BIOL1040 Module 3

Support and Movement

50.1 Sensory receptors transduce stimulus energy and transit signals to the central nervous system

- All sensory processes begin with stimuli, and all stimuli represent forms of energy.
- A sensory receptor converts stimulus energy to a change in membrane potential, thereby regulating the output of action potentials to the CNS.
- When a stimulus is received and processes by the nervous system, a motor response is generated.
    - One of the simplest responses is reflex.
- There are four basic functions common to sensory pathways:
    - Sensory reception
    - Transduction
    - Transmission
    - Perception

Sensory Reception and Transduction

- A sensory pathway begins with sensory reception, the detection of a stimulus by sensory cells.
    - Some a neurons and others are cells that regulate neurons.
- The term sensory receptor describes a sensory cell or organ, as well as the subcellular structure that detects stimuli.
- After stimuli is detected, the effect in all cases is either to open or close ion channels.
    - The resulting flow of ions across the membrane changes the membrane potential.
- The conversion of a physical or chemical stimulus to change in the membrane potential of a sensory receptor is called sensory transduction.
    - The change in membrane potential itself is known as a receptor potentials.
    - They are graded potentials, meaning that their magnitude varies with stimulus strength.

Transmission

- Sensory information travels through the nervous system as nerve impulses, or action potentials.
- Neurons that act directly as sensory receptors produce action potentials and have an axon that extend into the CNS.
    - Non-neuronal sensory cells form chemical synapses with sensory (afferent) neurons and typically respond to stimuli by increasing the rate at which the afferent neurons produce action potentials.
- The size of a receptor potential increases with the intensity of the stimulus.
    - If the receptor is a sensory neuron:
        - A larger receptor potential results in more frequent action potentials.
    - If the receptor is not a sensory neuron:
        - A large receptor potential usually causes more neurotransmitters to be released.
- Processing of sensory information can occur before, during, and after transmission of action potentials to the CNS.
    - In many cases, integration begins as soon as information is received.

Perception

- When action potentials reach the brain via sensory neurons, circuits of neurons process this input, generating the perception of stimuli.
    - Perceptions are constructions formed in the brain and do not exist outside of it.
    - How do we distinguish stimuli?
        - Answer lies in the connections that link sensory receptors to the brain.
        - Action potentials travel along neurons that are dedicated to a particular stimulus, which synapse with particular neurons in the brain or spinal cord.
        - Therefore, the brain distinguishes stimuli based solely by the path along which the AP arrive.

Amplification and Adaption

- The transduction of stimuli by sensory receptors is subject to two types of modification:
    - Amplification
    - Adaption

- Amplification:
    - Refers to the strengthening of a sensory signal during transduction.
    - Eg. The AP conducted from the eye to the human brain has about one hundred thousand times as much energy as the photons that triggered it.
    - It occurs in sensory receptor cells and often requires signal transduction pathways involving second messengers.
    - These pathways amplify a signal through the formation of many product molecules by a single enzyme.
    - It can also take place in accessory structures of a complex sense organ:
        - Eg. When pressure associated with sound waves is enhanced more than 20-fold before reaching receptors in the innermost part of the ear.
- Adaption:
    - Upon continued stimulation, many receptors undergo a decrease in responsiveness.
    - Without sensory adaption, you would be constantly aware of every heart beat and bit of clothing on your body.
    - It also allows us to see, hear, and smell changes in the environment that vary widely in stimulus intensity.

Types of Sensory Receptors:

