LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION
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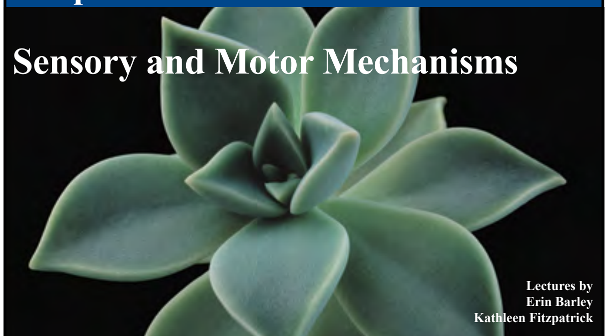
Chapter 50

Sensory and Motor Mechanisms



Lectures by
Erin Barley
Kathleen Fitzpatrick

Overview: Sensing and Acting

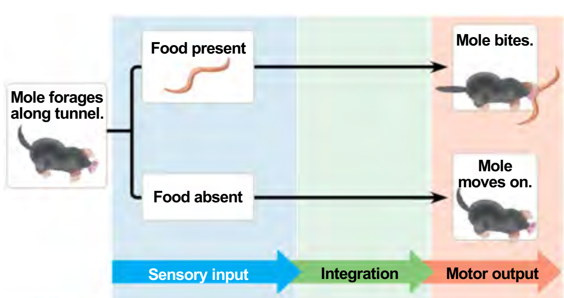
- The star-nosed mole can catch insect prey in near total darkness in as little as 120 milliseconds
- It uses the 11 appendages protruding from its nose to locate and capture prey
- Sensory processes convey information about an animal's environment to its brain, and muscles and skeletons carry out movements as instructed by the brain

Figure 50.1

Concept 50.1: Sensory receptors transduce stimulus energy and transmit signals to the central nervous system

- All stimuli represent forms of energy
- Sensation involves converting energy into a change in the membrane potential of sensory receptors
- When a stimulus's input to the nervous system is processed a motor response may be generated
- This may involve a simple reflex or more elaborate processing

Figure 50.2



Sensory Pathways

- Sensory pathways have four basic functions in common
  - – Sensory reception
  - – Tranduction
  - – Transmission
  - – Integration

Sensory Reception and Transduction

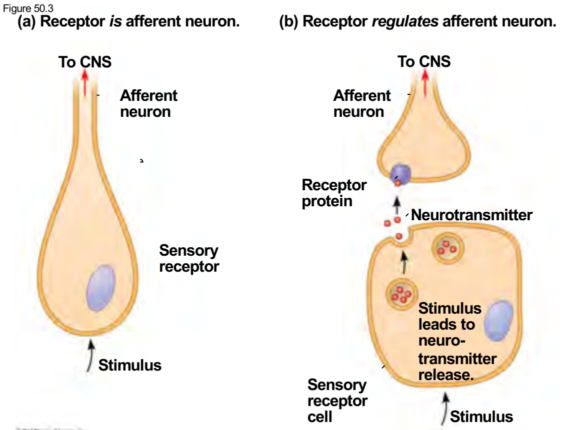
- Sensations and perceptions begin with **sensory reception**, detection of stimuli by sensory receptors
- **Sensory receptors** interact directly with stimuli, both inside and outside the body

- **Sensory transduction** is the conversion of stimulus energy into a change in the membrane potential of a sensory receptor
- This change in membrane potential is called a **receptor potential**
- Receptor potentials are graded potentials; their magnitude varies with the strength of the stimulus

Transmission

- After energy has been transduced into a receptor potential, some sensory cells generate the **transmission** of action potentials to the CNS
- Some sensory receptors are specialized neurons while others are specialized cells that regulate neurons
- Sensory neurons produce action potentials and their axons extend into the CNA

Figure 50.3



- The response of a sensory receptor varies with intensity of stimuli
- If the receptor is a neuron, a larger receptor potential results in more frequent action potentials
- If the receptor is not a neuron, a larger receptor potential causes more neurotransmitters to be released

