Unit 5 Notes: Homeostasis and Interacting Behavior

What is homeostasis?

• The ability of all living things (plants, animals, bacteria, etc.) to maintain stable internal conditions in response to changing environmental conditions.
• Stimuli: anything in the environment that causes a response
• Conditions inside living things must remain within tolerable limits or else the cells/organisms will not be able to function properly.
• What are some examples of things that need to be kept within a certain range in our bodies?
  • Body temperature
  • Blood pressure
  • Blood pH level
  • Glucose levels in the blood
  • Osmoregulation (water)
• How does the body maintain homeostasis?
  • Organ systems (digestive, circulatory, nervous) perform essential life functions.
  • Interactions between different organ systems are necessary to maintain homeostasis.
  • At the cellular level, the structure and function of the cell membrane contributes to cellular homeostasis.

Biological Organization

• Biological organization is a hierarchical system.
• Each level is more complex than the level below.
• Each level has properties that did not exist before.
• Cells (the smallest unit of life) → Tissues (a group of cells working together) → Organs (a group of tissues working together) → Organ systems (a group of organs working together)

Cell Structure

• Cytoplasm
  • Region of the cell that is within the plasma membrane
  • Includes the fluid, cytoskeleton, and all of organelles except the nucleus
  • Cytosol – Part of the cytoplasm that includes molecules and small particles, such as ribosomes, not membrane-bound organelles.
• Nucleus
  • Control center of the cell
  • Most prominent structure within a eukaryotic cell
• Plasma Membrane
  • Covers a cell’s surface
  • Acts as a barrier between the inside and outside of a cell
  • Composed of a phospholipid bilayer

Cell Transport and the Plasma Membrane

• In order for cells to function properly, materials (water, O2, glucose, CO2, ions, etc.) must be transported in and out.
• Cell Membrane:
  • Serves as a boundary between the cell and its environment allowing water, waste, and minerals in or out of the cell
  • The cell membrane maintains homeostasis by regulating what goes in and out of a cell.
  • It is selectively permeable, which means that the cell membrane allows some molecules in while keeping others out.
• What does the membrane select?
  • Small molecules CAN pass through the membrane with ease.
    • Water
    • Carbon dioxide
    • Oxygen
  • Large molecules and ions cannot pass through without help.
• The cell membrane is made of a phospholipid bilayer.
  • Hydrophilic head (water loving): glycerol and phosphate group
  • Hydrophobic tails (water fearing): fatty acid chains
• The Fluid Mosaic model: A structural model of the cell membrane showing that molecules are free to move sideways within the phospholipid bilayer.
  • Mosaic: an object comprised of bits and pieces embedded in a supporting structure
  • Fluid: constantly in motion
  • The plasma membrane gets this name because the proteins, lipids and carbohydrates imbedded in the membrane can move about in it.
• What is a carrier protein?
  • Carrier proteins are proteins which span the cell membrane creating a selectively permeable membrane that regulates which molecules enter and leave.
  • Used during facilitated diffusion and active transport
  • Carrier proteins are specific as to what they move across the cell membrane.
• What does concentration gradient mean?
  • A gradual change in the amount of substances on different sides of the cell membrane
  • Moving with (or down) the concentration gradient means HIGH \( \rightarrow \) LOW.
  • Moving against (or up) the gradient means LOW \( \rightarrow \) HIGH.

