Organ Systems in Mammals

- Work together to maintain **homeostasis**
  - A stable internal environment in cells
    - A condition needed for life to exist

**What is an organ system?**
- A group of **organs** that work together in order to accomplish a given function

- Organs are made of different **tissues** (e.g. different “layers” of the heart)

- Every tissue is composed of millions of **cells** of the same type doing the same thing!

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Types of Tissues

- Animals have four main categories of tissue

1) **Epithelial tissue**

- Also known as **epithelium**:
  - Covers the surface of the body
  - Lines organs and cavities within the body

- Some examples of organs lined with epithelial tissue:
  - Heart
  - Lung
  - Stomach
  - Small intestine
  - Large intestine
  - Urinary bladder

- Cells are bound tightly together
- Form a protective barrier
- Fall off and are continuously renewed
2) **Connective tissue**,
- Binds and support other tissues
- Sparse population of cells in an extracellular matrix consisting of a web of protein fibers within a uniform foundation that may be liquid, jellylike, or solid

3) **Muscle tissue**, 
- Consists of bundles of long cells called *muscle fibers*
- Has specialized proteins that contract when stimulated by a nerve

- **Skeletal muscle** (short segments of several muscle fibers)
  - Attached to bones by tendons
  - Voluntary movements

- **Cardiac muscle**
  - Responsible for the contraction of the heart
  - Involuntary

- **Smooth muscle**
  - Named for its lack of striations
  - Walls of various organs
  - Involuntary
4) **Nervous tissue**,
- Makes communication of sensory information possible
- Is found in the brain and spinal cord
- Consists of a network of neurons

![Diagram of Nervous System](image)

### How many types of organ systems?

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Materials Exchange with the environment

- In unicellular **protozoa**, exchange can happen by means of diffusion across cells.

- In simple animals like **jellyfish** and **flatworms**, the digestive system branches off so the food can be absorbed to other cells.

- In this way, systems like Digestive, Respiratory, and Urinary are not needed.

- Complex animals have extensively folded or branched internal surfaces that maximize surface area for exchange with the environment.

**Urinary system**

- Is responsible for **osmoregulation**: the control of the gain or loss of:
  - Water
  - Dissolved solutes, such as **salt**

- Produces **urine** by refining a filtrate derived from **blood**

- Urine production involves a differential membrane permeability in the tubes and:
  - **P** Passive transport (Diffusion + Osmosis)
  - **A** Active transport (ATP required)

**Filtration (1)**

- Water and solutes are forced by blood pressure across the selectively permeable membranes of a cluster of capillaries and into the excretory tubule.

**Reabsorption**

- Needed substances are reabsorbed and return to the body fluids.

**Secretion**

- Toxins and excess ions, are extracted from body fluids and added to the contents of the urine.

**Excretion**

- The filtrate leaves the system and the body... urine!
Vertebrate Kidneys
- Function in both excretion (cellular waste disposal) and osmoregulation
- Are composed of units called nephrons
  - Each nephron consists of a tubule and its associated blood vessels
  - Number more than a million in a kidney
  - Filter about 45 gallons of blood every day! (a human body has about 1.5)

Structure of the nephron
- Consists of a single long tubule and a ball of capillaries called the glomerulus
- Are the units of filtration, reabsorption, and secretion
- Happen because of two processes
  1. Diffusion + Osmosis (Passive transport)
     - due to different concentrations of solutes in the tubes and the interstitial fluid
  2. Active transport (ATP required)
     - due to a differential membrane permeability to the different solutes
(1) **Glomerulus & Bowman’s capsule**

- **Filtration by blood pressure**
  - Filtration of blood occurs from the glomerulus to the Bowman’s capsule (water, glucose, amino acids, ions)
  - ~45 gallons a day!
  - But the body has only 1.5 gallons… daily filtration is about 30 times the volume of blood in the body!
  - Filtration of small molecules at the Bowman’s capsule is nonselective
  - Filtrate is a mixture of solutes similar to the blood plasma

