RAMA UNIVERSITY

www.ramauniversity.ac.in

FACULTY OF ENGINEERING &TECHNOLOGY

DEPARTMENT OF BIOTECHNOLOGY

Mammalian Physiology

Digestive Systems

Animals use the organs of their digestive systems to extract important nutrients from food they consume, which can later be absorbed.

Key Points

- Animals obtain lipids, proteins, carbohydrates, essential vitamins, and minerals from the food they consume.
- The digestive system is composed of a series of organs, each with a specific, yet related function, that work to extract nutrients from food.
- Organs of the digestive system include the mouth, esophagus, stomach, small intestine, and the large intestine.
- Accessory organs, such as the liver and pancreas, secrete digestive juices into the gastrointestinal tract to assist with food breakdown.

Key Terms

- **digestion**: the process, in the gastrointestinal tract, by which food is converted into substances that can be utilized by the body
- **macromolecule**: a very large molecule, especially used in reference to large biological polymers (e.g. nucleic acids and proteins)
- **alimentary canal**: the organs of a human or an animal through which food passes; the digestive tract

Introduction to Animal Nutrition

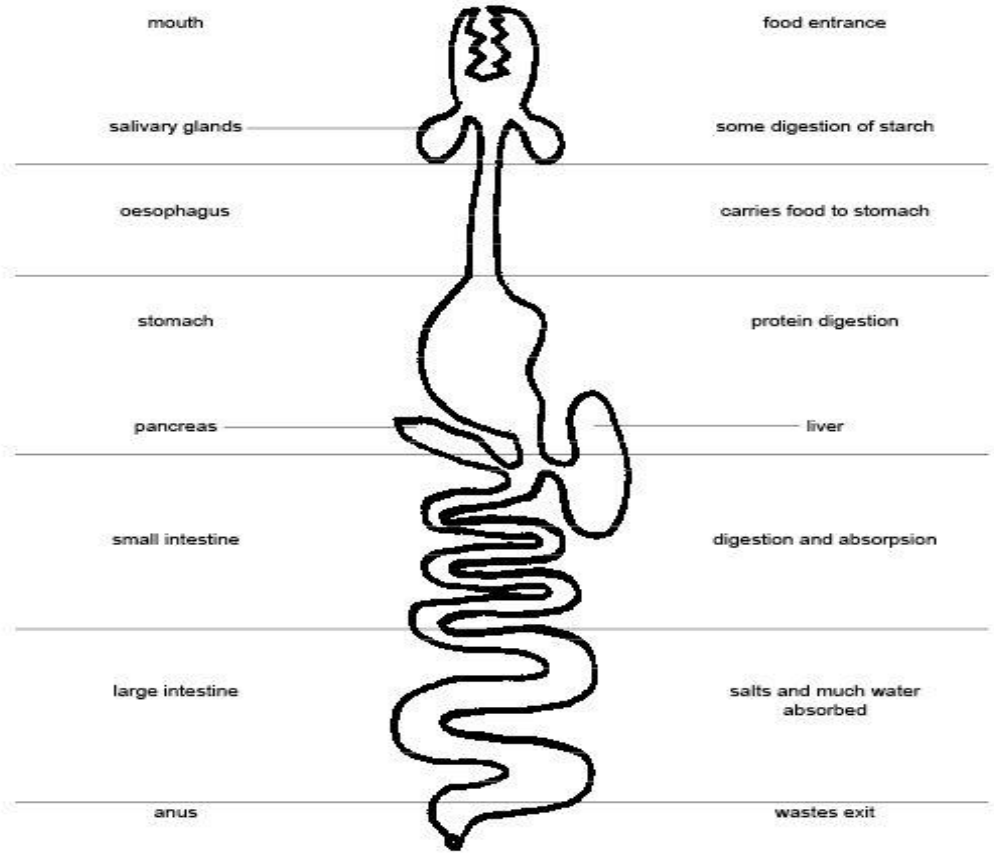
All living organisms need nutrients to survive. While plants can obtain the molecules required for cellular function through the process of photosynthesis, most animals obtain their nutrients by the consumption of other organisms. At the cellular level, the biological molecules necessary for animal function are amino acids, lipid molecules, nucleotides, and simple sugars. The food consumed consists of protein, fat, and complex carbohydrates, but the requirements of each are different for each animal.

Balanced human diet: For humans, fruits and vegetables are important in maintaining a balanced diet. Both of these are an important source of vitamins and minerals, as well as carbohydrates, which are broken down through digestion for energy.

Animals must convert these macromolecules into the simple molecules required for maintaining cellular functions, such as assembling new molecules, cells, and tissues. The conversion of the food consumed to the nutrients required is a multi-step process involving digestion and absorption. During digestion, food particles are broken down to smaller components which will later be absorbed by the body.

Digestive System

The digestive system is one of the largest organ systems in the human body. It is responsible for processing ingested food and liquids. The cells of the human body all require a wide array of chemicals to support their metabolic activities, from organic nutrients used as fuel to the water that sustains life at the cellular level. The digestive system not only effectively chemically reduces the compounds in food into their fundamental building blocks, but also acts to retain water and excrete undigested materials. The functions of the digestive system can be summarized as follows: ingestion (eat food), digestion (breakdown of food), absorption (extraction of nutrients from the food), and defecation (removal of waste products).



Generalized animal digestive system: This diagram shows a generalized animal digestive system, detailing the different organs and their functions.

The digestive system consists of a group of organs that form a closed tube-like structure called the gastrointestinal tract (GI tract) or the alimentary canal. For convenience, the GI tract is divided into upper GI tract and lower GI tract. The organs that make up the GI tract include the mouth, the esophagus, the stomach, the small intestine, and the large intestine. There are also several accessory organs that secrete various enzymes into the GI tract. These include the salivary glands, the liver, and the pancreas.

Challenges to Human Nutrition

One of the challenges in human nutrition is maintaining a balance between food intake, storage, and energy expenditure. Imbalances can have serious health consequences. For example, eating too much food while not expending much energy leads to obesity, which in turn will increase the risk of developing illnesses such as type-2 diabetes and cardiovascular disease.