### Types of Transport (Passive vs. Active)

• Passive Transport
  • Free movement of particles across the cell membrane
  • DOES NOT REQUIRE ENERGY to happen!
  • Three types:
    • Diffusion
      • Diffusion is the natural movement of particles from an area of higher concentration to an area of lower concentration resulting in equilibrium.
    • Osmosis
      • Osmosis is the diffusion of WATER across a selectively permeable membrane from an area of high concentration to an area of low concentration.
    • Facilitated diffusion
      • Passive transport of materials across cell membrane by carrier proteins embedded in the membrane.
      • Glucose moves this way.
• What is equilibrium?
  • Diffusion (and osmosis) occurs until equilibrium is reached.
  • Equilibrium is reached when the concentration of molecules is the same throughout a space they occupy.
• How do you describe situations that are not in equilibrium?
  • Tonicity is a measure of the osmotic pressure gradient.
  • Isotonic (Iso = same)
    • The concentration of water molecules and solutes are the same inside and outside the cell.
    • Solutes are dissolved in water, like salt or sugar
    • Water molecules will move across the membrane at the same rate in both directions.
    • NO NET MOVEMENT, cell remains the same
    • Solute concentrations are equal on both sides of the cell.
  • Hypertonic (Hyper = above)
    • Hypertonic solution = high solute / lower water on outside
    • Water will move OUT of the cell – the cell will shrink.
    • Plant cells will lose turgor pressure (the pressure water molecules exert on the cell wall).
    • Plasmolysis occurs (cell membranes shrivel).
  • Hypotonic (Hypo = below)
    • Lower concentration of solute on outside of cell when compared to the inside of cell
    • Water will move INTO the cell
    • Cell will swell or possibly burst (called cytolysis)
    • Plant cells will gain turgor pressure
• Active Transport
  • Transport of materials across the cell membrane AGAINST the concentration gradient.
    • REQUIRES ENERGY
    • Examples:
      • Protein Pumps
      • Endocytosis
      • Exocytosis
  • Cell Membrane Pumps
    • Ion channels and carrier proteins sometimes assist in active transport.
    • REQUIRES ENERGY
    • Against concentration gradient - from LOW to HIGH
• Endocytosis
  • Cell engulfs material with a portion of the membrane and releases the contents inside the cell within a vesicle.
• Exocytosis
  • Materials are secreted or expelled by the cell.
    • Vesicle from golgi apparatus or ER moves to cell membrane.
    • Used to release large molecules like proteins, waste products, and toxins
Tissues

- Four types of body tissue
  - **Muscle tissue** - composed of cells that contract.
    - Movement is the result of muscle tissues contracting in a coordinated fashion
  - **Nervous tissue** - contains cells that receive and transmit messages in the form of electrical impulses
  - **Epithelial tissue** - layers of cells that line or cover all internal and external body surfaces
    - Different types/shapes depending on function
    - Often provides a protective barrier
    - Your skin is epithelial tissue.
  - **Connective tissue** - binds, supports, and protects structures in the body
    - Most abundant and diverse type of tissue
    - Includes Bone, Cartilage, Tendons, Fat, and Blood
    - Connects or holds things together, such as groups of muscles
    - Characterized by large cells that are embedded in large amounts of an intercellular substance called **matrix**
- Tissues work together to form organs.

Body Systems and Homeostasis

Is there a body system I can live without? How does the body function as a system?

- Body systems
  - An organ system consists of several organs working together to complete a specific task.
  - Organ systems work together to maintain a stable internal environment – this is called **homeostasis**.
  - There are many organ systems in your body:
    - Skeletal, Circulatory, Muscular, Respiratory, Integumentary (skin), Nervous, Reproductive, Urinary, Digestive, Endocrine, Immune
• Useful vocabulary
  • **Hormone** – signaling molecules, secreted by glands (endocrine system)
  • **Neurotransmitter** – substance that transmits nerve impulses across a synapse (from one neuron to another neuron)
  • **Peristalsis** – waves of involuntary muscle contraction along the walls of a hollow organ to move substances forward

