Ingestion and Digestion in Animals

- **Ingestion** – the act of taking in food
- **Digestion** – the process by which complex macromolecules (food) are broken down into smaller monomers that are capable of passing through the membranes of the body.
- **Mechanical Digestion** – food is crushed and liquefied by teeth, tongue and peristaltic contractions increasing surface area for enzymes to work on
- **Chemical Digestion** – food is broken down into simple molecules by the activity of enzymatic secretions
- Digestion may be **intracellular** (occurring within a cell) or **extracellular** (occurring outside the body’s cells in a cavity or tube).

Protozoa

- Use **intracellular** digestion
- May engulf food by **phagocytosis** (as in amoebae) or cilia may sweep food into an **oral groove** and the **cytopharynx** (as in a paramecium).
- Food is enclosed in a **food vacuole**
- **Lysosomes** (organelles contain digestive enzymes) fuse with the food vacuole and release digestive enzymes that break down the macromolecules
- Once broken down, the molecules may diffuse into the cytoplasm and unusable products are eliminated from the vacuoles.

Hydra

- Use both **intracellular** and **extracellular** digestion
- Tentacles bring food to the “mouth” of the hydra and then release it into the **gastrovascular cavity** (cup-like sac)
- The endodermal cells lining the gastrovascular cavity (**gastrodermal cells**) secrete enzymes into the cavity and extracellular digestion of the macromolecules occurs
- Once the food is reduced to smaller fragments, the gastrodermal cells engulf the molecules and digestion is completed intracellularly
- Undigested food is expelled through the mouth

Earthworms

- Have a complete, one way digestive tract that is tube with an opening at either end (therefore earthworm use **extracellular** digestion)
- Food is moved in one direction through the tube. This method of digestion is more efficient because it allows digestion to become a stepwise process with sections of the tube specialized for specific stages of the process.
- Food that is ingested travels from the **mouth** to the **pharynx**, to the **esophagus** and into the **crop** where it is stored. It then enters the **gizzard** where it is ground up into smaller fragments and sent onto the **intestines** where digestion is completed and absorption occurs. The intestines contain a large dorsal fold that
provided increased surface area for digestion and absorption). Undigested food is then released from the **anus**.

### Insects
- Insects have digestive tracts very similar to those of earthworms, however they use jaws for chewing and salivary glands for more efficient digestion of food.

### Humans
- The human digestive system consists of the **Alimentary Canal** and **glands** that release secretions into the canal.
- The alimentary canal is the path of food through the body and consists of the mouth, the esophagus, the stomach, the small intestine, the large intestine and the rectum.
- Some glands line the canal and secrete substances directly into the canal, while other glands (pancreas and liver) are outside the canal and deliver secretions via ducts.

#### Step 1: The Mouth
- Food is chewed and broken down into smaller pieces in order to increase the surface area upon which enzymes may act (mechanical digestion).
- **Salivary glands** produce **saliva** which lubricates food and begins starch digestion. **Salivary Amylase** (ptyalin), an enzyme found in saliva, hydrolyzes polysaccharides, creating the disaccharide maltose (chemical digestion).

#### Step 2: The Esophagus
- Food forms a **bolus** (small, round mass) and is pushed into the throat where it is swallowed.
- The **epiglottis**, a flap of tissue, closes over the windpipe as the food is swallowed to prevent the bolus from going down the wrong tube.
- Bolus is moved down the esophagus to the stomach via **peristalsis** – the alternate, wavelike contractions and expansions of the involuntary muscles in the wall of the esophagus (mechanical digestion).