The recent rise in obesity and related diseases means that understanding the role of diet and nutrition in maintaining good health is more important than ever.

Herbivores, Omnivores, and Carnivores

Animals can be carnivores, herbivores, or omnivores in their eating strategies.

Key Points

- Herbivores are those animals, such as deer and koalas, that only eat plant material.
- Omnivores are those animals, such as bears and humans, that can eat a variety of food sources, but tend to prefer one type to another.
- While most carnivores, such as cats, eat only meat, facultative carnivores, such as dogs, behave more like omnivores as they can eat plant matter along with meat.
- Facultative carnivores can eat meat as well as plant material while obligate carnivores eat meat all the time.

Key Terms

- **omnivore**: an animal which is able to consume both plants (like a herbivore) and meat (like a carnivore)
- **obligate carnivore**: an animal that necessarily subsists on a diet consisting mainly of meat because it does not possess the physiology to digest vegetable matter
- **herbivore**: any animal that eats only vegetation (i.e. that eats no meat)
- **carnivore**: any animal that eats meat as the main part of its diet

Herbivores, Omnivores, and Carnivores

Herbivores are animals whose primary food source is plant-based. Examples of herbivores include vertebrates like deer, koalas, and some bird species, as well as invertebrates such as crickets and caterpillars. These animals have evolved digestive systems capable of digesting large amounts of plant material. The plants are high in fiber and starch, which provide the main energy source in their diet. Since some parts of plant materials, such as cellulose, are hard to digest, the digestive tract of herbivores is adapted so that food may be digested properly. Many large herbivores have symbiotic bacteria within their guts to assist with the breakdown of

cellulose. They have long and complex digestive tracts to allow enough space and time for microbial fermentation to occur. Herbivores can be further classified into frugivores (fruit-eaters), granivores (seed eaters), nectivores (nectar feeders), and folivores (leaf eaters).

(a) (b)

Examples of herbivores: Herbivores, such as this (a) mule deer and (b) monarch caterpillar, eat primarily plant material. Some herbivores contain symbiotic bacteria within their intestines to aid with the digestion of the cellulose found in plant cell walls.

Omnivores are animals that eat both plant- and animal- derived food. Although the Latin term omnivore literally means “eater of everything”, omnivores cannot really eat everything that other animals eat. They can only eat things that are moderately easy to acquire while being moderately nutritious. For example, most omnivores cannot live by grazing, nor are they able to eat some hard-shelled animals or successfully hunt large or fast prey. Humans, bears, and chickens are examples of vertebrate omnivores; invertebrate omnivores include cockroaches and crayfish.

(a)

(b)

Examples of omnivores: Omnivores such as the (a) bear and (b) crayfish eat both plant- and animal-based food. While their food options are greater than those of herbivores or carnivores, they are still limited by what they can find to eat, or what they can catch.

Carnivores are animals that eat other animals. The word carnivore is derived from Latin and means “meat eater.” Wild cats, such as lions and tigers, are examples of vertebrate carnivores, as are snakes and sharks, while invertebrate carnivores include sea stars, spiders, and ladybugs. Obligate carnivores are those that rely entirely on animal flesh to obtain their nutrients; examples of obligate carnivores are members of the cat family. Facultative carnivores are those that also eat non-animal food in addition to animal food. Note that there is no clear line that differentiates facultative carnivores from omnivores; dogs would be considered facultative carnivores.

(a)

(b)

Examples of carnivores: Carnivores such as the (a) lion eat primarily meat. The (b) ladybug is also a carnivore that consumes small insects called aphids.

Invertebrate Digestive Systems

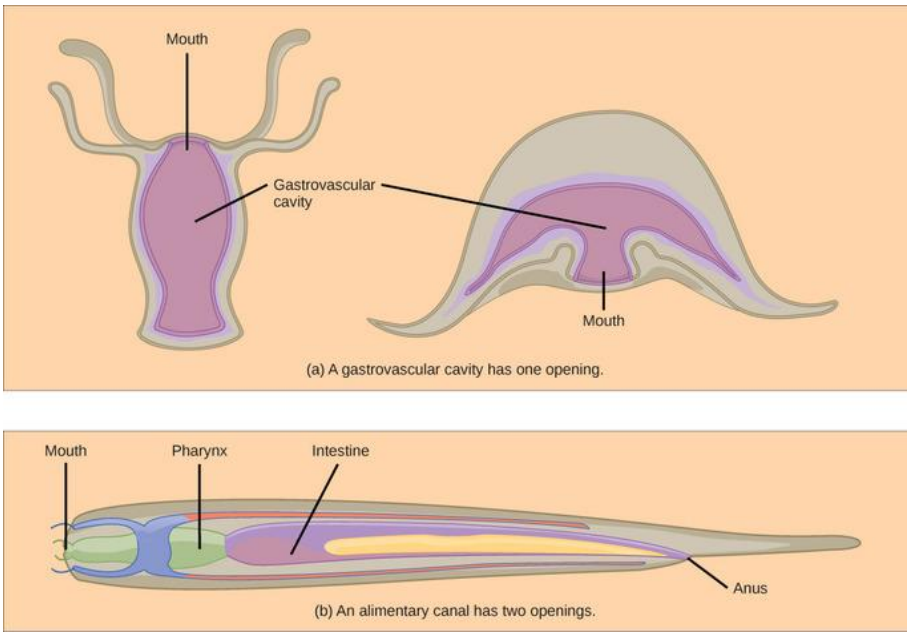
Invertebrate digestive systems include a gastrovascular cavity with one opening or an alimentary canal with a true mouth and anus.

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.

Key Terms

- **alimentary canal**: the organs of a human or an animal through which food passes; the digestive tract
- **intracellular digestion**: Intracellular digestion is a form of digestion which takes place within the cytoplasm of the organism. Intracellular digestion takes place in animals without a digestive tract, in which food items are brought into the cell for digestion.
- **extracellular digestion**: Extracellular digestion is a process in which animals feed by secreting enzymes through the cell membrane onto the food. The enzymes break the food into molecules small enough to be taken pass through the cell membrane into the cell. These nutrients are transferred into the blood or other body fluids and distributed to the rest of the body.
- **extracellular**: occurring or found outside of a cell
- **casting**: the excreta of an earthworm or similar creature
- **intracellular**: Intracellular digestion is a form of digestion which takes place within the cytoplasm of the organism. Intracellular digestion takes place in animals without a digestive tract, in which food items are brought into the cell for digestion.



