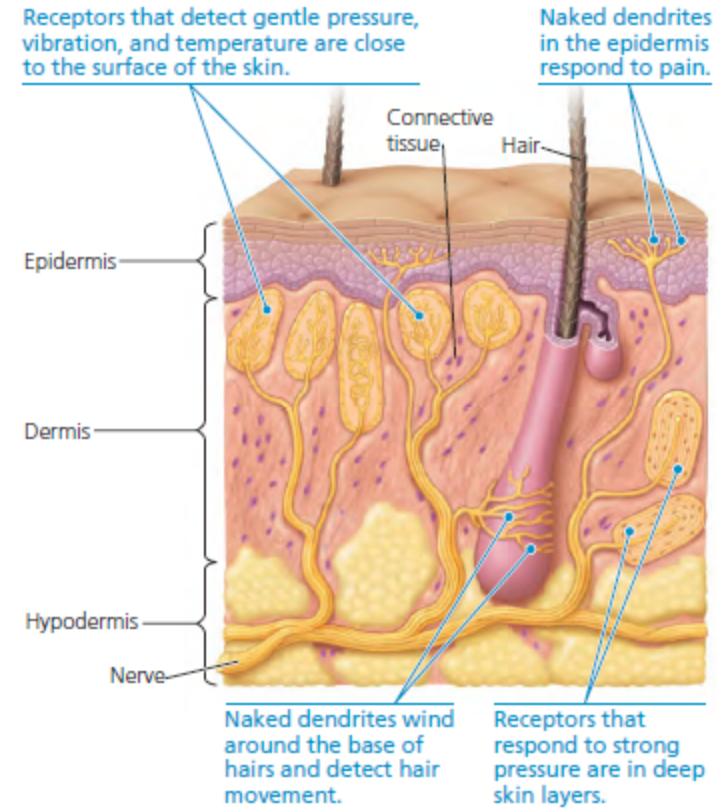
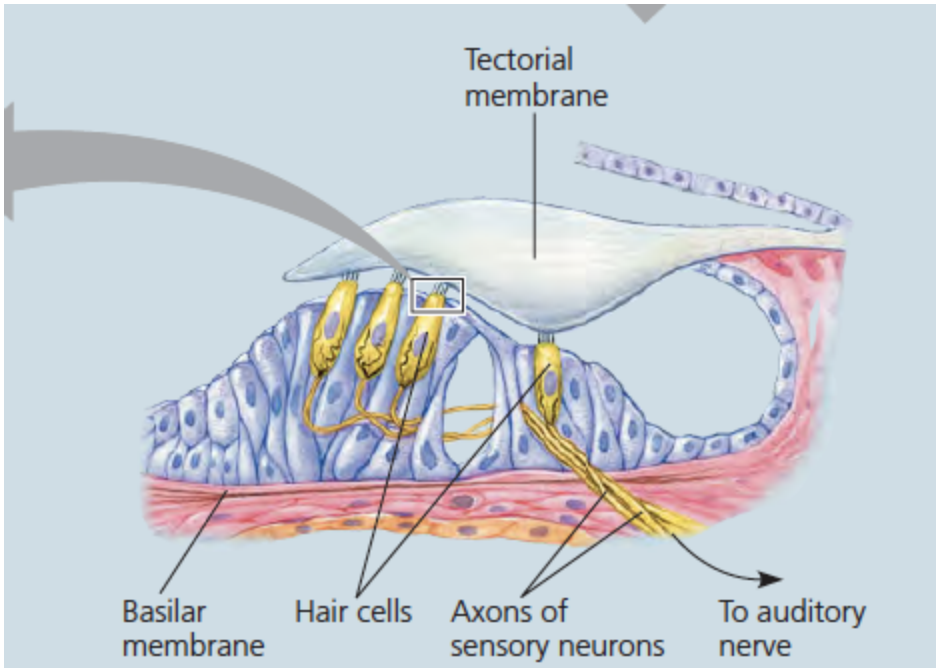
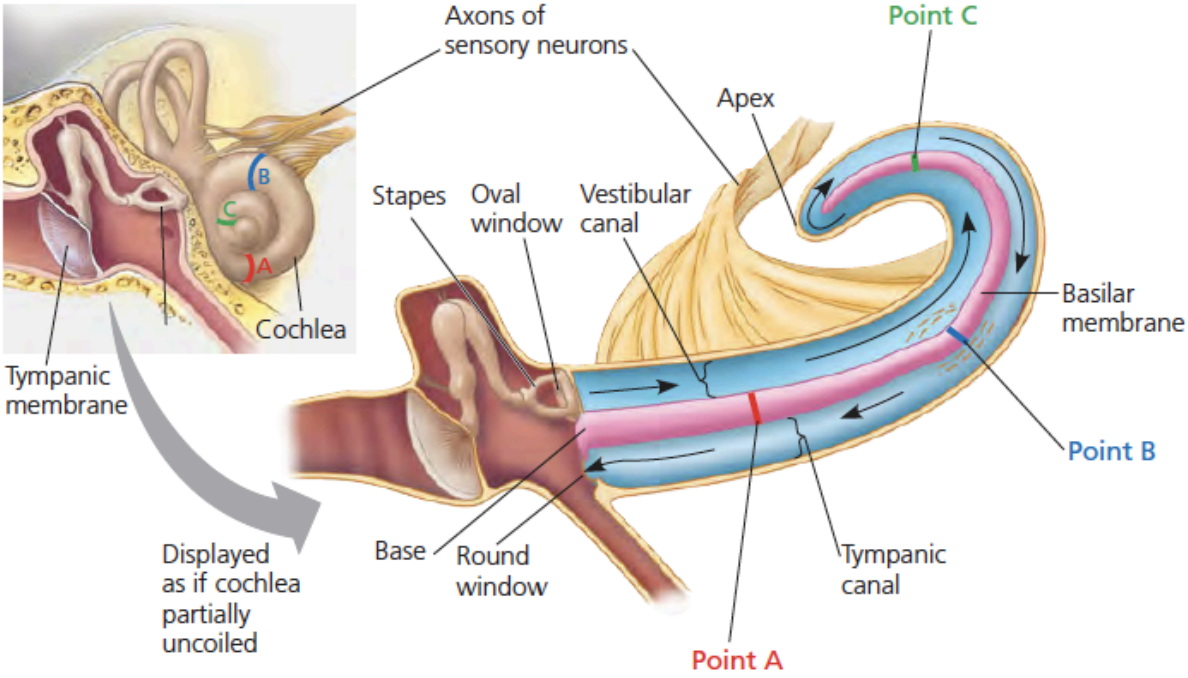
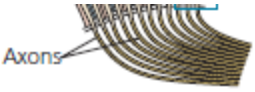
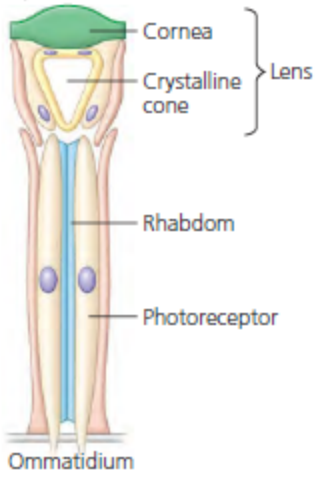
Cheat Sheet


