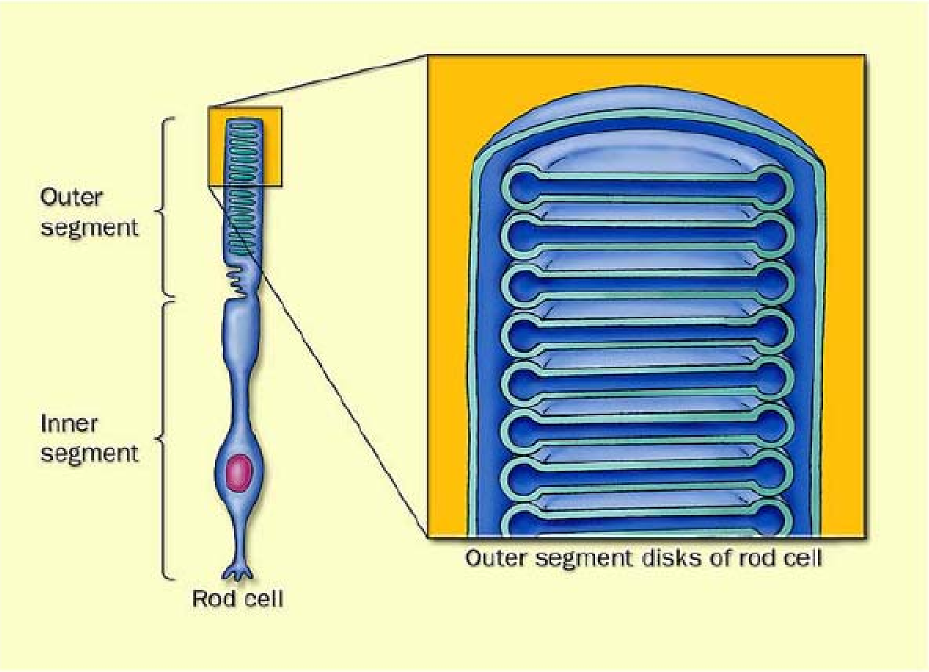


Vertebrate photoreceptors



Vertebrate photoreceptors

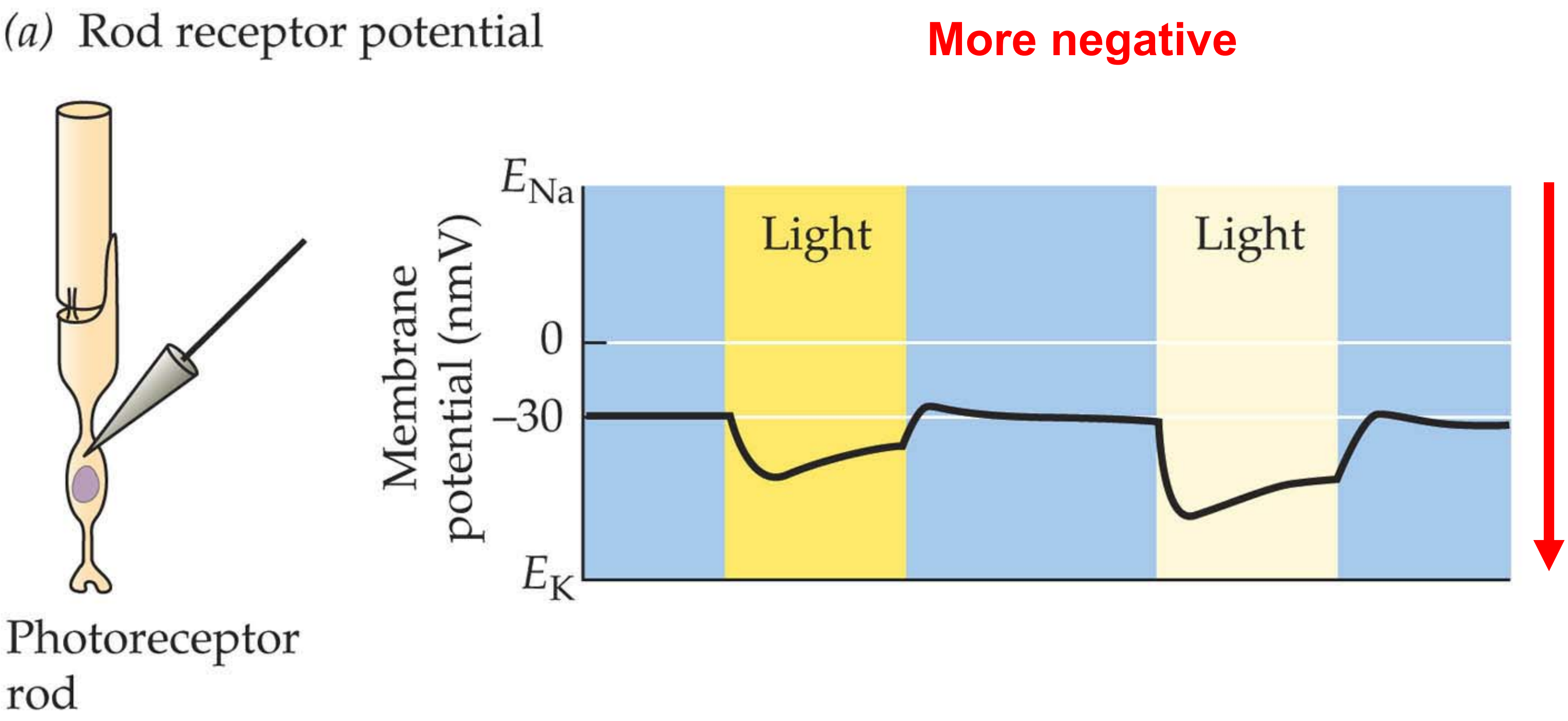




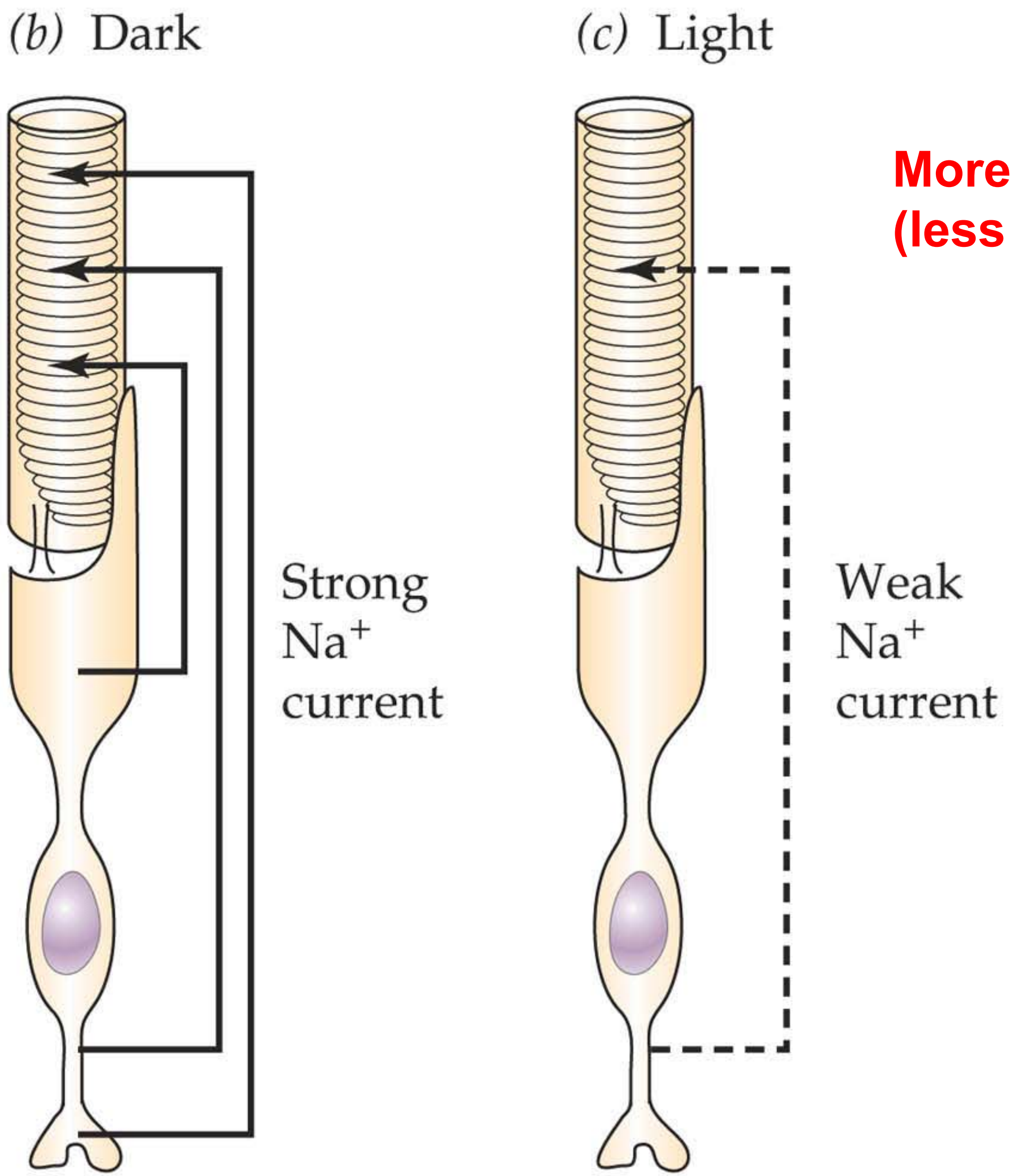
Rod and Cone cells:

- long, narrow, specialized sensory neurons
- They have two distinct cellular compartments:
  a) **outer segment:** contain dozens of membranous disks loaded with the membrane protein **rhodopsin**
  b) **inner segment**: containing the nucleus and many mitochondria, which produce ATP essential for phototransduction
- They have a transmembrane electrical potential (V_m),

Light hyperpolarizes vertebrate photoreceptors



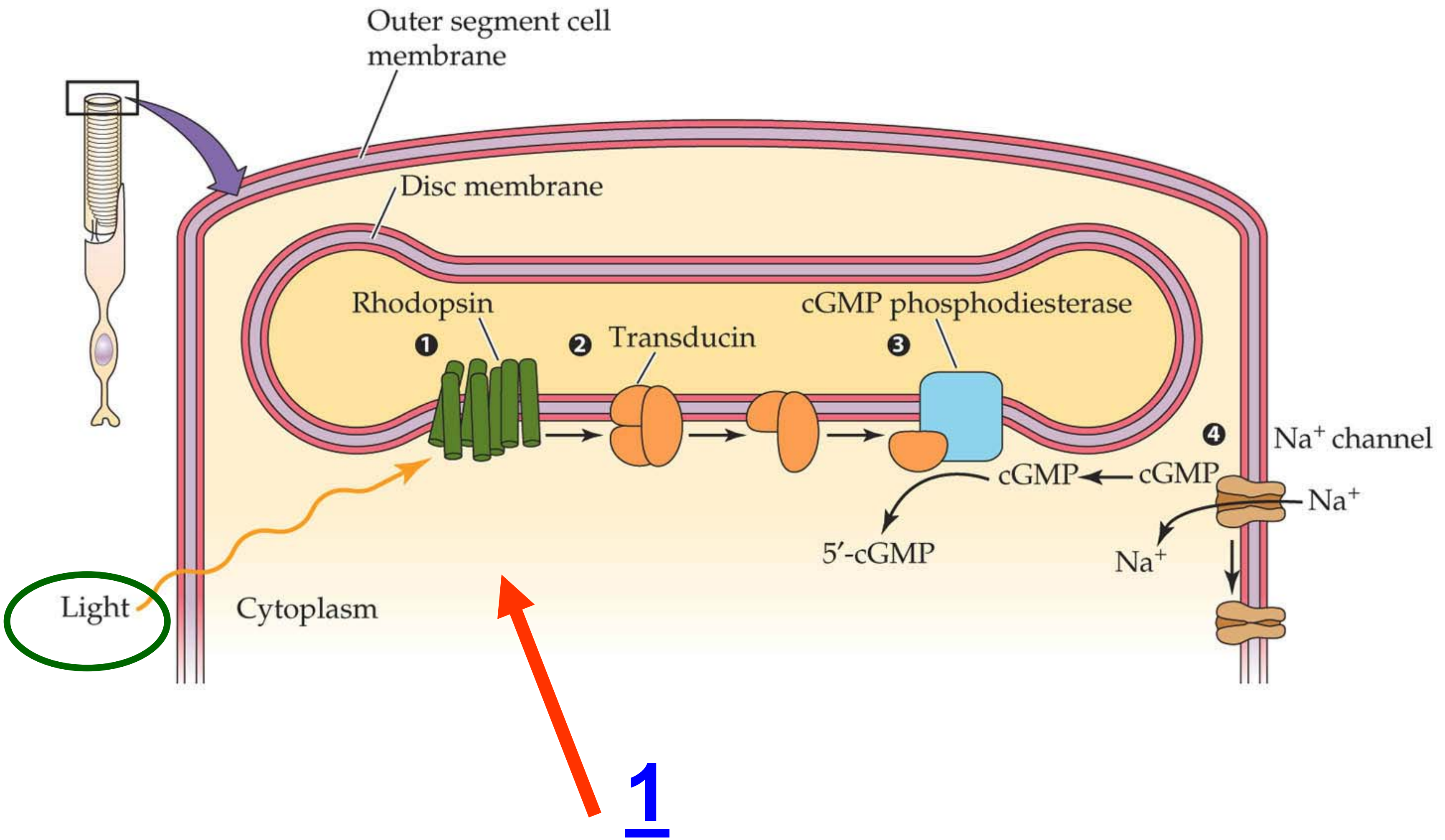
Light hyperpolarizes vertebrate photoreceptors



More negative
(less positive)