Invertebrate digestive systems: (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.

Invertebrate Digestive Systems

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

Intracellular Digestion

The simplest example of digestion 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, jelly fish, and sea anemones). The gastrovascular cavities of these organisms contain one open which serves as both a “mouth” and an “anus”.

Invertebrates with Extracellular Digestion: Invertebrates like grasshoppers have alimentary canals with specialized compartments for digestion. Their food is broken down in their digestive tract (extracellular digestion), rather than inside their individual cells (intracellular digestion).

Ingested material enters the mouth and passes through a hollow, tubular cavity. The food particles are engulfed by the cells lining the gastrovascular cavity and the molecular are broken down within the cytoplasm of the cells (intracellular).

Extracellular Digestion

The alimentary canal is a more advanced digestive system than a gastrovascular cavity and carries out extracellular digestion. Most other invertebrates like segmented worms (earthworms), arthropods (grasshoppers), and arachnids (spiders) have alimentary canals. The alimentary canal is compartmentalized for different digestive functions and consists of one tube with a mouth at one end and an anus at the other.

Once the food is ingested through the mouth, it passes through the esophagus and is stored in an organ called the crop; then it passes into the gizzard where it is churned and digested. From the gizzard, the food passes through the intestine and nutrients are absorbed. Because the food

has been broken down exterior to the cells, this type of digestion is called extracellular digestion. The material that the organism cannot digest is eliminated as feces, called castings, through the anus.

Most invertebrates use some form of extracellular digestion to break down their food. Flatworms and cnidarians, however, can use both types of digestion to break down their food.

Vertebrate Digestive Systems

Vertebrates may have a single stomach, several stomach chambers, or accessory organs that help to break down ingested food.

Key Points

- Monogastric animals have a single stomach that secretes enzymes to break down food into smaller particles; additional gastric juices are produced by the liver, salivary glands, and pancreas to assist with the digestion of food.
- The avian digestive system has a mouth (beak), crop (for food storage), and gizzard (for breakdown), as well as a two-chambered stomach consisting of the proventriculus, which releases enzymes, and the true stomach, which finishes the breakdown.
- Ruminants, such as cows and sheep, are those animals that have four stomachs; they eat plant matter and have symbiotic bacteria living within their stomachs to help digest cellulose.
- Pseudo-ruminants (such as camels and alpacas) are similar to ruminants, but have a three-chambered stomach; the symbiotic bacteria that help them to break down cellulose is found in the cecum, a chamber close to the large intestine.

Key Terms

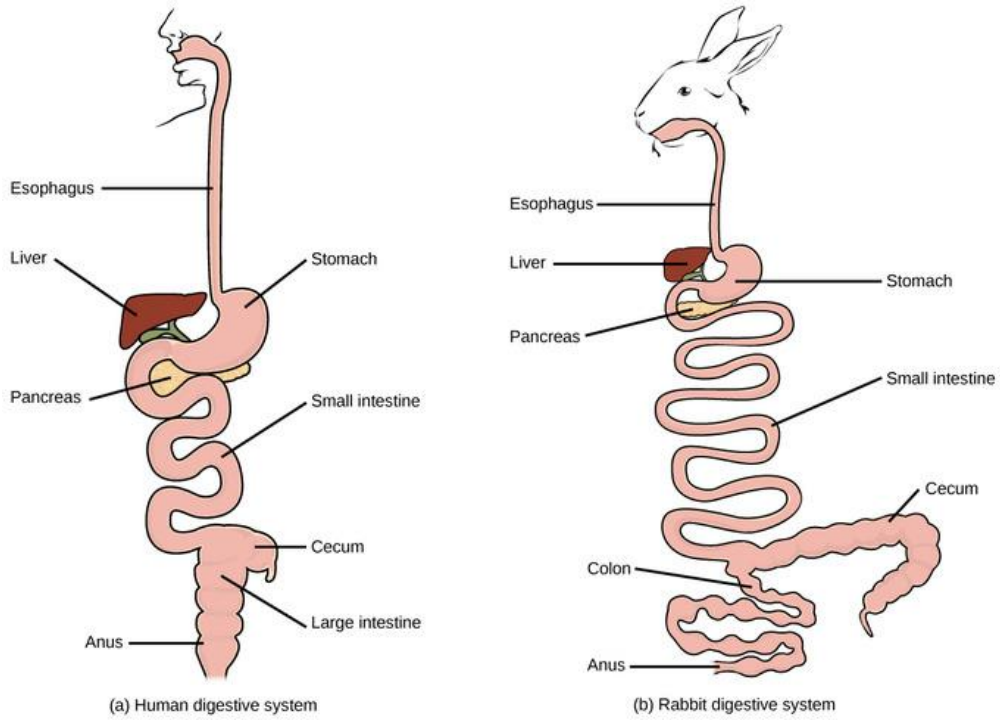
- **peristalsis**: the rhythmic, wave-like contraction and relaxation of muscles which propagates in a wave down a muscular tube
- **proventriculus**: the part of the avian stomach, between the crop and the gizzard, that secretes digestive enzymes
- **cellulose**: a complex carbohydrate that forms the main constituent of the cell wall in most plants

Vertebrate Digestive Systems

Vertebrates have evolved more complex digestive systems to adapt to their dietary needs. Some animals have a single stomach, while others have multi-chambered stomachs. Birds have developed a digestive system adapted to eating un-masticated (un-chewed) food.