Receptors that detect gentle pressure, vibration, and temperature are close to the surface of the skin.
Naked dendrites in the epidermis respond to pain.
Connective tissue
Hair
Epidermis
Dermis
Hypodermis
Nerve
Naked dendrites wind around the base of hairs and detect hair movement.
Receptors that respond to strong pressure are in deep skin layers.

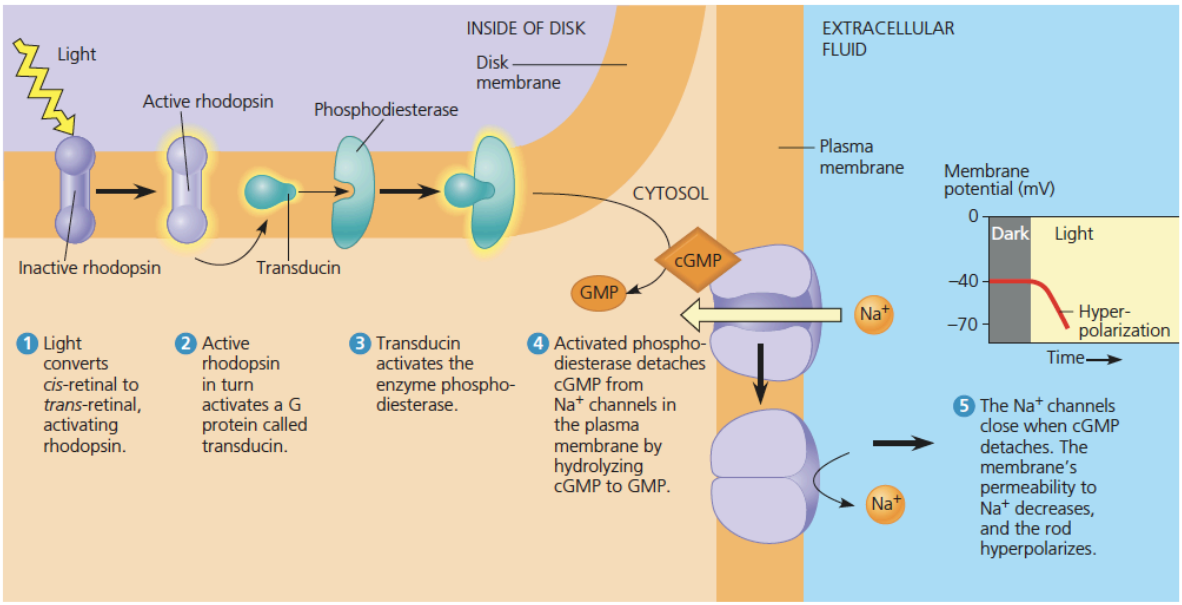

Tectorial membrane
Basilar membrane
Hair cells
Axons of sensory neurons
To auditory nerve

