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Chapter 46 Animal Sensory Systems and Movement

I. How Do Sensory Organs Convey Information to the Brain?
  A. The type and sensitivity of sensory systems varies among different animals.
    1. Moths mate at night under conditions in which it is difficult or impossible to see.
      a. Females emit pheromones.
      b. Males have large, feathery antennae that can detect even one molecule of pheromone.
      c. Males fly toward an increasing concentration of pheromone.
    2. Bats are also active at night, hunting moths.
      a. Bats emit high-pitched sounds that echo off objects indicating the direction & shape of objects.
      b. Moths, detecting sounds of an onrushing bat, go into a chaotic escape flight to evade the moth.
    3. Senses that humans don't have
      a. Some aquatic predators detect electric fields in the muscles of passing prey.
      b. Many birds, sea turtles, and other animals detect magnetic fields.
      c. Biologists who work on these animals have the challenge of studying stimuli they cannot themselves detect.
    4. Accurate sensory information is essential for guiding the movements of animals.

  B. Sensory Transduction
    1. Each type of sensory information is detected by a sensory neuron or specialized receptor cell that synapses with a sensory neuron.
      a. The brain integrates information from sensory neurons of different types.
      b. Electrical impulses are sent to specific muscle groups.
    2. Review of how nerve-impulse transmission works
      a. Electrical potential arises when charges across a cell membrane are separated, as when ion concentrations differ on either side.
      b. At rest, the inside of a neuron is more negative relative to the outside.
      c. Changes in electrical potential are recorded with microelectrodes.
      d. Ion flows that cause the interior of the neuron to become
    3. Sensory receptors & neurons transduce the sensory information into changes in membrane polarization.
      a. Sensory stimuli cause ions to flow across the membrane.
      b. If a large change in potential occurs, an action potential is sent to the brain.
      c. If all types of sensory information are converted to electrical signals, how is it possible for the brain to interpret the information?

  C. Transmitting Information to the Brain
    1. Receptor cells tend to be highly specialized.
      a. Each receptor in a human ear responds best to certain sound frequencies.
      b. The train of action potentials from a receptor cell contains information about
    2. Each sensory neuron sends its information to a specific portion of the brain.
    3. Different regions of the brain are specialized for interpreting different types of stimuli.

II. Hearing

  A. Hearing is the ability to sense changes in pressure called sound.
    1. Sound consists of pressure waves of air or water.
    2. The number of pressure waves per second is the frequency of the sound.
    3. Different sound frequencies are perceived as different pitches.
    4. Other types of pressure changes can be sensed by some animals.
      a. Crabs use pressure detection to sense gravity.
      b. Other types of pressure-receptor cells in animals monitor stretching of blood vessels or muscles or direct pressure on the skin.

  B. How do sensory cells respond to sound waves and other forms of pressure?
    1. Direct physical pressure on a cell membrane, or distortion by bending, causes ion channels in the pressure-receptor cell to open or close.

a. The membrane depolarizes or hyperpolarizes.
b. A new pattern of action potentials is sent down a sensory neuron.

2. Hair cells are pressure receptors.
   a. Stiff outgrowths, called stereocilia, are located at one end of the cell.
   b. Stereocilia are arranged in increasing order of height, & extend into a fluid-filled chamber.
   c. The extracellular fluid around stereocilia has a very high K^+ concentration.
   d. If stereocilia bend in one direction, K^+ channels open and depolarize the cell.
   e. If stereocilia bend in the opposite direction, K^+ channels close and the cell hyperpolarizes.

