Digestive Systems in Single-Celled Organisms, and Invertebrates

- All organisms require nutrients that supply energy and matter needed for survival.
- These nutrients can be divided into 6 main categories: carbohydrates (sugars), fats (lipids), proteins, vitamins, minerals, and water.
- Each species of organism has a specialized mechanism that is used for feeding – bringing nutrients into its body structure.
- The system used to digest (or break down the nutrients into usable parts) becomes more complex and the organisms themselves become more complex.
- In complex digestive systems, the organs have a structure that will complement its function.
- The purpose of a digestive system is to break down food into particles that are small enough to be absorbed and used inside of the cells of the organism.

Amoeba – an amoeba (and other protists) has intracellular digestion. This means that digestion occurs inside of the cell. A food particle is taken in across the cell membrane (ingested). Digestive enzymes (proteins that break down large nutrient particles into smaller, absorbable ones), are added to the food vacuole inside of the cell, which break down the food particle. Nutrients that are needed by the amoeba are absorbed into the cell membrane. Wastes that are left over remain inside the vacuole and eventually are egested (removed) from the cell.

Most other organisms use a process of extracellular digestion when breaking down food particles. With extracellular digestion, digestive enzymes are secreted from cells onto the food. Only nutrients that are required by the cell are taken in across the cell membrane. The cell does not take in waste materials from the food.

Examples of organisms that use extracellular digestion:

Even though digestion is inside the body of the animal, it is occurring outside of any cell. A hydra has a one-opening digestive system – food enters the mouth, and wastes are released from the mouth after digestion occurs.
Earthworm

The earthworm’s digestive system shows specialization within its **alimentary canal** (2 opening passage way through which food travels through the body). Soil is sucked in through the mouth by the muscular pharynx. It then is stored in the crop temporarily. The food is ground up in the gizzard. The food enters the intestine, where digestive enzymes are secreted onto the food from the cells lining the intestine. Required nutrients can then be absorbed into the earthworm’s circulatory system. Unused material passes out of the digestive tract through the anus.

Grasshopper

The grasshopper also has a specialized alimentary canal. Mouthparts break down food into small enough pieces to ingest. Salivary glands secrete saliva that mixes with food in the mouth to help its passage through the esophagus, and to start digesting the food. Food moves along the esophagus and is temporarily stored in the crop. From there food is ground in the gizzard, then enters the stomach. Gastric pouches outside the stomach wall make digestive enzymes that mix with the food and complete digestion. Nutrients are absorbed into blood vessels surrounding the stomach wall. Wastes travel through the intestine, and are egested from the body through the anus.
Vertebrate Digestive Systems

In vertebrate, and some invertebrate digestive systems, food is first **ingested** (taken into the body), then **digested** (broken down into smaller, absorbable parts), then nutrients are absorbed (enter the blood stream and are carried to body cells where they are either used as energy sources or as building blocks for cells), before wastes are **egested** (released from the body).

There are 2 main types of digestion that occur:

- **Mechanical digestion** – the physical break down of food particles into smaller particles that can be swallowed or moved through the alimentary canal. This is often accomplished by chewing or grinding food.
- **Chemical digestion** – the addition of digestive enzymes and acid chemically breaks bonds between large nutrient particles. When these bonds are broken, the smaller nutrient particles can then be absorbed into cells.
  
  o When **carbohydrates** are digested, the smaller nutrient particles are **sugars** (mainly **glucose**)
  
  o When **proteins** are digested, the smaller nutrient particles are **amino acids**
  
  o When **lipids** are digested, the smaller nutrient particles are **fatty acids** and **glycerol**.

**Fish**

Food enters the mouth of the fish, which is equipped with teeth to push food into the right direction, down the esophagus. In a fish, teeth are not used for chewing (**mechanical digestion**). Muscular contractions (**peristalsis**) move the food through the esophagus to the stomach. Digestive enzymes and hydrochloric acid are secreted onto the food, and extracellular digestion begins. Digestion continues in the small intestine. Further along in the small intestine, nutrients are absorbed by diffusion into the cells of the small intestine and then into the circulatory system, which transports them around the body. Undigested matter moves to the large intestine. Here water is absorbed from the waste, and bacteria living in the large intestine digest some of the waste. Waste is excreted through the anus.
Human digestive system and accessory organs

