# CHAPTER 50: SENSORY AND MOTOR MECHANISMS

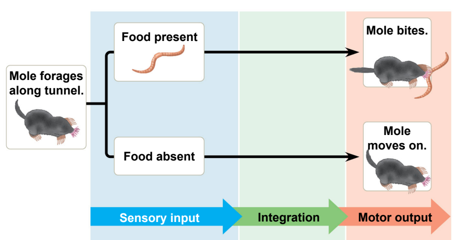
AP Biology 2013



# SENSORY RECEPTORS

- All stimuli represent forms of energy
- Sensation involves converting energy into a change in membrane potential of sensory receptors
- This could lead to a motor response through a simple reflex or more elaborate processing

Figs. 50.1 & 50.2






- Sensory pathways have four basic functions:
  - Sensory reception - detection of a stimulus by receptors that interact directly with stimuli both inside and outside of the body
  - Transduction - conversion of stimulus energy into a change in the membrane potential of a sensory receptor
  - Transmission - action potentials to the CNS that can vary in intensity
    - Amplification - strengthening of a stimulus
    - Sensory adaptation - decrease in responsiveness to continued stimulation
  - Integration - begins as the information is received and occurs at all levels of the nervous system

# SENSORY RECEPTORS

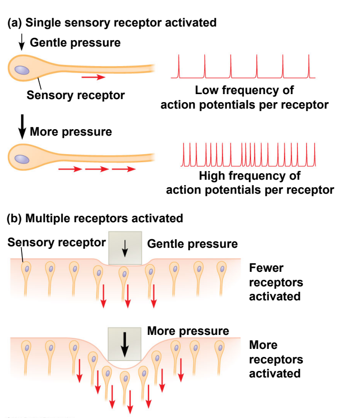
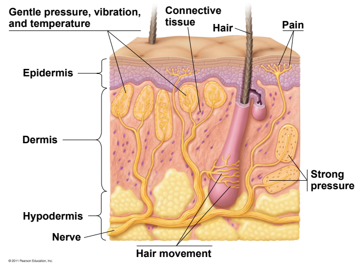


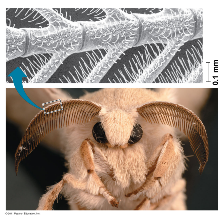

Fig. 50.4

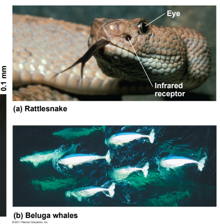
# TYPES OF SENSORY RECEPTORS

- Mechanoreceptors - sense physical deformation (pressure, stretch, motion, and sound)
  - Rely on dendrites of sensory neurons
- Chemoreceptors - transmit information about total solute concentration of a solution and receptors that respond to individual kinds of molecules
- Electromagnetic receptors - detect various forms of electromagnetic energy (light, electricity, and magnetism)
  - Infrared receptors in snakes




Figs. 50.5-50.7





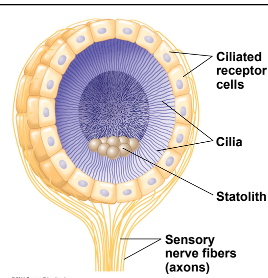

# TYPES OF SENSORY RECEPTORS

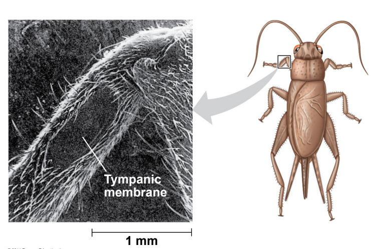
- Thermoreceptors - respond to heat or cold and help regulate body temperature by signaling both surface and body core temperature
- Pain receptors (nociceptors) - respond to excess heat, pressure, or specific classes of chemicals released from damaged or inflamed tissues
  - Class of naked dendrites in the epidermis