- Mechanoreceptors:
    - Sense physical deformation caused by forms of mechanical energy, such as pressure, touch, stretch, motion, and sound.
    - Typically consists of ion channels linked to structures that extend outside of the cell, such as cilia, as well as internal structures, such as the cytoskeleton.
    - Bending or stretching of the external structure generates tension, which alters ion permeability and therefore alters membrane potential
    - Eg. The vertebrate stretch receptor, a mechanoreceptor that detects muscle movement, triggers the knee-jerk reflex.
        - Vertebrate stretch receptors are dendrites of sensory neurons that spiral around the middle of certain small skeletal muscle fibres.
        - When the muscle fibres are stretched, the sensory neurons depolarise, triggering nerve impulses that reach the spinal cord, activate motor neurons, and generate a reflex response.
    - Also responsible for mammalian sense of touch.
    - Often embedded in layers of connective tissue.
        - Eg. Receptors that detect light touch or vibration are close to the surface of the skin.
- Chemoreceptors:
    - Include both general receptors – those that transmit information about total solute concentration – and specific receptors – those that respond to individual kinds of molecules.
        - Eg. Osmoreceptors in the mammalian brain detect changes in total solute concentration of the blood and stimulate thirst when osmolarity increases.
        - Most animals have specific receptors for glucose, oxygen, carbon dioxide, and amino acids.
- Electromagnetic Receptors:
    - Detects forms of electromagnetic energy, such as light, electricity, and magnetism.
        - Eg. The platypus has electroreceptors on its bill that are though to detect the electric field generated by the muscles of crustaceans and small fish.
    - Many animals appear to use the Earth's electromagnetic field lines to orient themselves as they migrate.
        - The mineral magnetite may be responsible for this.
- Thermoreceptors:
    - Detect heat and cold.
        - Eg. Venomous snakes rely on thermoreceptors to detect the infrared radiation emitted by warm prey.
    - Human thermoreceptors, which are located in the skin and in the anterior hypothalamus, send information to the body's thermostat in the posterior hypothalamus.
    - Applying capsaicin to a sensory neuron causes an influx of calcium ions → activates receptors that respond to 'hot' things → Hence spicy food is perceived as hot.
- Pain Receptors:

- Extreme pressure or temperature, as well as certain chemicals, can damage animal tissues.
- To detect stimuli that reflect such noxious conditions, animals rely on nociceptors (pain receptors).
- By triggering defection reactions, such as withdrawal from danger, the perception of pain serves an important function.
    - Eg. Damaged tissues produce prostaglandins, which act as local regulators of inflammation.
    - Prostaglandins worsen pain by increasing nociceptor sensitivity to noxious stimuli.
- Aspirin and ibuprofen reduce pain by inhibiting the synthesis of prostaglandins.

50.1 Summary
- The detection of a stimulus precedes sensory transduction, the change in the membrane potential of a sensory receptor in response to a stimulus.
    - The resulting receptor potential controls transmission of action potentials to the CNS, where sensory information is integrated to generate perceptions.
    - The frequency of APs in an axon and the number of axons activated determine stimulus strength.
    - The identity of the axon carrying the signal encodes the nature or quality of the stimulus.
- Mechanoreceptors respond to stimulus such as pressure, touch, stretch, motion, and sound.
- Chemoreceptors detect either total solute concentrations or specific molecules.
- Electromagnetic receptors detect different forms of electromagnetic radiation.
- Thermoreceptors signal surface and core temperatures of the body.
- Nociceptors detect pain in response to excess heat, pressure, or specific classes of chemicals.

50.2 Summary
- Most invertebrates sense their orientation with respect to gravity by means of statocysts.
    - Specialised hair cells form the basis for hearing and balance in mammals and for detection of water movement in fish and aquatic amphibians.
    - In mammals, the tympanic membrane (ear drum) transmits sound waves to bones of the middle ear, which transmit the waves through the oval window to the fluid in the coiled cochlea of the inner ear.
    - Pressure waves in the fluid vibrate the basilar membrane, depolarising hair cells and triggering action potentials that travel via the auditory nerve to the brain.
    - Receptors in the inner ear function in balance and equilibrium.

50.3 Summary
- Invertebrates have varied light detectors, including simple light-sensitive eyespots, image-forming compound eyes, and single-lens eyes.
    - In the vertebrate eye, a single lense is used to focus light on photoreceptors in the retina.
    - Both rods and cones contain a pigment, retinal, bonded to a protein (opsin).
    - Absorption of light by retinal triggers a signal transduction pathway that hyperpolarises the photoreceptors, causing them to release less neurotransmitter.
    - Synapses transmit information from photoreceptors to cells that integrate information and convey it to the brain along axons that form the optic nerve.