Phototransduction

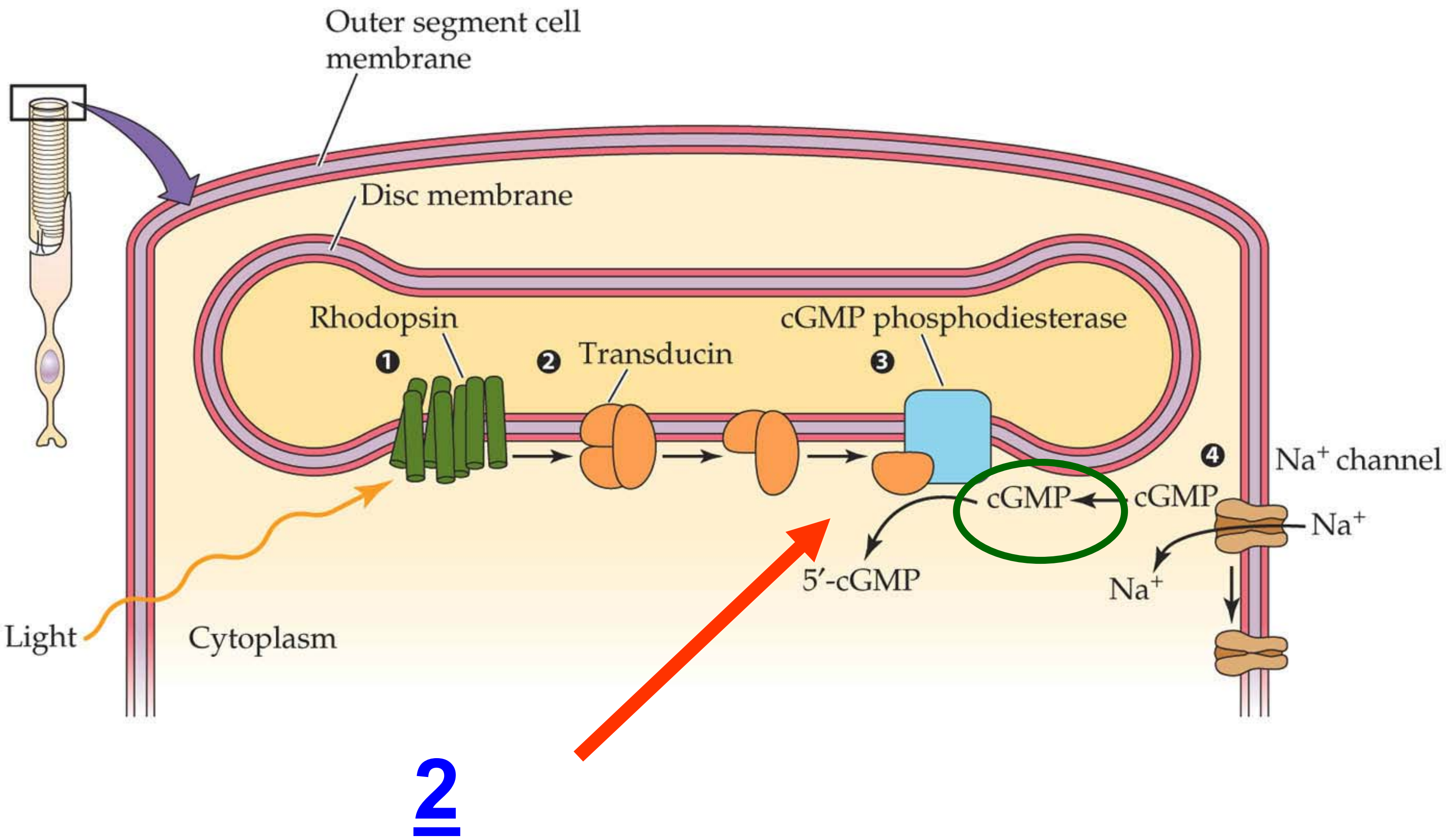
1. Light activates rhodopsin



ANIMAL PHYSIOLOGY, Figure 13.14

Phototransduction

2. Rhodopsin decreases concentration of cGMP

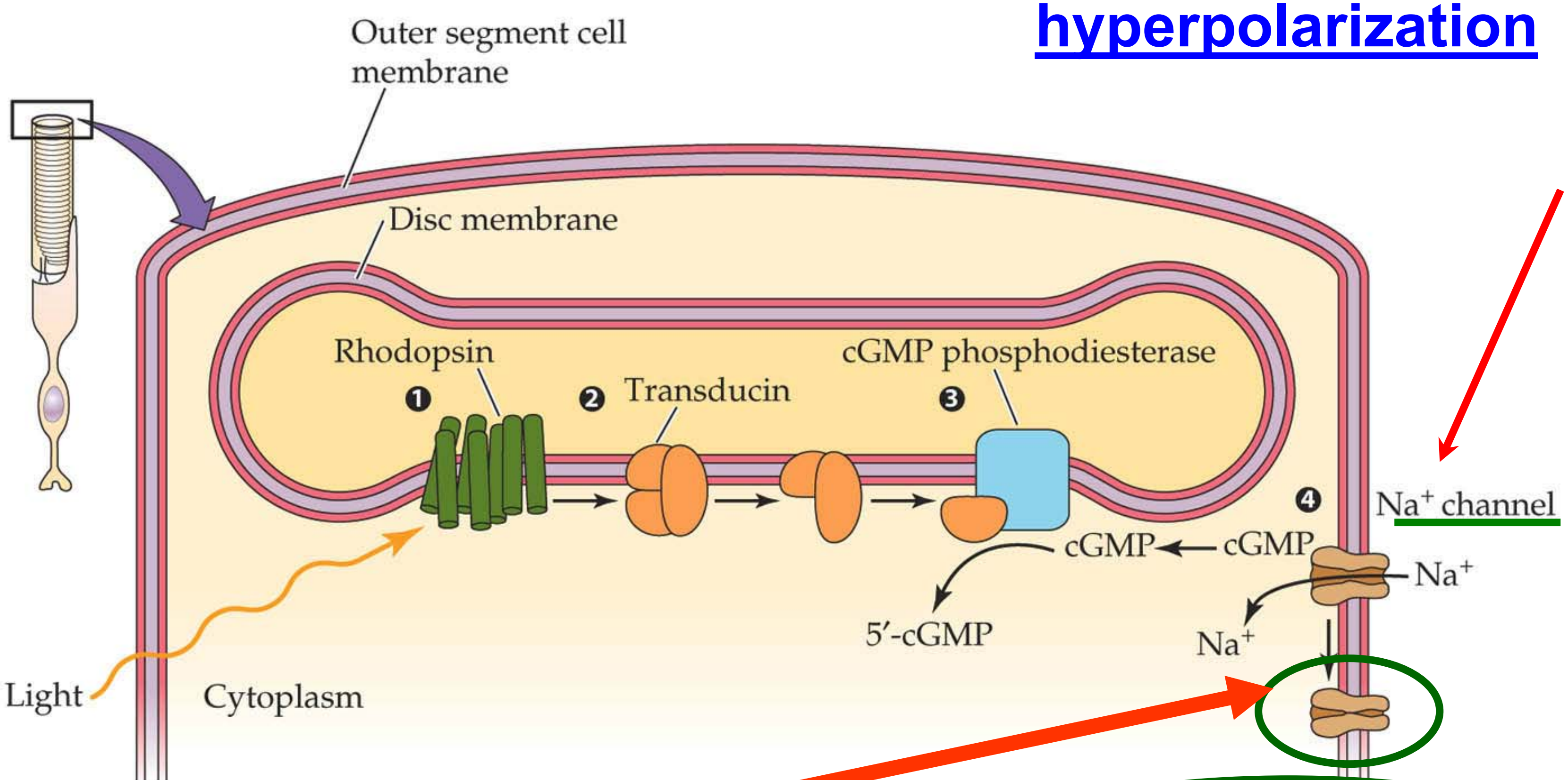


ANIMAL PHYSIOLOGY, Figure 13.14 © 2004 Sinauer Associates, Inc.

Phototransduction

3. Decrease in concentration of cGMP closes ion channels

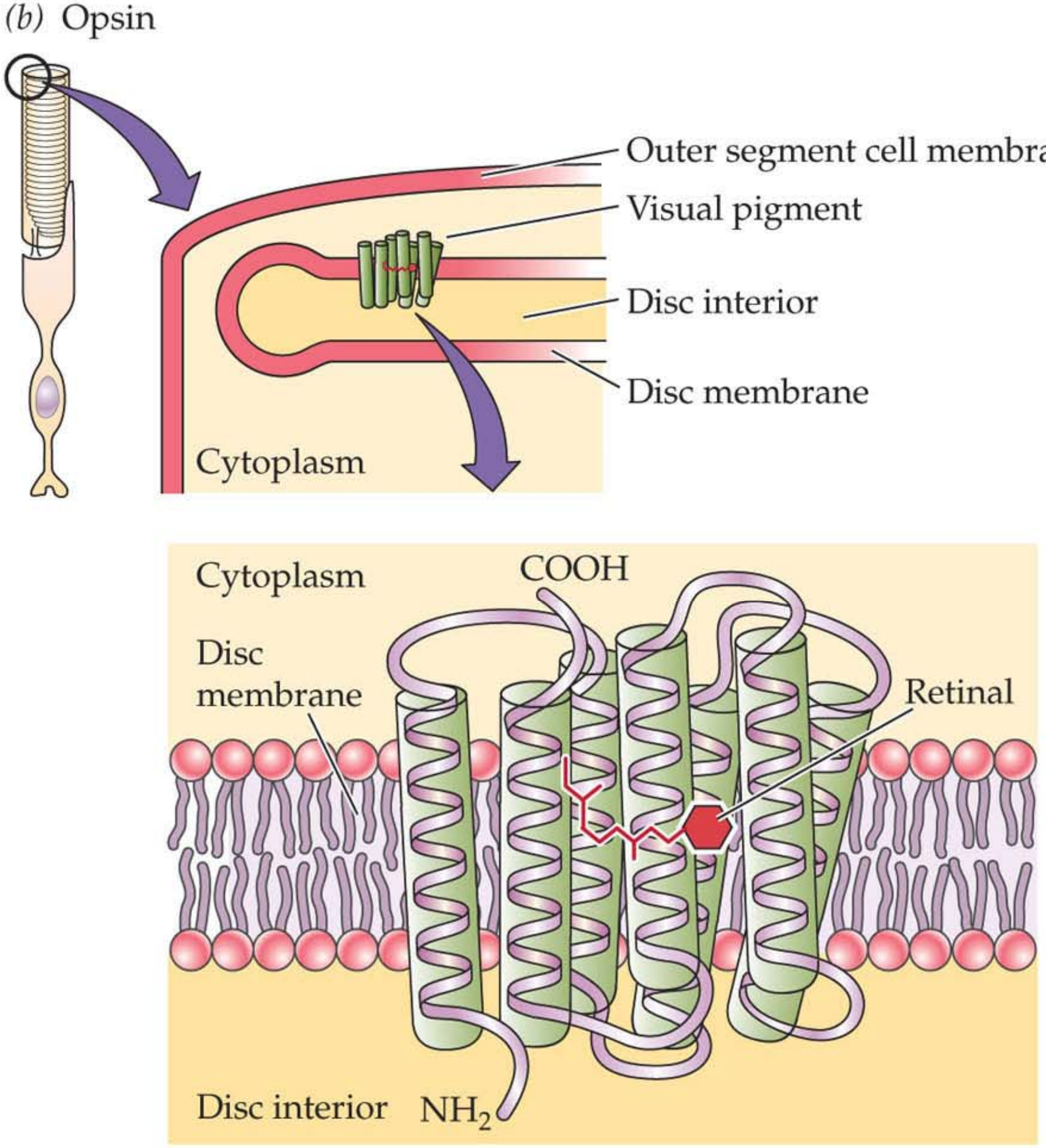
hyperpolarization

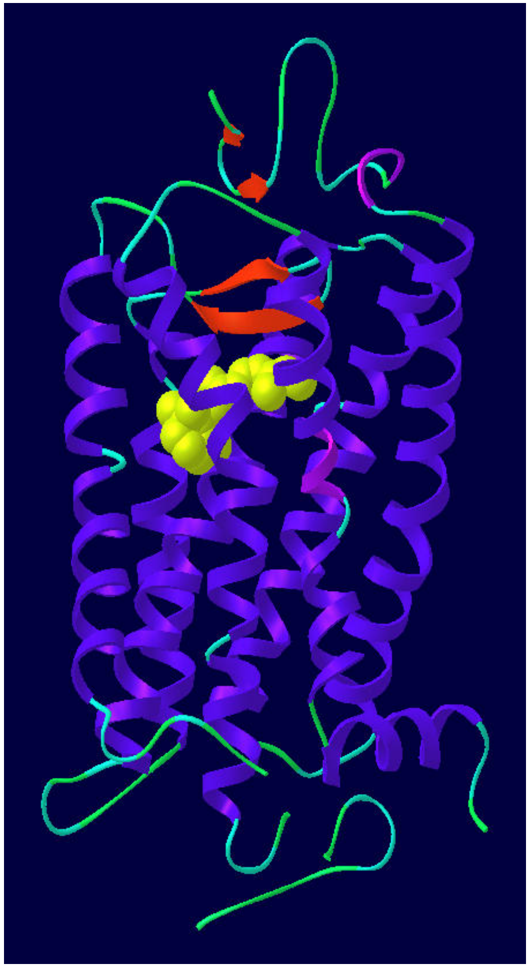


3

membrane potential

Rhodopsin is a photopigment composed of two parts: retinal and opsin



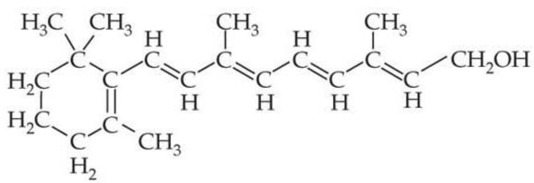


G-protein coupled receptor
-7 transmembrane protein-

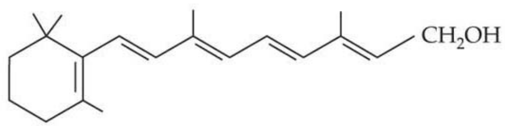
Rhodopsin is a photopigment composed of two parts: retinal and opsin

Retinal is the chromophore

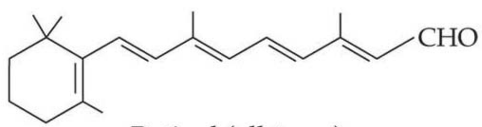
(*a*) Retinal and vitamin A



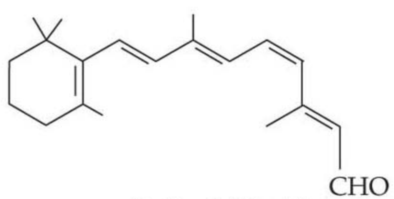
Complete structure of vitamin A (all-*trans*)



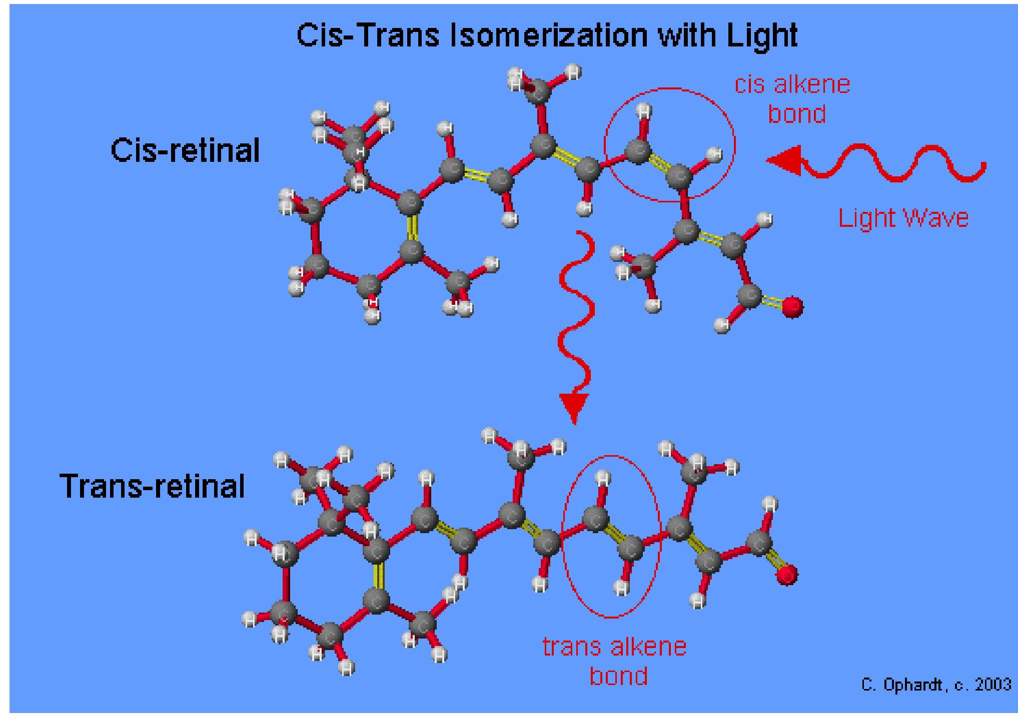
Condensed structure of vitamin A (all-*trans*)



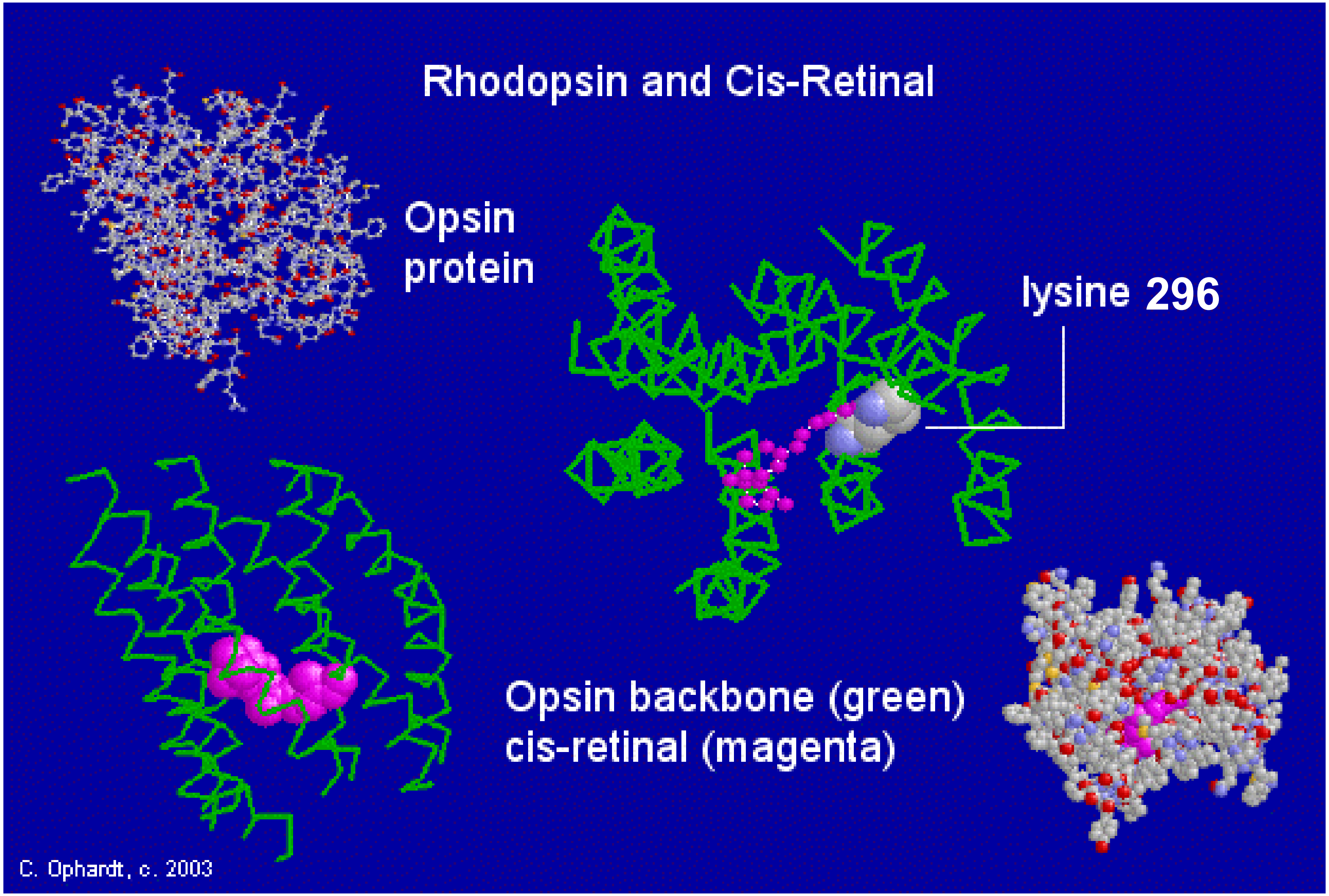
Retinal (all-*trans*)