# HEARING AND EQUILIBRIUM

- Mechanoreceptors
- Invertebrates - sensory organs called statocysts that contain mechanoreceptors and function in sense of equilibrium
- Arthropods - sense sound with body hairs that vibrate or with localized ears consisting of tympanic membranes and receptor cells
- Terrestrial vertebrates - sensory organs for hearing and equilibrium are associated in the ear

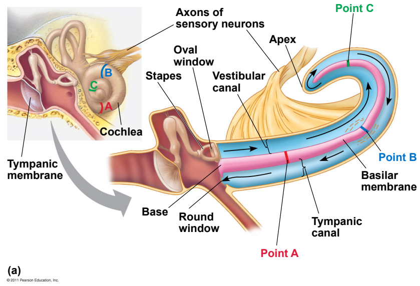


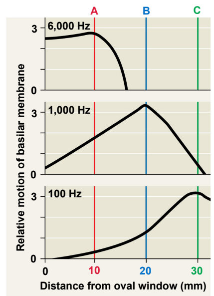




Figs. 50.8 & 50.9

# HEARING

- Vibrating objects create percussive waves in the air that causes the tympanic membrane to vibrate
- Three bones of the middle ear transmit vibrations to the oval window on the cochlea
- Vibrations create pressure waves in the fluid of the cochlea that travels through the vestibular canal and ultimately strike the round window
- Pressure waves in the vestibular canal cause the basilar membrane to vibrate up and down causing its hair cells to bend



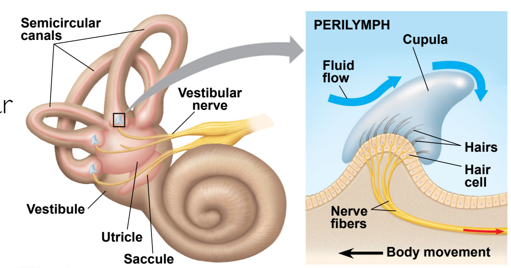




Fig, 50.12

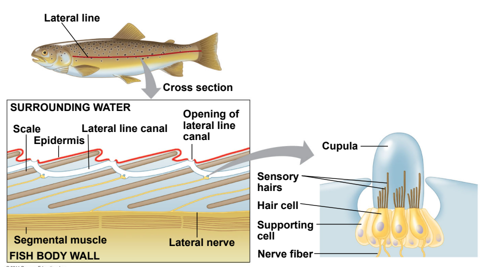


# EQUILIBRIUM

- Organs in the inner ear detect body position and balance
- Utricle, saccule, and semicircular canals in the inner ear function in balance and equilibrium
- In fish, the lateral line system contains mechanoreceptors with hair cells that respond to water movement



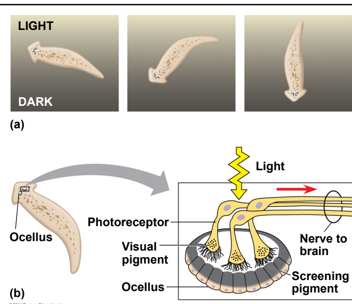

Figs. 50.13 & 50.14



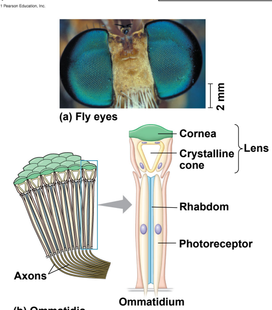



# VISION

- Most invertebrates have light-detecting organs (photoreceptors)
  - Planarians have an eye cup that provides information about light intensity and direction but does not form images
  - Compound eye - consist of several thousand light detectors called ommatidia (insects and crustaceans)
  - Single lens eye - work in a camera-like way (jellies, spiders, and molluscs)

