CHAPTER 4: Digestive Systems and Nutrition

I. Invertebrate Digestive Systems

Animals have evolved different types of **digestive systems** to break down the different types of **food** they consume. **Invertebrates** can be classified as those that use **intracellular digestion** and those with **extracellular digestion**.

1.1. Intracellular Digestion

The simplest example of digestion is **intracellular digestion**, which takes place in a **gastrovascular cavity** with only **one opening**. Most animals with **soft bodies** use this type of digestion, including **Platyhelminthes** (**flatworms**), **Ctenophora** (**comb jellies**), and **Cnidaria** (**coral**, **jellyfish**, and **sea anemones**). The **gastrovascular cavity** of these organisms contains one **opening** which serves as both a **mouth** and an **anus**.

Digestion in simple animals occurs through a series of basic steps. Food is first **ingested** through the mouth into the **gastrovascular cavity**, where **enzymes** are secreted to partially break it down. Specialized cells then **engulf food particles** by phagocytosis, forming food vacuoles that fuse with **lysosomes** for intracellular digestion. The resulting nutrients are **absorbed** into the cytoplasm for energy and growth, while **undigested wastes** are expelled back through the mouth/anus by exocytosis.

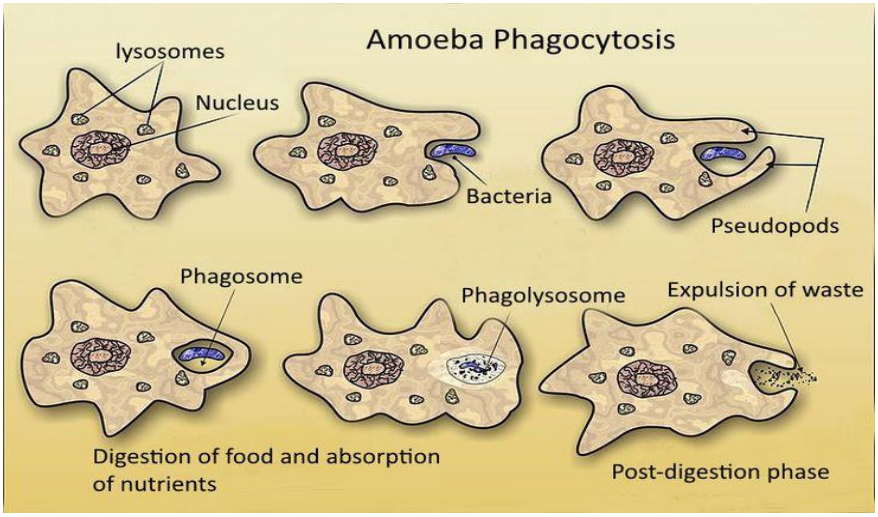


Fig. Process Of Nutrition In Amoeba

1.2. Extracellular Digestion

The **alimentary canal** is a more advanced digestive system than the gastrovascular cavity and performs **extracellular digestion**. It is a **complete and compartmentalized tube** that extends from the **mouth** to the **anus**, allowing food to pass in one direction and enabling specialized regions for different digestive functions. Most invertebrates such as **segmented worms (earthworms)**, **arthropods (grasshoppers)**, and **arachnids (spiders)** possess this type of system.

In **extracellular digestion**, food is broken down outside the cells within the **digestive cavity or alimentary canal**. Food is first **ingested** through the mouth, passes through the **esophagus**, and is **stored in the crop**, where it softens. It then enters the **gizzard**, where muscular grinding reduces it into smaller particles. **Digestive enzymes** secreted into the gut break down complex molecules into simpler nutrients, which are then **absorbed** through the intestinal walls into body fluids for cellular use. Finally, **undigested material** is compacted and **eliminated** through the anus.