Figure 50.4

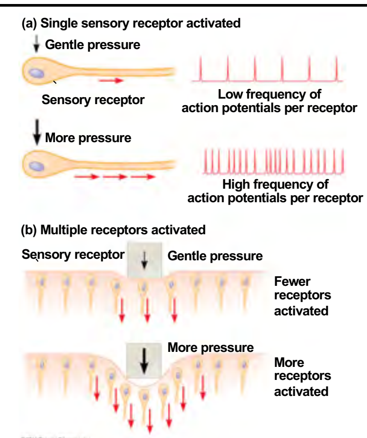


Figure 50.4a

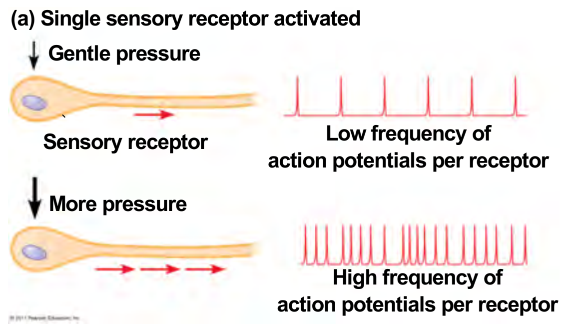
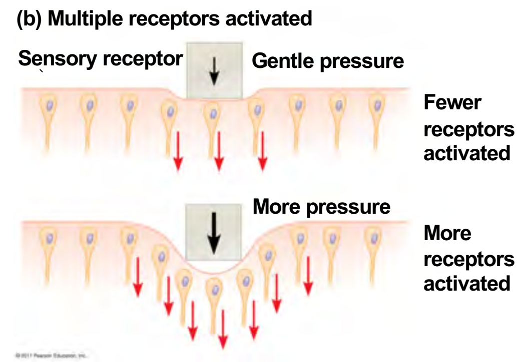


Figure 50.4b



Perception

- **Perceptions** are the brain's construction of stimuli
- Stimuli from different sensory receptors travel as action potentials along dedicated neural pathways
- The brain distinguishes stimuli from different receptors based on the area in the brain where the action potentials arrive

Amplification and Adaptation

- **Amplification** is the strengthening of stimulus energy by cells in sensory pathways
- **Sensory adaptation** is a decrease in responsiveness to continued stimulation

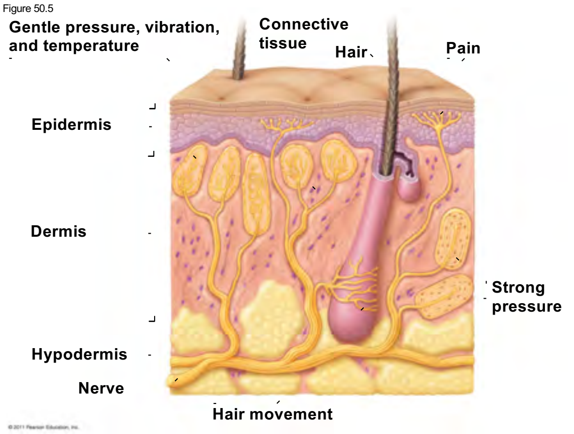
Types of Sensory Receptors

- Based on energy transduced, sensory receptors fall into five categories
  - Mechanoreceptors
  - Chemoreceptors
  - Electromagnetic receptors
  - Thermoreceptors
  - Pain receptors

Mechanoreceptors

- **Mechanoreceptors** sense physical deformation caused by stimuli such as pressure, stretch, motion, and sound
- The knee-jerk response is triggered by the vertebrate stretch receptor, a mechanoreceptor that detects muscle movement
- The mammalian sense of touch relies on mechanoreceptors that are dendrites of sensory neurons

Figure 50.5



Chemoreceptors

- General **chemoreceptors** transmit information about the total solute concentration of a solution
- Specific chemoreceptors respond to individual kinds of molecules
- When a stimulus molecule binds to a chemoreceptor, the chemoreceptor becomes more or less permeable to ions
- The antennae of the male silkworm moth have very sensitive specific chemoreceptors

Figure 50.6

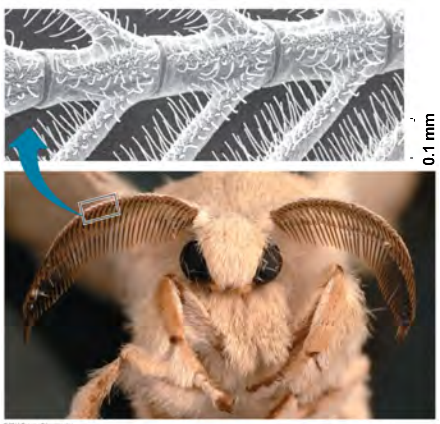


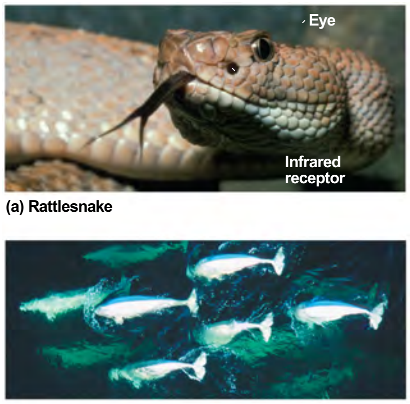
Figure 50.6a

Figure 50.6b

Electromagnetic Receptors

- **Electromagnetic receptors** detect electromagnetic energy such as light, electricity, and magnetism
- Some snakes have very sensitive infrared receptors that detect body heat of prey against a colder background
- Many animals apparently migrate using the Earth's magnetic field to orient themselves

Figure 50.7



(a) Rattlesnake

(b) Beluga whales

Figure 50.7a

(a) Rattlesnake

Figure 50.7b

(b) Beluga whales

Thermoreceptors

- **Thermoreceptors**, which respond to heat or cold, help regulate body temperature by signaling both surface and body core temperature
- Mammals have a number of kinds of thermoreceptors, each specific for a particular temperature range