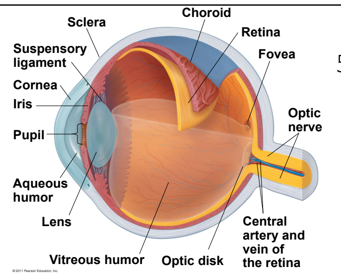


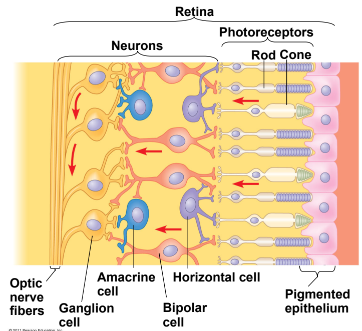

Figs. 50.15 & 50.16



# VISION

- Vertebrates
  - Camera like eyes that evolved independently and differ from single-lens eyes of invertebrates
  - Main parts of the vertebrate eye:
    - Sclera - includes the cornea
    - Choroid - pigmented layer
    - Conjunctiva - covers the outer surface of the sclera
    - Iris - regulates the pupil
    - Retina - contains the photoreceptors
    - Lens - focuses light on the retina




Figs. 50.17 & 49.19

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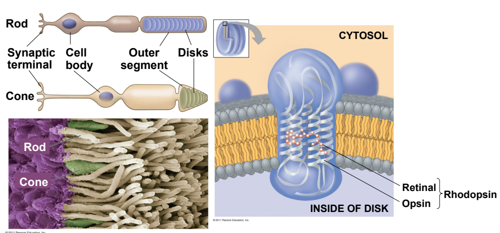
# VISION



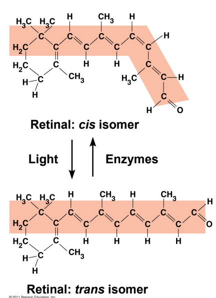




Fig. 50.17

- Retina contains two types of photoreceptors
  - Rods - sensitive to light but do not distinguish color
    - Contains pigment rhodopsin which changes shape when it absorbs light
  - Cones - distinguish color but not as sensitive
  - Each rod or cone contains visual pigments that consist of a light-absorbing molecules (retinal) bound to a protein (opsin)

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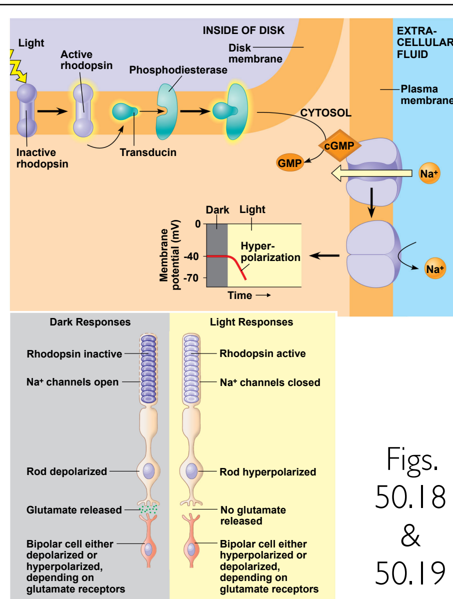
# VISION

- Absorption of light by retinal triggers a signal transduction pathway
- Dark - both rods and cones release the neurotransmitter glutamate into synapses with neurons called bipolar cells which are hyperpolarized or depolarized
- Light - rods and cones hyperpolarize shutting off release of glutamate; bipolar cells are depolarized or hyperpolarized




Figs. 50.18 & 50.19

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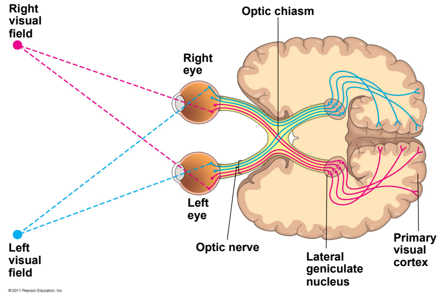
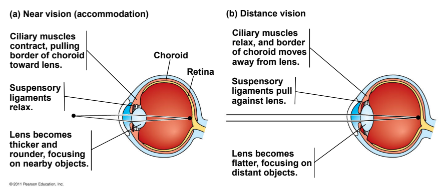
# VISION