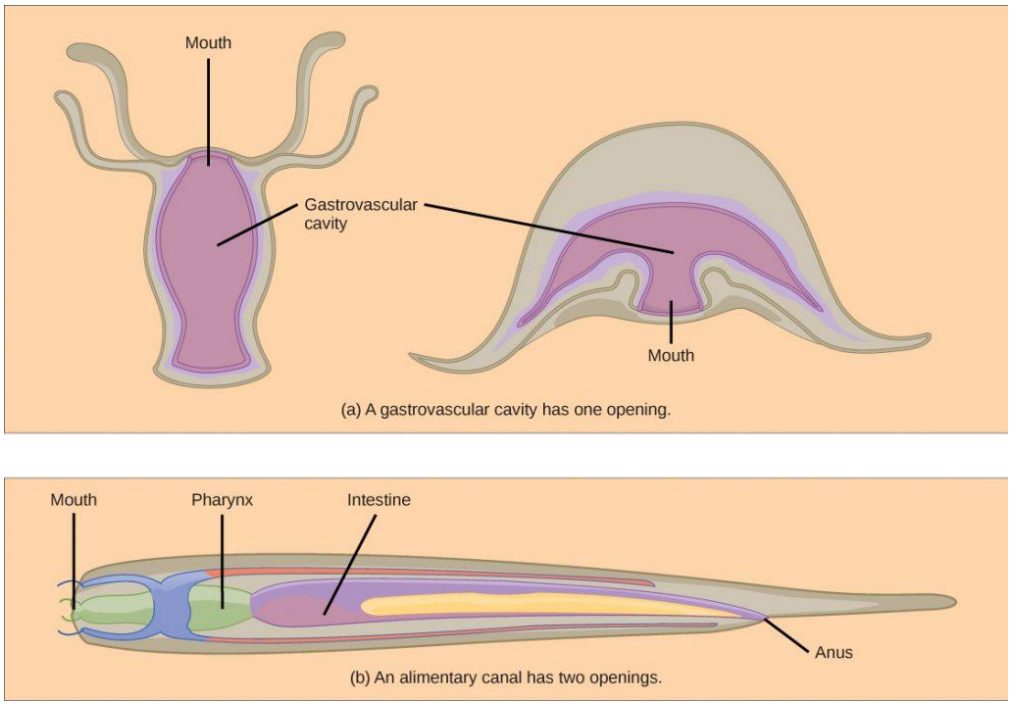


Figure 1 . a) A gastrovascular cavity has a single opening through which food is ingested and waste is excreted, as shown in this hydra and in this jellyfish medusa. (b) An alimentary canal has two openings: a mouth for ingesting food, and an anus for eliminating waste, as shown in this nematode.

Key Points

• The simplest invertebrate **digestive system** in a **gastrovascular cavity** consists of only **one opening** that serves as both the **mouth** for taking in **food** and the **anus** for **excretion**.

• The **gastrovascular cavity** has **cells** lining it that secrete **digestive enzymes** to break down the **food particles** through a process called **intracellular digestion**.

• An **alimentary canal** is a long **tube** that begins with a **mouth**, then goes to the **esophagus**, then to the **crop**, **gizzard**, **intestine**, and finally, to an **anus**; this is used in the process of **extracellular digestion**.

• Most **invertebrates** use **extracellular digestion**; however, there are a few **phyla** that can use both **intracellular** and **extracellular digestion.** Examples include **Porifera**, **Cnidaria**, and **Platyhelminthes**, in which digestion begins **extracellularly** in a cavity or canal and is completed **intracellularly** within specialized cells.

II. Digestive system in Vertebrates

All vertebrates (fish, amphibians, reptiles, birds, mammals) have a digestive system adapted to their diet (herbivores, carnivores, omnivores). The system is generally **tubular** (alimentary canal) with accessory glands, but there are **structural differences** among groups.

2.1. General Structure of Vertebrate Digestive System

- **Mouth and Oral Cavity**
  - Teeth (shape depends on diet: sharp in carnivores, flat in herbivores).
  - Salivary glands → secrete enzymes (amylase in some species).
  - Tongue → helps in manipulation and swallowing.
- **Pharynx and Esophagus**
  - Passage for food.
  - Swallowing involves muscular contractions.
- **Stomach**
  - Stores and mixes food.
  - Secretes gastric juice (HCl + pepsin) → protein digestion.
  - May be simple (monogastric, e.g., humans, carnivores) or complex (ruminants like cows with 4 chambers).
- **Small Intestine**
  - Major site of digestion and absorption.
  - Enzymes from pancreas (amylases, proteases, lipases).
  - Bile from liver → emulsifies fats.