Retinal (11-*cis*)

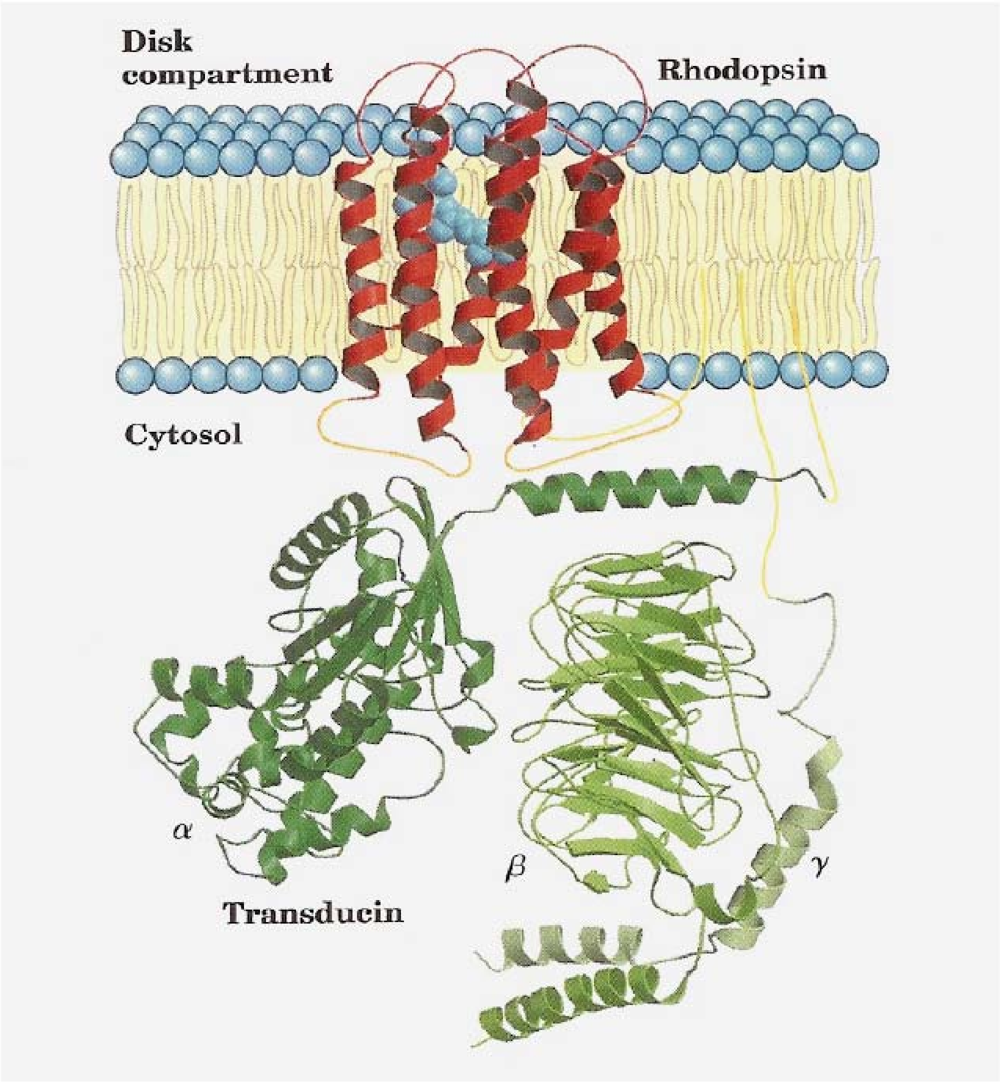


Rhodopsin is a photopigment composed of two parts: retinal and opsin



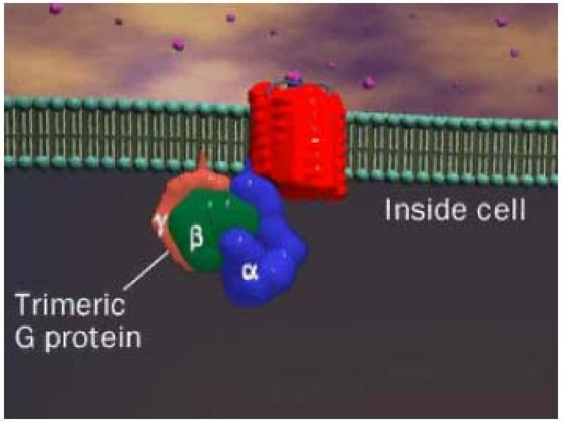
Phototransduction

Structure of Rhodopsis complexed with the G protein (transducin)



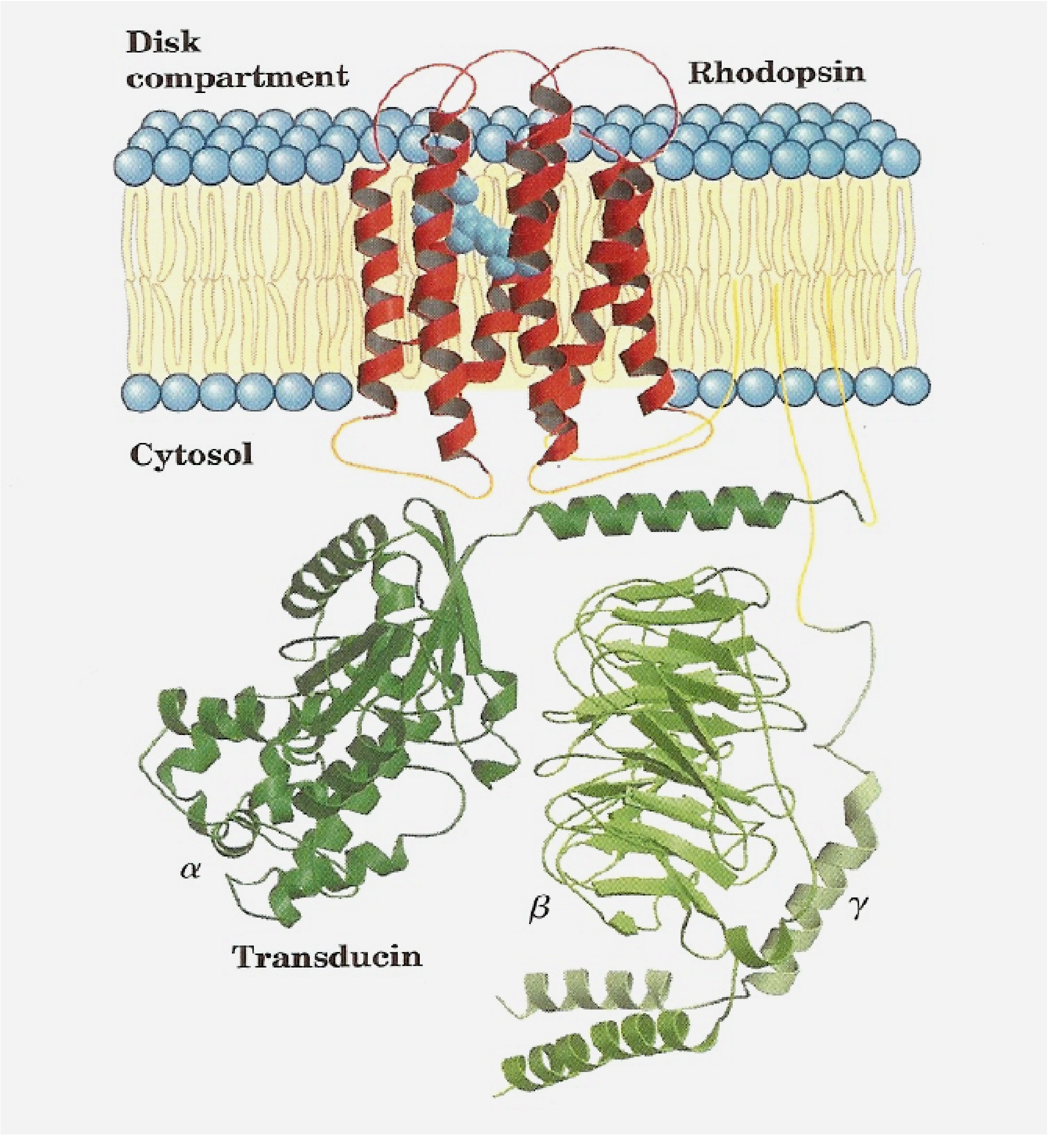
G protein

- Transducin is trimeric GTP-binding protein
- The three subunits are called Ta,Tß & ˙ Tγ
- It can bind either GDP or GTP.
- When GDP is bound, all three subunits remain together



Phototransduction

Structure of Rhodopsis complexed with the G protein (transducin)



G protein

- Transducin is trimeric GTP-binding protein
- The three subunits are called Ta,Tß & T?
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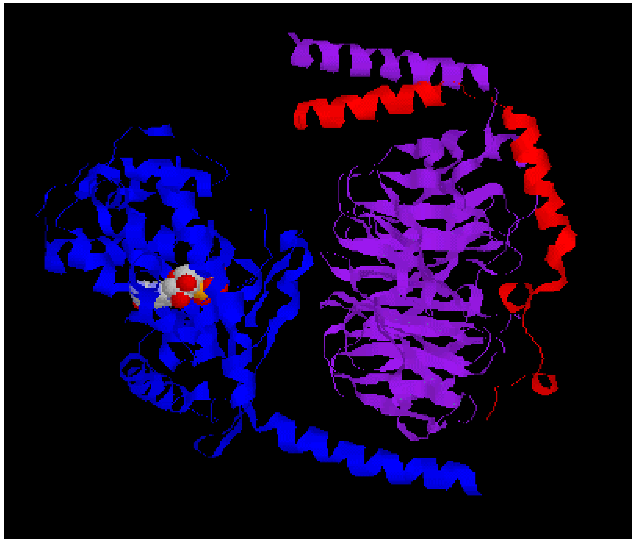
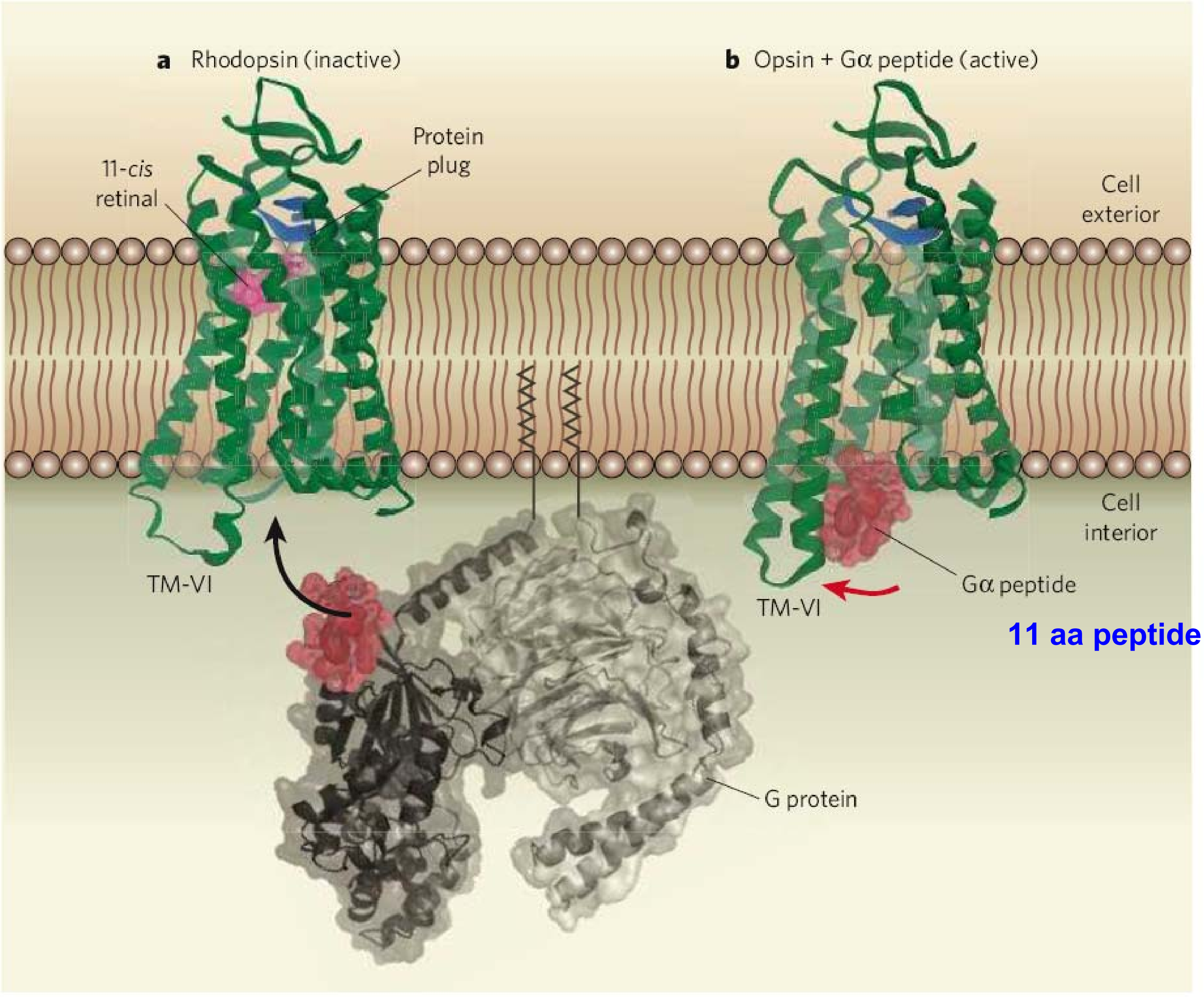
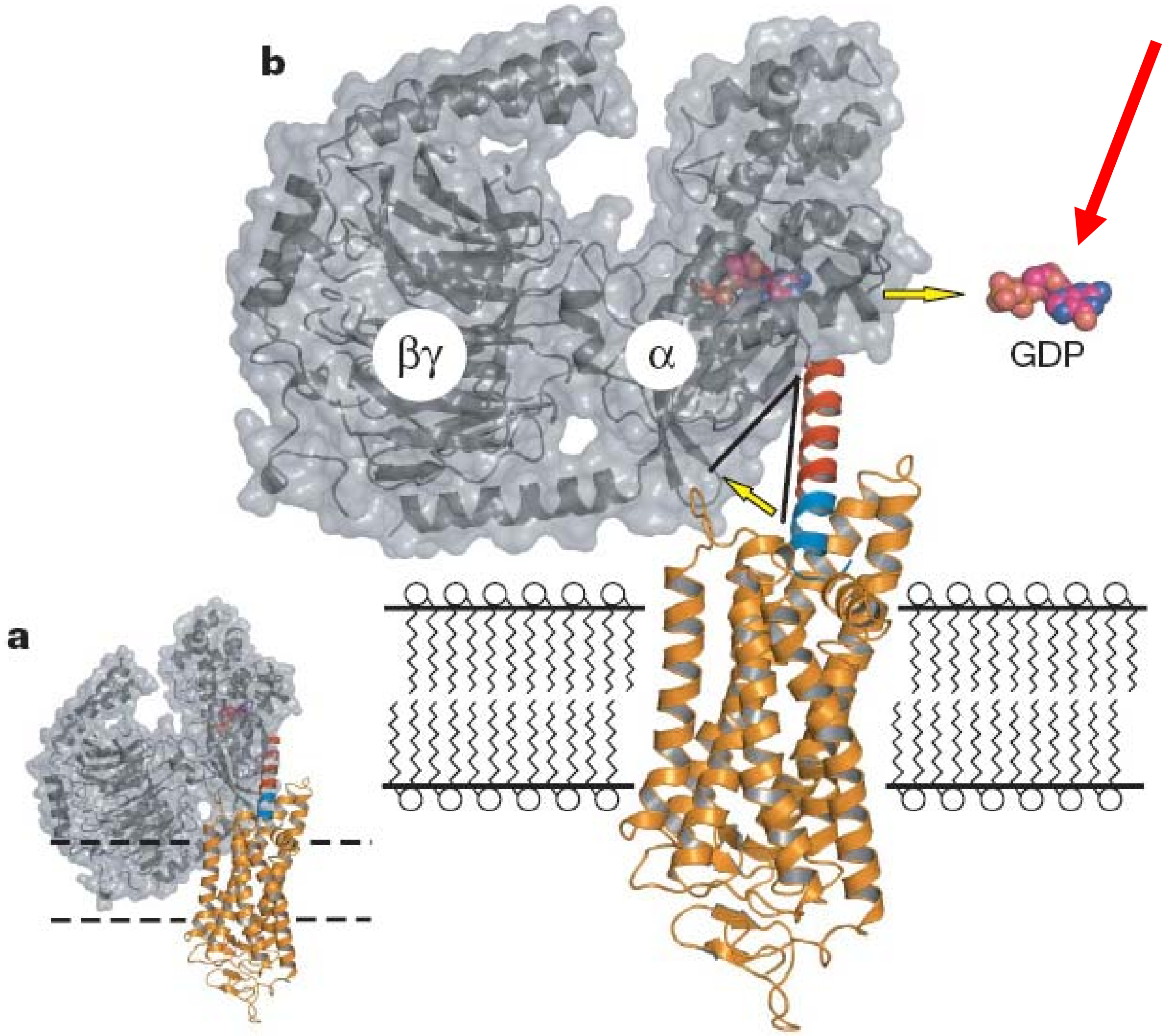