- Three other types of neurons contribute to information processing in the retina: ganglion cells, horizontal cells, and amacrine cells
- Signals from rods and cones travel from bipolar cells to ganglion cells
- Axons of ganglion cells are part of the optic nerve transmit information to the brain
- Ganglion cell axons lead to the lateral geniculate nuclei of the thalamus which relays information to the primary visual cortex




Figs. 50.20 & 50.22

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# TASTE AND SMELL

- Gustation (taste) and olfaction (smell) are both dependent on chemoreceptors
- Insect taste receptors are located within sensory hairs called sensilla which are located on feet and in mouthparts
- Taste in humans - modified epithelial cells are organized into taste buds
    - Five taste perceptions: sweet, sour, salty, bitter, and umami (savoriness)
    - Transduction of taste occurs by several mechanisms

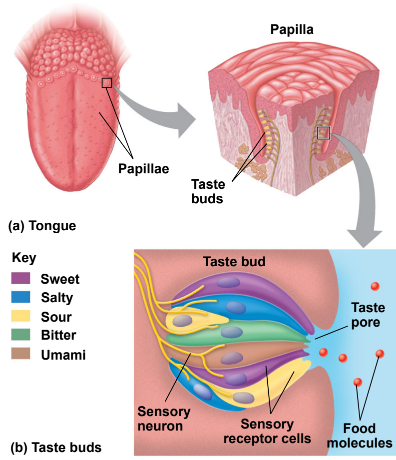


Fig. 50.24

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# TASTE AND SMELL

- Smell in humans - olfactory receptor cells are neurons that line the upper portion of the nasal cavity
    - When odorant molecules bind to specific receptors a signal transduction pathway is triggered by sending action potentials to the brain

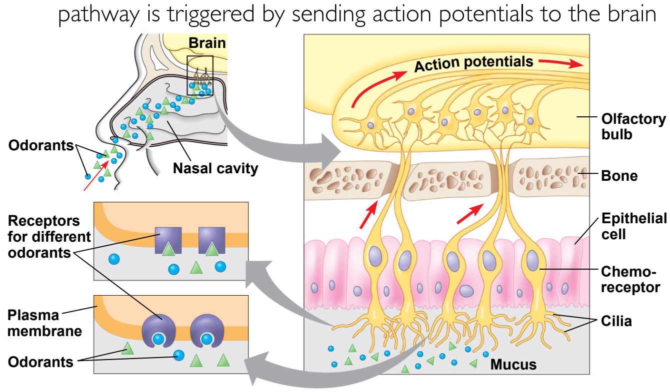


Fig. 50.25

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# MUSCLES

- Action of muscle is always to contract
- Muscles are attached to the skeleton in antagonistic pairs
- Skeletal muscle consists of bundles of long fibers running parallel to the length of the muscle
- Muscle fiber is a bundle of smaller myofibrils arranged longitudinally
- Myofibrils are composed of two kinds of myofilaments:
    - Thin filaments - two stands of actin and one strand of regulatory protein
    - Thick filaments - staggered arrays of myosin molecules

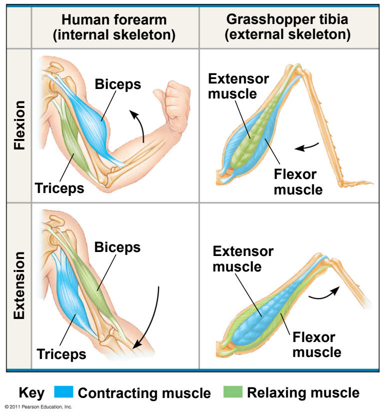


Fig. 50.34

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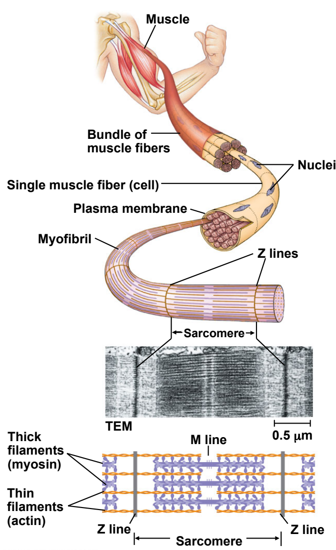
# MUSCLE