• Organ systems maintain homeostasis
  • All of the organs and organ systems of the human body work closely together. This is because they are closely regulated by the nervous and endocrine systems.
  • The **nervous system** controls virtually all body activities, and the **endocrine system** secretes **hormones** that regulate these activities.
  • Functioning together, the organ systems supply body cells with all the substances they need and eliminate their wastes.
  • Maintain levels:
    ▪ Temperature
    ▪ pH
    ▪ Blood pressure
    ▪ Blood volume
    ▪ And other conditions at just the right levels to support life processes.
  • Some ways that organ systems help maintain homeostasis:
    ▪ **Respiratory system:** A high concentration of carbon dioxide in the blood triggers faster breathing. The lungs exhale more frequently, which removes carbon dioxide from the body more quickly.
    ▪ **Urinary system:** A low level of water in the blood triggers retention of water by the kidneys. The kidneys produce more concentrated urine, so less water is lost from the body.
    ▪ **Endocrine system:** A high concentration of sugar in the blood triggers secretion of insulin by an endocrine gland called the pancreas. Insulin is a **hormone** that helps cells absorb sugar from the blood.

• **Digestive system**
  • Mouth, esophagus, stomach, liver, pancreas, small and large intestine
  • The digestive system stores and breaks down food, absorbs nutrients (in the small intestine), and eliminates waste (water is absorbed and feces are produced in the large intestine).
  • Digestive system, Bacteria and our Immune System
    ▪ Trillions of bacteria normally live in the large intestine.
      ▪ Bacteria out number our own cells 10 to 1.
    ▪ Necessary for survival
      ▪ Most of them are helpful.
      ▪ Some of the bacteria **produce vitamins**, which are absorbed by the large intestine.
    ▪ Other functions of intestinal bacteria include:
      ▪ Controlling the growth of harmful bacteria.
      ▪ Breaking down indigestible food components.
      ▪ Producing substances that help prevent colon cancer.
      ▪ Breaking down toxins before they can poison the body.
      ▪ Communicate with immune system
  • How does the digestive system help maintain homeostasis?
    ▪ What could go wrong?
• **Celiac disease**: Your immune system thinks gluten (protein in wheat) is dangerous and attacks; the villi that line your intestinal tract are damaged. (Villi absorb nutrients as they pass through the intestine.)
• **Heartburn**: Stomach acid regurgitates into the esophagus, causing pain. Scarring may cause a narrowing of the esophagus.
• **Intestinal parasites** (ex. tapeworms, roundworms, giardia, cryptosporidium): Live in the intestines of the host.
• Nutrient absorption is affected.

• **Urinary system**
  • The urinary system filters waste products and excess water from the blood and excretes them from the body.
  • The kidneys play many vital roles in homeostasis.
    • They filter all the blood in the body many times each day and produce a total of about 1.5 liters of urine.
    • The kidneys **control the amount of water, ions, and other substances** in the blood by excreting more or less of them in urine.
    • The kidneys also **secrete hormones** that help maintain homeostasis.
    • Erythropoietin, for example, is a kidney hormone that stimulates bone marrow to produce red blood cells when more are needed.
  • What do the kidneys do when you are dehydrated?
    • The kidneys themselves are also **regulated by hormones**. For example, antidiuretic hormone from the hypothalamus stimulates the kidneys to produce more concentrated urine when the body is low on water.