Pain Receptors

- In humans, **pain receptors**, or **nociceptors**, are a class of naked dendrites in the epidermis
- They respond to excess heat, pressure, or chemicals released from damaged or inflamed tissues

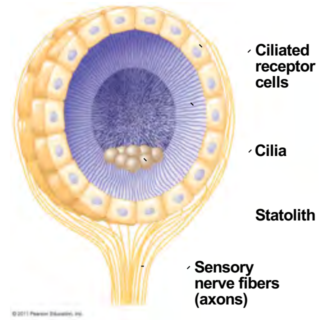
Concept 50.2: The mechanoreceptors responsible for hearing and equilibrium detect moving fluid or settling particles

- Hearing and perception of body equilibrium are related in most animals
- For both senses, settling particles or moving fluid are detected by mechanoreceptors

Sensing Gravity and Sound in Invertebrates

- Most invertebrates maintain equilibrium using mechanoreceptors located in organs called **statocysts**
- Statocysts contain mechanoreceptors that detect the movement of granules called **statoliths**

Figure 50.8



- Many arthropods sense sounds with body hairs that vibrate or with localized “ears” consisting of a tympanic membrane and receptor cells

Figure 50.9

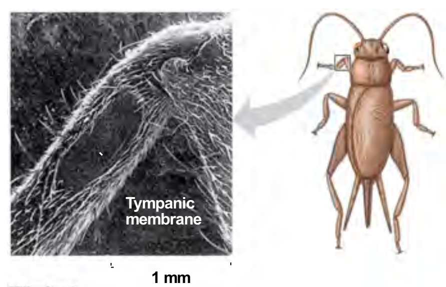
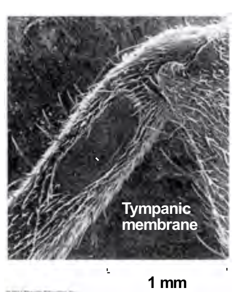


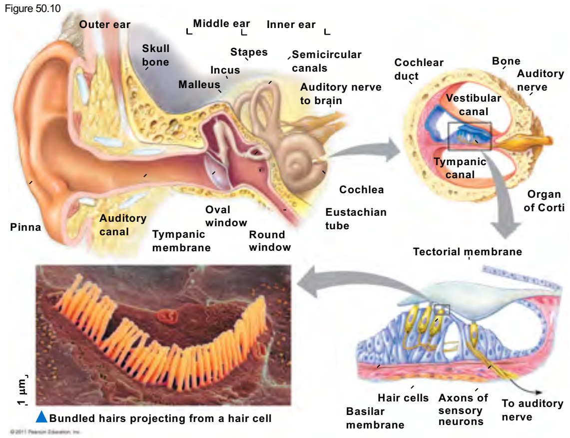
Figure 50.9a



Hearing and Equilibrium in Mammals

- In most terrestrial vertebrates, sensory organs for hearing and equilibrium are closely associated in the ear

Figure 50.10



Bundled hairs projecting from a hair cell

Figure 50.10a

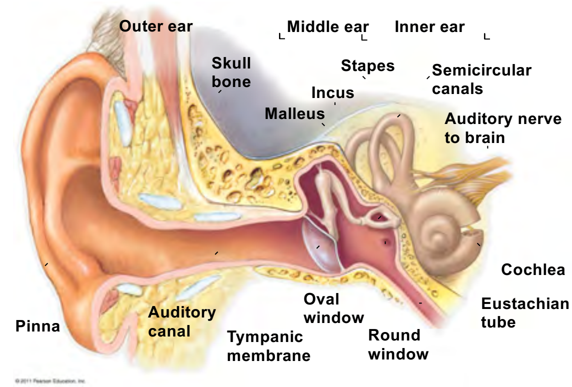


Figure 50.10b

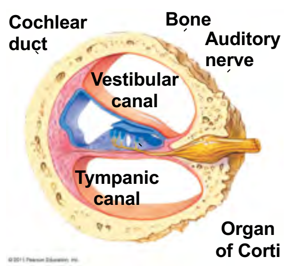


Figure 50.10c

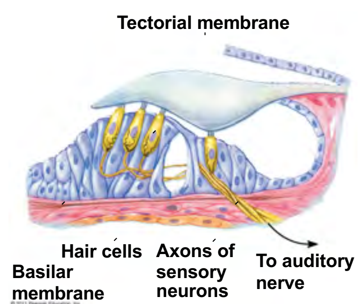


Figure 50.10d

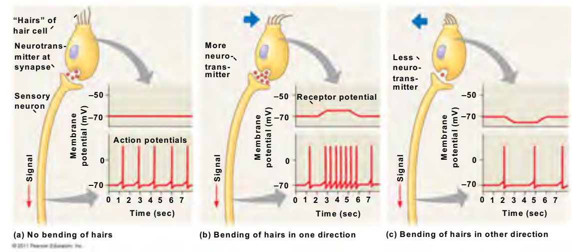
▲ Bundled hairs projecting from a hair cell