- Skeletal muscle is also called striated muscle because of the arrangement of myofilaments that creates a pattern
- Sarcomere - repeating unit (bordered by Z lines)
- Area that contains myofilaments are called the I band, A band, and H zone
- Sliding-filament model - filaments slide past each other longitudinally producing more overlap between tin and thick filaments
    - This causes the I band and H zone to shrink

Figs. 50.26

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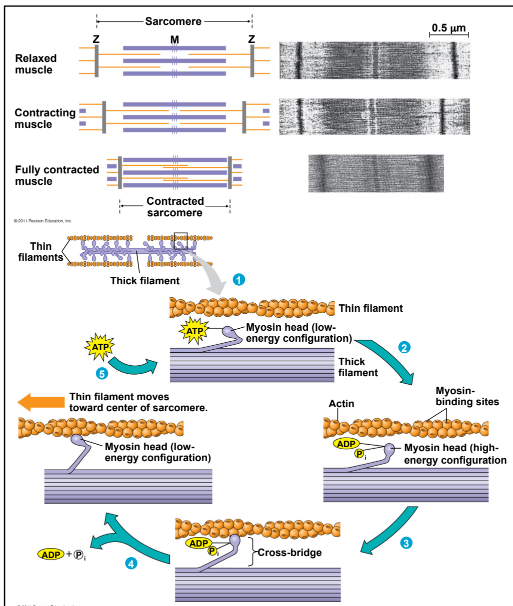


# MUSCLE

- Sliding of filaments is based on the interaction between actin and myosin molecules
- The "head" of a myosin molecule binds to an actin filament pulling the thin filament toward the center of the sarcomere

Fig. 50.27 & 50.28

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# MUSCLE

- Muscle only contracts when stimulated by a motor neuron
- When a muscle cell is at rest, the myosin binding sites on the thin filament are blocked by a regulatory protein (tropomyosin)
- For contraction, the binding sites must be uncovered.
  - Caused by calcium ions binding to another set of regulatory proteins (troponin complex)
- Stimulus leading to the contraction of a skeletal muscle fiber is an action potential in a motor neuron that makes a synapse with a muscle fiber

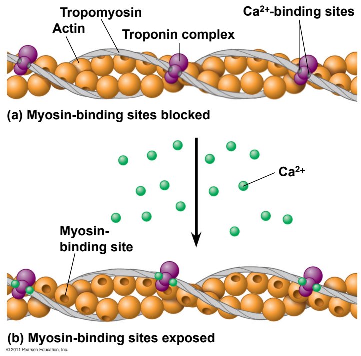


Fig. 50.29

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# MUSCLE

- Synaptic terminal of the motor neuron releases a nuerotransmitter (acetylcholine) to depolarize the muscle and cause it to produce an action potential
- Action potentials travel to the interior of the muscle fiber along infoldings of the plasma membrane (transverse tubules)
  - Action potential along the T tubules causes release of $Ca^{2+}$
  - $Ca^{2+}$ binds to the troponin-tropomyosin complex on thin filaments exposing the myosin binding sites