- Some other facts…
  - Kidneys account for 0.4% of body weight, but receive about 25% of the blood
  - 99% of the filtrate is reabsorbed and only 1% becomes urine

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**Regulation of Kidney Function**

- Is done directly by the brain by means of a hormonal control

- Receptors cells in the hypothalamus
  - Monitor the concentration of solutes in the blood, the **Antidiuretic hormone (ADH)**
  - Is released at a critical value of 300 osm/L

- The more of the hormone is released the more water is returned to the blood
- **Negative feedback**
  - Controls the production of ADH
Kidney Malfunction

- Two types of dialysis, **hemodialysis** and **peritoneal dialysis**, and a third investigational type, intestinal dialysis

**HEMODIALYSIS:**
- The patient's blood is pumped through the blood compartment of a dialyzer, exposing it to a semipermeable membrane. The cleansed blood is then returned via the circuit back to the body

**PERITONEAL DIALYSIS:**
- A solution containing minerals and glucose is run through a tube into the peritoneal cavity, the abdominal body cavity around the intestine, where the peritoneal membrane acts as a semipermeable membrane

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Respiratory system

**What is it?**
- Specialized surfaces adapted for gas exchange between the body and the respiratory medium, either air or water (air, water)
  - In mammals, additional “tubes” carry the air to the lungs

**How does the gas exchange take place?**
- **Always** by diffusion
  - Net flow of molecules from a region of high to low concentration
  - Diffusion is effective only at short distances
  - The respiratory surfaces need to be very thin then!

**What is the purpose of respiration?**
- Together with the circulatory system
  - Provide oxygen to cells
  - So they can perform cellular respiration

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Mammalian System

- A system of branching ducts
- Conveys air to the lungs

Air path

1. nostril
2. pharynx
3. larynx
4. trachea
5. bronchi
6. bronchiole
7. alveoli

Efficiency of exchange is limited by the surface area
- **Alveoli** do the gas exchange: tiny sacs with a total area of 753 ft²
- Walls of alveoli and capillaries is very thin → better diffusion of gases

How do we move the air inside the lungs?

- In mammals, the **diaphragm** and **intercostal muscles** contract allowing air to move in and out of the lungs

**Inhalation**
- Intercostal muscles contracts and diaphragm moves downward
  - Volume in chest cavity increases
  - this lowers pressure inside than outside
  - and air flows to the lungs by negative pressure

What controls the breathing mechanism?

- The main breathing control centers
  - Are located in the **medulla oblongata** and **pons**
  - Several homeostatic mechanisms exist to control breathing in humans
Why do we breathe faster when exercising?

**Amount of CO₂ in blood**

**NORMAL RESPIRATION…**
Impulses to the diaphragm and rib muscles stimulate them to contract, causing inhalation

**SENSORS**
Several centers in the circulatory system detect changes in the concentration of CO₂ and O₂ and send signals to the brain
- Aorta
- Carotids arteries

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3
\]

Carbonic acid
Toxic to the body in high concentrations

- Low pH is sensed
- Nerves impulses to the diaphragm and intercostal muscles increases
- More rapid and deeper breathing

How does blood transport the O₂?
- Inside red blood cells
  - Always attached to hemoglobin molecules

How does blood transport the CO₂?
- Once the blood has picked up the CO₂ in the tissues
  - 7% of it is dissolved in the plasma
  - 25% is transported by the red blood cells attached to hemoglobin molecules
  - 68% that remains is transported in the blood in the form of bicarbonate ions (HCO₃⁻)

\[
\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-
\]
Circulatory system
- Is responsible for transporting everything between cells and the environment
- Composed of heart (pump) + blood vessels (tubes) + blood (liquid)

**Arteries, Veins, and Capillaries**

- **Arteries** carry blood away from the heart
- **Veins** carry blood to the heart
- **Capillaries** are tiny, thin-walled vessels where gas exchange between blood and cells occur

**Heart chambers and valves**
- **Valves** dictate a one-way flow of blood through the heart
- Cardiac valves (1,2,3,4) open and close in response to blood pressure levels (mechanical stimulus, no energy is used!)
- **Atria** receive the blood and **ventricles** pump the blood out of the heart