Hearing

- Vibrating objects create percussion waves in the air that cause the tympanic membrane to vibrate
- The three bones of the middle ear transmit the vibrations of moving air to the oval window on the cochlea
- These vibrations create pressure waves in the fluid in the cochlea that travel through the vestibular canal

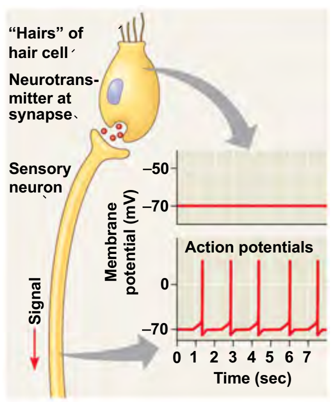
- Pressure waves in the canal cause the basilar membrane to vibrate, bending its **hair cells**
- This bending of hair cells depolarizes the membranes of mechanoreceptors and sends action potentials to the brain via the auditory nerve

Figure 50.11



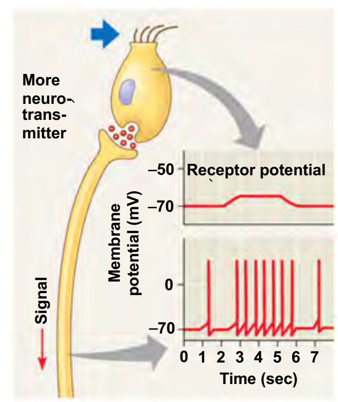
(a) No bending of hairs (b) Bending of hairs in one direction (c) Bending of hairs in other direction

Figure 50.11a



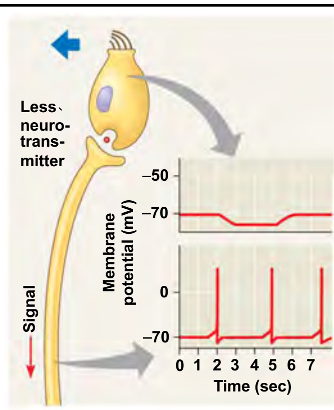
(a) No bending of hairs

Figure 50.11b



(b) Bending of hairs in one direction

Figure 50.11c



(c) Bending of hairs in other direction

- The fluid waves dissipate when they strike the **round window** at the end of the tympanic canal

Figure 50.12

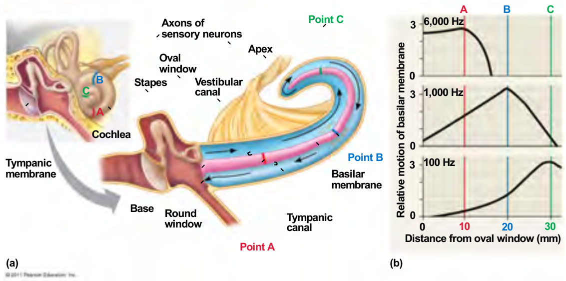
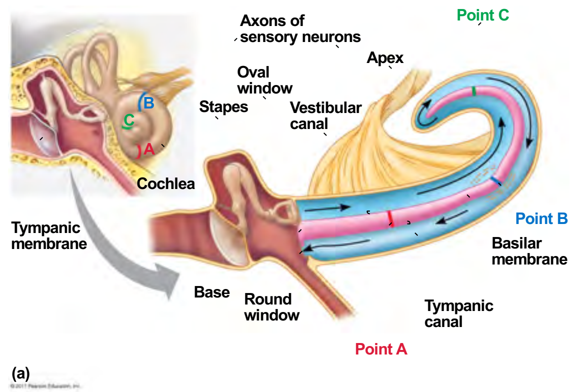
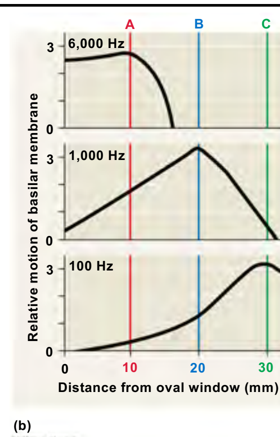


Figure 50.12a



- The ear conveys information about
  - *Volume*, the amplitude of the sound wave
  - *Pitch*, the frequency of the sound wave
- The cochlea can distinguish pitch because the basilar membrane is not uniform along its length
- Each region of the basilar membrane is tuned to a particular vibration frequency

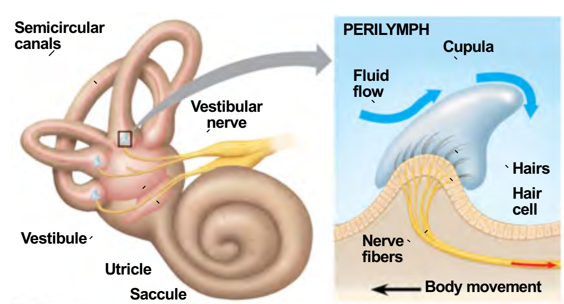
Figure 50.12b



Equilibrium

- Several organs of the inner ear detect body movement, position, and balance
  - The **utricle** and **saccule** contain granules called otoliths that allow us to perceive position relative to gravity or linear movement
  - Three semicircular canals contain fluid and can detect angular movement in any direction