Monogastric: Single-chambered Stomach

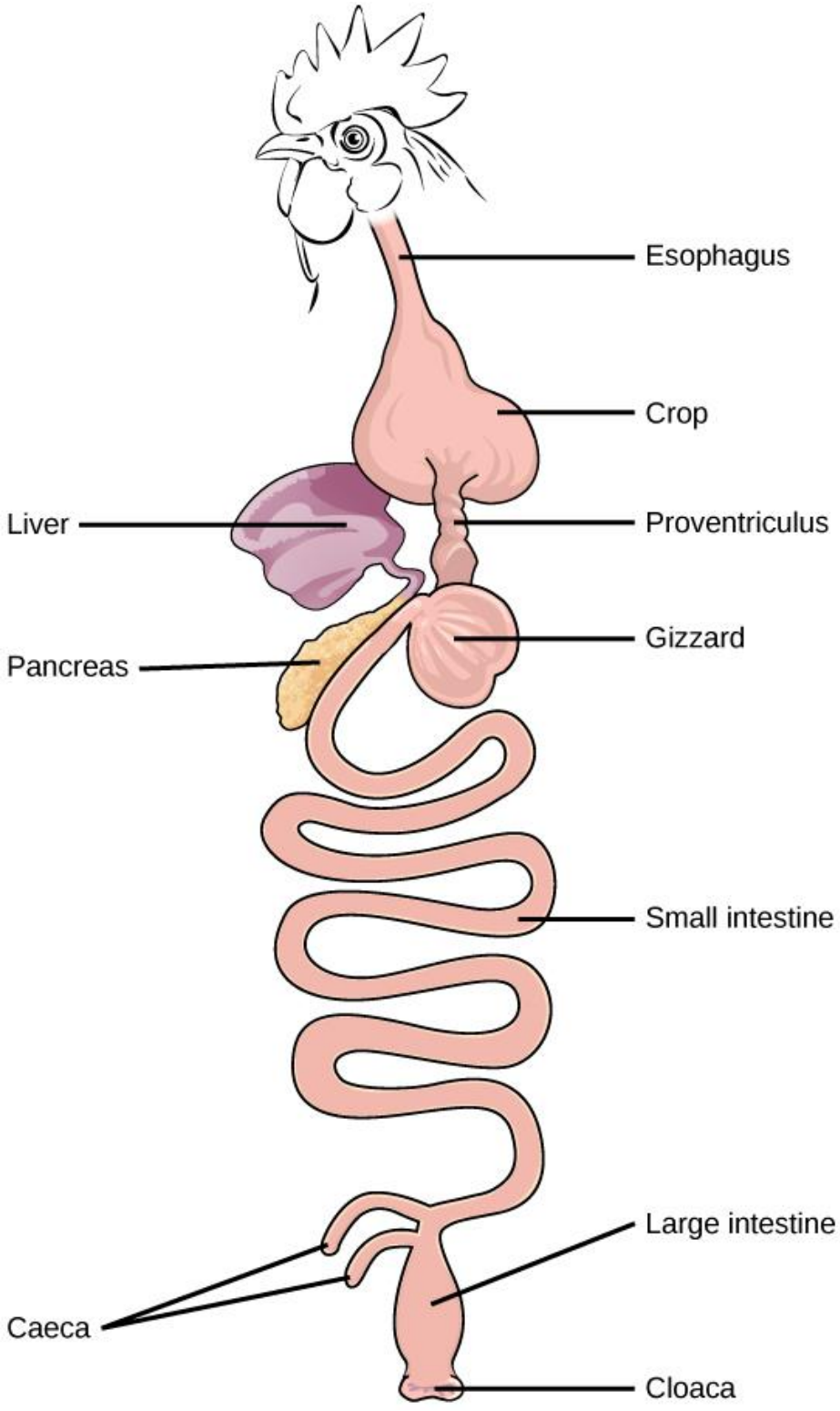
As the word monogastric suggests, this type of digestive system consists of one (“mono”) stomach chamber (“gastric”). Humans and many animals have a monogastric digestive system. The process of digestion begins with the mouth and the intake of food. The teeth play an important role in masticating (chewing) or physically breaking down food into smaller particles. The enzymes present in saliva also begin to chemically break down food. The esophagus is a long tube that connects the mouth to the stomach. Using peristalsis, the muscles of the esophagus push the food towards the stomach. In order to speed up the actions of enzymes in the stomach, the stomach has an extremely acidic environment, with a pH between 1.5 and 2.5. The gastric juices, which include enzymes in the stomach, act on the food particles and continue the process of digestion. In the small intestine, enzymes produced by the liver, the small intestine, and the pancreas continue the process of digestion. The nutrients are absorbed into the blood stream across the epithelial cells lining the walls of the small intestines. The waste material travels to the large intestine where water is absorbed and the drier waste material is compacted into feces that are stored until excreted through the rectum.



Mammalian digestive system (non-ruminant): (a) Humans and herbivores, such as the (b) rabbit, have a monogastric digestive system. However, in the rabbit, the small intestine and cecum are enlarged to allow more time to digest plant material. The enlarged organ provides more surface area for absorption of nutrients.

Avian

Birds face special challenges when it comes to obtaining nutrition from food. They do not have teeth, so their digestive system must be able to process un-masticated food. Birds have evolved a variety of beak types that reflect the vast variety in their diet, ranging from seeds and insects to fruits and nuts. Because most birds fly, their metabolic rates are high in order to efficiently process food while keeping their body weight low. The stomach of birds has two chambers: the proventriculus, where gastric juices are produced to digest the food before it enters the stomach, and the gizzard, where the food is stored, soaked, and mechanically ground. The undigested material forms food pellets that are sometimes regurgitated. Most of the chemical digestion and absorption happens in the intestine, while the waste is excreted through the cloaca.



