Sensory and Motor Systems

- **Sensations** are action potentials that reach the brain via sensory neurons.
- **Perception** is the awareness and interpretation of the sensation.
- Sensory receptors transduce stimulus energy and transmit signals to the nervous system.
- **Sensory reception** begins with the detection of stimulus energy by **sensory receptors.**
  - **Exteroreceptors** detect stimuli originating outside the body.
  - **Interoreceptors** detect stimuli originating inside the body.
  - Sensory receptors convey the energy of stimuli into membrane potentials and then transmit signals to the nervous system.
- **Mechanoreceptors** respond to mechanical energy.
  - For example, **muscle spindles** are an interoreceptor that responds to the stretching of skeletal muscle.
  - For example, **hair cells** detect motion.
- **Pain receptors** = **nocioceptors.**
  - Different types of pain receptors respond to different types of pain.
  - Prostaglandins increase pain by decreasing a pain receptors threshold.
    - Anti-inflammatories work by inhibiting prostaglandin synthesis.
- **Thermoreceptors** respond to heat or cold.
  - Respond to both surface and body core temperature.
- **Chemoreceptors** respond to chemical stimuli.
  - General chemoreceptors transmit information about total solute concentration.
  - Specific chemoreceptors respond to specific types of molecules.
  - Internal chemoreceptors respond to glucose, O_2, CO_2, amino acids, etc.
  - External chemoreceptors are **gustatory receptors** and **olfactory receptors**.
- **Electromagnetic receptors** respond to electromagnetic energy.
  - **Photoreceptors** respond to the radiation we know as visible light.
  - Electroreceptors: some fish use electric currents to locate objects.

A diversity of photoreceptors has evolved among invertebrates

- **Eye cups** are among the simplest photoreceptors
  - Detect light intensity and direction — no image formation.
  - The movement of a planarian is integrated with photoreception.
- Image-forming eyes.
  - **Compound eyes** of insects and crustaceans.
    - Each eye consists of up to several thousand light detectors, called **ommatidia**, each with its own light-focusing lens.
    - This type of eye is very good at detecting movement.
- **Single-lens eyes** are found in invertebrates such as jellies, polychaetes, spiders, and mollusks.
  - The eye of an octopus works much like a camera and is similar to the vertebrate eye.
- **Sclera**: a tough white layer of connective tissue that covers all of the eyeball except the cornea.
  - **Conjunctiva**: external cover of the sclera — keeps the eye moist.
- **Cornea**: transparent covering of the front of the eye.
  - Allows for the passage of light into the eye and functions as a fixed lens.
- **Choroid**: thin, pigmented layer lining the interior surface of the sclera.
  - Prevents light rays from scattering and distorting the image.
  - Anteriorly it forms the **iris**.
    - The iris regulates the size of the **pupil**.

- **Retina**: lines the interior surface of the choroid.
  - Contains photoreceptors.
    - Except at the **optic disk** (where the optic nerve attaches).
- The **lens** and **ciliary body** divide the eye into two cavities.
  - The anterior cavity is filled with **aqueous humor** produced by the ciliary body.
    - Glaucoma results when the duct that drain aqueous humor are blocked.
  - The posterior cavity is filled with **vitreous humor**.
  - The lens, the aqueous humor, and the vitreous humor all play a role in focusing light onto the retina.
- Photoreceptors of the retina.
  - About 125 million **rod cells.**
    - Rod cells are light sensitive but do not distinguish colors.
  - About 6 million **cone cells**.
    - Not as light sensitive as rods but provide color vision.
    - Most highly concentrated on the **fovea** – an area of the retina that lacks rods.
- **Rhodopsin (retinal** + **opsin)** is the visual pigment of rods.
- The absorption of light by rhodopsin initiates a signal-transduction pathway that ultimately leads to sight.

The mammalian hearing organ is within the ear

- The **outer ear** includes the external pinna and the auditory canal.
  - Collects sound waves and channels them to the **tympanic membrane** (eardrum), which separates the outer ear from the inner ear.
- From the tympanic membrane sound waves are transmitted through the **middle ear**, in which vibrations are conducted through three small bones collectively called **ossicles** (individually, the malleus, incus, and stapes).
  - From the stapes the sound wave is transmitted through the **oval window.**
  - Then the vibrations are conducted to the inner ear.
- The **inner ear** consists of a labyrinth of channels housed within the temporal bone.
  - The **cochlea** is the part of the inner ear concerned with hearing.
    - Structurally it consists of the upper vestibular canal and the lower tympanic canal, which are separated by the cochlear duct.
    - The vestibular and tympanic canals are filled with perilymph.
  - The cochlear duct is filled with endolymph.
  - The **organ of Corti**, which is in the cochlea, contains the receptors of the ear, which are hair cells with hairs that project into the cochlear duct.
  - The cochlea transduces the energy of the vibrating fluid into action potentials, in a wave that dissipates at the round window.
  - Some organs in the inner ear are responsible for detecting body position and balance. These are the **semicircular canals**.

