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44 Animal Sensory Systems

44.1 How Do Sensory Organs Convey Information to the Brain?

- ▷ **Transduction:** conversion of an external stimulus to an internal signal in the form of action potentials along sensory neurons.
 - Requires a sensory receptor:
 1. *Mechanoreceptors*: respond to changes in pressure.
 2. *Photoreceptors*: respond to particular wavelengths of light.
 3. *Chemoreceptors*: detect specific molecules.
 4. *Thermoreceptors*: respond to changes in temperature.
 5. *Nociceptors*: sense harmful stimuli such as tissue injury.
 6. *Electroreceptors*: detect electric fields.
 7. *Magnetoreceptors*: detect magnetic fields.
 - Frequency of action potential firing rate can indicate the intensity of the stimulus.
- ▷ **Transmission:** the process of sending the signal to the central nervous system.

44.2 Mechanoreception: Sensing Pressure Changes

- ▷ **Statocyst:** an fluid filled organ that helps use to help sense pressure created by gravity.
- ▷ Direct physical pressure causes ion channels to open and close, creating voltage gated action potentials.
- ▷ **The Mammalian Ear:**
 - *Outer ear*: collects incoming pressure waves and funnels them into tube known as the ear canal, which leads to the **tympanic membrane**, or eardrum.

- *Middle ear*: contains three tiny bones that the eardrum passes vibrations to in order to amplify sound. One of the bones, called **stapes**, vibrates against a membrane called the **oval window**, which separates the middle ear from the inner ear.
- *Inner ear*: the oval window oscillates in response to vibrations which generates waves in a chamber known as the **cochlea**. These waves are pressure inputs the hair cells respond to.
- ▷ Hair cells, forming rows that sit in the middle chamber, are embedded in a tissue that sits atop the **basilar membrane**. In addition, the hair cells' stereocilia touch another smaller surface called the **tectorial membrane**.
- ▷ This sandwiching of hair cells produce very specific responses to various frequencies, allowing us to distinguish between them.
- ▷ **Lateral line system**: a mechanoreceptor organ that most fish and larval amphibians use. Consists of embedded gel-like domed structures called cupulae that lay inside canals along the length of the body.

44.3 Photoreception: Sensing Light

▷ The Insect Eye:

- **Compound eyes**: eyes composed of hundreds of thousands of light-sensing columns called **ommatidia**.
- Each ommatidium has lens that focuses light into a smaller number of receptor cells—usually four.

▷ The Vertebrate Eye:

- **Simple eye**: a structure with a single lens that focuses incoming light onto a layer of many receptor cells.
- **Structure of the Vertebrate Eye**:
 - *white of the eye*: outermost layer of the eye that consists of tough rind of white tissue called the *sclera*.
 - *Cornea*: a transparent sheet of connective tissue on the front of the

sclera.

- *Iris*: pigmented, round muscle just inside the cornea that can contract or expand to control the amount of light entering the eye.
- *Pupil*: hole in the center of the iris.
- *Lens*: works with the cornea to focus incoming light.
- *Retina*: a layer of photoreceptors and several layers of neurons.
 - The photoreceptors are held in place by the pigmented epithelium.
 - photoreceptors synapse with an intermediate layer of connecting neurons called **bipolar cells**.
 - Bipolar cells synapse with neurons called **ganglion cells**, which form the innermost layer of the retina.
 - The axons of the ganglion cells project to the brain via optic nerve.
 - Photoreceptors come in two distinct types:
 - **Rods**: sensitive to dim light but not to color.
 - **Cones**: sensitive to different wavelengths of light, but not dim light.
 - **Opsin**: a transparent membrane protein that associates with a molecule of pigment in the **retinal**.
 - **Rhodopsin**: a two molecule complex similar to opsin in rod cells.

44.4 Chemoreception: Sensing Chemicals

- ▷ Chemoreception occurs when chemicals bind to chemoreceptors, initiating action potentials in sensory neurons.
- ▷ **Gustation**: the sense of taste.
- ▷ **Olfaction**: sense of smell.
- ▷ **Taste buds**: clustered structures containing about 100 spindle shaped taste cells that make synapses with sensory neurons.
- ▷ *Salty*: due to sodium ions dissolved in food.

- ▷ *Sourness*: due to presence of protons.
- ▷ *Umami*: due to monosodium glutamate.
- ▷ **Odorants**: airborne molecules.
- ▷ **Olfactory bulb**: part of the brain where olfactory signals are processed and interpreted.
- ▷ **Pheromone**: a chemical that is secreted into the environment that affects the behavior or physiology of animals.

44.5 Other Sensory Systems

- ▷ Thermoreceptors are located in the central nervous system and also commonly found skin and other outer surfaces of animals.
- ▷ *nociceptor*: senses extreme temperatures as well as other painful stimuli produced by chemicals, excessive pressure, and tissue damage.
- ▷ **Ampullae of Lorenzini**: tiny pores scattered across a shark's head contain structures that are responsible for their electroreception. Sharks can detect electrical potentials as small as a nanovolt.
- ▷ *Electrogenic fishes* have specialized organs near their tails that generate electric fields stronger than those of regular nerves or muscles.
- ▷ *Magnetoreception*: seen in many organisms, including fungi, invertebrates, and all other vertebrate classes.