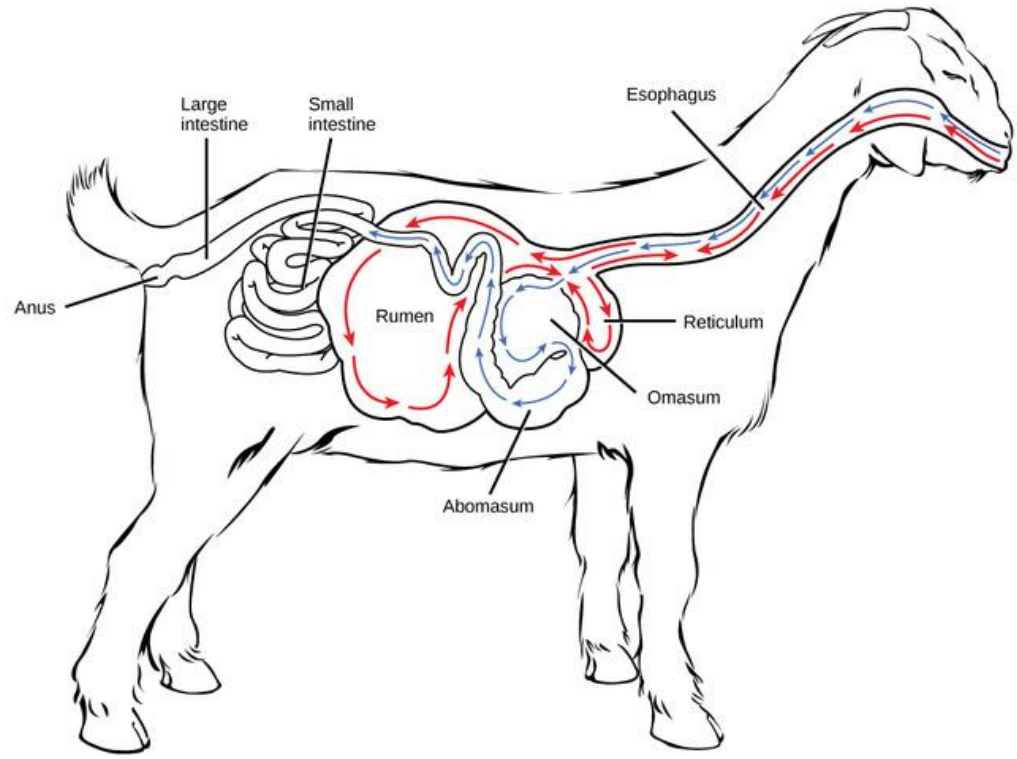
Bird digestive system: The avian esophagus has a pouch, called a crop, which stores food. Food passes from the crop to the first of two stomachs, called the proventriculus, which contains digestive juices that break down food. From the proventriculus, the food enters the second stomach, called the gizzard, which grinds food. Some birds

swallow stones or grit, which are stored in the gizzard, to aid the grinding process. Birds do not have separate openings to excrete urine and feces. Instead, uric acid from the kidneys is secreted into the large intestine and combined with waste from the digestive process. This waste is excreted through an opening called the cloaca.

Ruminants

Ruminants are mainly herbivores, such as cows, sheep, and goats, whose entire diet consists of eating large amounts of roughage or fiber. They have evolved digestive systems that help them process vast amounts of cellulose. An interesting feature of the ruminants' mouth is that they do not have upper incisor teeth. They use their lower teeth, tongue, and lips to tear and chew their food. From the mouth, the food travels through the esophagus and into the stomach.

To help digest the large amount of plant material, the stomach of the ruminants is a multi-chambered organ. The four compartments of the stomach are called the rumen, reticulum, omasum, and abomasum. These chambers contain many microbes that break down cellulose and ferment ingested food. The abomasum, the "true" stomach, is the equivalent of the monogastric stomach chamber. This is where gastric juices are secreted. The four-compartment gastric chamber provides larger space and the microbial support necessary to digest plant material in ruminants. The fermentation process produces large amounts of gas in the stomach chamber, which must be eliminated. As in other animals, the small intestine plays an important role in nutrient absorption, while the large intestine aids in the elimination of waste.



Ruminant mammal digestive system: Ruminant animals, such as goats and cows, have four stomachs. The first two stomachs, the rumen and the reticulum, contain prokaryotes and protists that are able to digest cellulose fiber. The ruminant regurgitates cud from the reticulum, chews it, and swallows it into a third stomach, the omasum, which removes water. The cud then passes onto the fourth stomach, the abomasum, where it is digested by enzymes produced by the ruminant.

Pseudo-ruminants

Some animals, such as camels and alpacas, are pseudo-ruminants. They eat a lot of plant material and roughage. Digesting plant material is not easy because plant cell walls contain the polymeric sugar molecule cellulose. The digestive enzymes of these animals cannot break down cellulose, but microorganisms present in the digestive system can. Since the digestive system must be able to handle large amounts of roughage and break down the cellulose, pseudo-ruminants have a three-chamber stomach. In contrast to ruminants, their cecum (a pouched organ at the beginning of the large intestine containing many microorganisms that are necessary for the digestion of plant materials) is large. This is the site where the roughage is fermented and digested. These animals do not have a rumen, but do have an omasum, abomasum, and reticulum.

Digestive System: Mouth and Stomach

Animal digestion begins in the mouth, then moves through the pharynx, into the esophagus, and then into the stomach and small intestine.

Key Points

- Mechanical and chemical digestion begin in the mouth with the chewing of food and the release of saliva, which starts carbohydrate digestion.
- The epiglottis covers the trachea so the bolus (ball of chewed food) does not go down into the trachea or lungs, but rather into the esophagus.
- The tongue positions the bolus for swallowing and then peristalsis pushes the bolus down the esophagus into the stomach.
- In the stomach, acids and enzymes are secreted to break down food into its nutrient components.
- The churning of the stomach helps to mix the digestive juices with the food, turning it into a substance called chyme.