• **Skeletal system**
  • The skeletal system protects internal organs, provides attachment surfaces for muscles, produces blood cells, and stores minerals.
  • How does the skeletal system help maintain homeostasis?
    • **Maintaining mineral homeostasis** is a very important function of the skeleton, because just the right levels of *calcium* and other minerals are needed in the blood for normal functioning of the body.
      • If **mineral levels are high**, bones absorb some of the minerals and store them as mineral salts, which is why bones are so hard.
      • When blood levels of **minerals are too low**, bones release some of the minerals back into the blood, thus **restoring homeostasis**.
  • As an attachment site for muscles, the skeletal system allows us to **respond to stimuli** and interact with our environment.
  • What happens when you don’t get enough calcium?
    • Brittle bones (osteoporosis)
    • Weak teeth
    • Muscle weakness
    • Calcium supplies the chemical energy that triggers contractions of the heart muscle and other muscles in your body.
    • Calcium also facilitates the release of neurotransmitters (chemicals that carry the body’s messages to the brain).
  • Too much calcium?
    • Kidney stones.
• **Muscular system**
  - The muscular system provides structure, supports and moves trunk and limbs and moves substances through the body.
  - Types of Muscle:
    - **Skeletal** – Voluntary muscles, attached to the skeleton by tendons. Contraction causes skeleton to move.
    - **Smooth** – Involuntary muscle, found in hollow parts (stomach, intestines, blood vessels and the bladder). Also known as visceral muscle (internal organs).
    - **Cardiac** – Involuntary muscle, found only in the walls of the heart. When cardiac muscle contracts, the heart beats and pumps blood. Contains a lot of mitochondria, which produce ATP for energy. This helps the heart resist fatigue.
  - Both skeletal and cardiac muscles appear striated, or striped, because their cells are arranged in bundles. Smooth muscles are not striated because their cells are arranged in sheets instead of bundles.
  - The muscular system relies upon the nervous system
    - Muscles rely upon the nervous system to relay instructions about when to contract.
      - Example: Raising your hand in class.
      - Your brain or spinal cord sends electrical messages to nerve cells, called motor neurons, in your arm and shoulder. The motor neurons, in turn, stimulate muscle fibers in your arm and shoulder to contract, causing your arm to rise.
    - Involuntary contractions of cardiac and smooth muscles are also controlled by nerves.

• **Circulatory system**
  - The circulatory system transports nutrients and wastes to and from all body tissues.
  - Heart, blood vessels, blood
  - Transports hormones, oxygen, nutrients from food, cellular wastes.
  - The circulatory system creates its own electricity.
    - Cardiac muscle contracts **without** stimulation by the nervous system.
    - Specialized cardiac muscle cells send out electrical impulses that stimulate the contractions. As a result, the atria and ventricles normally contract with just the right timing to keep blood pumping efficiently through the heart.
  - Blood vessels help regulate body processes by either constricting (becoming narrower) or dilating (becoming wider). These actions occur in response to signals from the autonomic nervous system or the **endocrine system**.
    - Constriction occurs when the muscular walls of blood vessels contract. This reduces the amount of blood that can flow through the vessels. Dilation occurs when the walls relax. This increases blood flows through the vessels.
    - Constriction and dilation allow the circulatory system to change the amount of blood flowing to different organs.
    - For example, during a **fight-or-flight response**, dilation and constriction of blood vessels allow more blood to flow to skeletal muscles and less to flow to digestive organs.
    - **Dilation** of blood vessels in the skin allows more blood to flow to the body surface so the body **can lose heat**.
Constriction of these blood vessels has the opposite effect and helps **conserve body heat**.

**Respiratory system**
- The respiratory system carries air into and out of the lungs, where gases (oxygen and carbon dioxide) are exchanged.
- O₂ is delivered to body cells and CO₂ is picked up from body cells.
- **Respiration vs. cellular respiration**
  - Cellular respiration - metabolic process by which cells obtain energy by “burning” glucose. Uses O₂ and releases CO₂.
  - Respiration by the respiratory system supplies the oxygen and takes away the carbon dioxide.
- The respiratory system relies upon the circulatory system
- Blood carries O₂ and CO₂ gases –
  - O₂ diffused into the bloodstream via alveoli (end-most point in the lungs), from there the O₂ goes...
    - Pulmonary capillaries → heart → arteries → peripheral capillaries → body cells → O₂ is used in cellular respiration and CO₂ is produced → body cells → peripheral capillaries → veins → heart → pulmonary veins → environment
- How does the respiratory system help maintain homeostasis?
  - It provides cells with oxygen the need for cellular respiration. Cells cannot survive for long without oxygen.
  - Gas exchange is also needed to carry away CO₂ waste. Some of the CO₂ in the blood dissolves to form **carbonic acid**, which keeps blood **pH within a normal range**.
    - Blood pH may become unbalanced if the rate of breathing is too fast or too slow. When **breathing is too fast**, blood contains too little carbon dioxide and becomes too **basic**. When breathing is **too slow**, blood contains too much carbon dioxide and becomes too **acidic**.