Rhodopsin structure

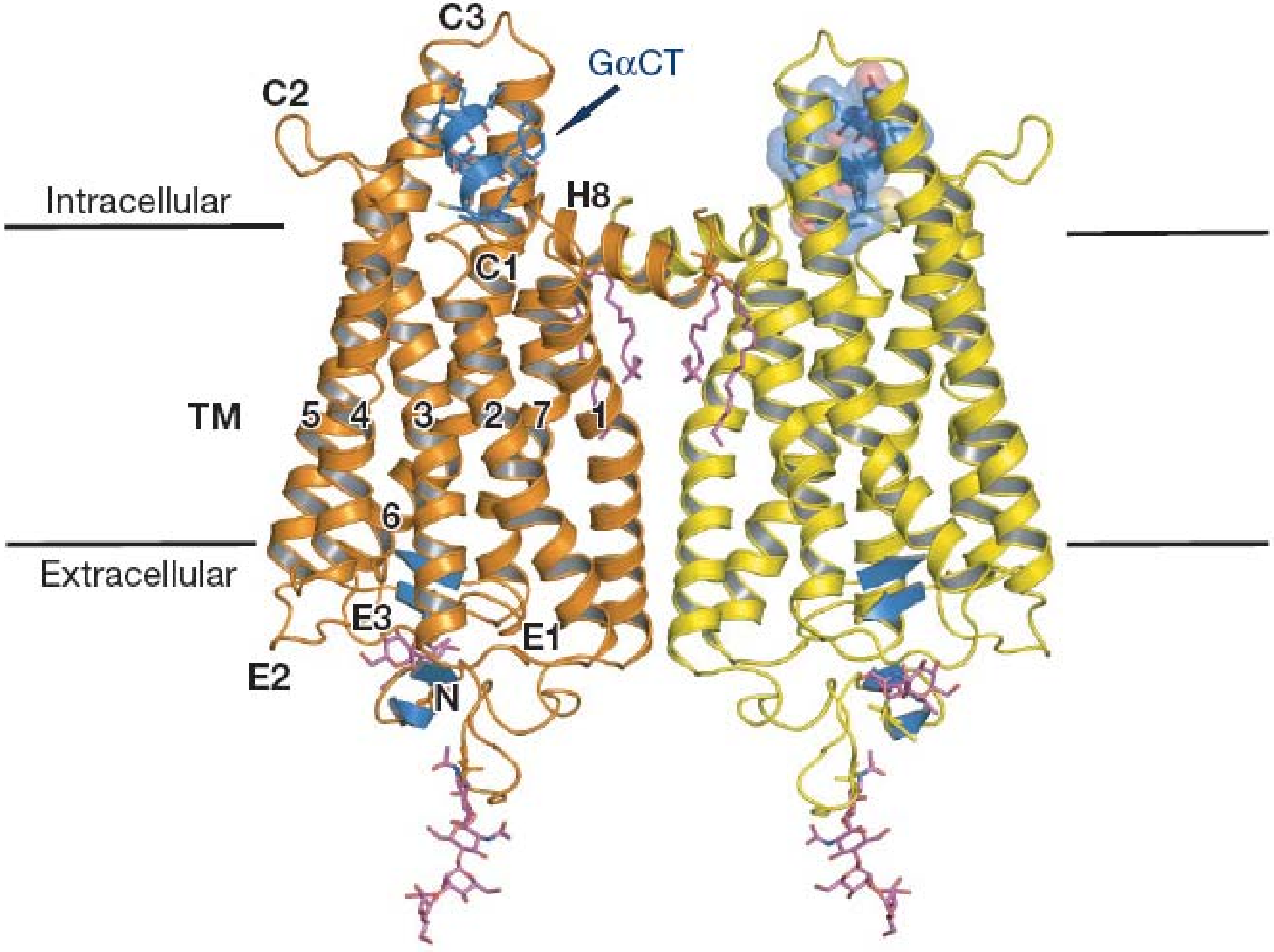


11 aa peptide

Rhodopsin structure

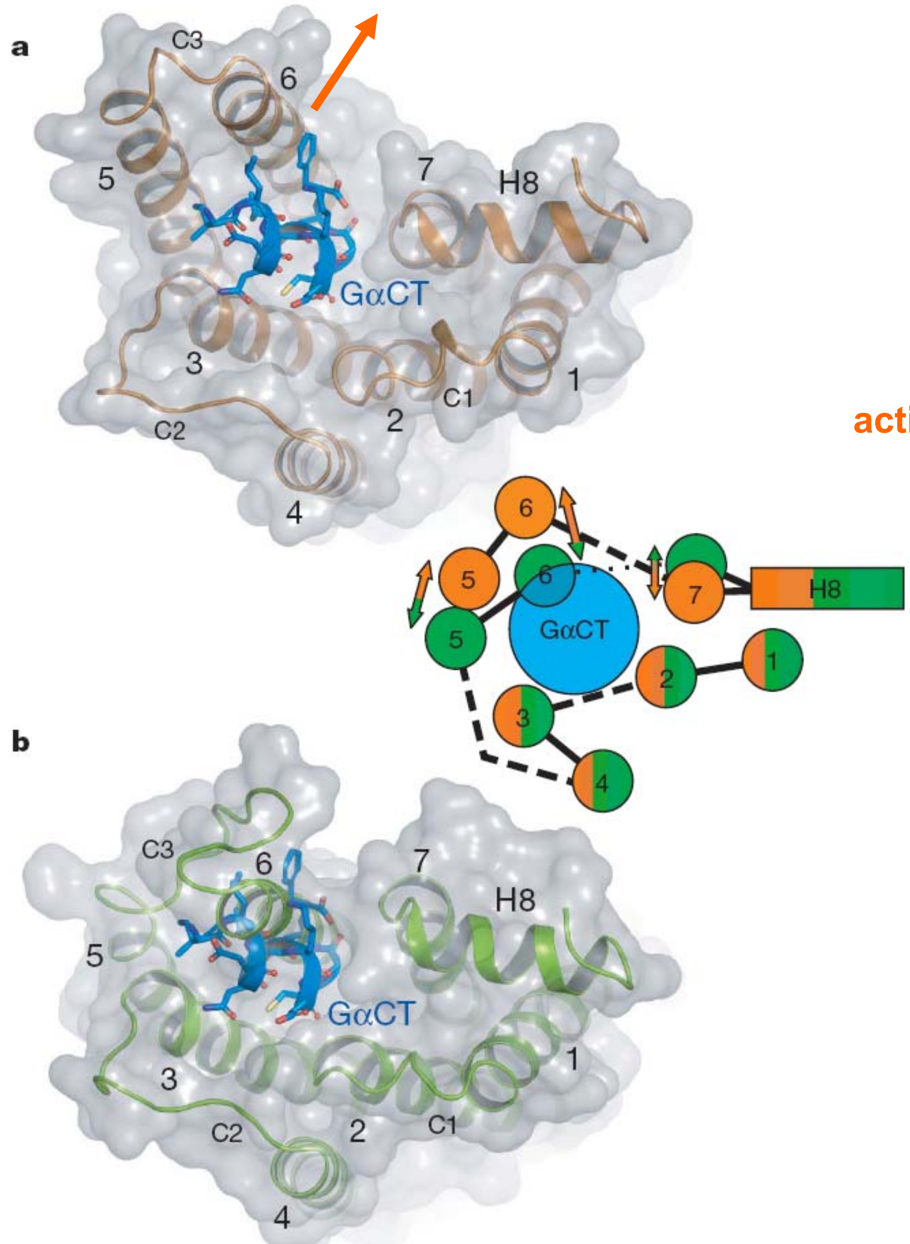


Structure of rhodopsin-GαCT complex



Structure of rhodopsin-GαCT complex (cytoplasm view)

active

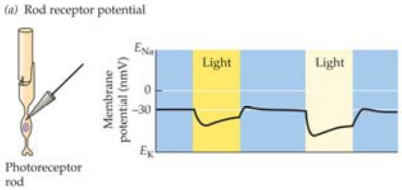


active

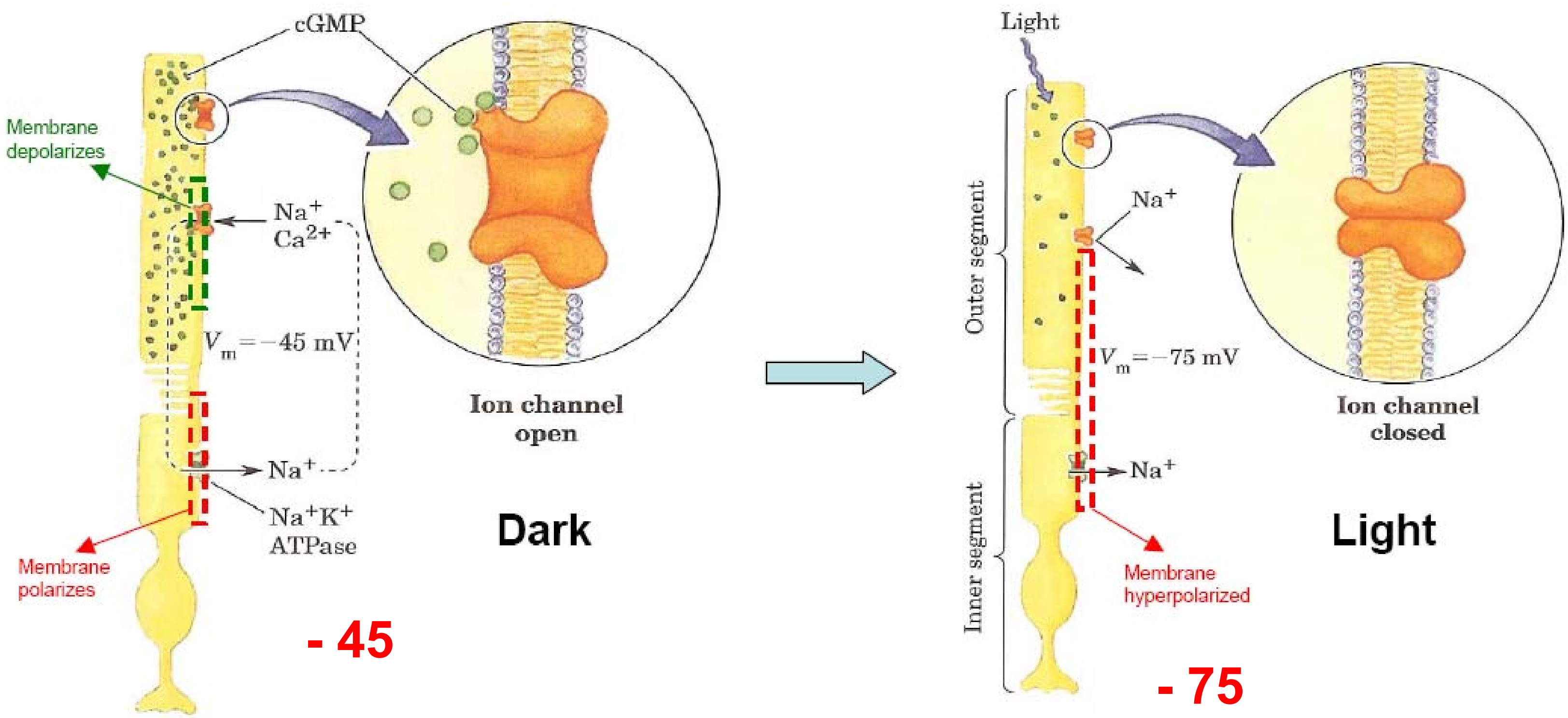
inactive

inactive

Phototransduction



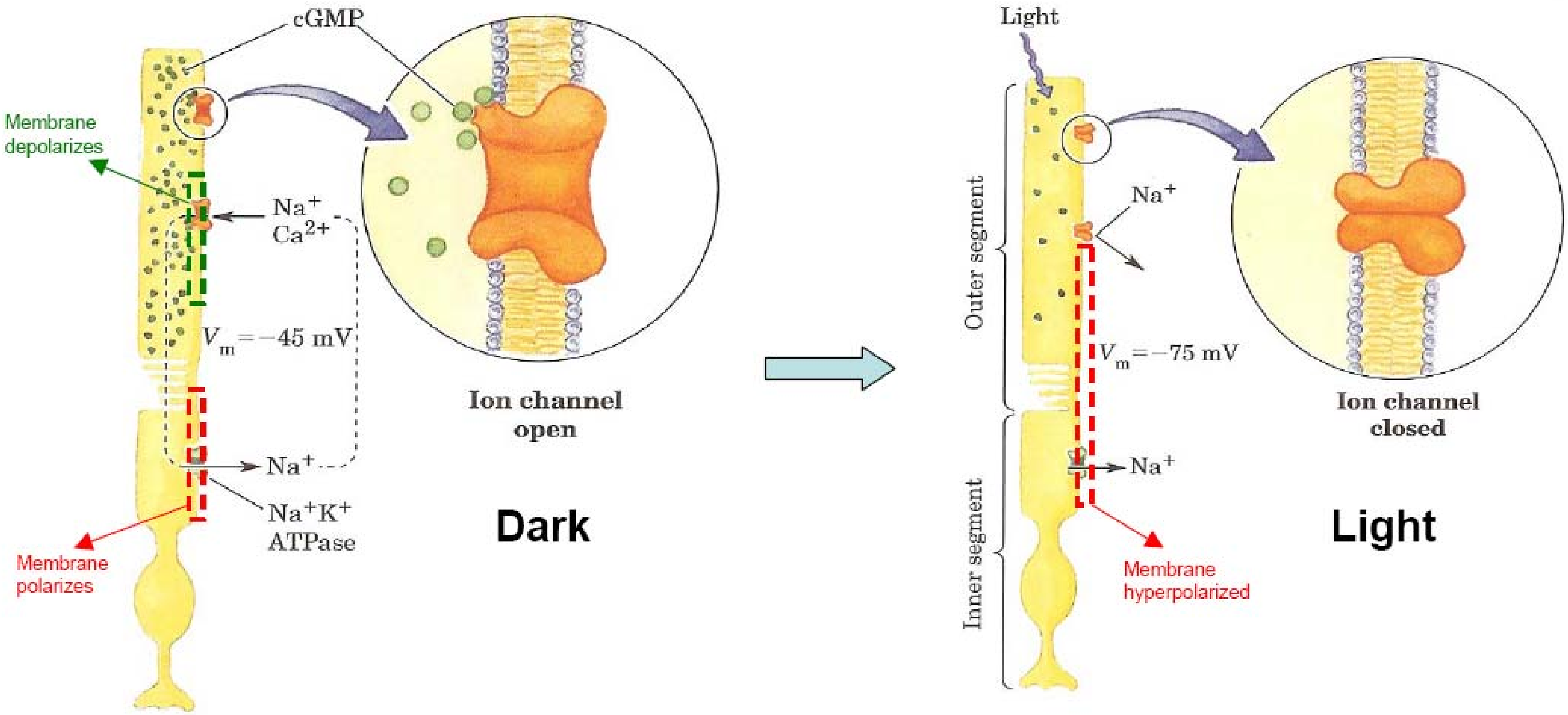
Rod and Cone cells have a transmembrane electrical potential (V_m)



V_m is produced by the pumping activity of two transmembrane proteins:

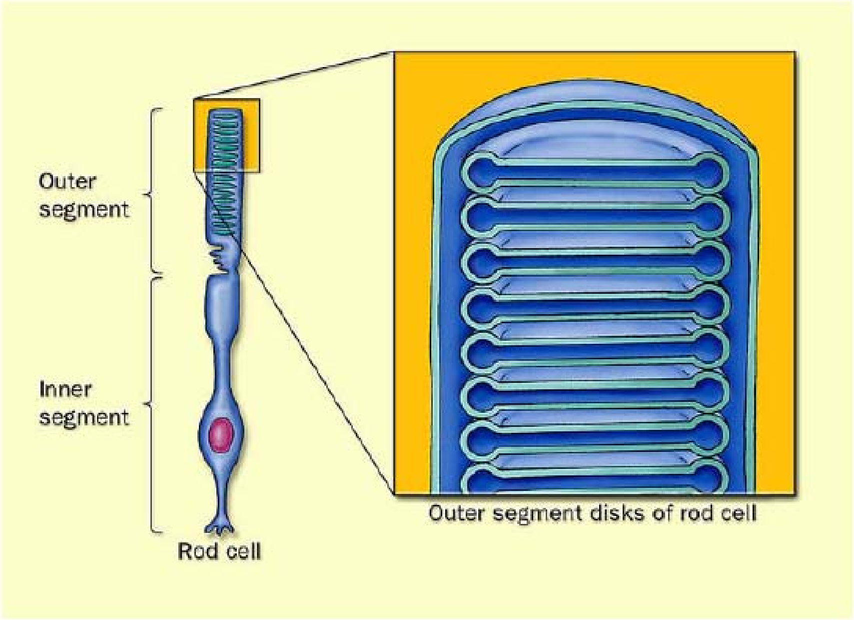
- Na^+K^+ ATPase (located in inner segment)→ pumps3 Na^+ out for every 2 K^+ in→ polarizes the membrane
- Ion channel gated by cGMP (located in outer segment)→ pumps Na+ or Ca+ into the cell → depolarizes the membrane .

