
Review of Digestion in Animal Kingdom

1. Types of Digestive Tracts
2. 2 Major Feeding Strategies
3. Diet

Human Digestive Tract

1. Mouth
2. Pharynx
3. Esophagus
4. Stomach
5. Small Intestine
6. Large Intestine

Accessory Organs

1. Pancreas
2. Liver
3. Gall Bladder

Digestive Enzymes

Nutrition

1. Carbohydrates
2. Lipids
3. Proteins

Vitamins and Minerals
Dictionary definition of the word *digest* – to change food taken into the body into an absorbable form

Another definition – digestion is the chemical and mechanical process by which large food molecules are broken down into smaller molecules than can pass through the cell’s plasma membrane.

A very simple observation and question – unlike animals, plants do not have a system of organs and glands specialized for digestion - WHY? (Plants make their own food – they normally do not eat or ingest their food) (Anyone know of an exception)

Review of Digestion in the Animal Kingdom

1. Types of Digestive Tracts

   A. Most animals have some sort of gut or series of specialized organs where digestion occurs. However, some primitive organisms do not have a digestive tract.

   B. Functions of a digestive tract

      1) ingests food

      2) breaks food down into smaller molecules that can pass through plasma membrane of cells

      3) absorbs these nutrient molecules

      4) eliminates un-digestible remains

   C. In animals there are 3 conditions in regard to the presence and structure of a digestive tract

      1) No Digestive Tract (Digestion by individual cells)

         a) In single cell, simple organisms like protozoans, digestion occurs in the food vacuoles of individual cells.
b) Also, in sponges, a primitive group of multi-cellular marine animals, digestion occurs in the food vacuoles of individual cells. There is no specialized organ system.

2) Incomplete Digestive Tract

a) Organisms that possess an incomplete digestive tract are usually said to possess a sac body plan.

b) An incomplete digestive tract normally has a single opening that is often called the mouth.

c) There is no anus and the mouth is used both for
   - entrance for food
   - exit for wastes

d) The sac body plan can be simply drawn as

   ![Diagram of a sac body plan]

   mouth

   arrow

   body

   stomach

   crop

   gizzard

   intestines

e) There are usually no specialized organs like a stomach, crop, gizzard, and intestines.

f) Examples of multicellular organisms that possess an incomplete digestive tract are
   - Hydra
   - planarians
3) Complete Digestive Tract

a) Organisms that possess a complete digestive tract are usually said to possess a tube within a tube body plan.

b) The complete digestive tract normally possesses
   - mouth for entrance for food
   - anus for exit of wastes

c) The tube within a tube body plan can be simply drawn as

![Diagram of digestive tract]

- Organisms with complete digestive tracts usually have specialized organs like a stomach, crop, gizzard, and intestines

h) Examples of organisms that possess an complete digestive tract are
   - earthworms
   - arthropods like crayfish and insects
   - vertebrates like fish, amphibians, reptiles, birds, and mammals (includes humans)

2. 2 Major Feeding Strategies

   A. Continuous Feeders

      1) Includes filter feeders like clams, mussels, and oysters
2) Water is constantly pumped through their body cavity and food particles like small algae, protozoans, and small invertebrates are captured.

3) Continuous feeders do not require elaborate storage organs like large stomachs or crops in their digestive tract

B. Discontinuous Feeders

1) Discontinuous feeders have periods of no feeding between meals

2) Humans are discontinuous feeders

3) Discontinuous feeders normally require storage organs like a large stomach or crop in their digestive tracts

3. Diet

A. The digestive tracts of organisms are adapted to the type of food they eat

B. Recall the 3 types of heterotrophs we discussed earlier

1) Carnivores – eats animals

2) Herbivores – eats plants

3) Omnivores – eats plants and animals

C. Examples of some adaptations to diet include

1) Carnivores
   a) have pointed canine teeth for killing
   b) short incisors for scraping bones
   c) pointed molars for slicing flesh

2) Herbivores – have reduced canine teeth, eats plants
   a) have reduced canine teeth
   b) sharp incisors for clipping vegetation
   c) large flat molars and premolars for grinding and crushing vegetation
3) **Ruminants** - like deer, cows, and sheep are **herbivores** and have a *specialized part* of the **stomach** called a **rumen** that helps them **digest grass**

4) The **intestines** of **herbivores** tend to be **longer** than the **intestines** of **carnivores** (meat being rich in protein is more easily digested than plant material)

**Human Digestive Tract**

(See Handout of Figure 34.5, page 637, Textbook, Mader, 10th Ed.)