C. The Mammalian Ear
1. In the ear, airborne sound waves are translated into water-borne waves.
2. The outer ear consists of the tympanic membrane and ear canal.
   a. Sound waves reaching the ear cause the tympanic membrane to vibrate.
   b. The membrane vibrates with the same frequency as the sound wave.
   c. The vibrations are passed to the middle ear.
3. The middle ear amplifies sound.
   a. The vibrations of the tympanic membrane are passed to the ear ossicles.
   b. The ear ossicles consist of three bones.
   c. The last bone, the stapes, vibrates against the oval window, causing it to oscillate.
   d. Oscillations of the oval window cause pressure waves in the fluid-filled cochlea.
4. The inner ear contains the fluid-filled cochlea.
   a. Pressure waves in the cochlea fluid are sensed by hair cells.
   b. How can hair cells distinguish different frequencies of sound?
5. The cochlea detects the frequency of sounds.
   a. The cochlea is divided by internal membranes into three chambers.
   b. The upper and lower chambers are filled with fluid and transmit vibrations to the middle chamber.
   c. Hair cells are located in the middle chamber.
   d. Hair cells are sandwiched between the basilar and tectorial membranes.
   e. When a segment of the basilar membrane vibrates, the stereocilia are bent one way and then the other by the tectorial membrane.
   f. Ion channels in the hair cells open, & an action potential is sent along sensory neurons to the brain.
   g. Complex sounds contain a many frequencies & causeing a specific pattern of hair cells to fire action potentials.
   h. The brain learns to associate certain patterns with certain sounds.

D. Sensory Worlds: What Do Other Animals Hear?
1. Elephants communicate through infrasonic sounds.
   a. Elephants recorded with a microphone capable of picking up extremely low-frequency sound.
   b. Infrasounds are those whose frequency is too low for humans to hear.
   c. Recent research shows that elephants have the best infrasonic hearing of any land mammal.
2. Ultrasonic hearing in bats is above the sound range of humans.
   a. Griffin and Galambos (1930s) detected ultrasonic sounds emitted from bats.
   b. If bats have their ears plugged or mouth taped shut, they frequently fly into objects.
   c. If the bat's eyes are masked, they never fly into objects.
   d. Conclusion: The bats are using mouth and ears, not their eyes, to navigate (echolocation).
   e. Dolphins, shrews, and other animals also use sonar to navigate.

III. Vision

A. Most animals are able to sense light.
1. Light-detecting eyespots are found in flatworms.
2. Image-forming eyes are found in vertebrates, mollusks, cephalopods, and arthropods.
   a. Insects have a compound eye composed of numerous ommatidia.
   b. Vertebrates have a camera eye.

B. The Vertebrate Eye
1. The outermost layer is the sclera, a rind of white tissue with a transparent front that forms the cornea.

2. Inside the cornea is a round, colored muscle called the iris, which contracts or expands to adjust the size of the pupil.
3. The size of the pupil determines the amount of light that reaches the lens.
4. The cornea and lens together focus light onto the retina at the back of the eye.
5. The retina has a layer of photoreceptors at the back, farthest from the entering light.
    a. Photoreceptors synapse with neurons in the layer next to them, and these synapse with other neurons in the innermost retinal layer.
    b. Axons from innermost neurons form the optic nerve, which extends to the brain.
    c. Why is the retina arranged with the photoreceptors at the back, or outermost layer?
6. What do photoreceptor cells do?
    a. Photoreceptors in vertebrates are either rods or cones.
    b. Rod and cone cells are modified neurons that use light absorption to regulate their secretion of neurotransmitters.
    c. Rods are highly sensitive to dim light, but not to color; thus night vision is largely black and white.
    d. Cones are highly sensitive to different colors, but less sensitive to dim light.
    e. Rods dominate the retina of humans.
    f. One small spot in the center of the retina, the fovea, has only cones.
    g. The high density of cones in the fovea maximizes image resolution.
7. How do rods and cones detect light?
    a. Rods and cones have outer segments packed with disc membranes.
    b. Embedded in the membranes are many copies of the protein rhodopsin.
    c. Rhodopsin consists of a protein (opsin) associated with a light-absorbing molecule (retinal).
8. Color vision: the puzzle of Dalton's eye
    a. The 18th-century chemist J. Dalton realized that he and his brother had red-green color blindness.
    b. Dalton's hypothesis: Red wavelengths failed to reach his eyes due to absorption by a bluish fluid in his eyes.
    c. Dalton specified that when he died, his eyes should be removed and examined to determine if his hypothesis was true.
    d. What caused Dalton's color blindness?
    e. Hypothesis: The brain distinguishes colors by integrating information from the three types of opsins.
    f. Does this hypothesis explain Dalton's color blindness?