#### Step 3: The Stomach
- **Gastric glands** secrete the enzyme pepsin.
- **Pepsin** breaks down proteins into proteoses and peptones, intermediate products of digestion that are shorter chains of amino acids.
- Gastric glands also secrete **hydrochloric acid** which:
  1. Provides the low pH at which pepsin functions optimally
  2. Kills any ingested microorganisms
  3. Helps in dissolving minerals for absorption
- Throughout the period when food is in the stomach it is constantly being churned and mixed by peristaltic action with **gastric juices** (pepsin, rennin, hydrochloric acid and water). This is a form of mechanical digestion.
- After digestion in the stomach, the food becomes a semi-liquid paste called **chyme**.
- Chyme leaves the stomach through the narrow **phylorus** and enters the small intestine via a muscular valve called the **phyloric syphincter**.

#### Step 4: Small Intestine
- Digestion is completed in the small intestine
Mechanical digestion continues in the small intestine as peristaltic action moves food along and mixes it with digestive juices.

- There are digestive juices secreted from the **intestinal glands** in the walls of the small intestine, the **pancreas** and the **liver**.
- Intestinal Glands secrete:
  1. **Erepsin** – breaks down proteins into amino acids
  2. **Maltase** – digests maltose into glucose
  3. **Lactase** – digests lactose into glucose and galactose
  4. **Sucrose** – digests sucrose into fructose and glucose
  5. **Lipase** – digests fats into fatty acids and glycerol (present in minimal amounts)

- Pancreas secretes pancreatic juices into the upper end of small intestines via the **pancreatic duct**
- Pancreatic juices include:
  1. **Trypsin** – digests proteoses and peptones into amino acids
  2. **Amylopsin** – breaks down starch into maltose
  3. **Lipase** – hydrolizes fats into fatty acids and glycerol

- The liver produces **bile** which is a substance (NOT AN ENZYME) that emulsifies fat, allowing it to be more readily digested by lipase. This is a type of mechanical digestion.
- Bile is stored in the **gallbladder** and travels to the small intestines by means of the **bile duct**

**Step 5: Absorption of Digested Food (Small Intestines/Liver)**

- After digestion in the mouth, stomach and small intestine, almost all macromolecules have been broken down into their monomers:
  - Carbohydrates / Polysaccharides – glucose
  - Lipids – fatty acids and glycerol
  - Proteins – amino acids
- Absorption occurs in the small intestine
- Finger-like projections called **villi** on the walls of the small intestine increase surface area for absorption
- Inside the villi there is a network of **capillaries** and a **lacteal** (lymph vessel). Nutrients diffuse through the villi into the capillaries. **(Note:** fatty acids and glycerol do not directly enter the blood but instead diffuse into the lacteal)
- All capillaries in the villi go to the **portal vein** which leads to the **liver** where excess glucose in the blood is stored as **glycogen**. (Later when glucose levels in the blood fall the liver converts glycogen back into glucose and releases it into the blood to restore blood sugar levels)
- Nutrients are circulated to cells of body via blood

**Step 6: Large Intestine (Colon)**

- Indigestible remains pass into large intestine and are moved by peristalsis to the lower end of the large intestine (rectum) and are excreted through the **anus**.
- Water is absorbed back into blood
- **Appendix** – is small off-shoot of colon that has no apparent use in humans
Excretion

- **Excretion** – removal of metabolic wastes from the body *(Note: Don’t confuse this with elimination, which is the removal of indigestible materials)*
- **Metabolic Wastes** include: carbon dioxide, water, nitrogenous wastes, mineral salts

Protozoa and Hydra

- All cells are in contact with the surrounding environment so excretion may take place by **diffusion** across cell membranes
- Some protozoa (like the paramecium) have a **contractile vacuole** that periodically actively pumps water (which is constantly flowing to the cell because the cell is hypertonic to its environment) out of the cell so that cell’s volume and pressure may be maintained.