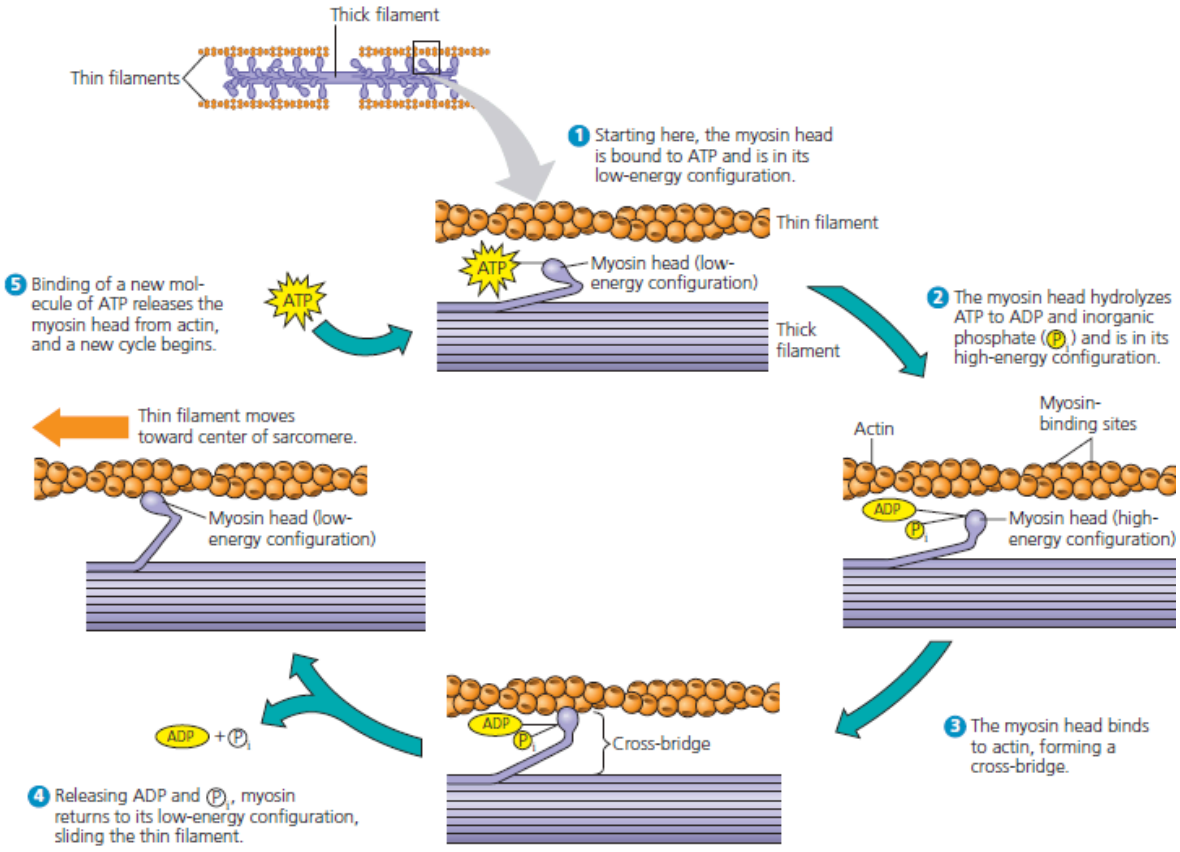




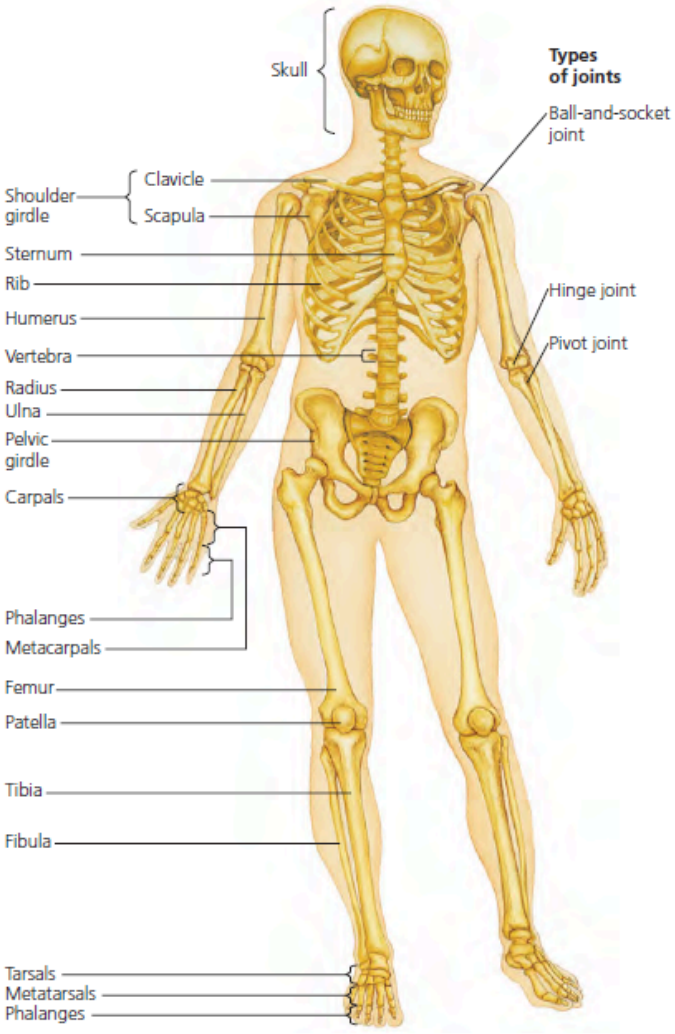


(b) The cornea and crystalline cone of each ommatidium together function as a lens that focuses light on the rhabdom, an organelle formed by and extending inward from a circle of photoreceptors. The rhabdom traps light, serving as the photosensitive part of the ommatidium. Information gathered from different intensities of light entering the many ommatidia from different angles is used to form a visual image.


Light
Active rhodopsin
Phosphodiesterase
INSIDE OF DISK
Disk membrane
EXTRACELLULAR FLUID
Plasma membrane
Inactive rhodopsin
Transducin
CYTOSOL
cGMP
GMP
Na+
Membrane potential (mV)
0
Dark
Light
–40
–70
Hyper-polarization
Time
1 Light converts cis-retinal to trans-retinal, activating rhodopsin.
2 Active rhodopsin in turn activates a G protein called transducin.
3 Transducin activates the enzyme phospho-diesterase.
4 Activated phospho-diesterase detaches cGMP from Na+ channels in the plasma membrane by hydrolyzing cGMP to GMP.
5 The Na+ channels close when cGMP detaches. The membrane's permeability to Na+ decreases, and the rod hyperpolarizes.

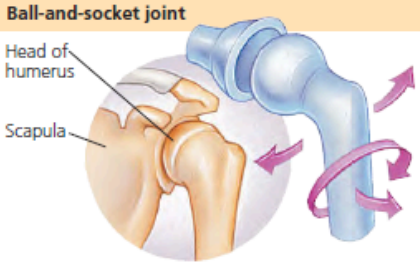

Thick filament
Thin filaments