C. Sensory Worlds: Do Other Animals See Color?
1. Different species have opsins with different peak light sensitivities.
    a. Coelacanths have two opsins that detect different wavelengths of blue light.
    b. Many correlations have been made between opsin structure and visual function.
2. Numerous other organisms probably perceive much richer color spectra than do humans.
    a. Some animals have four or more different opsins.
    b. Birds and insects are able to perceive ultraviolet light.
    c. Rattlesnakes and pit vipers sense infrared light.

IV. Taste and Smell

A. The senses of taste and smell originate in chemoreceptors.
1. Chemoreceptors detect the presence of specific molecules.
    a. The chemosenses respond to thousands of different molecules.
    b. To understand how requires an understanding of how specific molecules bind to certain receptors.
2. Animals use taste and smell to find food, assess mates, and avoid danger.

B. Taste: Detecting Molecules in the Mouth
1. Taste buds occur in the mouth and throat, but most are located on the tongue.
    a. Each taste bud contains about 100 spindle-shaped taste cells.
    b. Taste cells synapse to taste neurons that make connections to the brain.
    c. Salty tastes - due to Na^+ in food entering Na^+ channels in taste cells & depolarizing the membrane.
    d. Sourness is due to H^+ in food entering proton channels in taste cells & depolarizing the membrane.

e. The molecular mechanisms of bitter and sweet tastes have been difficult to determine.

2. Why do many different foods taste bitter?
   a. Molecules with very different structures are perceived as bitter tasting.
   b. A laboratory accident suggested that the ability to taste bitterness had a genetic component.
   c. The gene(s) involved in sensing bitter tastes were identified by comparing genetic markers in PTC "tasters" and "nontasters."
   d. The results were compared to a similar search in the mouse genome.
   e. Result: A family of 40–80 genes were identified that code for receptor proteins, each of which binds only one type of bitter molecule.
   f. Animals use the extensive array of bitter receptors to avoid toxic compounds in plants, many of which have a bitter taste.
3. What is the molecular basis of sweetness and other tastes?
   a. Membrane receptors for sweetness have yet to be identified.
   b. Membrane receptors for the amino acid monosodium glutamate (MSG) have been discovered.
   c. MSG causes the sensation of umami—the perception of a meaty taste.

C. Olfaction: Detecting Molecules in the Air
1. Smell allows animals to monitor airborne molecules that convey information.
2. Molecules that cause odor contain information about prey and members of their own species.
3. Olfactory receptor neurons are located in a mucus layer in the roof of the nose.
   a. Odor molecules bind to olfactory receptor neurons.
   b. The neurons project into the olfactory bulb of the brain.
4. How do olfactory receptor neurons distinguish one type of odorant from another?
   a. Initial hypothesis
   b. Buck and Axel (1991) found that hundreds of receptors exist.
   c. Recent results

V. Movement

A. Skeletons
1. Skeletons provide attachment sites for muscles and support for soft tissues.
   a. Exoskeletons are hard, hollow structures that enclose the body.
   b. Hydrostatic skeletons provide support from the pressure of internal fluids.
   c. Endoskeletons are hard structures inside the body.
2. Endoskeletons are composed of connective tissue made of cartilage and bone.
   a. The gelatinous matrix of cartilage provides padding between bones.
   b. Bone cells are in a hard, extracellular matrix of calcium phosphate, some calcium carbonate, and protein fibers.
   c. Bones articulate at joints in ways that allow limbs to swivel, hinge, or pivot.
3. The ends of skeletal muscles are often attached to two different bones by tendons.
   a. Tendons are bands of tough, fibrous connective tissue.
   b. Muscles can exert force only by contracting.
   c. Pairs of muscles must work in opposition to move a bone back and forth.
   d. Muscles are paired into antagonistic muscle groups.
   e. Animals with exoskeletons have flexors and extensors inside hollow joints.
   f. Animals with hydrostatic skeletons have paired circular & longitudinal muscles working in concert.
   g. Information from sensory systems activates the motor neurons that coordinate the running, flying, and eating movements of animals.