Earthworms

- Excrete water, mineral salts and nitrogenous wastes in the form of **urea**
- Each segment of an earthworm contains a pair of **nephridia tubules** which lead to openings to the external environment located on the lower surface of the worm
- Wastes are collected in the tubules by means of a ciliated, funnel like entrance in the preceding segment and leave the earthworm through the pores on its lower surface

Insects

- Malpighian tubules, small tubes which lie in the open blood spaces, extract water, mineral salts and nitrogenous wastes from the blood.
- Wastes are then passed into the hind gut from the tubules and are excreted through the anus along with indigestible substances
- Nitrogenous wastes are in the form of uric acid which is excreted in a solid crystallized form. This adaptation is a water conservation mechanism.

Humans

- **Renal Artery** (large artery) carries blood of high waste concentration to the **kidneys** (you have two of ‘me)
- Artery branches into arteriole and eventually into many tiny capillaries arranged in a ball-shaped cluster called a **glomerulus**.
- High blood pressure in the glomerulus squeezes smaller molecules in the blood (water, glucose, urea, salts, fatty acids and amino acids) out of the capillaries and into a cup-shaped structure surrounding the glomerulus called **Bowman’s capsule** *(Note: Molecules that are charged or too large to pass into bowman’s capsule, such as proteins and blood cells, remain in the blood)*
- Bowman’s capsule forms the starting end of the **nephron tubule**. The filtrate will travel down the nephron tubule and become increasingly modified as it progresses.
  1. **Proximal Convoluted Tubule** – active transport pumps glucose, amino acids, sodium, and proteins back into blood and water follows by osmosis. This stage returns necessary metabolites to the blood and concentrates the urinary filtrate.
  2. **Loop of Henle** – located in the region of the kidney known as the **medulla**. The medulla has a very high concentration of extracellular sodium. This
causes water to be drawn out of the filtrate by osmosis as the filtrate travels down the loop. On its way back up, sodium is pumped out of the filtrate and into the medulla. These two steps help to reduce the volume of urinary filtrate and maintain the high sodium concentration in the medulla.

3. **Distal Tube** – filtrate passes through this region. If secretion of the hormone **aldosterone** is triggered by low extracellular sodium content, increased absorption of sodium from the filtrate will occur in the distal tube.

- The filtrate from several nephrons collects in a **collecting duct**. The collecting duct passes back down through the high extracellular sodium content of the medulla. Here the hormone **ADH** (antidiuretic hormone) regulates the concentration of the filtrate by controlling the permeability of the collecting duct walls.

- The filtrate resulting from these steps is known as urine. **Urine** primarily consists of water along with urea (nitrogenous waste from the breakdown of amino acids in the liver), mineral salts and other materials.

- Urine from many collecting ducts drains into the **renal pelvis** and then passes out of the kidney to the **ureter**.

- Urine leaves the bladder in intervals via a tube called the **urethra**.

- The blood that was circulating in the capillaries of the kidney now leaves as filtered blood via the **renal vein**.

**Respiration**

- Respiration **provides O₂** and **removes CO₂**.
- Animals need oxygen to drive the electron transport chain and ATP production in cellular respiration.
- Animals must expel CO₂ produced from burning glucose in the Krebs cycle.
- Gas exchange must occur across a **moist surface**

**Protozoa**

- Every cell is in contact with the organism’s external environment and lipid bilayer membranes are fully permeable to O₂ and CO₂, therefore gas exchange may occur by direct **diffusion** across cell membranes.

**Earthworm**

- Cells on the external surface of the earthworm’s body secrete mucus, providing a moist surface for gas exchange from the air to the blood through diffusion.
- The worm’s blood circulates, carrying O₂ to cells and removing CO₂ (and other waste products) from cells and bringing it to the skin where it may exit the body via diffusion through the moist skin.

**Insects**

- Have small openings on the side of the segments of their abdomen called **spiracles**
- These openings lead to a network of highly branched air tubules called **tracheae** which achieve close contact with almost all the cells in the body. This system is highly efficient as it allows for the direct intake, distribution and removal of
respiratory gases. No oxygen carrier is needed, however this system limits the size
of arthropods because the tracheae must be able to contact almost every cell in the
body
- Air is pumped in and out of the body by muscular contractions of the abdomen.