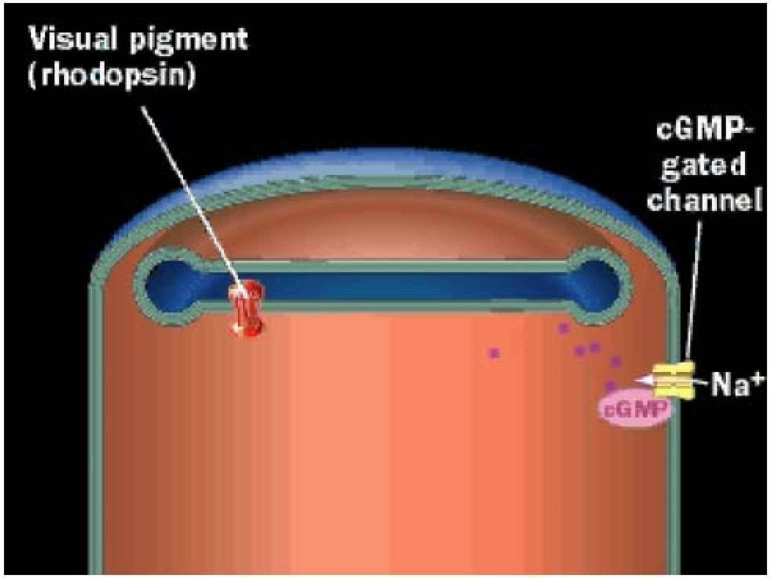
Phototransduction



How does light decrease in the concentration of cGMP ?

Phototransduction

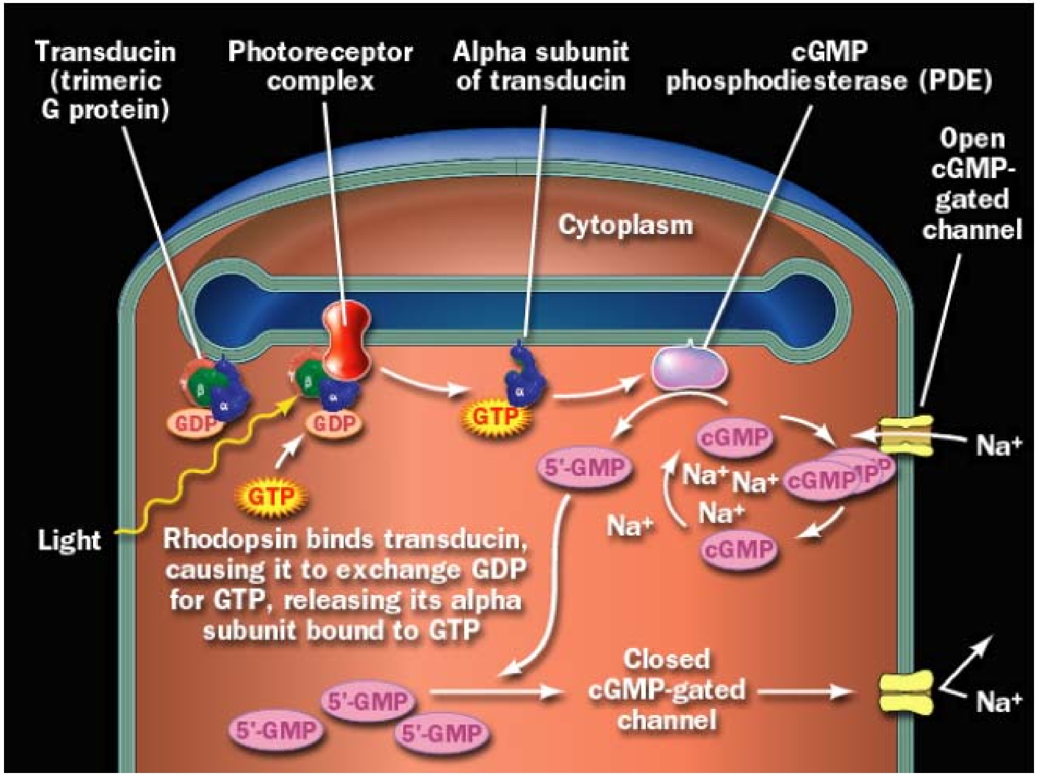


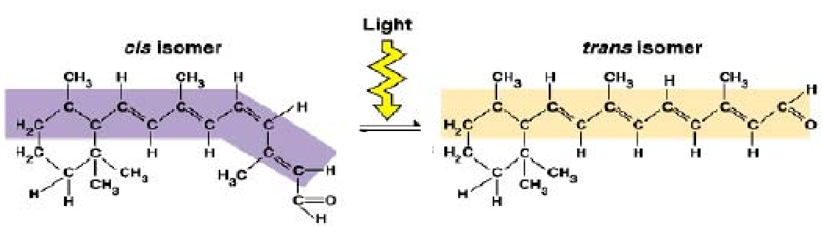


Phototransduction

LIGHT

Sequence of events after light absorption



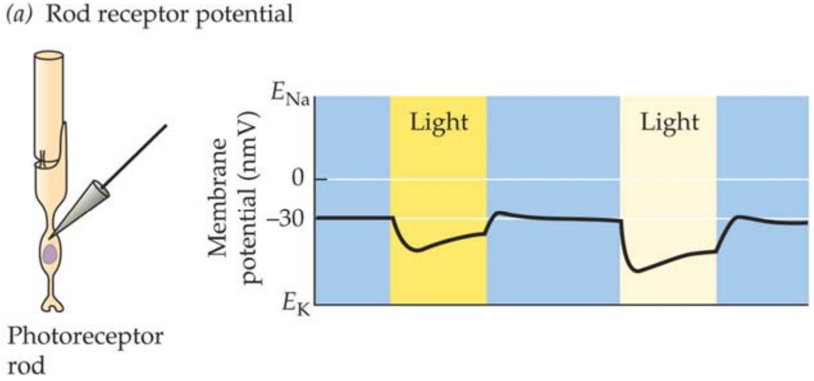


- Light absorption converts 11-cis-retinal to all-trans-retinal
- This change in chromophore causes conformational change in the rhodopsin (first stage of visual transduction)
- Excited rhodopsin interact with G protein Transducin
- Interaction of transducin with rhodopsin, catalyses the replacement of bound GDP by GTP.
- Transducin dissociates into Tß? and GTP boundTa.
- GTP bound Tα carries the signal from excited rhodopsin to the PDE (cGMP specific phosphodiesterase). PDE which was inactive in dark due to bound inhibitor become activated (due to removal and binding of inhibitor with Tα).
- Each activated PDE degrates many molecules of cGMP to biologically inactive 5'-GMP. This cause lowering of [cGMP] in outer segment within fraction of a second.
- Due to low [cGMP], the cGMP gated ion channels get closed.
- This blocks the reentry of Na^+ and Ca^+into the outer segment.
- Membrane gets hyperpolarized

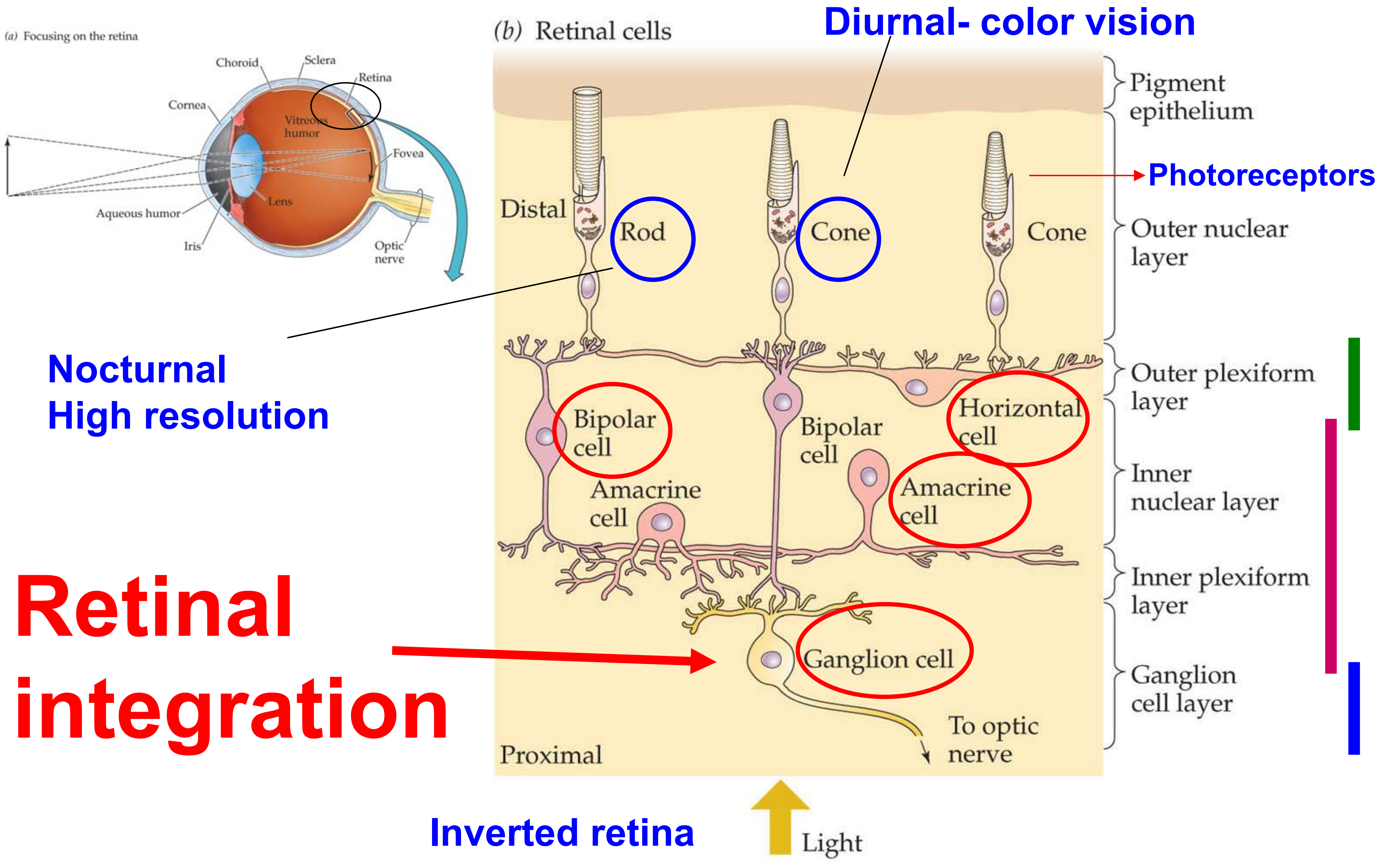
Sensitivity to light → Sensitivity to pattern