**Nervous system**
- The nervous system carries electrical messages throughout the body.
- Divided into two main systems:
  - The **central nervous system** (CNS)
    - Brain and spinal cord
  - The **peripheral nervous system** (PNS)
    - All other nerves
- **Neuron Structure**
  - **Cell body** - the nucleus and other cell organelles.
  - **Dendrites** - extend from the cell body and receive nerve impulses from other neurons.
  - **Axon** - long extension of the cell body that transmits or sends nerve impulses to other cells.
    - The axon branches at the end, forming axon terminals. These are the points where the neuron communicates with other cells.
      - The **synapse** - Place where an axon terminal meets another cell.
      - The **neurotransmitter** molecules are released from neurons to communicate to another cell.
      - Neurons rely upon **active transport** to maintain the resting potential (it’s ready to go into action at any time).

**Peripheral Nervous System**
- Types of Neurons - Classified based on the direction in which they carry nerve impulses.
• Afferent (Sensory) neurons carry nerve impulses from tissues and organs to the spinal cord and brain.
• Efferent (Motor) neurons carry nerve impulses from the brain and spinal cord to muscles and glands
• Interneurons carry nerve impulses back and forth between sensory and motor neurons.
  • **Somatic Nervous System** (SNS)
    • Controls skeletal muscle - voluntary control; raising your hand, speaking, running, includes all the senses and reflexes, etc.
  • **Autonomic Nervous System** (ANS)
    • Controls everything we don’t think about to keep us alive – involuntary; smooth muscle control.
      • The *sympathetic* division deals with emergency situations. It prepares the body for “*fight or flight*.”
      • The *parasympathetic* division controls involuntary activities that are not emergencies, “*rest and digest*.”
    • How does the nervous system help maintain homeostasis?
      • Somatic nervous system - also controls some unconscious movements called *reflexes*.
        • Reflex - very rapid motor response that is not directed by the brain; self-protective. Reflexes help to preserve the external state of the body and enable organisms to respond appropriately to stimuli.
        • In a reflex, nerve impulses travel to and from the spinal cord in a reflex arc. In this example, the person jerks his hand away from the flame without any conscious thought. It happens unconsciously because the nerve impulses bypass the brain.

• **Integumentary system**
  • The integumentary system provides a protective covering for the body, helps regulate body temperature, aids in sensory reception, functions in absorption of materials.
    • Skin, hair, nails
    • The skin is the body’s largest organ.
  • How does the integumentary system help maintain homeostasis?
    • **Temperature Regulation**
      • When the body is too warm, sweat is released by the sweat glands and spreads over the skin surface. As the sweat evaporates, it cools the body. Blood vessels in the skin also dilate (*vasodilation*), or widen, when the body is too warm. This allows more blood to flow through the skin, bringing body heat to the surface, where it radiates into the environment.
      • When the body is too cool, sweat glands stop producing sweat, and blood vessels in the skin constrict (*vasoconstriction*), or narrow, thus conserving body heat. Hair insulates the body (mostly the head) and prevents heat loss.
    • **Sensory receptors** (afferent neurons) notify us of danger or intruders.
      • Pain
      • Pressure (touch)
      • Temperature – more cold than hot receptors

• **Immune system**
  • The immune system provides protection against infection and disease.
- Lymph nodes and vessels, white blood cells
- How does the immune system help maintain homeostasis?
  - What is the purpose of a fever?
    - Most bacteria and viruses that cause infections in people thrive best at 98.6°F.
    - Fever is a defense against infection.
  - What happens if a fever gets too high for too long?