Figure 50.13



Hearing and Equilibrium in Other Vertebrates

- Unlike mammals, fishes have only a pair of inner ears near the brain
- Most fishes and aquatic amphibians also have a **lateral line system** along both sides of their body
- The lateral line system contains mechanoreceptors with hair cells that detect and respond to water movement

Figure 50.14

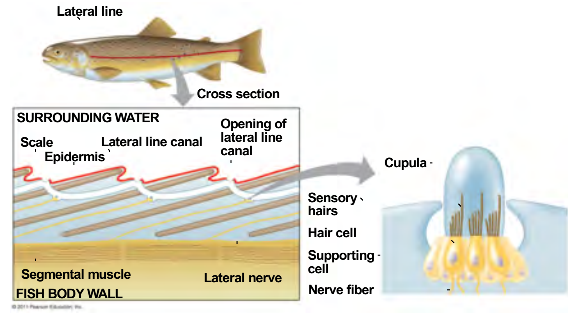


Figure 50.14a

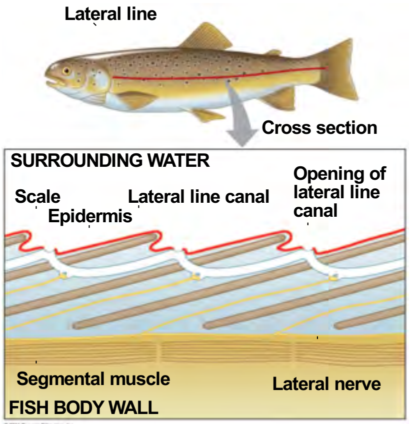
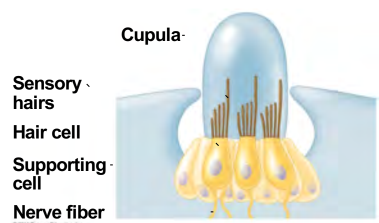


Figure 50.14b



Concept 50.3: Visual receptors on diverse animals depend on light-absorbing pigments

- Animals use a diverse set of organs for vision, but the underlying mechanism for capturing light is the same, suggesting a common evolutionary origin

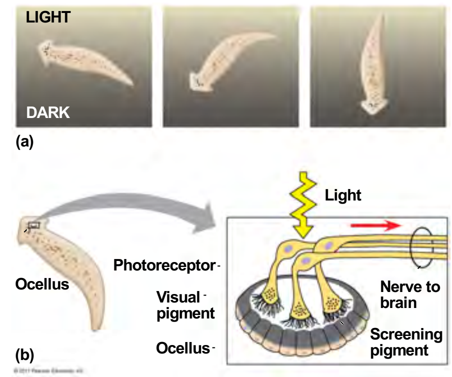
Evolution of Visual Perception

- Light detectors in the animal kingdom range from simple clusters of cells that detect direction and intensity of light to complex organs that form images
- Light detectors all contain **photoreceptors**, cells that contain light-absorbing pigment molecules

Light-Detecting Organs

- Most invertebrates have a light-detecting organ
- One of the simplest light-detecting organs is that of planarians
- A pair of ocelli called eyespots are located near the head
- These allow planarians to move away from light and seek shaded locations

Figure 50.15



Compound Eyes

- Insects and crustaceans have **compound eyes**, which consist of up to several thousand light detectors called **ommatidia**
- Compound eyes are very effective at detecting movement

Figure 50.16

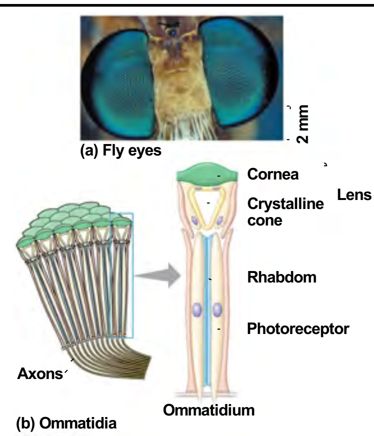


Figure 50.16a

Single-Lens Eyes

- **Single-lens eyes** are found in some jellies, polychaetes, spiders, and many molluscs
- They work on a camera-like principle: the **iris** changes the diameter of the **pupil** to control how much light enters
- The eyes of all vertebrates hae a single lens

The Vertebrate Visual System

- In vertebrates the eye detects color and light, but the brain assembles the information and perceives the image