Key Terms

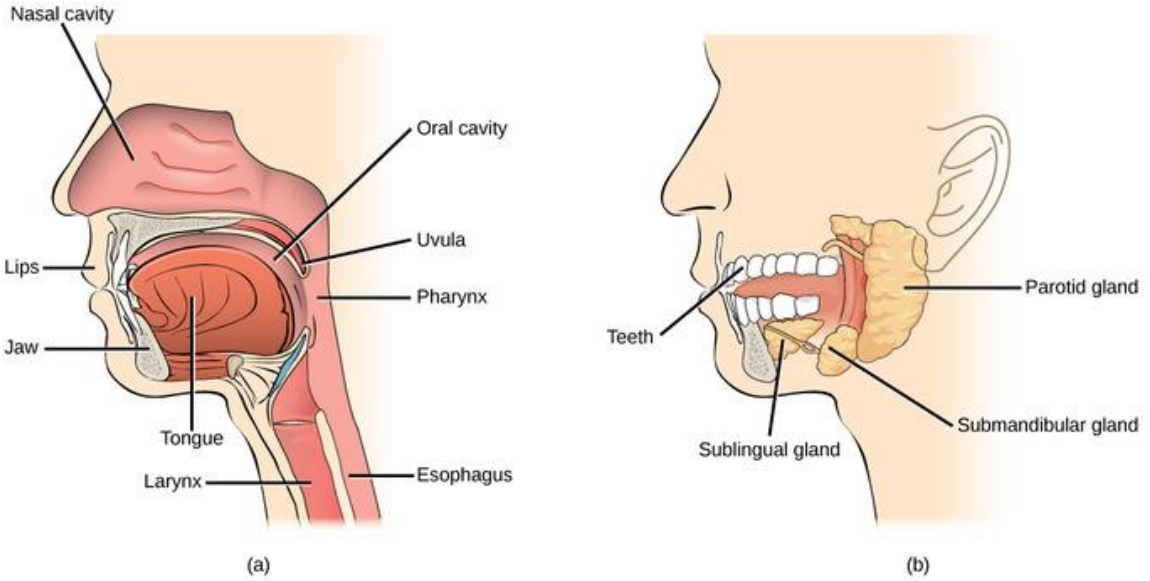
- **bolus**: a round mass of something, especially of chewed food in the mouth or alimentary canal
- **peristalsis**: the rhythmic, wave-like contraction and relaxation of muscles which propagates in a wave down a muscular tube
- **pepsin**: a digestive enzyme that chemically digests, or breaks down, proteins into shorter chains of amino acids
- **chyme**: the thick semifluid mass of partly digested food that is passed from the stomach to the duodenum

Parts of the Digestive System

The vertebrate digestive system is designed to facilitate the transformation of food matter into the nutrient components that sustain organisms. The upper gastrointestinal tract includes the oral cavity, esophagus, and stomach.

Oral Cavity

The oral cavity, or mouth, is the point of entry of food into the digestive system. The food is broken into smaller particles by mastication, the chewing action of the teeth. All mammals have teeth and can chew their food.



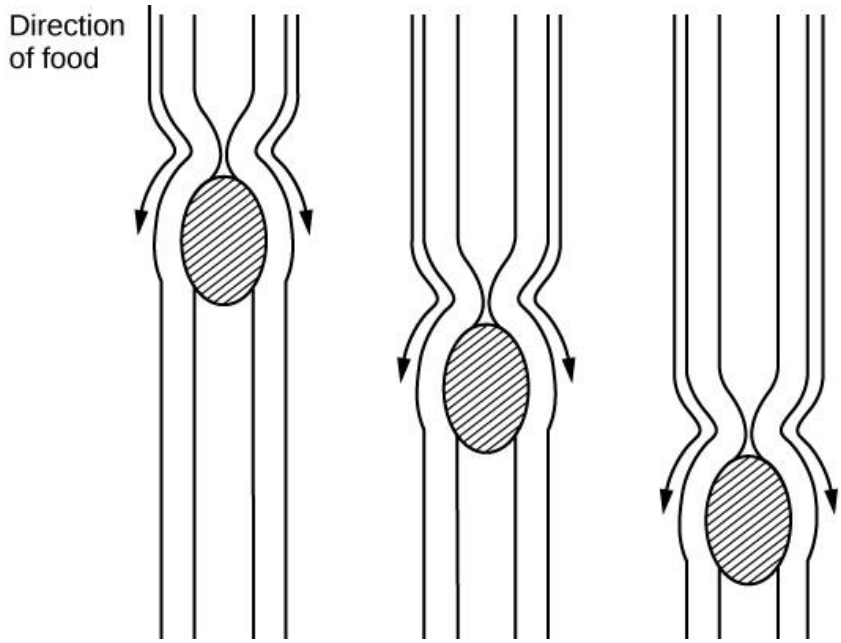
Digestion begins in the oral cavity: Digestion of food begins in the (a) oral cavity. Food is masticated by teeth and moistened by saliva secreted from the (b) salivary glands. Enzymes in the saliva begin to digest starches and fats. With the help of the tongue, the resulting bolus is moved into the esophagus by swallowing.

The extensive chemical process of digestion begins in the mouth. As food is chewed, saliva, produced by the salivary glands, mixes with the food. Saliva is a watery substance produced in the mouths of many animals. There are three major glands that secrete saliva: the parotid, the submandibular, and the sublingual. Saliva contains mucus that moistens food and buffers the pH of the food. Saliva also contains immunoglobulins and lysozymes, which have antibacterial action to reduce tooth decay by inhibiting growth of some bacteria. In addition, saliva contains an enzyme called salivary amylase that begins the process of converting starches in the food into a disaccharide called maltose. Another enzyme, lipase, is produced by the cells in the tongue. It is a member of a class of enzymes that can break down triglycerides. Lingual lipase begins the breakdown of fat components in the food. The chewing and wetting action provided by the teeth and saliva shape the food into a mass called the bolus for swallowing. The tongue aids in swallowing by moving the bolus from the mouth into the pharynx. The pharynx opens to two passageways: the trachea, which leads to the lungs, and the esophagus, which leads to the stomach. The tracheal opening, the glottis, is covered by a cartilaginous flap, the epiglottis.

When swallowing, the epiglottis closes the glottis, allowing food to pass into the esophagus, not into the trachea, preventing food from reaching the lungs.