A: Mouth
B: Esophagus
C: Stomach
D: Small intestine
E: Colon
F: Rectum
G: Liver
H: Gallbladder
I: Pancreas
J: Appendix
K: Stomach
L: Liver
M: Pancreas
N: Small intestine
<table>
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<tr>
<th>Structure</th>
<th>Function</th>
<th>Diagram</th>
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<tr>
<td><strong>Mouth</strong></td>
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</tr>
<tr>
<td>1. Teeth</td>
<td>1. used for mechanical digestion (biting, tearing, shredding and grinding food)</td>
<td><img src="image1" alt="Diagram of Mouth" /></td>
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<tr>
<td>2. Salivary glands</td>
<td>2. produces saliva used to moisten and soften food for easier swallowing, and to start chemical digestion. Salivary amylase breaks down starch (carbohydrate) into maltose, and salivary maltase breaks down maltose into glucose (simple sugar).</td>
<td><img src="image2" alt="Diagram of Mouth" /></td>
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<tr>
<td>3. Tongue</td>
<td>3. positions food for proper chewing, aids in swallowing and tastes food</td>
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</tr>
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<td>4. Uvula</td>
<td>4. blocks entrance to nasal passage during swallowing</td>
<td></td>
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<tr>
<td><strong>Pharynx</strong></td>
<td>Tube connecting mouth and two different tubes (esophagus leading to stomach, and trachea leading to lungs).</td>
<td><img src="image3" alt="Diagram of Pharynx" /></td>
</tr>
<tr>
<td><strong>Epiglottis</strong></td>
<td>Cartilage flap that prevents food from entering trachea during swallowing</td>
<td><img src="image4" alt="Diagram of Epiglottis" /></td>
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<tr>
<td><strong>Esophagus</strong></td>
<td>Long muscular tube that carries food from the pharynx to the stomach. Food is carried down the tube by a wave-like contraction of muscles called <strong>peristalsis</strong>.</td>
<td><img src="image5" alt="Diagram of Esophagus" /></td>
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<tr>
<td><strong>Stomach</strong></td>
<td>Muscular organ responsible for some mechanical digestion and some chemical digestion of food. Inner lining of stomach has long ridges called <strong>rugae</strong> that contain glands that secrete <strong>gastric juice</strong> (<strong>hydrochloric acid</strong> and digestive enzymes like <strong>pepsin</strong> and <strong>lipase</strong>).</td>
<td><img src="image6" alt="Diagram of Stomach" /></td>
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<td>- <strong>Hydrochloric acid</strong> helps to destroy bacteria in food and activates pepsin.</td>
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<tr>
<td></td>
<td>- <strong>Pepsin</strong> begins digestion of protein into smaller chains of polypeptides and amino acids.</td>
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<tr>
<td></td>
<td>- <strong>Lipase</strong> breaks down fats into glycerol and fatty acids.</td>
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<td></td>
<td>There are <strong>mucous glands</strong> lining the stomach that secrete a protective layer of mucous that coats the stomach, to prevent</td>
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digestion of the muscular wall of the stomach.

**Rugae** grinds food, and mixes it with liquids so that when food leaves the stomach, it does so in a liquid form called **chyme**.

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<td>Small intestine</td>
<td>Where most chemical digestion and absorption of nutrients occurs.</td>
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<tr>
<td>1. mesentery</td>
<td>1. Thin membrane that attaches small intestine to back of abdomen and keeps loops of intestines orderly</td>
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<tr>
<td>2. duodenum</td>
<td>2. First section of small intestine. Chemical digestion of chyme continues here. Digestive chemicals from the liver, gall bladder and pancreas are added to the food in the duodenum.</td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
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</table>
| Intestinal juices produced by cells lining small intestine contain enzymes needed to break down nutrients: | a. **maltase** – breaks down maltose into glucose  
   b. **sucrase** – breaks down sucrose into glucose and fructose  
   c. **peptidases** – break down peptides into amino acids.                                                                                   | ![Diagram](image2) |
<p>| 3. jejunum     | 3. Where most absorption takes place. <strong>Villi</strong> line the surface and increase surface area for absorption of nutrients                                                                                      |         |
| 4. ileum       | 4. More nutrient absorption occurs here                                                                                                                                                                   |         |
| Large intestine | Main function is to reabsorb water back into the blood stream so that a solid feces is expelled from the anus. There is some absorption of nutrients here. As well, bacteria reside here. They receive food and in return make certain vitamins necessary for humans (like vitamin K). | <img src="image3" alt="Diagram" /> |</p>
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<td><strong>Liver and gall bladder</strong></td>
<td>Makes <strong>bile</strong> (digestive juice used to emulsify fats – it makes large fat droplets into smaller droplets that are more easily acted on by digestive enzymes like lipase). The bile is sent to the gall bladder, where it is concentrated (water is removed) and stored for secretion into the duodenum.</td>
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<td><strong>Pancreas</strong></td>
<td>Sends inactive enzymes in a <strong>pancreatic juice</strong> into the duodenum. Pancreatic juice contains <strong>sodium bicarbonate</strong> that neutralizes the acidic chyme, and 28 digestive enzymes, including <strong>amylases</strong> (break down starch to maltose), <strong>lipases</strong> (break down fats into glycerol and fatty acids), and <strong>trypsinogen</strong> (breaks down proteins into amino acids). The pancreas contains cells called the <strong>Islets of Langerhans</strong> that secrete hormones into the blood that aid in the absorption of sugars from the blood into the cells of the body (<strong>insulin</strong>), and aid in the release of these sugars when blood sugars are low (<strong>glucagon</strong>).</td>
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<td><strong>Appendix</strong></td>
<td>A vestigial organ, thought to have been used to help in digesting leaves in primates (hosting bacteria needed to break down cellulose from the cell walls of plants). Now thought to possible be involved in immune functions as well as possibly hold beneficial bacteria needed in the large intestine.</td>
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Tracing the pathway of food (hamburger) through the human digestive system.