Figure 50.17a

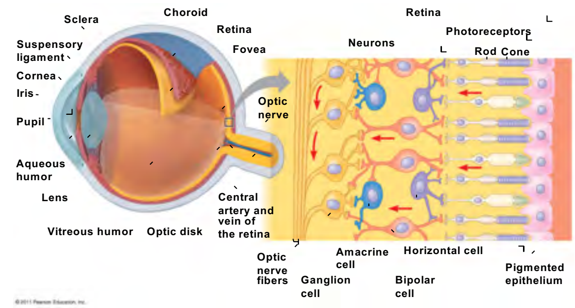


Figure 50.17aa

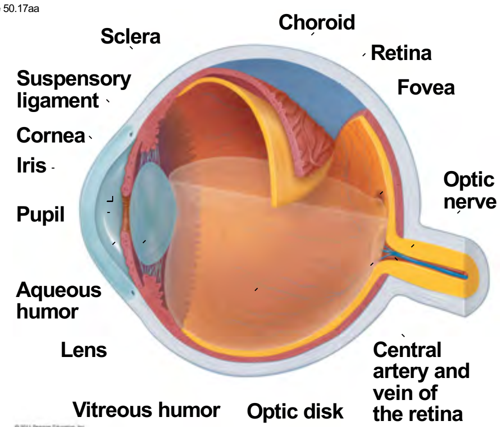


Figure 50.17ab

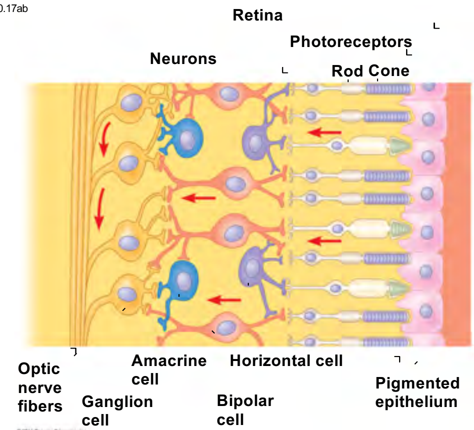


Figure 50.17b

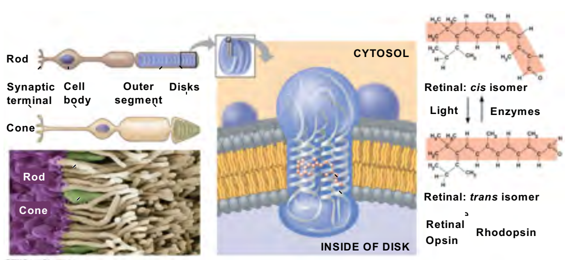


Figure 50.17ba

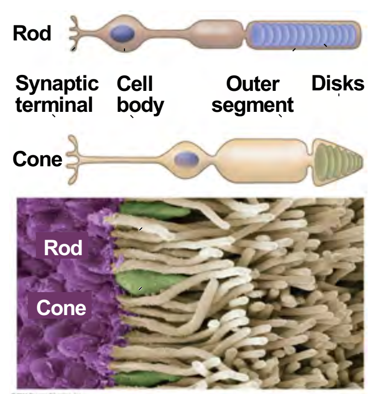


Figure 50.17bb

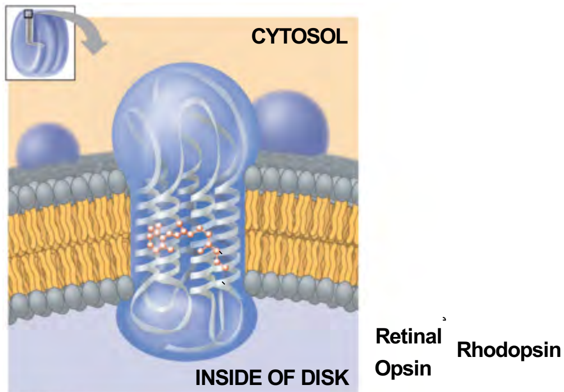


Figure 50.17bc

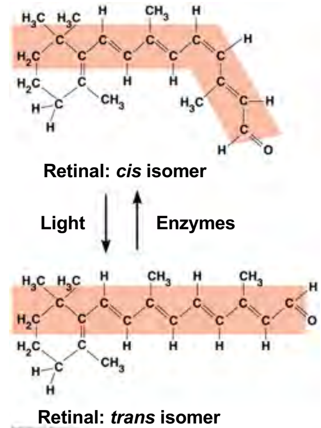


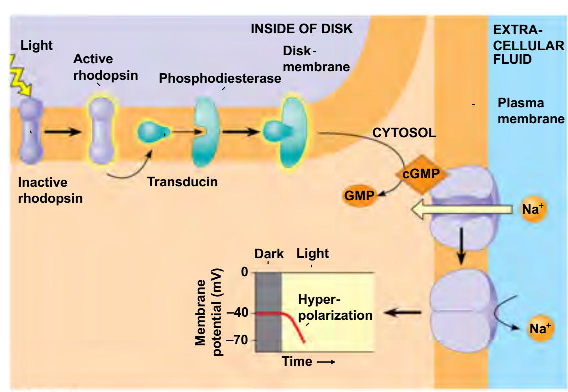
Figure 50.17bd

Sensory Transduction in the Eye

- Transduction of visual information to the nervous system begins when light induces the conversion of *cis*-retinal to *trans*-retinal
- *trans*-retinal activates rhodopsin, which activates a G protein, eventually leading to hydrolysis of cyclic GMP