Esophagus

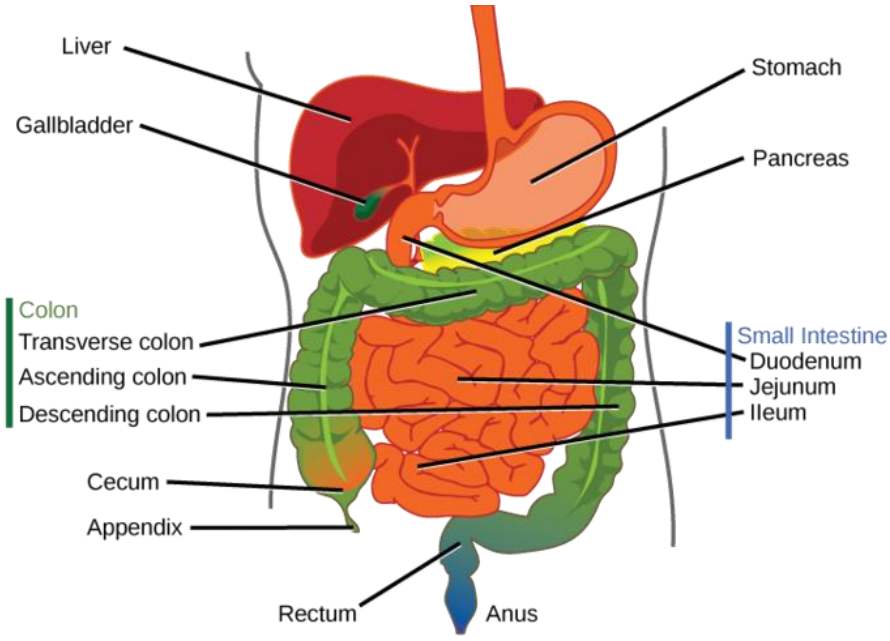
The esophagus is a tubular organ connecting the mouth to the stomach. The chewed and softened food passes through the esophagus after being swallowed. The smooth muscles of the esophagus undergo a series of wave like movements called peristalsis that push the food toward the stomach. The peristalsis wave is unidirectional: it moves food from the mouth to the stomach; reverse movement is not possible. The peristaltic movement of the esophagus is an involuntary reflex, taking place in response to the act of swallowing.



Esophagus: The esophagus transfers food from the mouth to the stomach through peristaltic movements.

Stomach

A large part of digestion occurs in the stomach. The stomach, a saclike organ, secretes gastric digestive juices. The pH in the stomach is between 1.5 and 2.5. This highly- acidic environment is required for the chemical breakdown of food and the extraction of nutrients. When empty, the stomach is a rather small organ; however, it can expand to up to 20 times its resting size when filled with food. This characteristic is particularly useful for animals that need to eat when food is available.



Stomach digestion: The human stomach has an extremely acidic environment where most of the protein gets digested.

The stomach is also the major site for protein digestion in animals other than ruminants. Protein digestion is mediated in the stomach chamber by an enzyme called pepsin, which is secreted by the chief cells in the stomach in an inactive form called pepsinogen. Another cell type, parietal cells, secrete hydrogen and chloride ions, which combine in the lumen to form hydrochloric acid, the primary acidic component of the stomach juices. Hydrochloric acid helps to convert the inactive pepsinogen to pepsin. The highly-acidic environment also kills many microorganisms in the food and, combined with the action of the enzyme pepsin, results in the hydrolysis of protein in the food. Chemical digestion is facilitated by the churning action of the stomach. Contraction and relaxation of smooth muscles mixes the stomach contents about every 20 minutes. The partially-digested food and gastric juice mixture is called chyme. Chyme passes from the stomach to the small intestine. Further protein digestion takes place in the small intestine. Gastric emptying occurs within two to six hours after a meal. Only a small amount of chyme is released into the small intestine at a time. The movement of chyme from the stomach into the small intestine is regulated by the pyloric sphincter.

Digestive System: Small and Large Intestines

Nutrients are absorbed in the small intestine and waste is prepared for elimination in the large intestine.

Key Points

- The small intestine is the primary site of enzyme activity and nutrient absorption during digestion.
- Enzymes from the liver and pancreas are added to the duodenum of the small intestine to aid with chemical breakdown; the remaining chyme is moved via peristalsis through the jejunum and the ileum into the large intestine.
- The large intestine reabsorbs water from the remaining food material and compacts the waste for elimination from the body by way of the rectum and the anus.
- The liver creates and secretes bile, which breaks down lipids; the pancreas secretes enzymes to assist with protein digestion.

Key Terms

- **villus**: a small projection from a mucous membrane, particularly those found in the intestines
- **sphincter**: a ringlike band of muscle that surrounds a bodily opening, constricting and relaxing as required for normal physiological functioning
- **duodenum**: the first part of the small intestine, starting at the lower end of the stomach and extending to the jejunum
- **colon**: part of the large intestine; the final segment of the digestive system, after (distal to) the ileum and before (proximal to) the anus

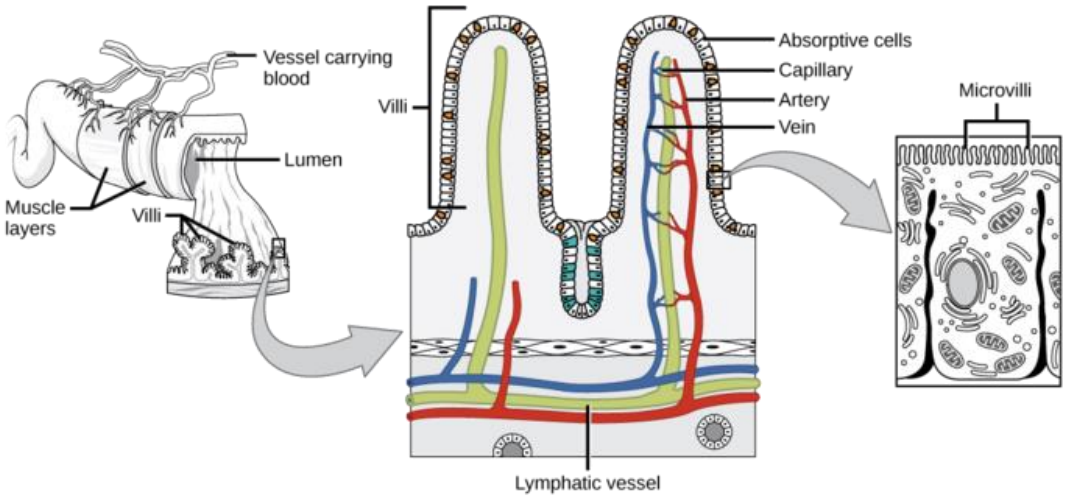
Parts of the Digestive System

The vertebrate digestive system is designed to facilitate the transformation of food matter into the nutrient components that sustain organisms. The lower gastrointestinal tract includes the small and large intestines, rectum, anus, and accessory organs.