Incisors bite the hamburger, canines tear it and molars grind it. The tongue’s taste buds detect the flavours. The tongue mixes the ground food with saliva secreted from the 3 pairs of salivary glands (parotid, sublingual and submaxillary). In the saliva is the enzyme salivary amylase, which starts the digestion of carbohydrates in the bun of the hamburger. Starch molecules are converted into glucose (the simplest carbohydrate). The tongue rolls the chewed food into a bolus (bullet shaped package) to ease its slide down the esophagus. The saliva makes the bolus slippery. As swallowing occurs, the epiglottis blocks the entrance to the trachea, and food instead moves down into the esophagus.

The bolus moves through the esophagus by peristalsis (wavelike contractions and relaxations of the muscles in the lining of the wall of the esophagus). Peristalsis is what allows astronauts to swallow in the absence of gravity. The bolus passes through the cardiac sphincter at the top of the stomach. This sphincter squeezes the esophagus shut once food enters the stomach. It prevents regurgitation so that stomach acid does not go back up into the esophagus.

Once in the stomach, gastric glands in the wall of the stomach secrete “gastric juice” containing hydrochloric acid and pepsinogen. The hydrochloric acid converts pepsinogen into pepsin, a protein-digesting enzyme. The pepsin chemically digests proteins into peptides (short strings of amino acids). In addition, lipase is secreted by the stomach but is inactive in the acidic environment. A sphincter at the bottom of the stomach, called the pyloric sphincter remains shut preventing food from pushing into the small intestine. In the stomach are inward folds called rugae that increase the surface area and stretching ability of the stomach. The inner wall of the stomach is coated in a layer of mucous that prevents the acid and pepsin form digesting the stomach itself. The muscles in the walls of the stomach contract, churning the food and mixing it with the digestive juices until a liquidy mixture called chyme is formed.

After several hours, the pyloric sphincter relaxes, allowing the chyme to enter the first part of the small intestine called the duodenum. Here the pancreas and the liver (and gall bladder) have connecting ducts so that secretions from these accessory organs can be added to the chyme. The bile (make in the liver, but stored in the gall bladder) emulsifies the fat found in the meat. This increases the surface area of the fat available for the lipase (from the stomach) to convert the fat to glycerol and fatty acids.

The pancreas secretes pancreatic juice into the duodenum. There are 2 main components of the pancreatic juice:

1. sodium bicarbonate, which neutralizes the acidic chyme.
2. 28 digestive enzymes including pancreatic lipase, amylase and trypsin. Trypsin helps break down proteins into amino acids.

Chemical digestion continues as the food moves by peristalsis down the jejunum and ileum.

Amino acids and glucose are absorbed through the walls of the villi and microvilli of the small intestine, directly into the blood stream. This absorption occurs by diffusion. Fatty acids and glycerol are engulfed by endocytosis into the lacteals of the villi and sent to the lymphatic system.

Undigested waste passes through the ileocaecal valve into the large intestine. In the large intestine, some vitamins (K and B) are made by the bacteria that live there. During the passage through (ascending, transverse and descending) the large intestine, most of the water is reabsorbed from the waste, forming solid feces. This moves through the rectum and is egested from the anus.
Chemical digestion of nutrients

The digestion of proteins – proteins are long strings of subunits called amino acids. There are 20 different amino acids that can be found in proteins.

PROTEIN - each shape represents a different amino acid

Protein digestion in the stomach – pepsin breaks long protein chains into shorted peptide chains

In small intestine – trypsins and peptidases break peptide chains into single or double amino acid units that are small enough for absorption

The digestion of carbohydrates – carbohydrates are long chains of subunits called simple sugars (often glucose). Complex carbohydrates may form simple chains (like starches), or may be very intricately connected into web-like structures.

CARBOHYDRATE – each shape represents one simple sugar.

Salivary and pancreatic amylase breaks down starch into maltose (a 2-sugar carbohydrate).

Maltase breaks down maltose into glucose molecules that can be absorbed into cells.

Digestion of lipids

Liver produces bile that emulsifies fat into smaller droplets

Pancreas produces lipase that breaks lipid into glycerol and 3 fatty acids

Fat molecule