*Human digestion occurs in 2 major ways*

**Mechanical**
- physical breakdown of food into smaller particles
- accomplished by chewing in mouth and physical churning and mixing in stomach and small intestine

**Chemical**
- chemical breakdown of food into smaller particles by enzymes
- enzymes secreted by organs of digestive tract as well as accessory glands
- specific enzymes break down specific macromolecules

1. **Mouth**
   A. Represents the beginning point of digestion
   B. **Possesses teeth** used to chew food
   C. The **tongue** has **taste buds** and is used to push food around for chewing and swallowing
   D. **Salivary glands** secrete **saliva** which contains the digestive enzyme **salivary amylase**
   E. **Salivary amylase begins** the digestion of starch, a complex carbohydrate
   F. The actions in the **mouth** prepare a **food mass** called a **bolus** that will be swallowed
2. Pharynx
   A. The **passageway** where food is **swallowed**
   B. This **part** of the **digestive tract** also serves as an **air passageway** for the **lungs**
   C. **What** keeps food **out** of the **trachea** — the **passageway** to the **lungs** (anyone ever choked on a food item??)
   D. When food is swallowed a **flap** of tissue called the **epiglottis** covers the **opening** to the **trachea**
   E. This **closes** the **air passageway** and **forces** food **down** the **esophagus**
   F. The possibility for **choking** is a **disadvantage** to having a **common passageway** for food and **air intake**. Can anyone **think** of an **advantage** to there being a **common passageway**?? (Ability to breathe when one has a cold and nasal passages are stopped-up — can breathe thru mouth)

3. Esophagus
   A. A **tubular structure** that takes food (the **bolus**) to the **stomach**
   B. **Muscular contractions** called **peristalsis** pushes food **toward** the **stomach**
   C. A lower **gastroesophageal sphincter** is located where the **esophagus enters** the **stomach**
   D. This **sphincter relaxes** and **opens** for a **few seconds** when food **enters** the **stomach**. It then **closes**
   E. **Heartburn** occurs due to **acid reflux** — when some of the **stomach contents** escape back up into the **esophagus**

4. Stomach
   A. The stomach is a **thick-walled J-shaped organ**
   B. The **wall** of the **stomach** has **deep folds** that **disappear** as the **stomach fills** and **stretches**
   C. The **capacity** of a **normal stomach** is about **1 liter**
   D. The **epithelial lining** of the **stomach** has **millions** of **gastric pits** that lead to **gastric glands** that produce **gastric juices**
E. These *gastric juices* include acids like *hydrochloric acid* (HCl), *pepsin*, and *digestive enzymes* for *breakdown* of proteins.

F. The stomach *churns* to mix food with *gastric juices* to form *chyme*.

G. A *thick layer* of *mucus* protects the *stomach wall* from the *harsh gastric secretions*.

H. *Ulcers* form where this protective layer is *destroyed* or *fails* to protect.

I. At the *base* of the *stomach* is another *sphincter* that opens and shuts in a way that *chyme* enters the *small intestine* slowly.

5. **Small Intestine**

A. Named for its *small diameter*, but could be called the “*long intestine*” -- about 6 meters (20 ft.) in length.

B. The *first 25 cm* of the *small intestine* is called the *duodenum*.

C. At the *duodenum* a duct dumps *bile* from the *liver* and *gall bladder* and *pancreatic juices* from the *pancreas* into the *small intestine*

D. *Chyme* is *mixed* with more *digestive enzymes* for further *breakdown* of food molecules.

E. The *wall* of the *small intestine* contains *finger-like projections* called *villi*.

F. *Villi* greatly *increase* the *surface area* of the *small intestine* which greatly *increases* its *ability* to *absorb nutrients* from its contents.

G. The *surface area* available for *absorption* in the *small intestine* has been *estimated* to be approximately that of a *tennis court*.

H. *Nutrients* like *sugars* and *amino acids* are *absorbed* into the *blood capillaries* of the *villi* and are *eventually distributed* to *cells* of the *body* by way of the *circulatory system*.