**Cardiac cycle**
- The heart contracts and relaxes in a rhythmic cycle called the **cardiac cycle**
- Contraction of **ventricles**, or pumping, phase is **systole**
- Relaxation of **ventricles**, or filling, phase is **diastole**

**Blood circulation**
- Blue indicates oxygen-poor blood
- Red indicates oxygen-rich blood
- **Aorta** Gas exchange Unloads O\(_2\) and loads CO\(_2\)
- **Oxygenation** Loads O\(_2\) and unloads CO\(_2\)
What maintains the Heart’s Rhythmic Beat?

- Some cardiac muscle cells work as a pacemaker.
  - They contract without any signal from the nervous system.
  - Impulses from the sinoatrial (SA) node, or pacemaker
  - Travel to the atrioventricular (AV) node
  - Atria contraction!
- At the AV node, the impulses are delayed
  - And then travel to the Purkinje fibers
  - Ventricles contraction

Cardiac cycle and EKG

- The impulses that travel during the cardiac cycle
- Can be recorded as an electrocardiogram (ECG or EKG)

Blood Vessels

- All blood vessels
  - Are built of similar tissues
  - Have three similar layers
  - Have very low pressure
  - Have valves to prevent blood from flowing backward (blood flows back to the heart mainly as a result of muscle action)
  - Have a less muscular wall

Blood Composition

- Several kinds of cells (45%)
  - Red blood cells (with no nucleus, specialized in oxygen transport)
  - White blood cells (immune system)
  - Platelets (involved in clotting)
  - Suspended in a liquid matrix called plasma (55%)

Hemoglobin

- Is contained in the erythrocytes or red blood cells
- Is a protein with an oxygen-binding component, that greatly increases the amount of oxygen that blood can carry
Digestive system

**Main stages of food processing**

- Ingestion, digestion, absorption, and elimination

The act of eating, is the first stage of food processing (oral cavity)

Nutrients are passed to the blood (small intestine)

Occurs as undigested material passes out of the digestive compartment (rectum, anus)

- Breaking food down into molecules small enough to be absorbed
- Involves enzymatic hydrolysis of polymers into their monomers (mouth, stomach, small intestine)

***The Oral Cavity***

- where **ingestion** occurs

**Saliva** has several functions…

1. Protects mouth from abrasion and lubricates food
2. Buffers neutralize pH and prevent tooth decay
3. Antibacterial agents kill germs

***The Stomach***

- where **digestion** occurs

- Secretes **gastric juice**, which converts a meal to acid **chyme**
  - Gastric juice is made up of hydrochloric acid (HCl) and the enzyme **pepsin**
- The lining of the stomach
  - Is coated with mucus, which prevents the **gastric juice** from destroying the cells
The Small Intestine

- **Absorption** of nutrients to the blood takes place in the small intestine.
- The circulatory system distributes the nutrients to all the cells in the body.

**Gall bladder**
- The gall bladder stores a digestive juice produced by the liver: **bile**.
- Responsible for **emulsification** of fats in the small intestine.

**Liver**
- When blood leaves the intestine it enters the liver.

**Functions** of the liver:
- To filter any foreign organisms.
- To detoxify many dangerous molecules that enter with blood.
- To modify nutrient molecules, e.g., glucose to glycogen.

**Pancreas**
- Secretion on bicarbonate ions that neutralize pH coming from the stomach.
- Produces proteases, protein-digesting enzymes.

**How the small intestine maximizes absorption**

- **Surface area** limits the amount of material that can be taken up.
  - The more surface area available,
  - The more absorption per unit of time.

**Solutions?**

1. Small intestine is very long! (18 to 24 feet)
2. Fingerlike projections called **villi**
3. Membranes of cells in the villi also have folds (microvilli)
A major function of the colon is to recover water that has entered the alimentary canal. The colon houses various strains of the bacterium *Escherichia coli*, some of which produce various vitamins. The wastes of the digestive tract, the feces, become more solid as they move through the colon, pass through the rectum and exit via the anus.