Spatial patterns

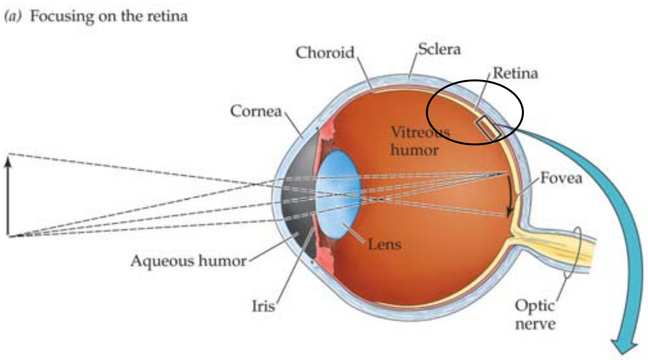
Temporal patterns

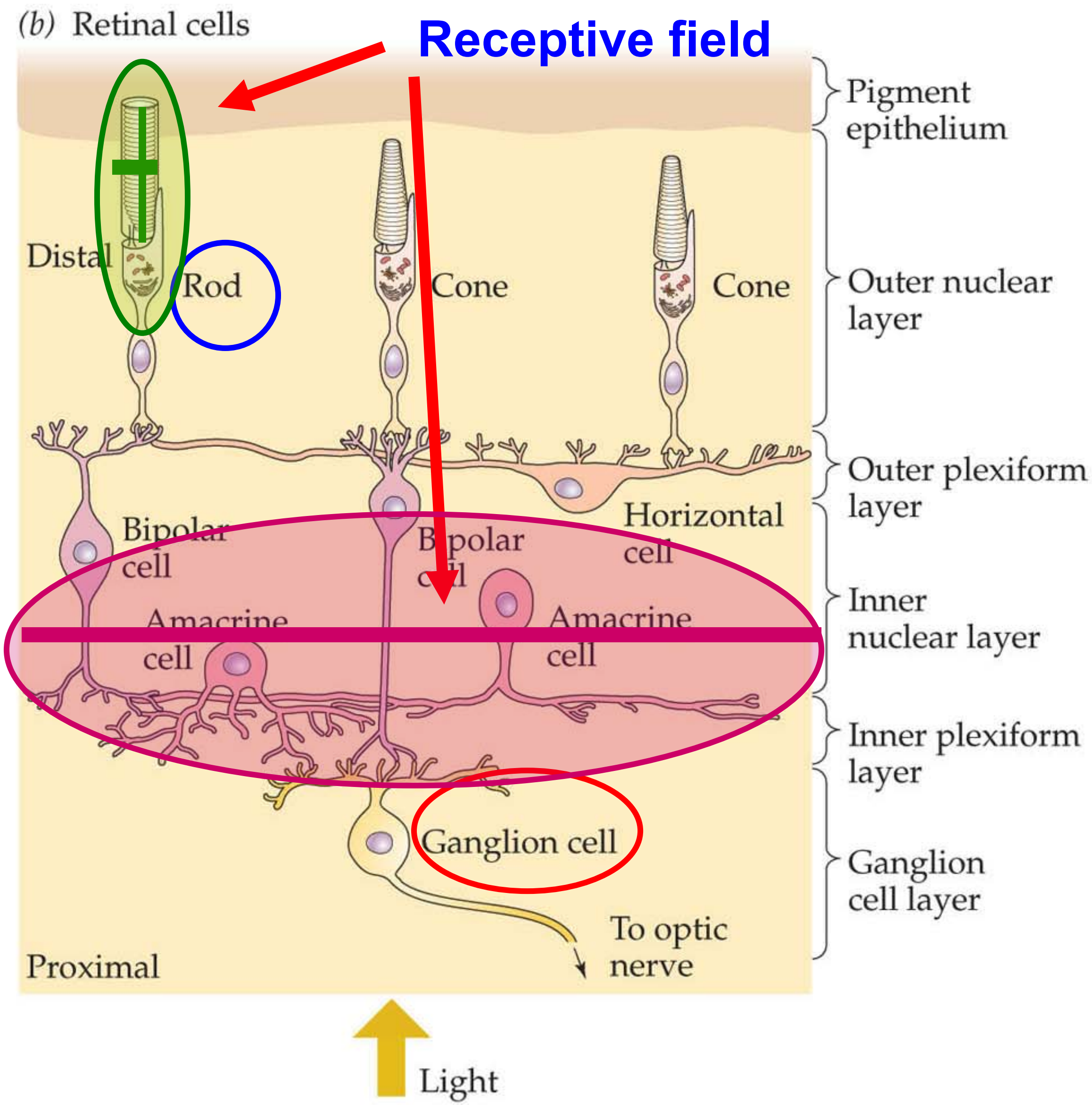


Structure of the mammalian eye and retina



Structure of the mammalian eye and retina

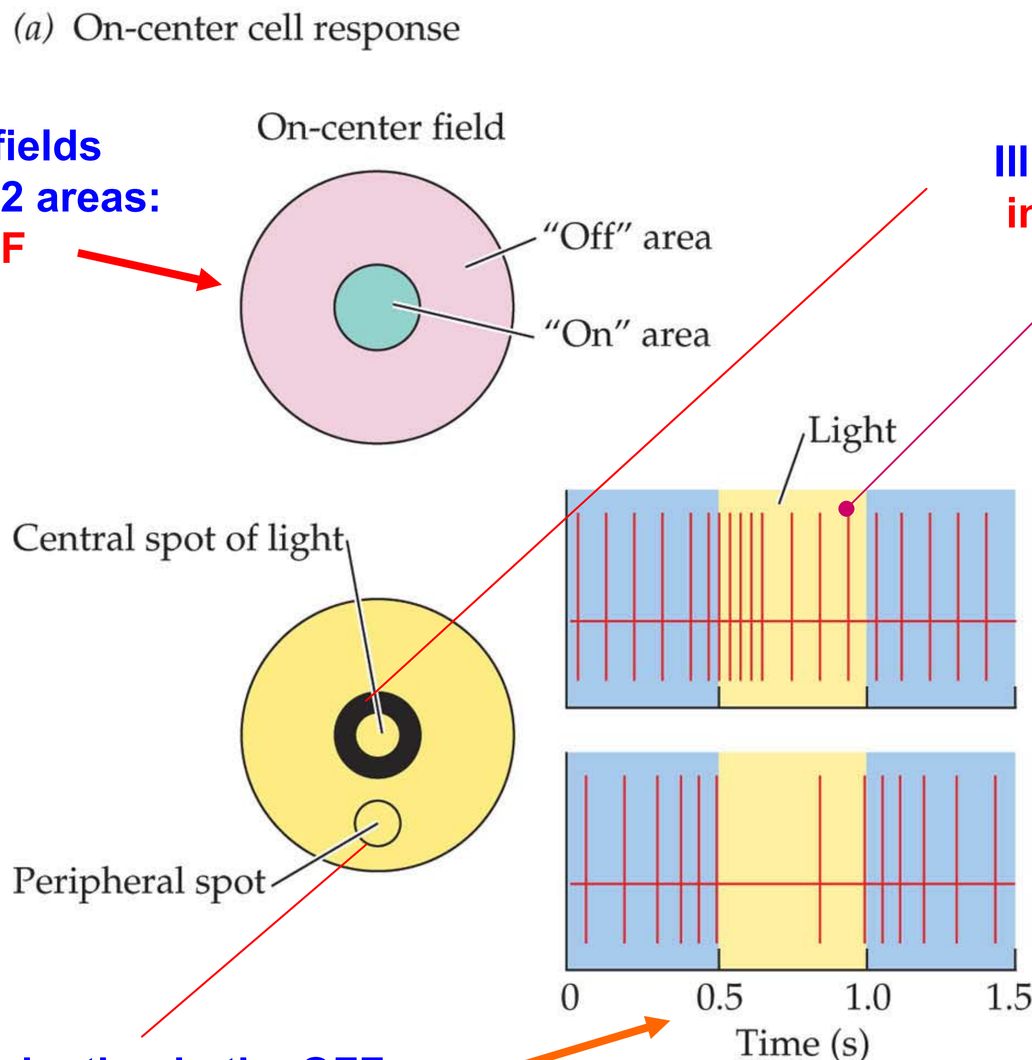




Retinal integration

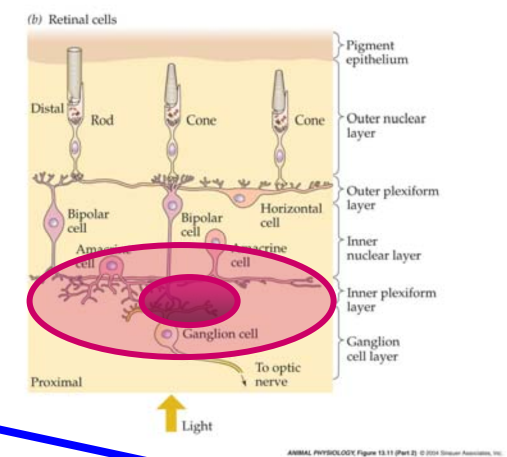
Receptive fields and responses of ganglion cells in the retina of a cat

Receptive fields divided in 2 areas: ON and OFF



Illumination in the center increases activity

Illumination in the OFF area decreases activity

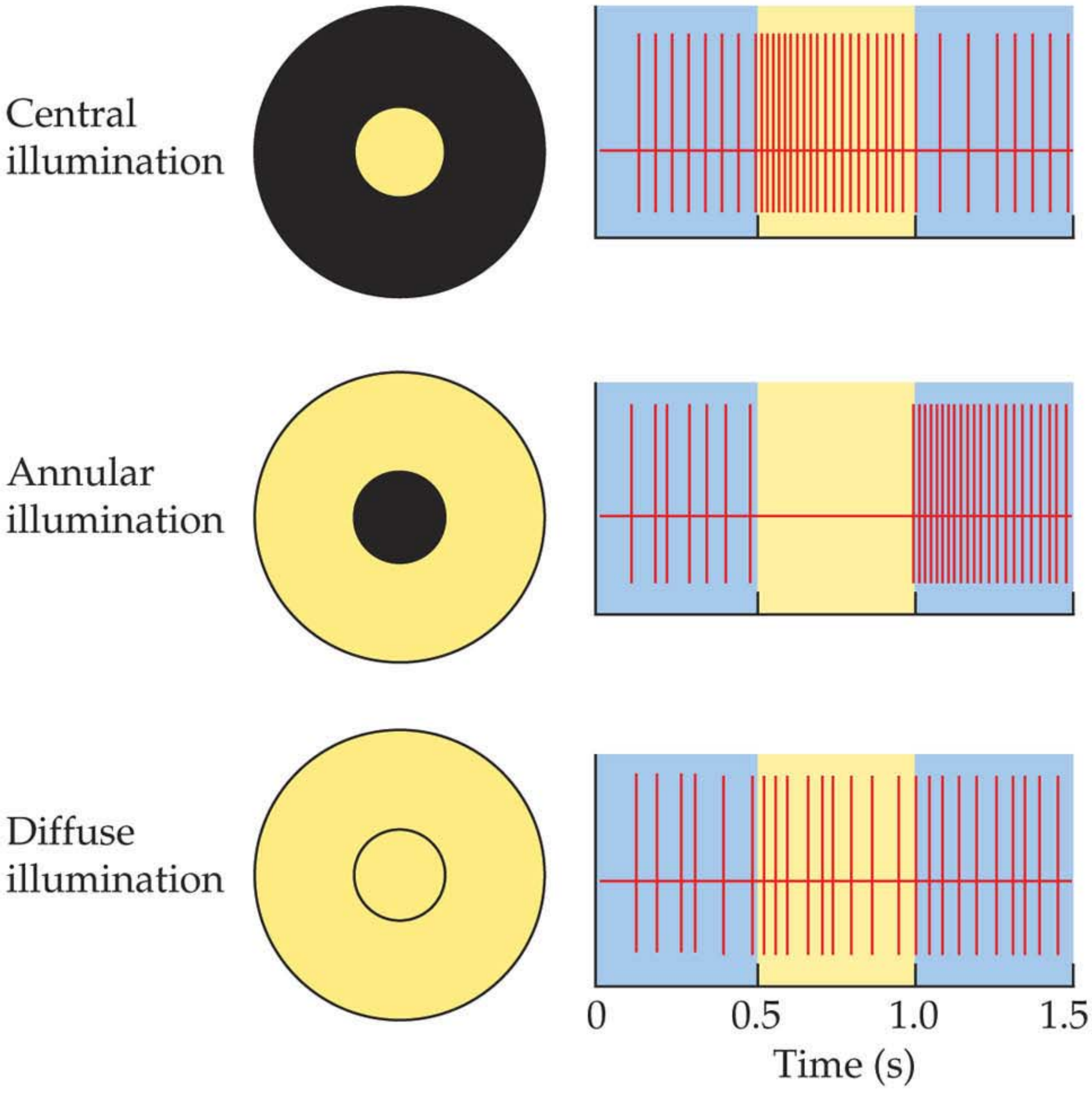


Receptive fields and responses of ganglion cells in the retina of a cat

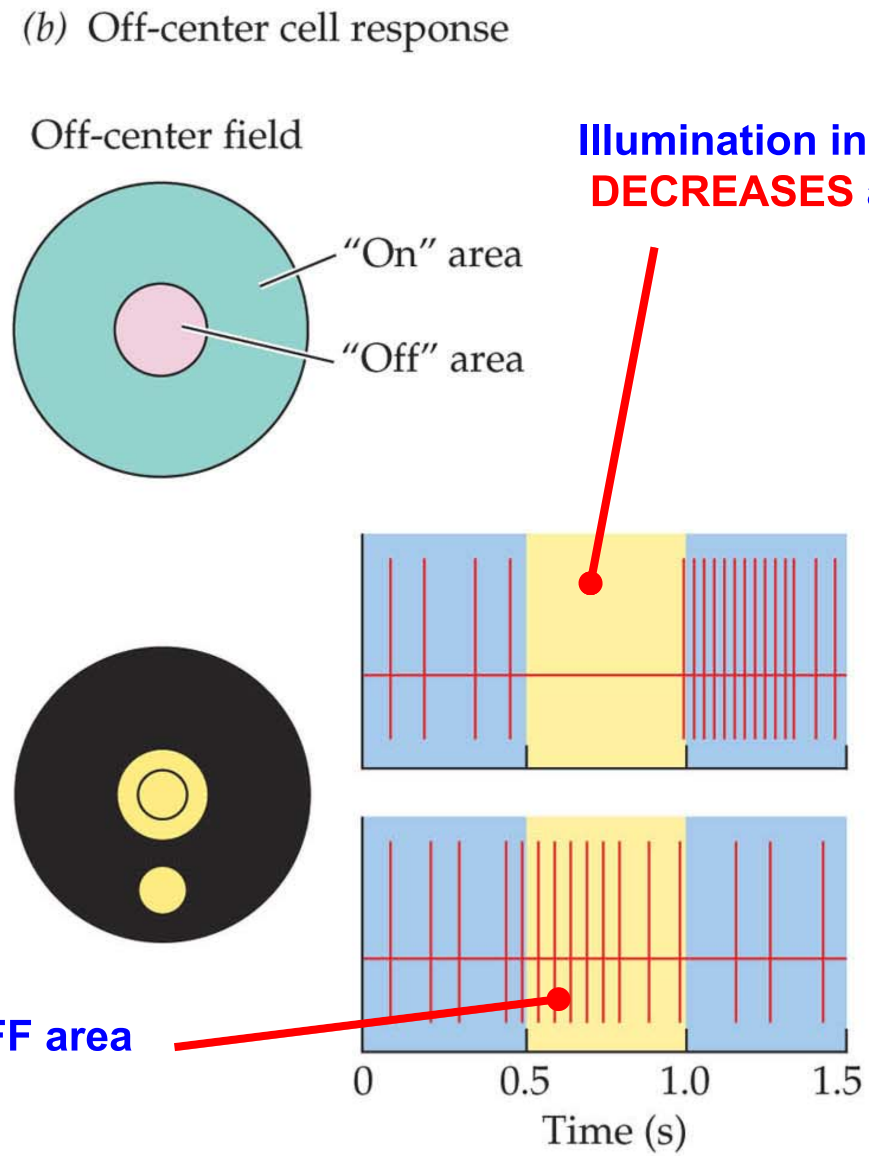
Maximal stimulation

Maximal inhibition

Little effect



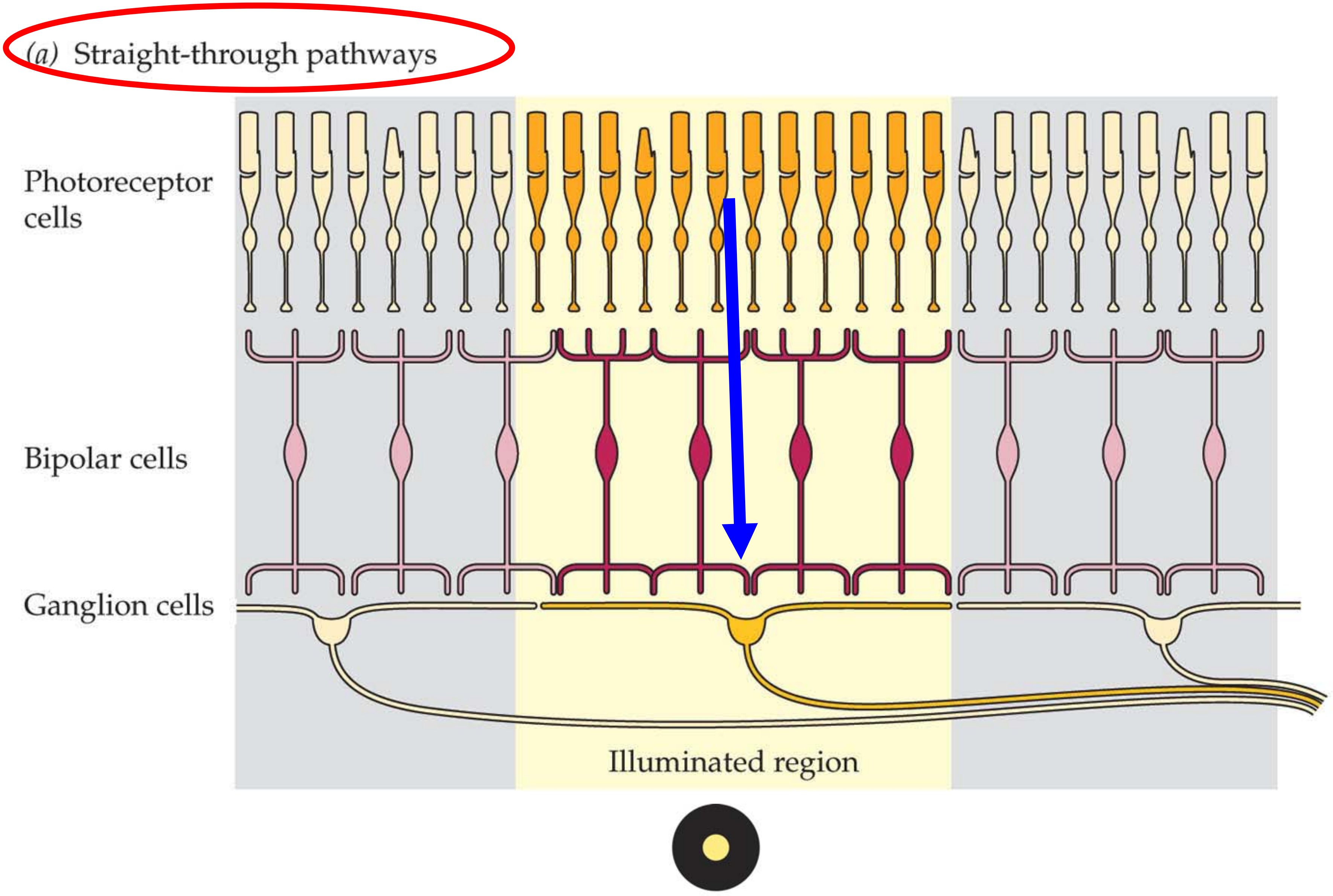
Receptive fields and responses of ganglion cells in the retina of a cat