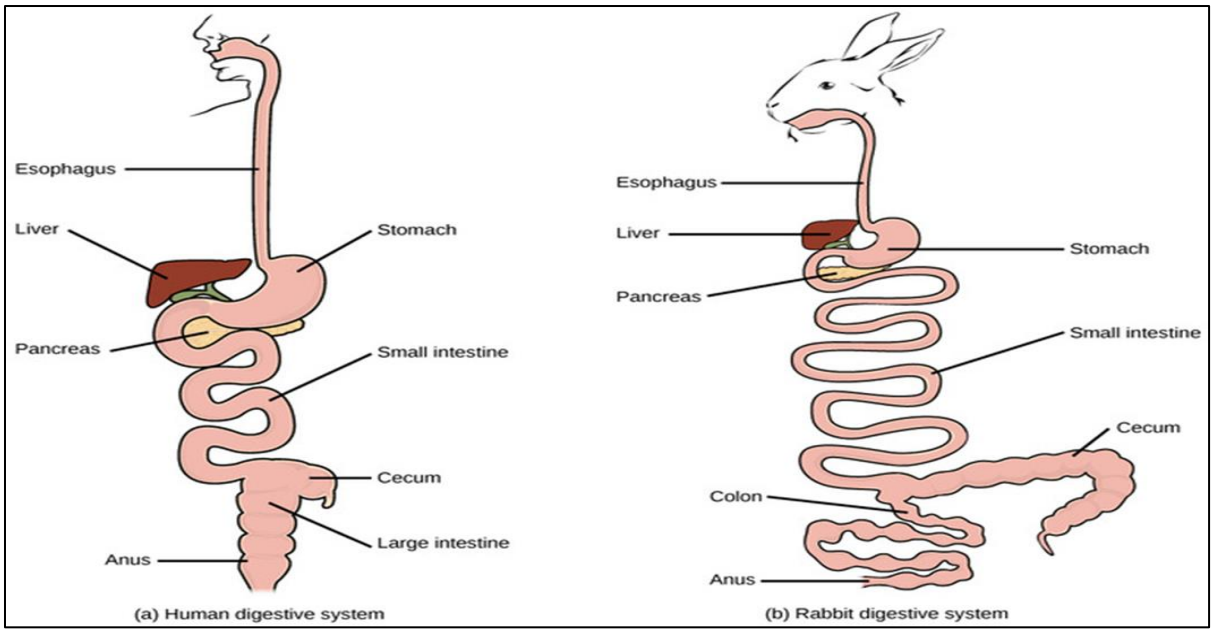
    - Villi and microvilli → increase surface area for absorption.
- **Large Intestine**
    - Absorbs water and salts.
    - Houses symbiotic bacteria (important in herbivores for cellulose digestion).
    - Forms and stores feces.
- **Anus/ Cloaca**
    - Expels undigested material.
    - Birds, reptiles, and amphibians have a **cloaca** (common opening for digestive, urinary, reproductive tracts).

2.2. Evolutionary Adaptations of Vertebrate Digestive Systems

- Vertebrates have evolved complex digestive systems adapted to their dietary needs.
    - Some have **single-chambered stomachs**.
    - Others have **multi-chambered stomachs**.
    - Birds have unique systems adapted for eating **un-masticated food**.

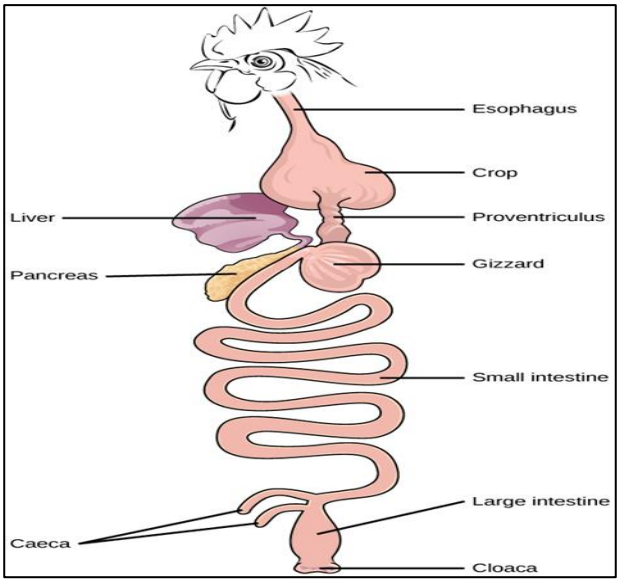
1. Monogastric Digestive System (Single-Chambered Stomach)

- Found in **humans and many animals**.
- **Process**:
    - **Mouth** → Teeth masticate food, saliva enzymes begin chemical digestion.
    - **Esophagus** → Moves food to stomach by peristalsis.
    - **Stomach** → Very acidic (pH 1.5–2.5), secretes gastric juices and enzymes to break down proteins.
    - **Small Intestine** → Pancreas, liver, and intestinal enzymes complete digestion; nutrients absorbed into bloodstream.
    - **Large Intestine** → Absorbs water, compacts waste into feces.
    - **Rectum/Anus** → Excretion of feces.