6. **Large Intestine**

A. *No digestion* occurs in the *large intestine*.

B. The *large intestines* mainly *absorb* H2O and *salts* to form *feces*.

C. The large intestines *store feces* and *regulate* the *elimination of feces*.
D. The large intestine includes the following

1) cecum – a blind sac where small intestine empties into large intestine. The appendix attached here

2) colon – major portion of large intestine

3) rectum – the last 20 cm of large intestine

4) anus – opening where wastes are voided

Accessory Organs

1. Pancreas
   A. Products that enter the blood stream from pancreas include

1) The hormones insulin and glucagon are secreted directly into the blood stream after eating

2) These hormones keep the blood glucose levels within normal limits

B. Pancreas also produces sodium bicarbonate and digestive enzymes that are emptied into the duodenum via the bile duct

1) Sodium bicarbonate neutralizes the acid chyme from the stomach

2) Digestive enzymes include
   a) pancreatic amylase - digests starches
   b) trypsin - digests proteins
   c) lipase - digests fats
2. Liver
A. The liver is the **largest gland** of the **human body**
B. The **substance** produced by the **liver** that is **important** in the **digestion** of food is **bile**.
   1) **Bile** is **delivered** by a **common bile duct** into the **duodenum** of the **small intestine**
   2) **Bile** is important in the **breakdown** of **fats** by a **process** called **emulsification**
   3) When **fats** are **emulsified** they are **broken down** into **smaller droplets** that provide more **surface area** for **digestive enzymes** to work
C. The liver has been called the **gate-keeper** of the **circulatory system** and **interacts directly** with the **circulatory system** to
   1) **Detoxifies** blood by **removing** and **metabolizing** poisonous **substances**
   2) **Stores** iron and the vitamins **D, B12, E, E, and K**
   3) Helps **regulate blood cholesterol level**, converting some to bile salts
   4) **Stores** glucose as **glycogen** after a meal, and **breaks down** glycogen to glucose to **maintain** the glucose **level** of blood between meals

3. Gall Bladder
A. The **gall bladder** is a **small** pear-shaped **muscular sac** attached to the **surface** of the **liver**
B. It **stores bile** from the **liver** and sends it into the **small intestine** at the **duodenum**

Digestive Enzymes

1. The **action** of **enzymes** in digestion is accomplished by a **reaction** called **enzymatic hydrolysis** (recall - hydrolysis means that H2O is added to something)
2. This can be simply written as follows

\[
\text{Food macromolecule} + \text{H}_2\text{O} \rightarrow \text{Smaller food molecule}
\]

\(\text{(H}_2\text{O is combined with a food molecule under the influence of a specific enzyme)}\)

3. The following is a tour (top to bottom) of digestive tract that provides some examples of enzymes and their actions

A. Mouth

1) **Enzyme – salivary amylase**
   a) *Salivary amylase* is an enzyme produced in salivary glands
   b) It is the first enzyme to begin work on food we eat
   c) Breaks down starch to a smaller molecule - maltose
   d) Note that maltose is still too large to be absorbed thru the walls of the small intestine - so additional breakdown will occur somewhere down the digestive tract
   e) Hydrolysis reaction can be written as

   \[
   \text{Starch} + \text{H}_2\text{O} \rightarrow \text{Maltose}
   \]

B. Stomach

1) **Enzyme – pepsin**
   a) *Protein digestion* begins in the stomach
   b) *Pepsin* is secreted by stomach walls
   c) Hydrolysis reaction can be written as

   \[
   \text{Protein} + \text{H}_2\text{O} \rightarrow \text{Peptides}
   \]
d) Again, later breakdown in small intestine breaks peptides into individual amino acids that are small enough to be absorbed thru the wall of the small intestine.

C. Small Intestine

1) Enzyme – pancreatic amylase
   a) Secreted by the pancreas
   b) Digests starch
   c) Hydrolysis reaction can be written as

\[
\text{Starch} + \text{H}_2\text{O} \xrightarrow{\text{pancreatic amylase}} \text{Maltose}
\]

2) Enzyme - trypsin
   a) Secreted by the pancreas
   b) Digests proteins
   c) Hydrolysis reaction can be written as

\[
\text{Protein} + \text{H}_2\text{O} \xrightarrow{\text{trypsin}} \text{Peptides}
\]