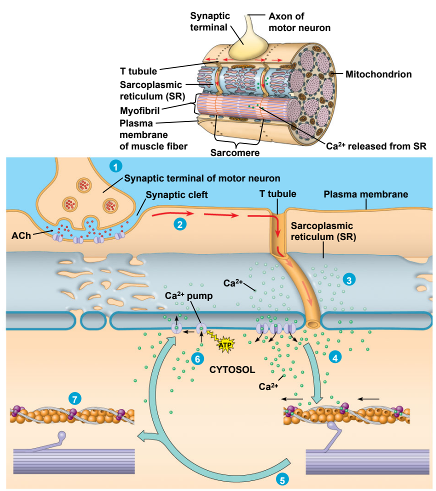


Fig. 50.30

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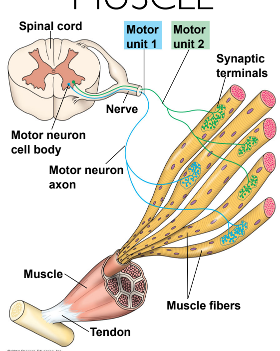
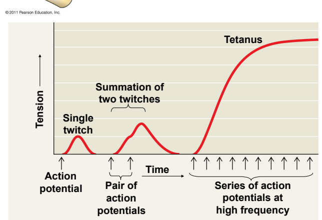
- Graded contractions - voluntarily control extent and strength of contractions
  - Vary number of fibers that contract
  - Vary rate at which fibers are stimulated
- Each muscle fiber is innervated by only on motor neuron, but each neuron may synapse with multiple muscle fibers
  - Motor unit - single motor neuron and all the muscle fibers it controls
- Twitch - single action potential in a motor neuron
- More rapid delivery produces a graded contraction
- Tetanus - state of sustained contraction

# MUSCLE




Figs. 50.31 & 50.32

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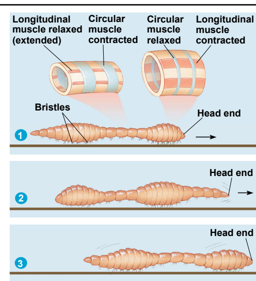
# TYPES OF MUSCLES FIBERS

- Skeletal muscle - many different functions
  - Slow-twitch - contract slowly, but sustain longer contractions
  - Fast-twitch - contract rapidly, but sustain shorter contractions
- Cardiac muscle - found only in the heart
  - Consists of striated cells that are electrically connected by intercalated discs and can generate action potentials without neural input
- Smooth muscle - found in walls of hollow organs
  - Contractions are slow and may be initiated by the muscles themselves or by stimulation of neurons in the autonomic nervous system

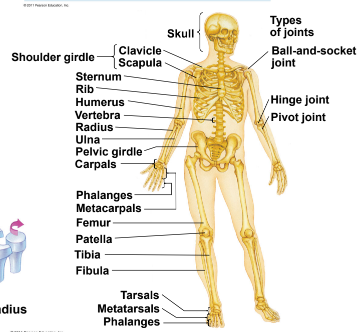


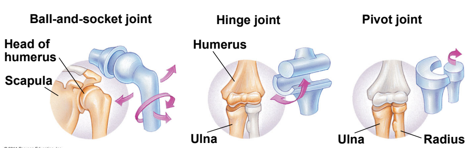
# SKELETONS

- Support, protection, and movement
- Types:
  - Hydrostatic skeleton - fluid held under pressure in a closed body compartment (cnidarians, flatworms, nematodes, and annelids)
    - Annelids use hydrostatic skeleton for peristalsis (movement through rhythmic waves)
  - Exoskeletons - exterior structure (molluscs and arthropods)
  - Endoskeleton - consists of hard supporting elements within an animal's soft tissue (sponges, echinoderms, and chordates)




Figs. 50.35 - 50.36






# LOCOMOTION

- Active travel from place to place
- Must overcome friction and gravity
- Flight - requires wings develop enough lift to overcome gravity
- Energy cost depends on mode of locomotion
- Animals that swim expend less energy than those who fly or run

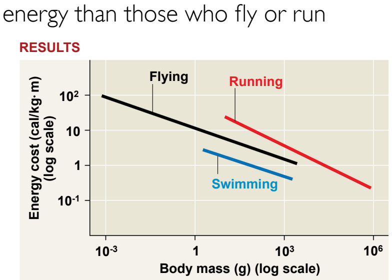



Fig. 50.40