1 Starting here, the myosin head is bound to ATP and is in its low-energy configuration.
Thin filament
ATP
Myosin head (low-energy configuration)
Thick filament
2 The myosin head hydrolyzes ATP to ADP and inorganic phosphate (Pi) and is in its high-energy configuration.
Actin
Myosin-binding sites
ADP
Pi
Myosin head (high-energy configuration)
3 The myosin head binds to actin, forming a cross-bridge.
Cross-bridge
4 Releasing ADP and Pi, myosin returns to its low-energy configuration, sliding the thin filament.
Thin filament moves toward center of sarcomere.
Myosin head (low-energy configuration)
5 Binding of a new molecule of ATP releases the myosin head from actin, and a new cycle begins.

▼ **Figure 50.36** **Bones and joints of the human skeleton.**



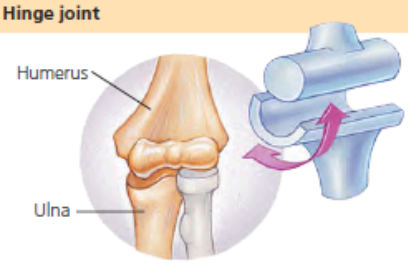
▼ **Figure 50.37** **Types of joints.**

Ball-and-socket joint



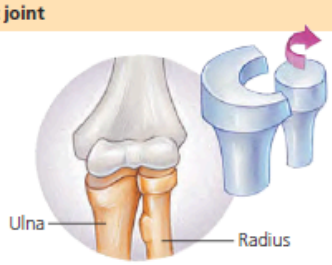
Ball-and-socket joints are found where the humerus contacts the shoulder girdle and where the femur contacts the pelvic girdle. These joints enable the arms and legs to rotate and move in several planes.

Hinge joint



Hinge joints, such as between the humerus and the head of the ulna, restrict movement to a single plane.