Perceptions of taste and smell are usually interrelated

- Taste receptors in insects are located on their feet.
- Taste buds are modified epithelial cells situated on different parts of the tongue and mouth.
- In mammals, taste receptors are located in **taste buds** most of which are on the surface of the tongue.
- Each taste receptor responds to a wide array of chemicals.
  - It is the pattern of taste receptor response that determines something's perceived flavor.

Movement and Locomotion

- **Locomotion** is active movement from one place to another.
- For locomotion on land powerful muscles and skeletal support are more important than a streamlined shape.
- Cellular and Skeletal Underpinning of Locomotion.
  - On a cellular level all movement is based on contraction.
    - Either the contraction of microtubules or the contraction of microfilaments.
- **Hydrostatic skeleton**: consists of fluid held under pressure in a closed body compartment.
  - Form and movement is controlled by changing the shape of this compartment.
  - The hydrostatic skeleton of earthworms allow them to move by **peristalsis**.
  - Advantageous in aquatic environments and can support crawling and burrowing.
  - Do not allow for running or walking.
- **Exoskeletons**: hard encasements deposited on the surface of an animal.
  - Mollusks are enclosed in a calcareous exoskeleton.
  - The jointed exoskeleton of arthropods is composed of a cuticle.
    - Regions of the cuticle can vary in hardness and degree of flexibility.
    - About 30 – 50% of the cuticle consists of chitin.
    - Muscles are attached to the interior surface of the cuticle.
    - This type of exoskeleton must be molted to allow for growth.
- **Endoskeletons**: consist of hard supporting elements within soft tissues.
  - Sponges have spicules.
  - Echinoderms have plates composed of magnesium carbonate and calcium carbonate.
  - Chordate endoskeletons are composed of cartilage and bone.
    - The bones of the mammalian skeleton are connected at joints by ligaments.

Muscles move skeletal parts by contracting

- Muscles come in **antagonistic pairs**.
- Structure and Function of Vertebrate Skeletal Muscle.
  - Skeletal muscle is attached to bones and responsible for the movement of bones.
  - It consists of long fibers, each of which is a single muscle cell.
  - Each muscle fiber is a bundle of **myofibrils**, which in turn are composed of two kinds of myofilaments: **thin filaments and thick filaments.**

- **Thin filaments** consist of two strands of actin and one tropomyosin coiled about each other.
- **Thick filaments** consist of myosin molecules.
- Skeletal muscle is striated, and the basic contractile unit of the muscle is the **sarcomere**.
- The **Z lines** make up the border of sarcomeres;
  - The **I band** is the area near the end of the sarcomere where only thin filament exists.
  - The **A band** is the entire length of the thin filaments.
- During **muscle contraction**, the length of the sarcomere is reduced.
- The **sliding filament model** states that the thick and thin filaments slide past each other so that their degree of overlap increases.
  - This is dependent on the interaction between the **actin** and **myosin** molecules that make up the thin and thick filaments.

- Muscle cells contract when stimulated by a **motor neuron**.
- To stimulate muscle contraction, an action potential in a motor neuron that makes a synaptic connection with the muscle cell releases acetylcholine at the **neuromuscular junction**.
  - This depolarizes the muscle cell and triggers an action potential.
  - The action potential spreads along **T tubules** (transverse tubules). This changes the permeability of the **sarcoplasmic reticulum** to calcium ions, and the newly released calcium ions bind to troponin and cause it to move, exposing the myosin sites on actin; the muscle contracts.
- Fast and Slow Muscle Fibers.
  - **Fast muscle fibers** are adapted for rapid, powerful contractions.
    - Fatigue relatively quickly.
  - **Slow muscle fibers** are adapted for sustained contraction.
    - Relative to fast fibers, slow fibers have.
      - Less sarcoplasmic reticulum, consequently Ca^{2+} remains in the cytosol longer.
      - The twitch in slow muscle fibers lasts about 5 times longer than in a fast fiber.
      - More mitochondria, a better blood supply, and **myoglobin,** an oxygen-storing protein.