### Homeostasis – Endocrine System

- **Endocrine system**
  - The endocrine system regulates metabolism, water and mineral balance, growth, behavior, development and reproduction.
  - Glands, pancreas, hypothalamus, specialized cells in the brain, heart, stomach and other organs.
  - Just like the nervous system, the endocrine system carries messages – using hormones (chemical messenger molecules).
  - Endocrine hormones travel throughout the body in the blood. However, each hormone affects only certain cells, called target cells. A target cell is the type of cell on which a hormone has an effect. A target cell is affected by a particular hormone because it has receptor proteins that are specific to that hormone. A hormone travels through the bloodstream until it finds a target cell with a matching receptor it can bind to. When the hormone binds to a receptor, it causes a change within the cell.
  - How does the endocrine system help maintain homeostasis?
    - The endocrine system plays an important role in maintaining homeostasis.
    - It produces and secretes the hormones that regulate many body processes.
    - Most hormones are regulated by feedback mechanisms.

### Homeostasis – Feedback Mechanisms

- **Feedback Mechanisms**
  - Feedback mechanisms are specific systems and structures that communicate and work together to keep levels and processes within normal ranges.
  - Positive feedback vs. negative feedback

- **Negative Feedback**
  - Negative feedback occurs when your systems need to slow down or completely stop a process that is happening.
  - Various receptors and effectors bring about a reaction to ensure that conditions remain favorable.
  - A receptor is a structure that monitors internal conditions, senses changes, and initiates a response (usually by sending signals to the brain).
  - Effectors are muscles, organs and other structures that receive signals from the brain. When an effector receives a signal from the brain, it changes the function in order to correct the change.
  - Which other system plays an important role in homeostasis by sending messages out to the body to elicit responses to stimuli?
• Negative Feedback – example:
  • When you eat, food travels into your stomach, and digestion begins. You don’t need your stomach working if you aren’t eating. The digestive system works with a series of hormones and nervous impulses to stop and start the secretion of acids in your stomach.

• Negative Feedback – example
  • Temperature Regulation:
    • Heat and cold receptors are located in the skin. When the body temperature rises, the hypothalamus sends a nerve signal to the sweat-producing skin glands, causing them to release about 1-2 liters of water per hour, cooling the body.
    • The hypothalamus also causes dilation of the blood vessels of the skin, allowing more blood to flow into those areas, causing heat to be convected away from the skin surface.
    • When body temperature falls, the sweat glands constrict and sweat production decreases. If the body temperature continues to fall, the body will generate heat by raising the body's metabolic rate and by shivering.

• Negative Feedback – example:
  • After you exercise, you feel thirsty because of the drop in water content in your blood. The hypothalamus senses this and signals the pituitary gland to release ADH (antidiuretic). ADH reduces the water content of urine. The hypothalamus senses that level in blood is back up and signals pituitary gland to stop making ADH.

• Positive Feedback
  • Positive feedback is the opposite of negative feedback in that it encourages a physiological process or amplifies the action of a system.
• Positive feedback is a cyclic process that can continue to amplify your body’s response to a stimulus until a negative feedback response takes over.
• Positive feedback is less common.
• Positive feedback – example:
  • Your stomach normally secretes a compound called pepsinogen that is an inactive enzyme. As your body converts pepsinogen to the enzyme pepsin, it triggers a process that helps convert other pepsinogen molecules to pepsin. This cascade effect occurs and soon your stomach has enough pepsin molecules to digest proteins.
• Positive feedback – example:
  • When you get a cut your cells produce the enzyme thrombin to aid in blood clotting. The production of thrombin causes more thrombin to be produced. Blood clotting will occur faster and faster.
• Positive feedback – example:

![Diagram of oxytocin stimulation in pregnancy]

• How could an imbalance of homeostasis cause disease?
  • Disease and cellular malfunction can be caused in two basic ways:
    • Deficiency – cells not getting all they need
    • Toxicity – cells being poisoned by things they do not need
• Which factors influence your ability to maintain homeostasis?
  • Internal influences
    • Genetic (Type 1 diabetes)
    • Predisposition to heart disease and some cancers
  • External influences
    • Environment exposure
    • Drug toxins
    • Lifestyle choices
    • Diet – lack of essential vitamins and minerals
    • Anemia – iron deficiency which affect oxygen content
    • Physical activity – adequate sleep and exercise