Pivot joint



Pivot joints enable rotating the forearm at the elbow and turning the head from side to side.

Chapter 50 Questions

1. **What is sensory reception?**
2. **What is a sensory receptor?**
3. **What is a receptor potential?**
4. **What is sensory transduction?**
5. **How is stimulus intensity encoded in action potentials?**
6. **What is perception?**
7. **What is amplification?**
8. **What is sensory adaptation?**
9. **What are mechanoreceptors?**
10. **What is the vertebrate stretch receptor?**
11. **Describe the sensory receptors in human skin.**
12. **What are chemoreceptors?**
13. **What are electromagnetic receptors?**
14. **What are thermoreceptors?**
15. **Why do spicy foods taste “hot”?**
16. **What is the TRP family of ion channel proteins?**
17. **What are nociceptors?**
18. **What are statocysts?**
19. **How do many insects detect sound?**
20. **What is the outer ear?**
21. **What is the middle ear?**
22. **What is the inner ear?**
23. **Describe the channels of the cochlea.**
24. **What are hair cells?**
25. **What is the organ of Corti?**
26. **How is sound converted to action potentials?**
27. **What is the round window?**
28. **What is volume?**
29. **What is pitch?**
30. **What is perilymph?**
31. **What are the utricle and saccule?**
32. **What are the semicircular canals?**
33. **How are the ear of fishes different from that of mammals?**
34. **What is the lateral line system?**
35. **Describe hearing in frogs/toads and reptiles.**
36. **What are photoreceptors?**
37. **What are ocelli?**
38. **What are compound eyes?**
39. **Describe the structure of an ommatidium.**
40. **What are single-lens eyes?**

41. What are the three layers that surround the human eye?
42. What is the cornea?
43. What is the iris?
44. What is the retina?
45. What is the optic disk?
46. What is the lens?
47. What are the liquids that fill the chambers of the eye?
48. Describe the organization of the retina.
49. Where are visual pigments embedded in photoreceptor cells?
50. What are rods?
51. What are cones?
52. What is the pigmented epithelium?
53. Describe vertebrate visual pigments.
54. How is light transduced?
55. Why are you briefly blinded if you walk from a bright sunlight to dark theater?
56. What is lateral inhibition?
57. What is a receptive field?
58. What is the optic chiasm?
59. Where to most ganglion cell axons lead to in the brain?
60. What vertebrates have very good color vision?
61. What are photopsins?
62. Why is red-green colorblindness common?
63. What is Leber's congenital amaurosis (LCA)?
64. How many rods and cones are in the human retina?
65. What is the fovea?
66. How does the lens change shape to focus?
67. What are gustation and olfaction?
68. Describe the chemical senses of insects.
69. What is DEET (N, N-diethyl-meta-toluamide)?
70. What are the five tastes in mammals?
71. How are taste receptor cells organized?
72. How are the sensations of sweet, umami, and bitter tastes identified?
73. How are sour tastants detected?
74. How are salty tastants detected?
75. How are odors detected?
76. What are thin filaments?
77. What are thick filaments?
78. What is skeletal muscle?
79. What is the sliding-filament model?
80. Describe the structure of thick filaments.
81. How do muscle fibers obtain enough energy?
82. What role do tropomyosin and the troponin complex play?
83. How do motor neurons trigger movement of Ca^{2+} into cytosol?

84. How is relaxation initiated?
85. What is amyotrophic lateral sclerosis (ALS)?
86. What is myasthenia gravis?
87. How are neurons connected with muscle fibers?
88. What is recruitment?
89. What is tetanus?
90. What are oxidative fibers?
91. What are glycolytic fibers?
92. What are fast-twitch fibers?
93. What are slow twitch fibers?
94. Why does doing high-endurance exercise improve fatigue-resistance?
95. What muscles are exclusively fast-twitch?
96. What is cardiac muscle?
97. What is smooth muscle?
98. What is special about the muscle of insect wings and clam shells?
99. What is a hydrostatic skeleton?
100. What are undulations?
101. What is peristalsis?
102. What is an exoskeleton?
103. How are the shells of most molluscs created?
104. What is a cuticle?
105. What is an endoskeleton?
106. Describe the endoskeleton of echinoderms.
107. Describe the vertebrate endoskeleton.
108. What is body posture?
109. Describe the bones of the human body.
110. What are the three types of joints in humans?
111. What is locomotion?
112. What are the most important factors of locomotion on land? sea? air?