B. How do muscles contract to cause movement?
1. Vertebrate skeletal and heart muscle is composed of fibers.
   a. Each fiber is a long, slender muscle cell.
   b. Each muscle cell contains many small strands called myofibrils.
   c. Fibers and myofibrils are not visible in the sheets and bands of muscles that surround most organs and blood vessels.
2. Vertebrates have three types of muscle tissue:
   a. Skeletal muscle

    b. Cardiac muscle
    c. Smooth muscle
3. The sliding-filament theory
    a. Sarcomeres give skeletal muscle a striped appearance.
    b. The Huxley-Hanson model has been verified by further research.
4. How do actin and myosin interact?
    a. Each myosin molecule has a head region that projects from the thick filament.
    b. Model proposed by Rayment et al.
    c. Most animal movement is powered by actin/myosin interactions, including:
5. How does relaxation occur?
    a. Sarcomeres also contain tropomyosin and troponin proteins.
    b. Troponin and tropomyosin are moved out of the way to allow contraction to occur by events that begin at neuromuscular junctions.
6. An overview of events at the neuromuscular junction
    a. A motor neuron secretes acetylcholine into the neuromuscular synapse.
    b. Membrane depolarization triggers a series of action potentials in the muscle fiber.
    c. Action potentials propagate through the fiber in axon-like T-tubules.
    d. T tubules intersect with sheets of sarcoplasmic reticulum.
    e. The action potential causes calcium channels to open in the sarcoplasmic reticulum.
    f. Released Ca^{++} ions cause a conformational change in troponin.
    g. Troponin moves tropomyosin away from the actin binding sites.

Chapter Vocabulary

sensory organ
sensory neuron
sensory receptor
motor neuron

sensory transduction
integration
nociceptors
thermoreceptors
mechanoreceptors
chemoreceptors
photoreceptors
electroreceptors
membrane voltage
membrane potential
electrical potential
resting potential
depolarization
hyperpolarization
action potential
microelectrode

antennae
moth pheromone

hearing
sound
pitches
statocyst

pressure waves
pressure receptor
hair cell
stereocilia
kinocilium
frequency
hertz (Hz)

outer ear
ear canal
tympanic membrane
middle ear
ear ossicles
stapes
oval window
inner ear
cochlea
basilar membrane
tectorial membrane

infrasound
infrasonic vocalizations
infrasonic calls
sonar
ultrasonic hearing
echolocation

electric field
magnetic field

vision
eyespot
camera eye
compound eye
ommatidia
sclera
cornea
iris
pupil
lens
retina
fovea
optic nerve
blind spot

photoreceptor cell
rhodopsin
retinal
opsin
bipolar cell

rod cell
cone cell
red-green color blindness
L cones
S cones
M cones

ultraviolet light
infrared light

olfaction
olfactory cells
gustation
taste buds
taste cells
olfactory receptors
olfactory receptor neurons
olfactory bulb
glomeruli

salty taste
sour taste
bitter taste
phenylthiocarbamide (PTC)
sweet taste
monosodium glutamate (MSG)
umami

locomotion
exoskeleton
hydrostatic skeleton
endoskeleton
connective tissue
cartilage
bone
tendon

antagonistic muscle group
flexor
extensor
hamstring
quadriceps

muscle fiber
myofibrils
smooth muscle
intercalated disk
sarcomeres
actin
thin filament
myosin
thick filament
sliding filament theory
rigor mortis
tropomyosin
troponin
acetylcholine
T tubules
sarcoplasmic reticulum
type I myosin
type IIa myosin
type IIx myosin
slow-twitch muscle fiber
fast-twitch muscle fiber
aerobic respiration
myoglobin
anaerobic respiration
lactic acid