3) Enzyme - lipase
   a) Secreted by the pancreas
   b) Digests fat molecules in fat droplets after they have been emulsified by bile from liver
   c) Hydrolysis reaction can be written as

\[
\text{Fat droplets} + \text{H}_2\text{O} \xrightarrow{\text{lipase}} \text{Glycerol} + 3 \text{Fatty acids}
\]
4) **Enzyme – maltase**  
   a) *Secreted by the small intestine*  
   b) *Digests maltose*  
   c) *Hydrolysis reaction* can be written as  
      \[
      \text{Maltose} + \text{H}_2\text{O} \rightarrow \text{Glucose} + \text{Glucose}
      \]

5) **Enzyme – pepsidases**  
   a) *Secreted by the small intestine*  
   b) *Digests peptides*  
   c) *Hydrolysis reaction* can be written as  
      \[
      \text{Peptides} + \text{H}_2\text{O} \rightarrow \text{Amino acids}
      \]

**Nutrition**  
* - The following are sometimes called *food groups*. We have studied them as the *major groups of organic molecules*. The presence of these food groups in *critical* to a *balanced diet* and *good health*

1. **Carbohydrates**  
   A. Includes *sugars, starches, and fiber*  
   B. After being *absorbed* from the *digestive tract* into the *blood stream*, all *sugars* are *converted* to *glucose* for *transport* to the *cells* for their use in *cellular respiration*  
   C. *Animals* store *glucose* as *glycogen* in the *liver*
D. Sources of starch include beans, peas, corn, cereal grains, and potatoes.

E. Fiber is the un-digestible carbohydrates derived from plant foods (usually contain cellulose).

F. Fiber is not an important nutrient for humans because it cannot be broken down small enough to be used.

G. However, fiber adds bulk to fecal material and makes bowel movements easier and more regular.

2. Lipids

A. Triglycerides (fats and oils) supply energy to the cell just like carbohydrates, but are harder to break down than carbohydrates.

B. Therefore fats are normally stored for a long term in the body (example - bears fatten up prior to hibernation in the winter).

C. Sources of plant derived fats include cranola oil, soybean oil, and corn oil.

D. Sources of animal derived fats include fatty fish, butter, meat, whole milk, and cheese.

3. Proteins

A. Digested proteins are broken into amino acids.

B. These amino acids are used to build hundreds of different types of cell proteins.

C. Of the total 20 different amino acids, 9 are considered essential because the human body cannot produce them.

D. These 9 must be in the human diet.

E. Sources of Complete or “High-Quality” Proteins

1) Normally contain all 9 essential amino acids.

2) Include animal products like eggs, milk, meat, and poultry.
F. Sources of Incomplete or "Low-Quality" Proteins

1) Usually missing 1 or more of the 9 essential amino acids
2) Include plant products like peanuts, other nuts, grains, and beans

Vitamins and Minerals

1. Vitamins are organic compounds (other than carbohydrates, lipids, and proteins) that are essential in the diet and regulate metabolic activities

2. Many vitamins are part of coenzymes
   
   A. Niacin is part of the coenzyme NAD+
   
   B. Riboflavin (a B vitamin) is part of the coenzyme FAD

3. Vitamin A is not a coenzyme - it is the precursor to a pigment required for night vision

4. Good sources of vitamins include fruits and vegetables

5. There are about 20 elements called minerals that the body needs to function. Important minerals include (Fe) iron, (Ca)calcium, (Mg) magnesium, and (Zn) zinc
FIGURE 34.5 The human digestive tract.
Trace the path of food from the mouth to the anus. The large intestine consists of the cecum, the colon (ascending, transverse, descending, and sigmoid colon), the rectum, and the anus. Note also the location of the accessory organs of digestion: the pancreas, the liver, and the gallbladder.

Accessory organs

Salivary glands: secrete saliva; contains digestive enzyme for carbohydrates

Digestive tract organs

Mouth
- Teeth chew food; tongue tastes and pushes food for chewing and swallowing

Pharynx
- Passageway where food is swallowed

Esophagus
- Passageway where peristalsis pushes food to stomach

Stomach
- Processes and stores nutrients; produces bile for emulsification of fats
- Secretes acid and digestive enzyme for protein; churns, mixing food with secretions, and sends chyme to small intestine

Small intestine
- Mixes chyme with digestive enzymes for final breakdown; absorbs nutrient molecules into body; secretes digestive hormones into blood
- Absorbs water and salt to form feces

Rectum
- Stores and regulates elimination of feces

Anus