- When cyclic GMP breaks down, Na^+ channels close
- This hyperpolarizes the cell
- The signal transduction pathway usually shuts off again as enzymes convert retinal back to the *cis* form

Figure 50.18

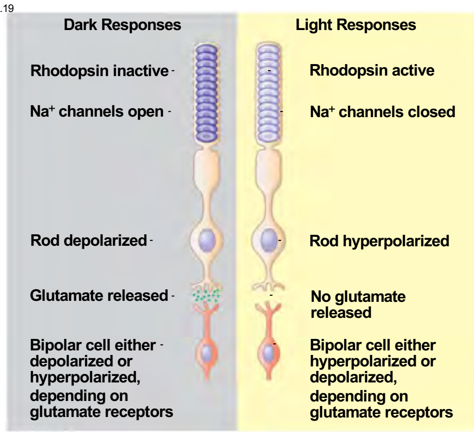


Processing of Visual Information in the Retina

- Processing of visual information begins in the retina
- In the dark, rods and cones release the neurotransmitter glutamate into synapses with neurons called **bipolar cells**
- Bipolar cells are either hyperpolarized or depolarized in response to glutamate

- In the light, rods and cones hyperpolarize, shutting off release of glutamate
- The bipolar cells are then either depolarized or hyperpolarized

Figure 50.19



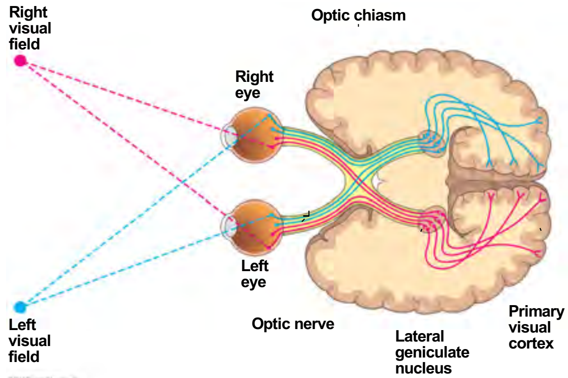
- Three other types of neurons contribute to information processing in the retina
  - Ganglion cells transmit signals from bipolar cells to the brain
  - Horizontal and amacrine cells help integrate visual information before it is sent to the brain
- Interaction among different cells results in **lateral inhibition**, enhanced contrast in the image

Processing of Visual Information in the Brain

- The optic nerves meet at the **optic chiasm** near the cerebral cortex
- Sensations from the left visual field of both eyes are transmitted to the right side of the brain
- Sensations from the right visual field are transmitted to the left side of the brain

- Most ganglion cell axons lead to the **lateral geniculate nuclei**
- The lateral geniculate nuclei relay information to the **primary visual cortex** in the cerebrum
- At least 30% of the cerebral cortex, in dozens of integrating centers, are active in creating visual perceptions

Figure 50.20



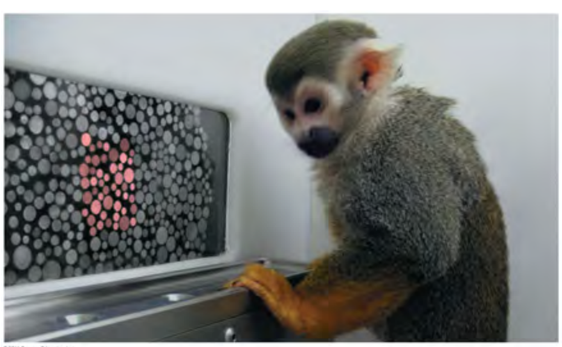
Color Vision

- Among vertebrates, most fish, amphibians, and reptiles, including birds, have very good color vision
- Humans and other primates are among the minority of mammals with the ability to see color well
- Mammals that are nocturnal usually have a high proportion of rods in the retina

- In humans, perception of color is based on three types of cones, each with a different visual pigment: red, green, or blue
- These pigments are called photopsins and are formed when retinal binds to three distinct opsin proteins

- Abnormal color vision results from alterations in the genes for one or more photopsin proteins
- In 2009, researchers studying color blindness in squirrel monkeys made a breakthrough in gene therapy

Figure 50.21



The Visual Field

- The brain processes visual information and controls what information is captured
- Focusing occurs by changing the shape of the lens
- The **fovea** is the center of the visual field and contains no rods, but a high density of cones