2. Avian Digestive System (Birds)

- Adaptation: **No teeth** → food is swallowed whole.
- Birds have **high metabolic rates** (need efficient digestion).
- **Specialized Structures**:
  - **Beak** → Adapted for diet (seeds, insects, fruits, nuts).
  - **Proventriculus** → Secretes gastric juices.
  - **Gizzard** → Stores food, grinds mechanically (sometimes with stones).
  - **Intestine** → Site of chemical digestion & absorption.
  - **Cloaca** → Common opening for waste excretion.
- Some undigested food forms **pellets** that are regurgitated.



3. Ruminant Digestive System (Four-Chambered Stomach)

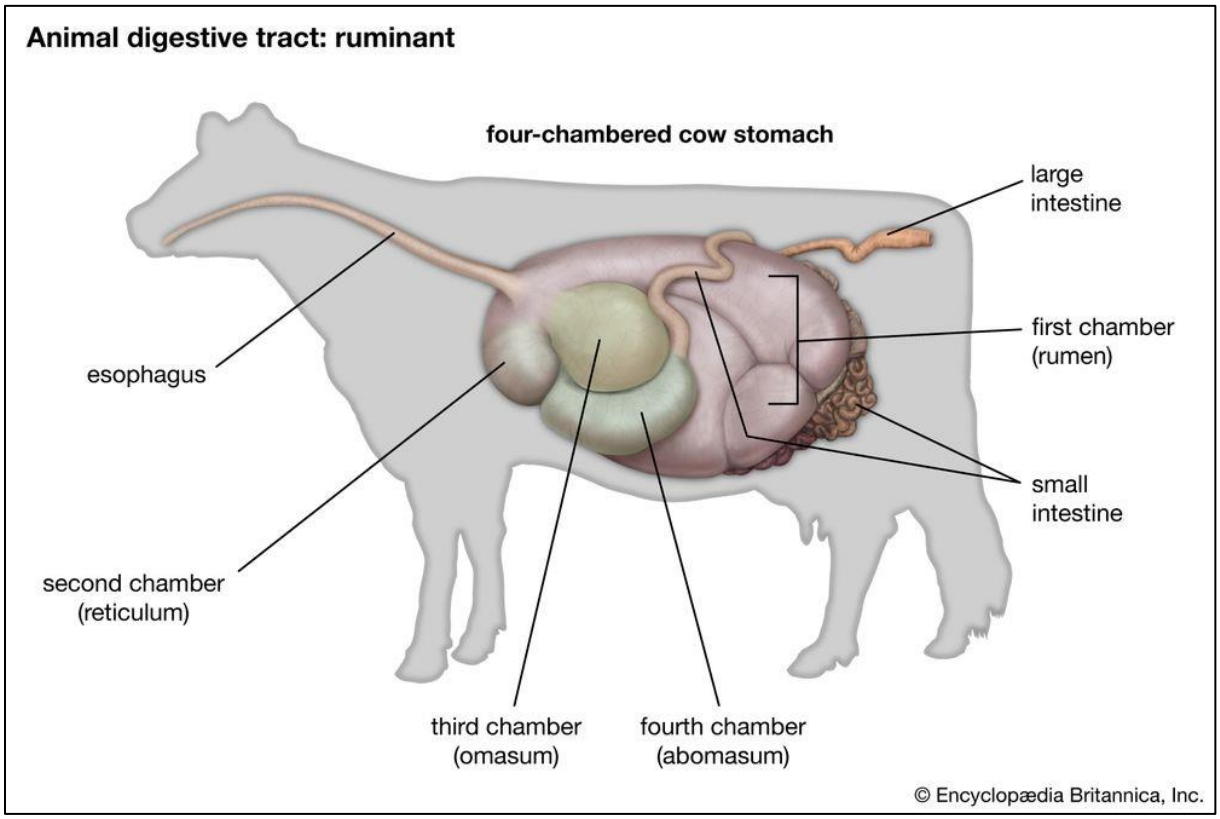
- Found in **cows, sheep, goats** (herbivores, high cellulose diet).
- **Special Features**:
  - No upper incisors → use lower teeth, tongue, lips for chewing.
- **Four Chambers**:

1. **Rumen** → fermentation vat with microbes.
2. **Reticulum** → traps large particles; regurgitation for re-chewing ("cud").
3. **Omasum** → absorbs water and nutrients.
4. **Abomasum** (true stomach) → secretes gastric juices like monogastric stomach.

Fermentation produces gases that must be released (eructation).

Small intestine → nutrient absorption.