**Fish**
- Water enters a fish’s mouth and passes over numerous thin-walled, thread like **gill
filaments** that are highly concentrated with capillaries
- The blood in the capillaries flows in the opposite direction of the water moving
over the gills, creating in what is known as **countercurrent exchange**. Countercurrent exchange allows blood of low O₂ concentration to come into
contact with water of high O₂ concentration, facilitating the efficient diffusion of
O₂ out of the water and into the blood.
- As the water passes over the gill filaments CO₂ diffuses out of the blood in the
capillaries and into the water
- O₂ rich blood is then transported throughout the body via the circulatory system
- After passing over the gills, water containing rich in discarded CO₂ passes out of
the fish through openings on either side of the head.

**Humans**

*The Path of Air*
1. Air enters the **nasal passages** through the **nostrils** in the nose where:
   - large hairs hold back dust
   - bacteria and dust are beat outward by cilia lining the walls of the nasal
     passages and trapped in the mucus secreted by epithelial cells
   - Air is moistened and warmed as it passes through the **sinuses** – cavities in
     the head connected with the nasal passages by narrow openings.
2. Air continues to the **pharynx** (throat) at the back of the mouth. If air enters
   through the mouth, it travels directly to the pharynx and is not filtered,
   warmed and moistened.
3. The **trachea** (windpipe) receives the air next.
   - Covered by a flap of tissue, the epiglottis, which is open during breathing
     and closed during digestion.
   - walls contain rings of cartilage that keep the passageway open
   - lined with ciliated epithelial cells that beat dust and bacteria out
   - **Larynx** (voice box) is located just below opening of trachea and contains
     the vocal chords
4. Trachea divides into two **bronchi**, which are tubes that carry air to the lungs.
   Each bronchus branches into smaller and smaller **bronchial tubes** or
   **bronchioles** which spread through the lungs.
5. At the end of each of the millions of bronchioles is an **alveolus** – air sac with
   thin, moist walls that is surrounded by a network of thin-walled capillaries.
6. O₂ diffuses across the thin walls of the alveoli and into the blood in the
   capillaries, binding with **hemoglobin** in red blood cells to create **oxy-
   hemoglobin**. CO₂ and water diffuse out of the blood and into the alveoli to be
   eliminated in exhalation.

*Inhalation and Exhalation*
- **Lungs** – elastic, spongy organs located in a close chamber call the thorax

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• **Pleura** – moist smooth membrane that lines the thorax and covers the outside of the lungs

• **Diaphragm** – muscular floor of the thorax made up of voluntary muscle that separates the thorax from the abdominal cavity below. Is curved upward when relaxed and flattens out when contracts.

• **Inhalation or Inspiration**
  - **Diaphragm contracts** (flattens out) and **rib muscles contract** causing ribs to be raised and to spread apart
  - These contractions **enlarge chest cavity** and **reduce internal pressure** on lungs causing the air from the outside (where pressure is higher) to be forced into the lungs
  - Lungs inflate

• **Exhalation or Expiration**
  - **Diaphragm relaxes** (curves upward) and **rib muscles relax**, lowering the ribs
  - Relaxation of these muscles causes **chest cavity to decrease in size**, compressing the air in the lungs and forcing it out

*Controlling Breathing*

• Breathing is a **voluntary** activity involving **voluntary muscles**

• It is automatically controlled by the **medulla oblongata**, therefore we do not need to “think about” breathing

• Primarily, CO₂ is carried in the blood in the form of **bicarbonate ions** which are converted back to CO₂ in the lungs in order to be exhaled. However, small amounts of CO₂ also bind with hemoglobin in the red blood cells.

• Rate of breathing is controlled by the **amount of CO₂ in the blood**:
  - Increased amounts of CO₂ in the blood trigger cells of the medulla oblongata to send impulses to the chest muscles and diaphragm to contract and expand more rapidly, thereby increasing breathing rate.