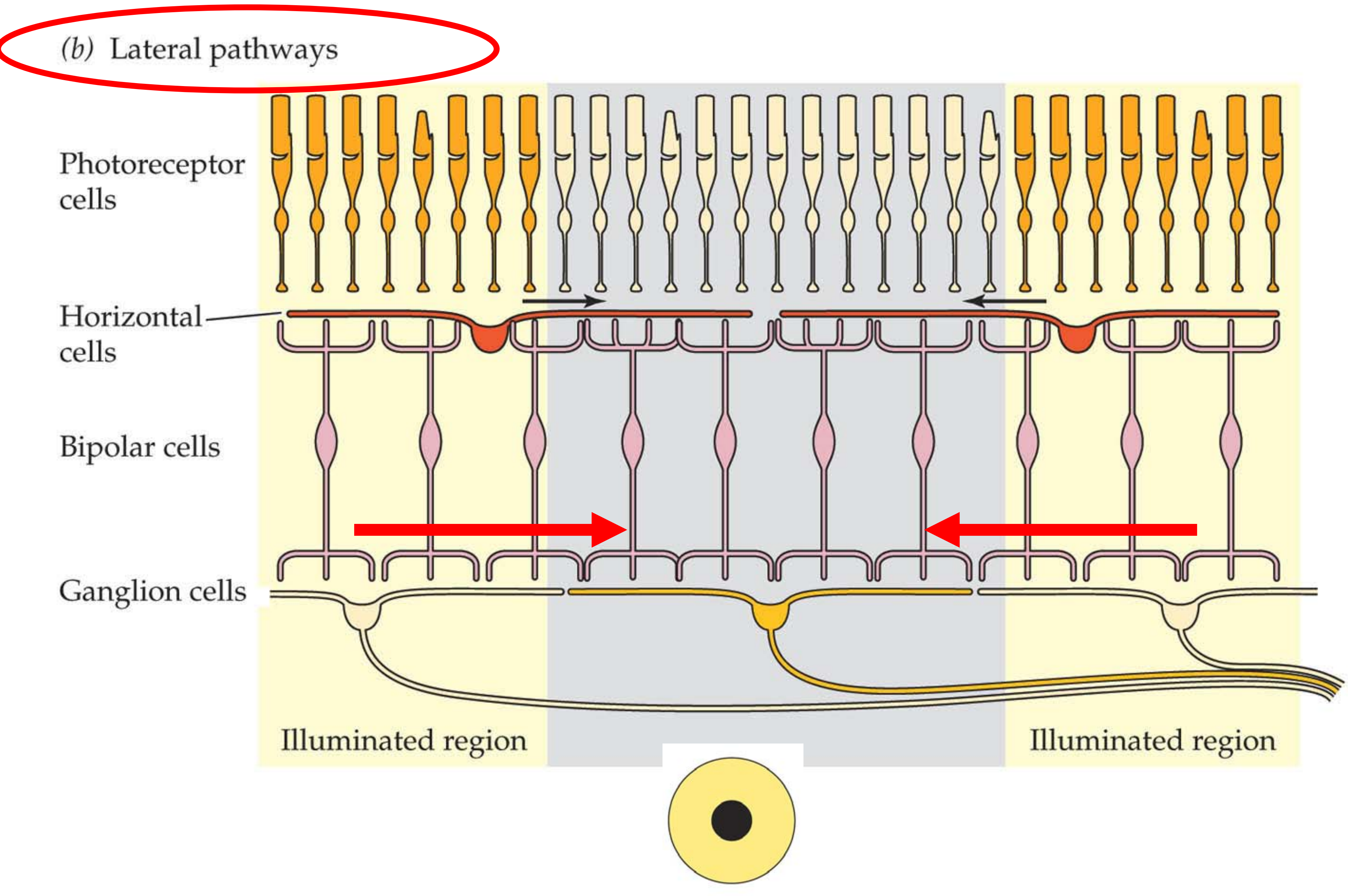
Illumination in the center DECREASES activity

Illumination in the OFF area increases activity

The synaptic connections of the retina

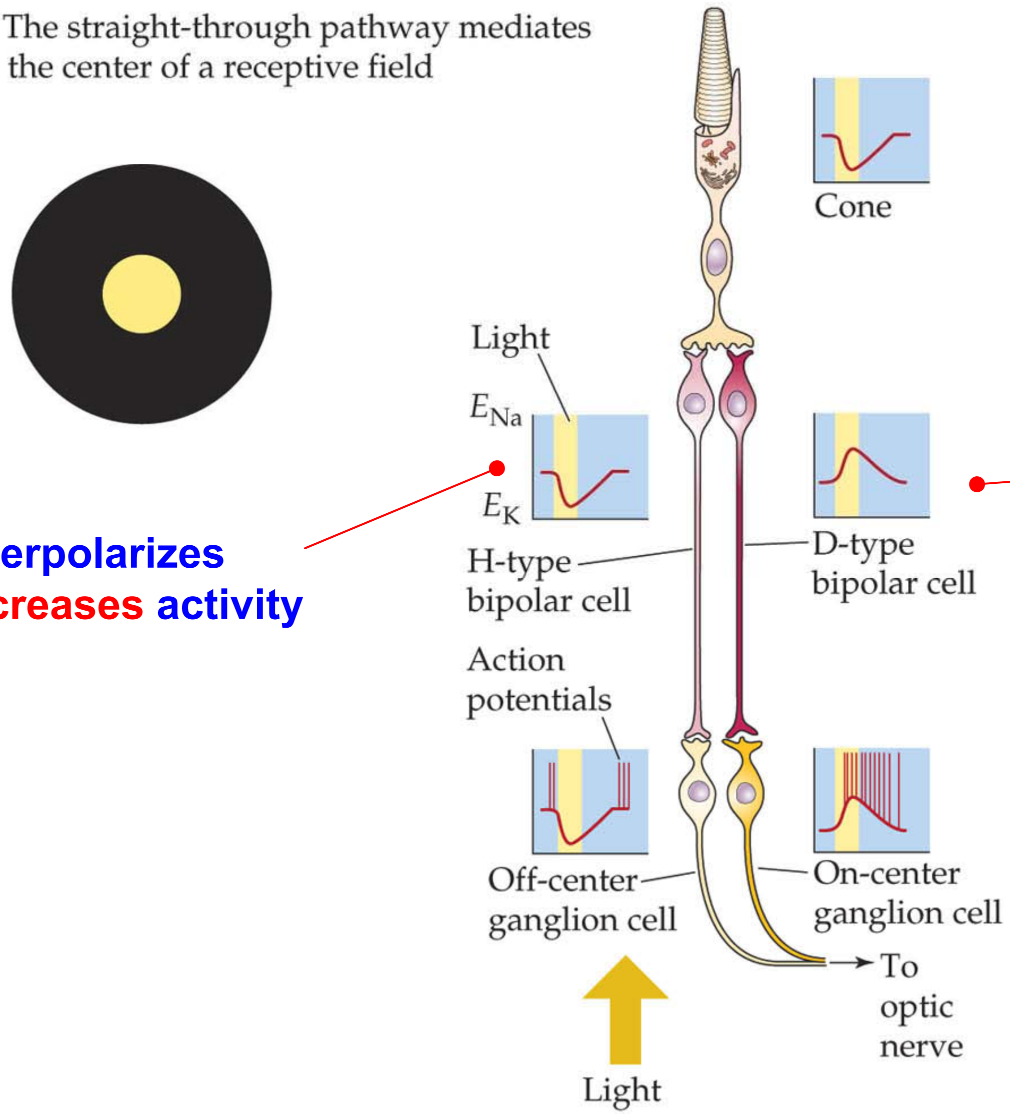


The synaptic connections of the retina



Retinal pathways determine receptive-field properties of retinal ganglion cells

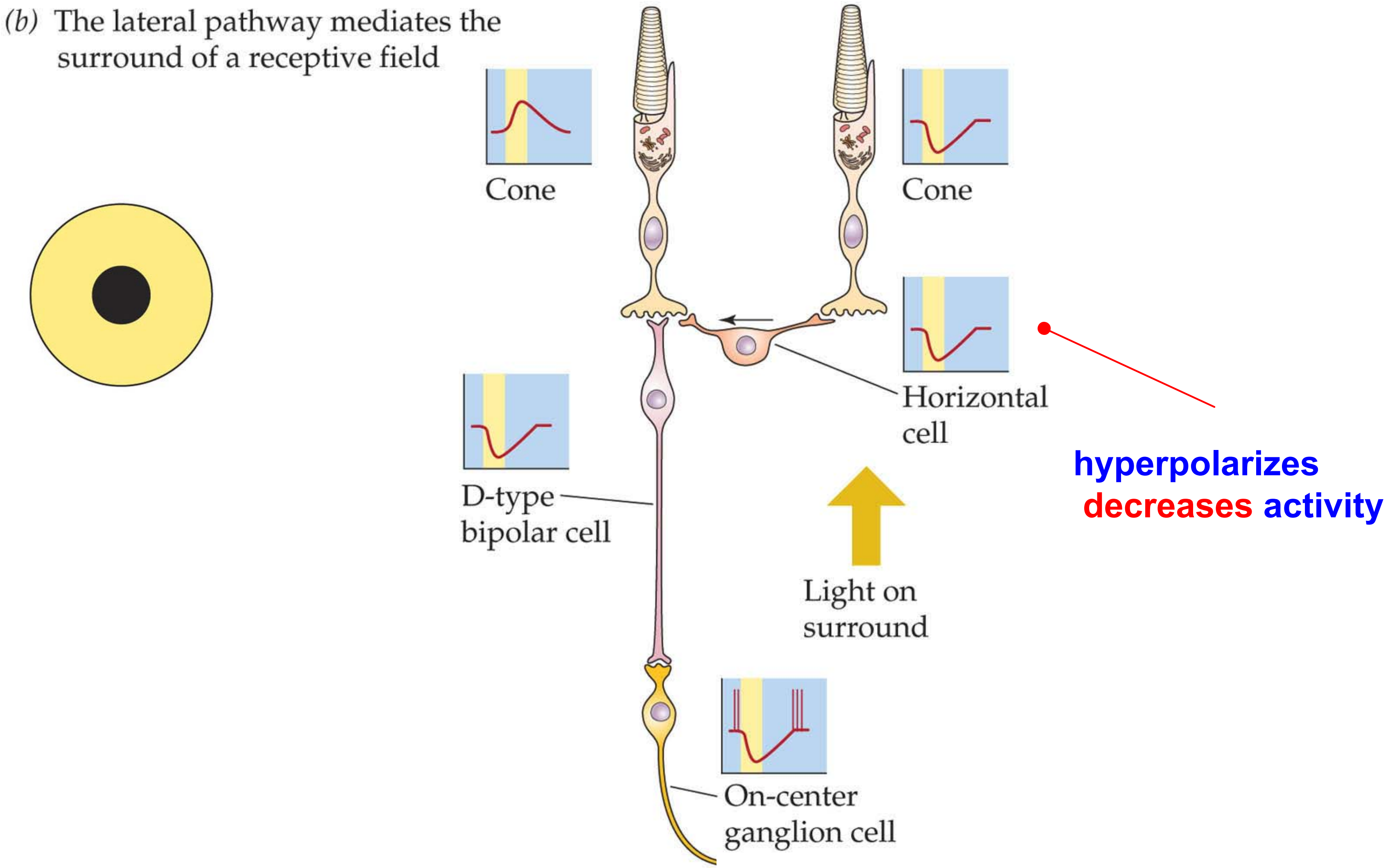
(a) The straight-through pathway mediates the center of a receptive field