45 Animal Movement

45.1 How Do Muscles Contract?

- ▷ **Muscle fiber:** a muscle fiber is a long, thin muscle cell.
- ▷ Within each muscle cell are many threadlike, contractile structures called **myofibrils**.
- ▷ Myofibrils often look striped or striated due to alternating light and dark units called **sarcomeres**, which repeat along the length of a myofibril.
- ▷ The question of how muscles contract simplifies to how sarcomeres shorten.
- ▷ **Thin filaments** are composed of actin.
- ▷ **Thick filaments** are composed of myosin.
- ▷ **Sliding-filament model:** filaments slide past one another during contraction, with the sarcomere shorting with no change between the lengths of thick and thin filaments themselves.
- ▷ ATP is required for myosin to release from actin once the two molecules have bound to each other.
- ▷ **Tropomyosin** and **Troponin** work together to block the myosin binding sites on actin. When the sites are blocked, the myosin-actin interaction cannot occur, relaxing the muscle.

45.2 Muscle Tissues

- ▷ **Smooth Muscle:**
 - Unbranched.
 - Tapered at each end.
 - Often organized into thin sheets.
 - Lack sarcomeres, which gave them their smooth appearance.
 - Relatively small and have a single nucleus.

- Essential for the lungs, blood vessels, digestive system, urinary bladder, and reproductive system.
- Involuntary

▷ **Cardiac Muscle:**

- Makes up walls of the heart.
- Contain sarcomeres and is striated.
- Unique branching structure.
- Directly connected end to end via specialized regions called intercalated discs which are critical to the flow of electrical signals and coordination of the heartbeat.
- Involuntary

▷ **Skeletal Muscle:**

- Exceptionally long, unbranched muscle fibers.
- Multinucleate
- Contains sarcomeres
- Voluntary
- Force depends on:
 - relative proportion of different fiber types.
 - organization of fibers within the muscle.
 - how the muscle is used.

▷ **Skeletal Muscle Fiber Types:**

- **Slow muscle fibers:**
 - oxidative.
 - appear red, due to high concentration of myoglobin.
 - myosin hydrolyzes ATP at a slow rate, causing slow contraction.
 - slow to fatigue due to many mitochondria and aerobic respiration.

- **Fast muscle fibers:**

- glycolytic.
- appear white, due to low myoglobin concentration.
- myosin hydrolyzes ATP at a rapid rate.
- fast to fatigue due to primarily relying on glycolysis.

- **Intermediate muscle fibers:**

- combination of both fast and slow.

46 Chemical Signals in Animals

46.1 Cell-to-Cell Signaling

- ▷ **Autocrine Signals:** signals that affect the same cell that releases them.
- ▷ **Paracrine Signals:** diffuse locally and act on target cells near the source cell.
- ▷ **Endocrine Signals:** hormones carried to distinct cells by blood or other body fluids and released by discrete organs called glands.
- ▷ **Neural Signals**, or neurotransmitters, act on other neurons.
- ▷ **Neuroendocrine Signals:** hormones released by neurons that act on distant cells.
- ▷ Many hormones can act as multiple signal types.
- ▷ All three types of signaling pathway—endocrine, neuroendocrine, and neuroendocrine-to-endocrine—are regulated by negative feedback, or feedback inhibition.

46.2 How do Hormones Act on Target Cells?

- ▷ There are three chemical classes of hormones:
 - Peptides are polypeptides.
 - Amino acid derivatives.
 - Steroids.
- ▷ Steroids and thyroid hormones cross plasma membranes much more readily than other types of hormones.
- ▷ **Cyclic AMP (cAMP):** the key ingredient in the activation of phosphorylase, which catalyzes a reaction that cleaves glucose molecules off glycogen.
- ▷ **Signal transduction cascade** can allow the binding of just a single molecule of epinephrine may trigger the release of millions or even billions of glucose molecules.

- ▷ Most steroid and thyroid hormones act by inducing a change in gene expression.

46.3 What do Hormones Do?

- ▷ Hormones coordinate the activities of cells in three arenas:
 - development, growth, and reproduction.
 - response to environmental challenges.
 - maintenance of homeostasis.
- ▷ A single hormone may affect a wide array of cells and tissues and induce a variety of responses.
- ▷ **Xenoestrogens:** foreign chemicals that bind to estrogen receptors and induce estrogenlike effects.
- ▷ Cortisol triggers the long-term response to stressors by inducing changes that conserve glucose for use by the brain.
- ▷ Glucocorticoids make amino acids available for glucose synthesis by promoting the degradation of contractile proteins in muscle. The resulting loss of muscle mass may cause severe weakness.

46.4 How is the Production of Hormones Regulated?

- ▷ In many cases, hormone production is directly or indirectly controlled by the nervous system, where the release of a hormone is regulated by hormones from the anterior pituitary.
- ▷ Hormone-secreting cells in the anterior pituitary are regulated by hormones released by the hypothalamus.
- ▷ Glucocorticoids accomplish feedback inhibition—they suppress their own production.
- ▷ *Cushing's disease:* the result when feedback inhibition fails.

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