Chapter 50 Answers

1. Detection of a stimulus by sensory cells.
2. Sensory cell/organ and subcellular structure that detects stimuli
3. Change in membrane potential due to opening/closing of ion channels due to stimulus
4. Conversion of stimulus to receptor potential
5. Frequency of action potentials changes (many neurons always generate action potentials but at a low rate)
6. Processing of input by circuits of neurons in brain
7. Strengthening of a sensory signal during transduction
8. Decrease in responsiveness upon continued stimulation
9. Sense physical deformation caused by mechanical energy. Consist of ion channels linked to extensions such as cilia and anchored to internal structures. Bending/stretching external structure alters ion channel permeability
10. Mechanoreceptor that detects muscle movement, triggers knee-jerk reflex, are dendrites of sensory neurons that spiral around middle of certain skeletal muscle fibers
11. See picture
12. Some transmit information about overall solute concentration, others respond to specific molecules
13. Detect forms of electromagnetic energy (e.g. light, electricity, magnetism)
14. Detect heat or cold
15. Contain capsaicin, applying capsaicin to sensory neurons causes influx of calcium ion, same receptor responds to heat
16. Transient receptor potential family, capsaicin and five other thermoreceptors. Receptor for temperatures under 28^{o}C activated by menthol
17. pain receptors, detect noxious (harmful) conditions, triggers defensive reactions
18. Organs in most invertebrates that sense gravity and maintain equilibrium. Statoliths (granules of sand grains/other dense materials) sit freely in chamber with ciliated cells. Statoliths resettle based on gravity, stimulate mechanoreceptors
19. Body hairs of differing thickness/length vibrate at different frequencies
20. External pinna and auditory canal, collects sound waves and channel them to tympanic membrane (eardrum, thin tissue)
21. Other side of tympanic membrane, three small bones (malleus/hammer, incus/anvil, and stapes/stirrup) transmit vibrations to oval window (membrane beneath stapes). Opens into Eustachian tube, passage that connects to pharynx to equalize pressure between middle ear/atmosphere.
22. Fluid filled chambers. Semicircular canals (function in equilibrium) and cochlea (coiled, bony chamber involved in hearing).
23. Upper vestibular and lower tympanic canal, separated by cochlear duct, both filled with fluid.

24. Sensory cells with hairlike projections that detect motion, have projection of rod-shaped hairs (each with core of microfilaments). Vibration of basilar membrane bends hairs against fluid and tectorial membrane
25. Contains mechanoreceptors of ear (hair cells with hairs projecting into cochlear duct, many hairs attached to tectorial membrane)
26. Vibrates tympanic membrane, vibrates middle ear, vibrates against oval window to create pressure waves in cochlea vestibular canal,. Pressure waves in vestibular canal press on basilar membrane, hair cells pressed against tectorial membrane
27. MEmbrane at end of tympanic canal of cochlea (pressure waves go to apex from vestibular canal, then enter tympanic), dissipates pressure waves, resets apparatus
28. Loudness determined by amplitude of sound wave (bends hair cells more)
29. Determined by sound wave's frequency. (relies of asymmetric structure of cochlea, basilar membrane not uniform. Narrow and stiff at oval window, wider/flexible at apex, each part of basilar membrane tuned to different frequency)
30. Liquid in ear
31. Chambers that allow us to perceive position with respect to gravity/linear movement, situated in vestibule behind oval window, contain hair cells that project into gelatinous material. In gel are small calcium carbonate particles (otoliths contact different hair cells) utricle horizontal saccule vertical
32. Connected to utricle, detect turning of head/linear acceleration. Hair cells form cluster and project into gelatinous cap (cupula).
33. Lack eardrum, cochlea, or opening to outside (vibration of water conducted to inner ear by skeleton of head, waves vibrate otholits to detect sound
34. Detection of low-frequency waves along either sides of body, water entering pores of line system bends cupula, leading to production of action potential, percieves self movement and other things movement in water
35. Frogs/toads - sound vibrations conducted to inner ear by tympanic membrane and single middle ear bone
    Reptiles are same but have cochlea
36. Sensory cells that contain light absorbing pigment molecules, genes that specify where and when they arise are shared by flatworms, annelids, arthropods, and vertebrates
37. Eyespots in head region of planarians, photoreceptors receive light only through opening without pigmented cells, planarian moves away from light
38. Eyes of insects, crustaceans, and some polychaete worms, consist of several thousands of light detectors called ommatidia (each has own light focusing lens), effective for detecting movement. Good color visions, some can see UV
39. see picture
40. In invertebrates, found in jellies, polychaete worms, spiders, molluscs. Like camera, small opening (pupil, through which light enters), iris changes diameter of pupil, single lens (muscles in invertebrates move it forward and back) directs light on layer of photoreceptors. Present in all vertebrates, in fishes = focuses like invertebrates, in others shape of lens is changed.