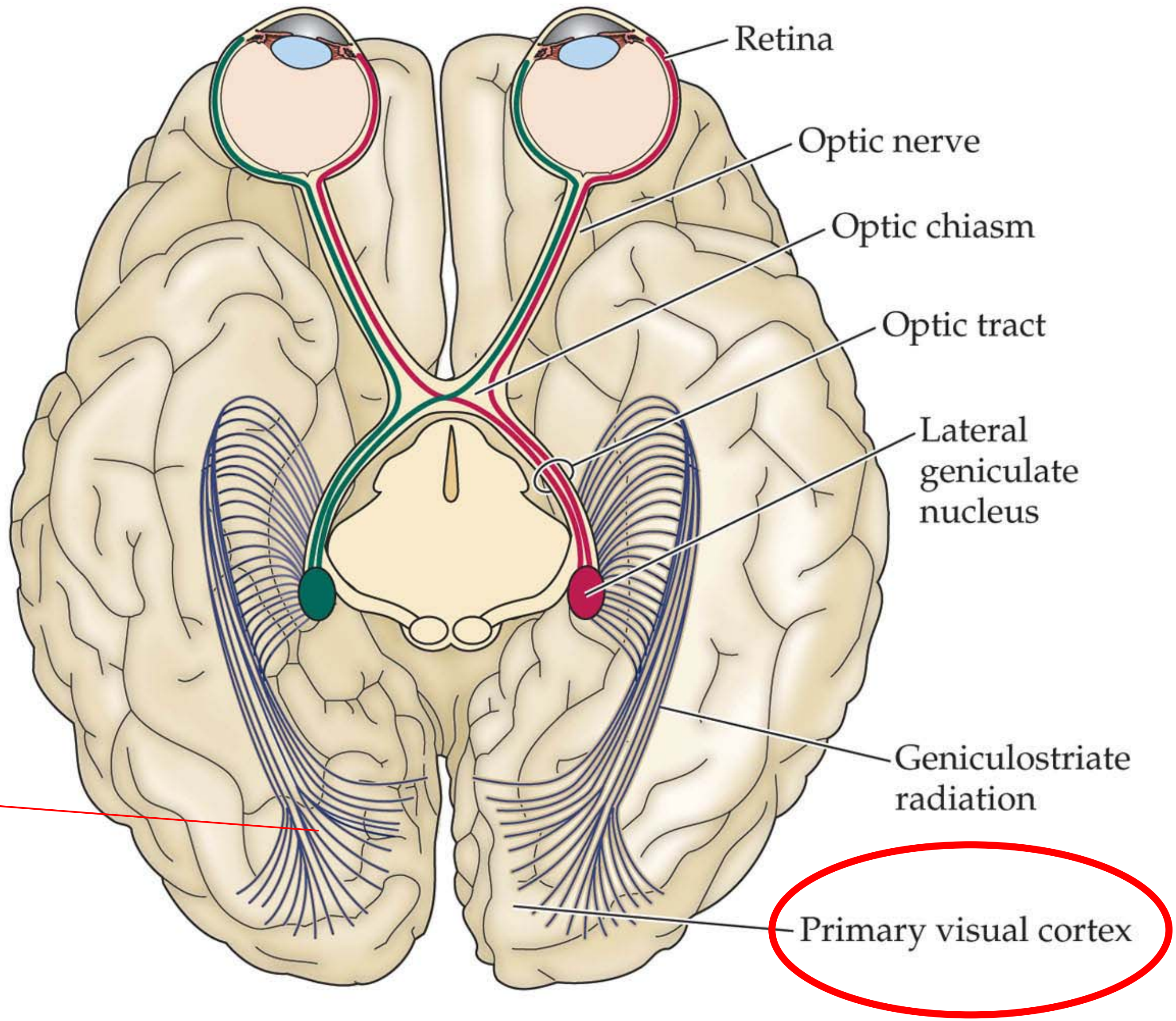
hyperpolarizes
decreases activity

Despolarizes
increases activity

Retinal pathways determine receptive-field properties of retinal ganglion cells



Central visual projections of a mammal

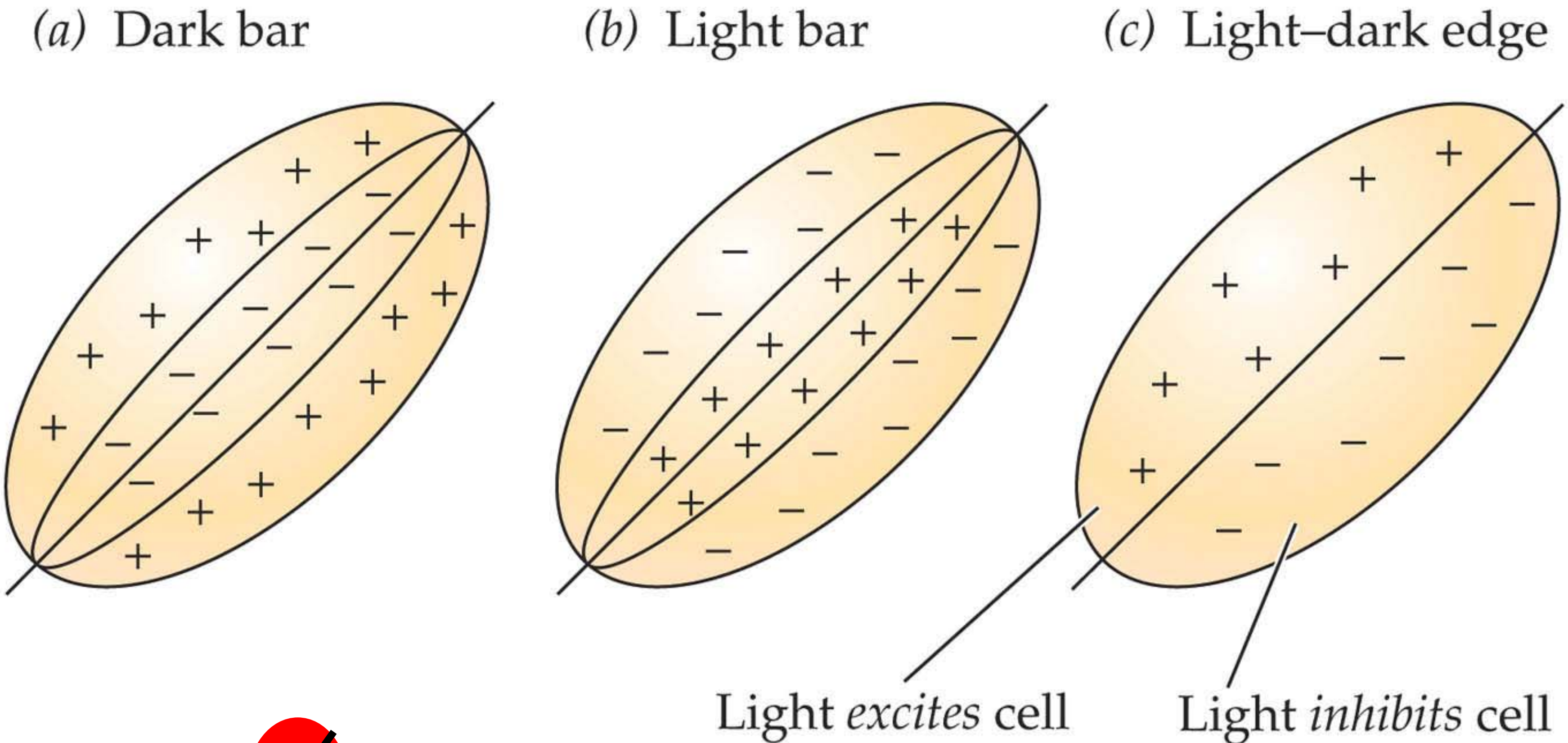


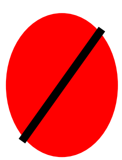
Simple cells

Complex cells

Receptive fields of simple cells in the visual cortex of a cat

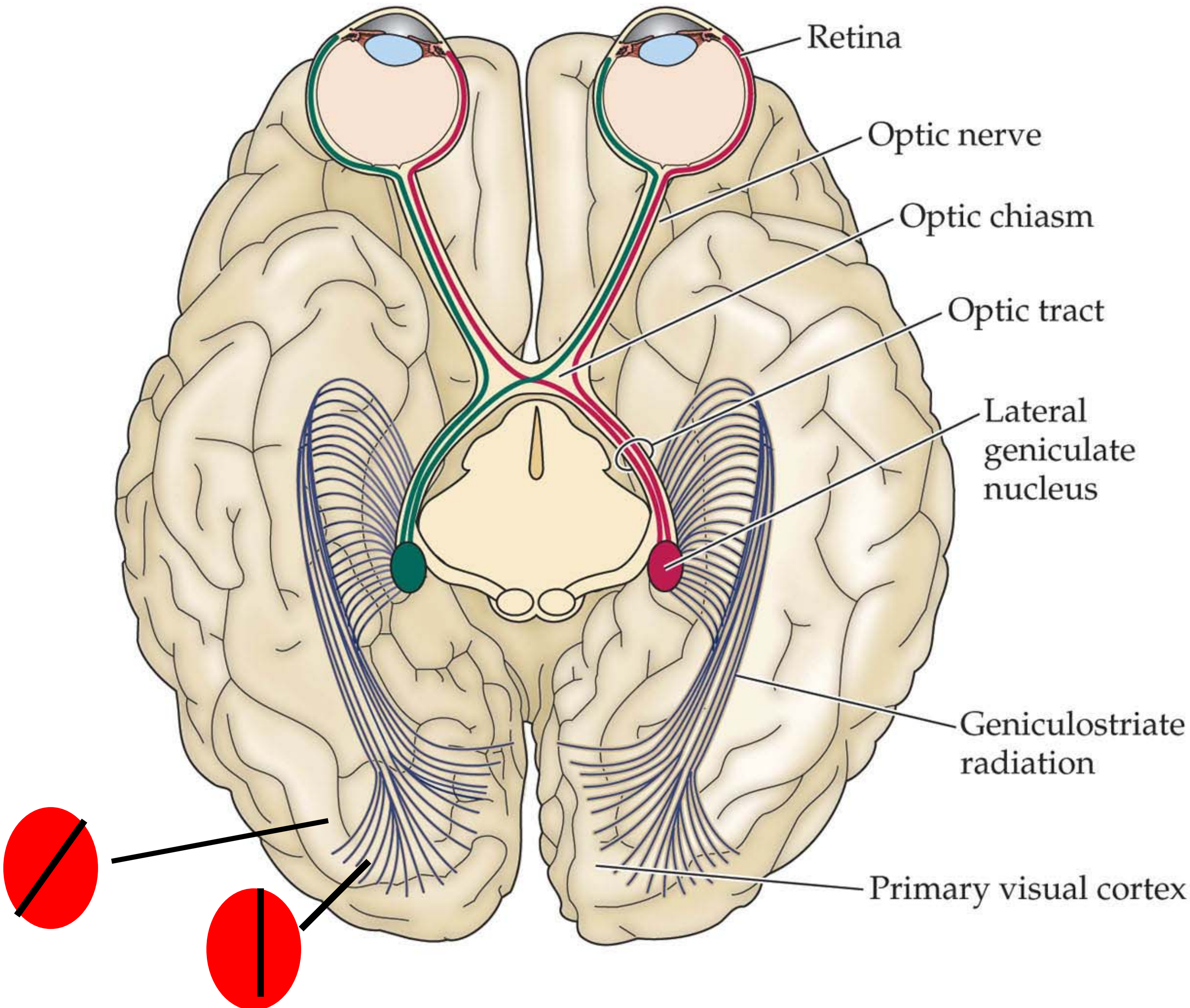
(Projections from retina)



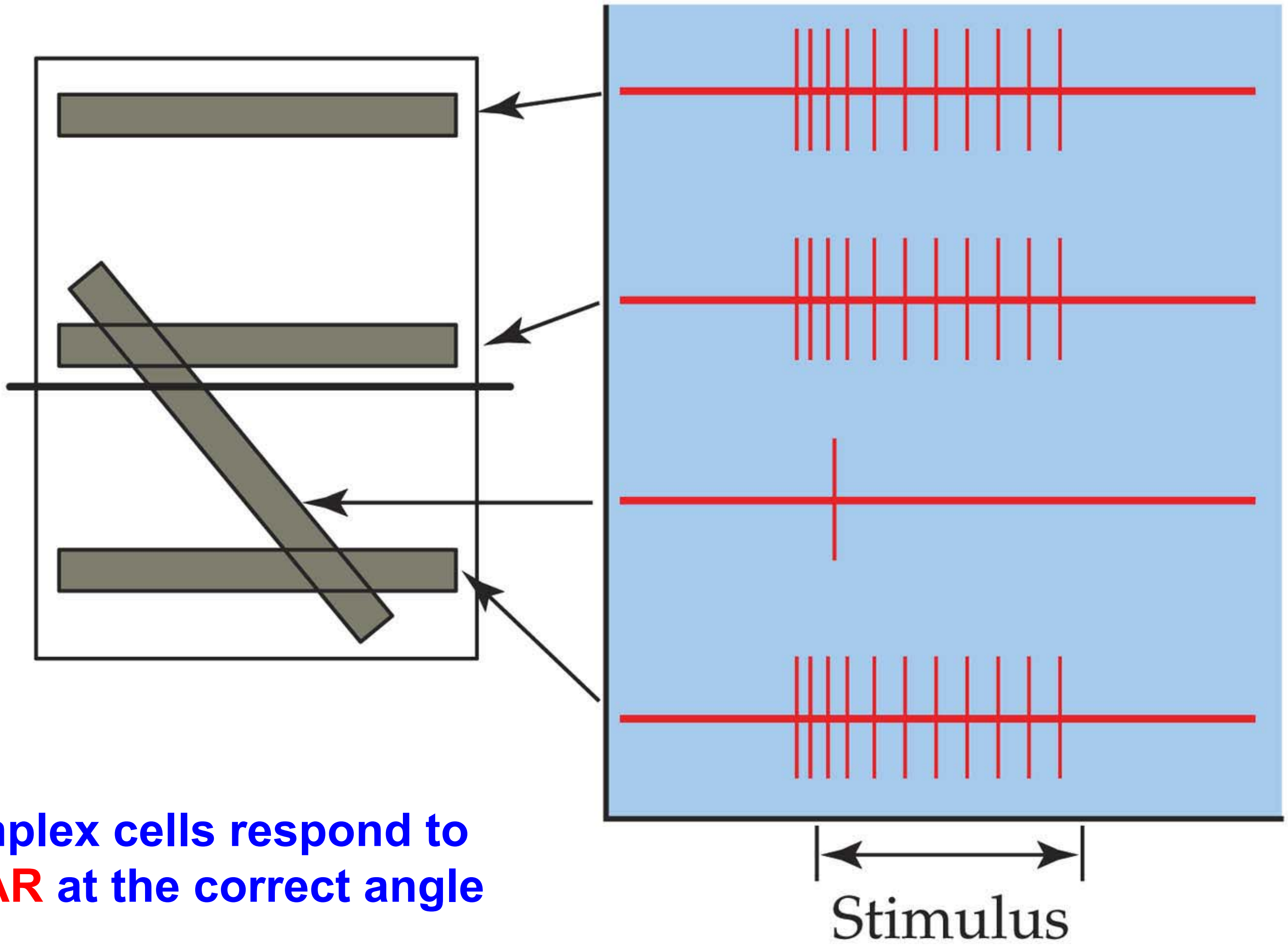


Axes of orientation

Central visual projections of a mammal

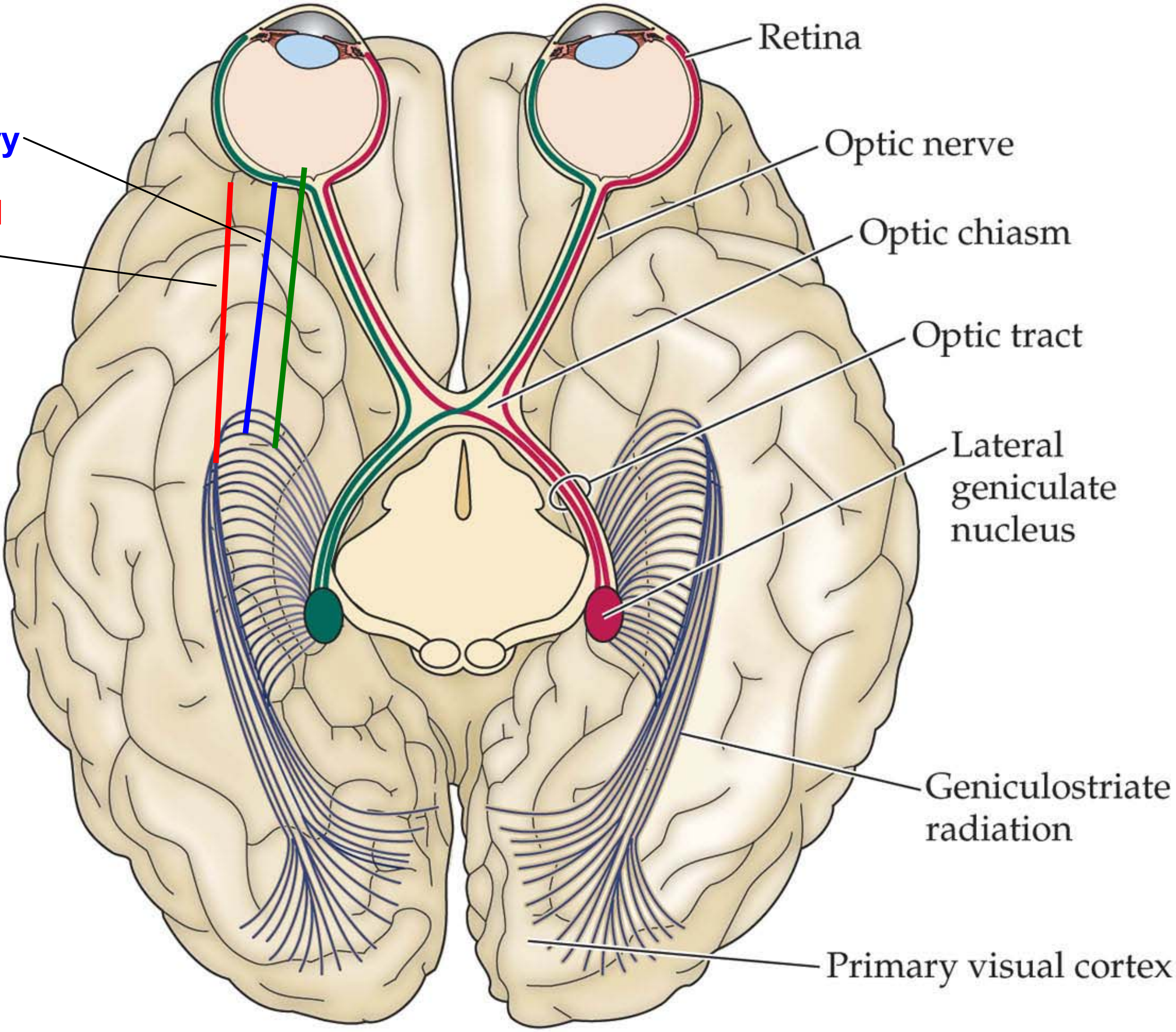


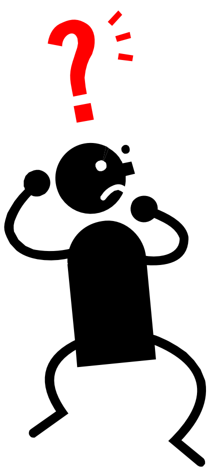
The receptive field of a complex cell in the visual cortex



Complex cells respond to a BAR at the correct angle

Parallel Organization





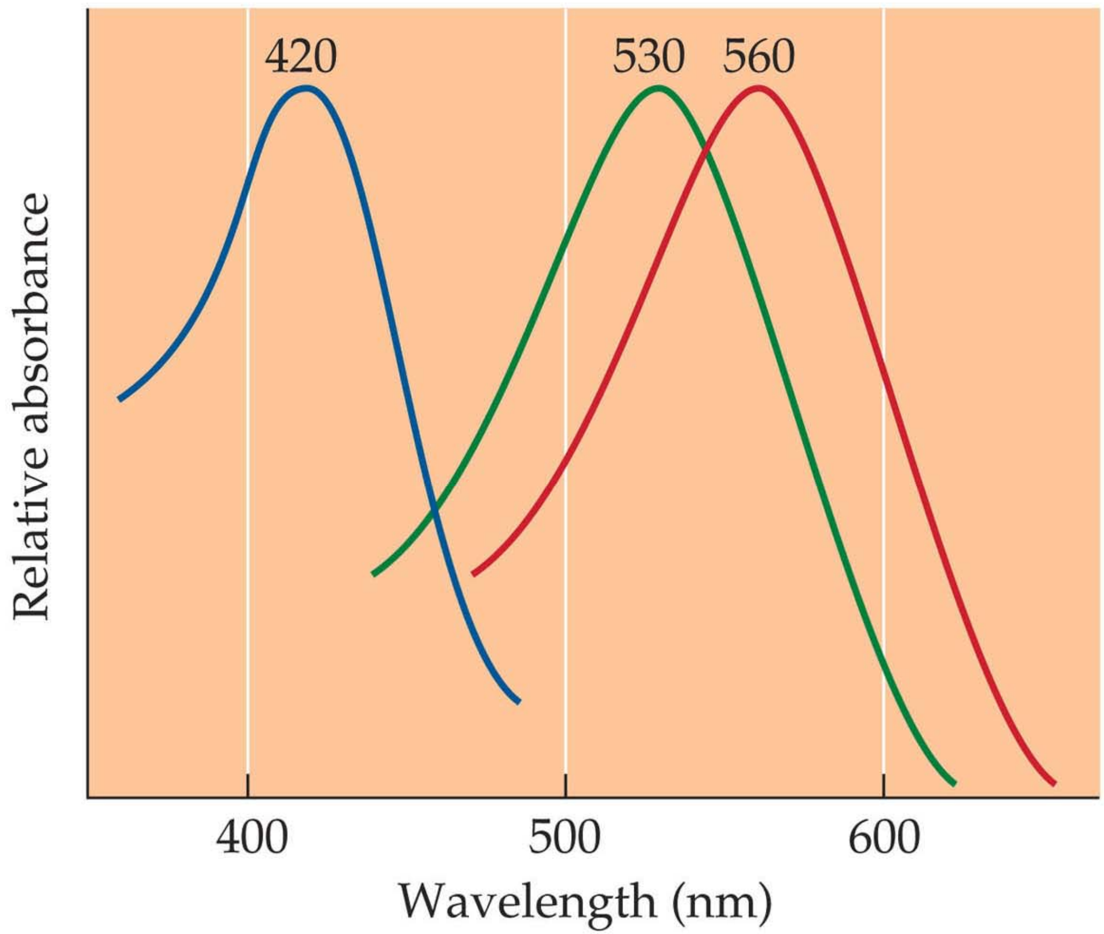
Hierarchical Organization

(multiple synapses)

Spectral sensitivities of human retinal cones

Different sensitivities of photoreceptors To different Wavelength of light

Red cones
Blue cones
Green cones



Trichromaticity theory