Large intestine → water absorption and waste elimination.



4. Pseudo-ruminant Digestive System (Three-Chambered Stomach)

- Found in **camels, alpacas**.
- Eat large amounts of roughage and plant material.
- **Differences from ruminants**:
  - **Three chambers** (no rumen).

- Have **omasum, reticulum, abomasum**.
- **Large cecum** → houses microorganisms to ferment and digest cellulose.

- Fermentation occurs mainly in the **cecum**, not a rumen.

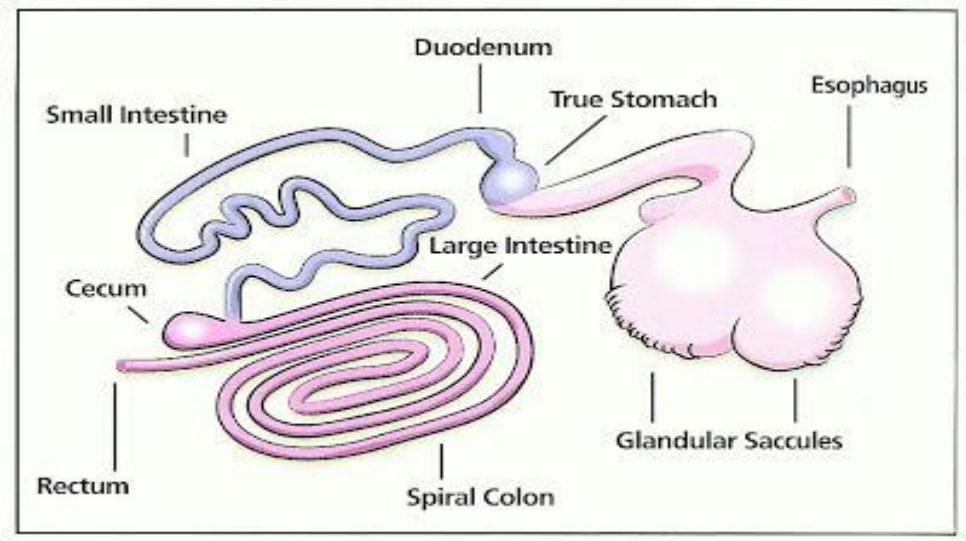


Diagram of an alpaca's gastrointestinal tract.

2. Enzymatic Digestion and Absorption

1. Definition

- **Enzymatic digestion** is the breakdown of large, complex food molecules into smaller, absorbable units by the action of **digestive enzymes**.
- **Absorption** is the process by which the end products of digestion pass through the intestinal lining into the **blood** or **lymph** to be transported to body cells.

2. Stages of Enzymatic Digestion

Digestive Organ	**Enzymes Released**	**Function**
Mouth	*Salivary amylase*	Begins digestion of **starch** into maltose.
Stomach	*Pepsin* (from pepsinogen activated by HCl)	Begins **protein** digestion into peptides.
Pancreas (to small intestine)	**Pancreatic amylase**, **Trypsin**, **Chymotrypsin**, **Lipase**	Continues carbohydrate digestion, breaks proteins into smaller peptides, and digests fats into fatty acids + glycerol.

Small Intestine (intestinal brush border)	**Maltase, Sucrase, Lactase, Peptidases**	Final breakdown of carbohydrates to **monosaccharides** and proteins to **amino acids**.

3. Enzymatic Digestion of Nutrients

Carbohydrates

- **Starch → Maltose** (by salivary & pancreatic amylase)
- **Maltose, Sucrose, Lactose → Glucose, Fructose, Galactose** (by intestinal enzymes)

Proteins

- **Proteins → Polypeptides** (by pepsin in the stomach)
- **Polypeptides → Amino acids** (by trypsin, chymotrypsin, and peptidases in the small intestine)

Fats (Lipids)

- **Bile** (from the liver) **emulsifies fats** → breaks them into tiny droplets.
- **Lipase** converts them into **fatty acids + glycerol**.

4. Absorption in the Small Intestine

- Occurs mainly in the **jejunum and ileum**.
- The inner surface of the small intestine has **villi** and **microvilli**, increasing the **surface area** for absorption.

Nutrient	**Absorbed Form**	**Absorption Location**	**Transported By**
Carbohydrates	**Monosaccharides** (e.g., glucose)	Small intestine	Enters **bloodstream**
Proteins	**Amino acids**	Small intestine	Enters **bloodstream**
Fats	**Fatty acids + glycerol**	Small intestine	Enters **lymphatic system** via **lacteals**