41. From outer to inner:
    Conjunctiva - Mucous membrane
    Sclera - connective tissue
    Choroid - thin, pigmented layer
42. Front of sclera, transparent
43. Front of choroid, colored, regulates amount of light entering pupil
44. Innermost layer of eyeball, just inside choroid.
45. Area where optic nerve exits eye, does not have photoreceptors
46. Transparent disk of protein, divides eye into two cavities
47. Aqueous humor (clear water substance at front of lens, blockage of ducts that drain fluid = glaucoma, increased pressure damages optic nerve), vitreous humor behind (jelly like)
48. Light passes through transparent layers of neuron to reach rods and cones. Each bipolar cell receives info from several rods/cones, ganglion from several bipolar, horizontal/amacrine cells integrate info. Optic disk lacks photoreceptors. Eventually sent to optic nerve/brain
49. In stack of membranous discs in outer segment
50. More sensitive to light than cones, do not distinguish colors (enable BW night vision)
51. Color vision, less sensitive, three types each with different sensitivity across visible spectrum
52. Outer edge of retina, associated with stacks of disks of photoreceptor cells
53. Light-absorbing molecule retinal (derivative of vitamin A) bound to membrane protein opsin (seven transmembrane alpha helices through disk membrane) (both together = visual pigment). VISUAL PIGMENT called rhodopsin in rods. Retinal converted to trans isomer by light (without kink, activates opsin protein), converted to cis by enzymes
54. Trans-retinal activates visual pigment (in rods, rhodopsin), which activates G protein, activates phosphodiesterase, hydrolyzes cGMP. cGMP normally keeps Na^+ channels open, but now Na^+ channels close, cell becomes hyperpolarized, shutting off release of glutamate, triggering change in membrane potential of bipolar cell (can hyperpolarize or depolarize in response), changing action potential transmission see picture
55. Bright light, rhodopsin remains active, response in rods becomes saturated, rods do not regain full responsiveness for several minutes. When saturated, called bleach because rhodopsin turns from purple to yellow
56. Horizontal cell inhibits more distant photoreceptors/bipolar cells that are not illuminated, sharpens edges and enhances contrast, occurs in brain and retina
57. Part of visual field to which a ganglion cell can respond
58. Near center of base of cerebral cortex, where optic nerves meet, formed by axons of ganglion cells. Axons in optic nerves routed so that left visual field transmitted to right side of brain and vice versa
59. Lateral geniculate nuclei, have axons that reach primary visual cortex in cerebrum
60. Most fishes, amphibians and reptiles (including birds)
61. 3 different visual pigments in 3 different cones, formed from retinal bound to three distinct opsin proteins

62. 5-8% in males, fewer than 1% in females, gene for red/green pigments X-linked. Blue pigment is on chromosome 7
63. Inherited retinal degenerative disease that causes severe loss of vision, can be treated with gene therapy
64. 125 million rods, 6 million cones
65. Center of visual field, no rods, high density of cones (150,000 per mm^2), ratio of cones to rods falls with distance to fovea
66. Ciliary muscles contract to thicken lens (near vision), ciliary muscles relax, causing choroid to move away from lens, suspensory ligaments pull against lens to flatten it (far vision)
67. Taste (detection of tastants present in solution), smell (detection of odorants in air), depend on chemoreceptors
68. Taste receptors within sensory hairs on feet and mouthparts (contains several chemoreceptors responsive to particular tastant class). Olfactory hairs on antennae smell airborne odorants
69. Chemical insect repellant, protects against bites by blocking mosquito olfactory receptor
70. Sweet, sour, salt, bitter, and umami. Umami = taste of glutamate. Monosodium glutamate (MSG) occurs in meat, aged cheese, imparts savory quality, receptors for all but salty identified
71. Each expresses receptor for single type of tastant. Are modified epithelial cells organized into taste buds scattered in several areas of tongue and mouth. Most associated with projections called papillae (any region of tongues can detect all tastes)
72. Require GPCR (one type of sweet receptor and one type of umami receptor, each assembled from different pair of GPCR proteins, 30 different for bitter).
73. Receptor belonging to TRP family, assemble into ion channel in plasma membrane, binding of sour substance causes depolarization.
74. Sodium channel detects sodium salts
75. Odorant binds to GPCR called olfactory receptor (OR) on plasma membrane of olfactory cilia, leads to production of cAMP. cAMP opens Na^+ and Ca^{2+} channels, leads to depolarization. Receptor cell sends impulses to olfactory bulbs of brain. Each expresses one of 380 OR genes in humans, those that express same gene transmit to same region in bulb
76. Mainly composed of globular protein actin, two strands of actin coiled around one another (similar to microfilaments)
77. Staggered arrays of myosin molecules
78. Moves bones and body, bundle of long fibers, each fiber is single cell with multiple nuclei, embryonic cells fuse to form fiber. Nuclei surrounded by longitudinal myofibrils (bundles of thick and thin filaments). Sarcomeres are repeating sections in myofibrils, basic contractile units of skeletal muscle. Borders (Z lines) line up in adjacent myofibrils creating striations. Thin filaments attach at Z lines, thick filaments anchored in middle of sarcomere (M line)
79. Well-accepted, thin and thick filaments ratchet past each other powered by myosin. See picture.