Figure 50.22

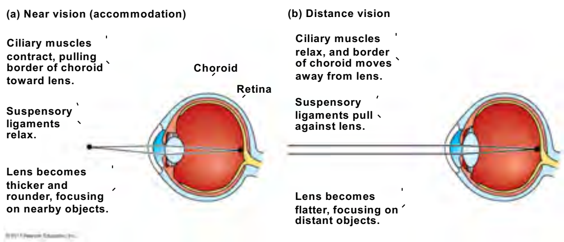


Figure 50.22a

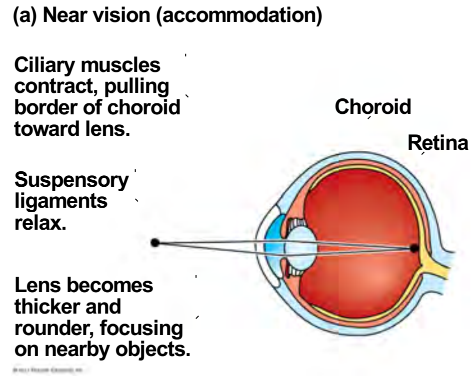
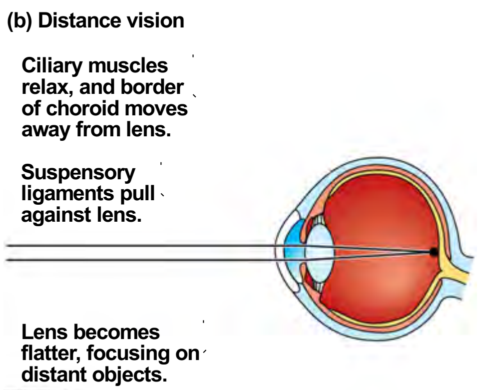


Figure 50.22b



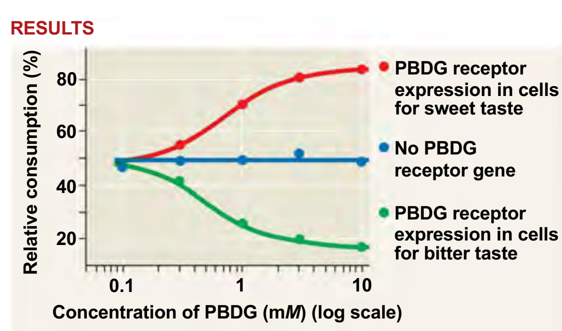
Concept 50.4: The senses of taste and smell rely on similar sets of sensory receptors

- In terrestrial animals
  - **Gustation** (taste) is dependent on the detection of chemicals called **tastants**
  - **Olfaction** (smell) is dependent on the detection of **odorant** molecules
- In aquatic animals there is no distinction between taste and smell
- Taste receptors of insects are in sensory hairs called sensilla, located on feet and in mouth parts

Taste in Mammals

- In humans, receptor cells for taste are modified epithelial cells organized into **taste buds**
- There are five taste perceptions: sweet, sour, salty, bitter, and umami (elicited by glutamate)
- Researchers have identified receptors for each of the tastes except salty
- Researchers believe that an individual taste cell expresses one receptor type and detects one of the five tastes

Figure 50.23



- Receptor cells for taste in mammals are modified epithelial cells organized into taste buds, located in several areas of the tongue and mouth
- Any region with taste buds can detect any of the five types of taste

Figure 50.24

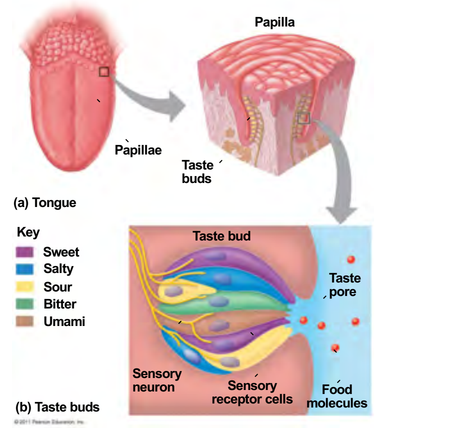


Figure 50.24a

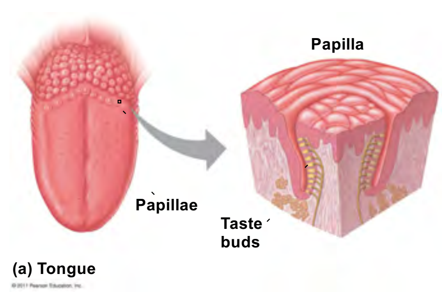
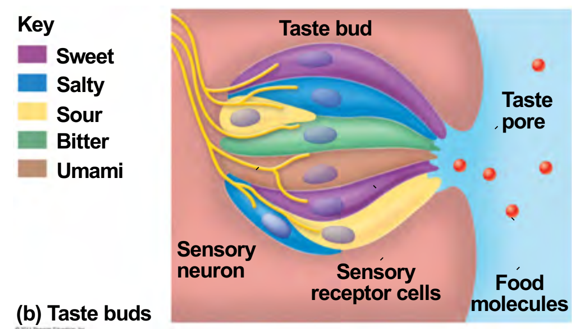


Figure 50.24b



Smell in Humans

- Olfactory receptor cells are neurons that line the upper portion of the nasal cavity
- Binding of odorant molecules to receptors triggers a signal transduction pathway, sending action potentials to the brain
- Humans can distinguish thousands of different odors
- Although receptors and brain pathways for taste and smell are independent, the two senses do interact

Figure 50.25