Small Intestine

Chyme moves from the stomach to the small intestine: the organ where the digestion of protein, fats, and carbohydrates is completed. The small intestine is a long tube-like organ with a highly-folded surface containing finger-like projections: the villi. The apical surface of each villus has many microscopic projections: the microvilli. These structures are lined with epithelial cells on

the luminal side to allow the nutrients from the digested food to be absorbed into the blood stream on the other side. The villi and microvilli, with their many folds, increase the surface area of the intestine and increase absorption efficiency of the nutrients.



Villi of the small intestine: Villi are folds on the small intestine lining that increase the surface area to facilitate the absorption of nutrients.

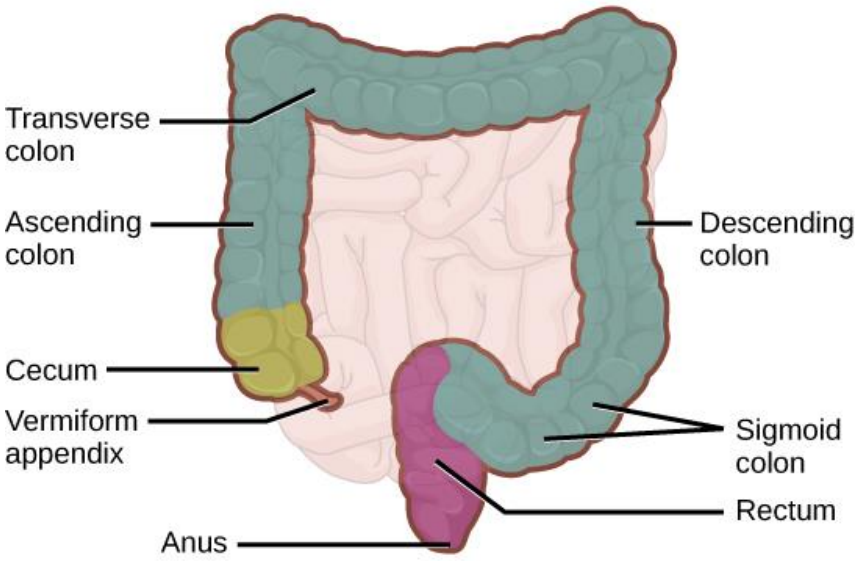
The human small intestine, over 6 m long, is divided into three parts: the duodenum, the jejunum, and the ileum. The “C-shaped,” fixed part of the small intestine, the duodenum, is separated from the stomach by the pyloric sphincter which opens to allow chyme to move from the stomach to the duodenum where it mixes with pancreatic juices. The alkaline solution is rich in bicarbonate that neutralizes the acidity of chyme and acts as a buffer. Digestive juices from the pancreas, liver, and gallbladder, as well as from gland cells of the intestinal wall itself, enter the duodenum. Absorption of fatty acids also takes place in there.

The second part of the small intestine is called the jejunum. Here, hydrolysis of nutrients is continued while most of the carbohydrates and amino acids are absorbed through the intestinal lining. The bulk of chemical digestion and nutrient absorption occurs in the jejunum.

The ileum is the last part of the small intestine. It is here that bile salts and vitamins are absorbed into blood stream. The undigested food is sent from the ileum to the colon through the ileocecal valve via peristaltic movements of the muscle. The vermiform, “worm-like,” appendix is located at the ileocecal valve. The appendix of humans secretes no enzymes and has an insignificant role in immunity.

Large Intestine

The large intestine reabsorbs water from undigested food material and processes waste material; although it is also capable of absorbing vitamins that are synthesized by the normal microflora housed herein. The human large intestine is much smaller in length than the small intestine, but larger in diameter. It has three parts: the cecum, the colon, and the rectum. The cecum joins the ileum to the colon. It is the receiving pouch for the waste matter. The colon, home to many bacteria or “intestinal flora” that aid in the digestive processes, can be divided into four regions: the ascending colon, the transverse colon, the descending colon, and the sigmoid colon. The main functions of the colon are to extract the water and mineral salts from undigested food and to store waste material. Due to their diet, carnivorous mammals have a shorter large intestine compared to herbivorous mammals.



Large intestine: The large intestine reabsorbs water from undigested food and stores waste material until it is eliminated.

Rectum and Anus

The rectum is the terminal end of the large intestine. Its primary role is to store the feces until defecation. The feces are propelled using peristaltic movements during elimination. The anus, an opening at the far-end of the digestive tract, is the exit point for the waste material. Two sphincters between the rectum and anus control elimination: the inner sphincter is involuntary, while the outer sphincter is voluntary.

Accessory Organs

The organs discussed above are those of the digestive tract through which food passes. Accessory organs are those that add secretions (enzymes) that catabolize food into nutrients. Accessory organs include salivary glands, the liver, the pancreas, and the gallbladder. The liver, pancreas, and gallbladder are regulated by hormones in response to the food consumed.

The liver, the largest internal organ in humans, plays a very important role in digestion of fats and detoxifying blood. It produces bile: a digestive juice that is required for the breakdown of fatty components of the food in the duodenum. The liver also processes the vitamins and fats along with synthesizing many plasma proteins.

The pancreas is another important gland that secretes digestive juices. The chyme produced from the stomach is highly acidic in nature; the pancreatic juices contain high levels of bicarbonate, an alkali that neutralizes the acidic chyme. Additionally, the pancreatic juices contain a large variety of enzymes that are required for the digestion of protein and carbohydrates.

The gallbladder, a small organ, aids the liver by storing bile and concentrating bile salts. When chyme containing fatty acids enters the duodenum, the bile is secreted from the gallbladder into the duodenum.