80. Each myosin molecule has long tail region, globular head region, tail adheres to other tails, head can bind to ATP, hydrolysis of ATP converts myosin to high energy form that binds to actin. Myosin head returns to low-energy form as it helps pull thin filament towards M line. Each end contains about 300 heads, each forms 5 bridges per second
81. Contain only enough ATP for few contractions. Creatine phosphate transfers phosphate group to ADP, can sustain contractions for 15 sec. Glycogen broken down to glucose, metabolized by aerobic respiration, can sustain contractions for an hour. Intense muscle activity uses lactic acid fermentation
82. Regulatory protein, set of other regulatory proteins, bound to actin strands, covers myosin binding sites. Motor neurons trigger release of Ca^{2+} into cytosol, which binds to troponin complex, exposing myosin binding sites (contraction begins)
83. Acetylcholine released. Binding of acetylcholine leads to depolarization that initiates action potential. Action potential spreads inward by infoldings of membrane called tranverse (T) tubules. T tubules make contact with sarcoplasmic reticulum (SR), specialized ER. Action potential opens Ca^{2+} channels in SR.
84. Proteins in SR pump Ca^{2+} back into SR.
85. Motor neurons in spinal cord and brainstem degenerate, muscle fibers atrophy. Progressive, usually fatal in 5 years after symptoms
86. Person produces antibodies to acetylcholine receptors, transmission between motor neurons/muscle fibers declines, can be controlled by drugs that inhibit acetylcholinesterase or suppress immune system
87. Motor neuron may synapse with many fibers, each fiber with only one neuron. Motor unit = single motor neuron and all its muscle fibers.
88. More and more corresponding motor neurons activated to increase force, force developed by muscle progressively increases.
89. Smooth, sustained contractions caused by action potentials at frequency so high that muscle fiber can't relax between contractions. Also a disease of uncontrolled muscle contraction caused by bacterial toxin
90. Fibers that rely mostly on aerobic respiration, have many mitochondria, rich blood supply, large amount of myoglobin (oxygen-storing protein, brownish red pigment, more affinity than hemoglobin). Dark meat
91. Larger diameter, less myoglobin, use glycolysis as primary ATP source, fatigue more readily. Light meat
92. Develop tension 2-3 times faster than slow-twitch fibers, enable rapid/powerful contractions, can be oxidative or glycolytic
93. Less SR, pumps Ca^{2+} more slowly, lasts 5x longer that fast, all are oxidative
94. If muscle used repeatedly for high endurance activities, some fast glycolytic fibers can develop into fast oxidative fibers
95. Eye and hand
96. Found only in heart and is striated, can initiate rhythmic depolarization/contraction without nervous system. Signals from pacemaker for heart spread because of intercalated disks (with gap junctions) electrically coupling each cardiac muscle cell to adjacent cells, long refractory period prevents summation/tetanus

97. Found in walls of hollow organs, found in eye (focusing/pupil diameter), lack striations, filaments not regularly arrayed.Thick filaments scattered, thin filaments attached to dense bodies (some tethered to plasma membrane). Less myosin, myosin not associated with specific actin strands, some only contract with neurons, others electrically coupled, contract/relax more slowly than striated muscles. Lack troponin complex and T tubules, SR not well developed, Ca^{2+} enters through plasma membrane. Calcium ions bind to calmodulin, that activates enzyme that phosphorylates myosin head
98. Wings beat faster than action potentials can arrive
    modification of certain proteins allow them to remain contracted for month with low energy consumption rate
99. Consists of fluid held under pressure in closed body compartment. In cnidarians, flatworms, nematodes, and annelids. Muscles change shape of fluid-filled compartments.
100. Wavelike motions in nematodes where longitudinal muscles contracting around body cavity move animal forward
101. Movement produced by rhythmic waves of muscle contractions passing from front to back
102. Hard covering deposited on an animal's surface.
103. Calcium carbonate secreted by mantle (sheetlike extension of body wall)
104. Coat secreted by epidermis in insects and other arthropods, jointed exoskeleton. 30-50% of arthropod version has chitin, fibrils embedded in protein matrix
105. Hardened internal skeleton, buried within soft tissues, in sponges, echinoderms, etc.
106. Formed by ossicles (hard plates composed of magnesium carbonate or calcium carbonate crystals
107. Cartilage, bone. in mammals more than 200 bones. Osteoblasts secrete bone matrix and build/repair bone. Osteoclasts resorb bone components for remodeling
108. Position of legs relative to main body, more important than leg size in mammals and birds
109. see picture
110. See picture
111. Active travel from place to place
112. Strong muscles/skeletal support, maintaining balance
    Overcoming drag (sleek, fusiform shape)
    wing shape, drag, and weight