CHAPTER 01 : NUTRITION IN ANIMALS

All animals require a nutritionally adequate diet to maintain homeostasis, or internal balance, despite changes in the external environment. A balanced diet provides the energy necessary for cellular work, as well as all the materials the body needs to build its own organic molecules.

1.1.Nutritional needs

A nutritionally adequate diet meets three types of needs :

► the energy (chemical) needs to do all the cellular work.

► the needs for organic molecules intended for biosynthesis (either carbon skeletons for the manufacture of molecules specific to the organism).

► the needs for essential nutrients, that is to say that the animals are not able to manufacture themselves from the ingested material and that they must obtain directly from the food.

Nutrients are simple compounds, it is the assimilable part of food. The nutrient in general terms is all the substances used by the body in order to maintain its proper functioning. We can classify nutrients according to the quantities found in the body :

* Macronutrients : Fats, Carbohydrates, Proteins, Water

* Micronutrients : minerals, vitamins The macronutrients will be digested and then absorbed to finally give the cellular nutrients: oses, fatty acids and amino acids.

1.2. Diets and types of ingestion

1.2.1. Dietary diets

Sharing the basic need to get food, animals differ in their way of feeding. All animals consume other organisms, whether dead or alive, whole or fragmented. (The definition of "fragmented" must be expanded to take into account parasites, such as certain flatworms, which absorb organic molecules directly from the animal host from digestion). In general, animals fall into three categories according to their diet :

Herbivores such as cattle, sea cucumbers and termites, feed mainly on plants or algae.

Carnivores, including sharks, buzzards and spiders, devour other animals.

Omnivores (from the Latin omni, which means "everything") do not really eat everything they find, but their diet is very varied since it consists of animals as well as plants. Omnivores include cockroaches, crows, bears and humans who have evolved into hunters, gatherers and detritivores.

The terms **herbivore**, **carnivore** and **omnivore** correspond to the types of food generally consumed, as well as to the adaptations that allow animals to obtain food and digest it. In reality, most animals feed opportunistically; they consume foods that do not fall under their main food category when these are available. For example, bovids and Cervids, herbivores, occasionally consume small animals or bird eggs, in addition to herbs and other plants.

Most carnivores obtain certain nutrients from plant materials remaining in the digestive tract of the absorbed prey. Note that all animals consume microorganisms when they ingest food.

1.2.2. Types of ingestion

The different ways of ingesting food fall into four main types : Ingestion by filtration, ►ingestion of the substrate, ► ingestion by suction ►bulk ingestion.

*** Ingestion by filtration**

Many aquatic animals feed on suspended matter (suspensivores), that is, they filter the food particles contained in the water. Clams and oysters, for example, use their gills to retain nutrient particles, which vibrating cilia then propel, along with a film of mucus, towards their mouths. Baleen whales, the largest animals in the world, also feed on suspended particles. These whales swim with their mouths open ingesting millions of small animals filtered from the enormous amount of water pushed through their baleen (horny blades attached to their upper jaw).

*** Ingestion of the substrate**

Animals live on their food source or inside it, making their way by eating. The processionary oak caterpillar, the larva of a moth (Thaumetopoea processionea), makes its way by eating the soft tissue of an oak leaf and leaving a trail of blackish feces in its path. Earthworms *(Lumbricus sp.)* also fall into this category, with the difference that they make their way by eating dirt. They thus recover detritus, that is to say partially decomposed organic materials, which they ingest at the same time as the earth *(saprophages)*.

• Ingestion by aspiration

Species derive nutrient-rich liquids from a living host. Thus, mosquitoes and leeches feed by absorbing the blood of other animals. Aphids draw the elaborate sap from the phloem of plants. Unlike these parasites that harm their hosts, other species that use suction ingestion do the latter a favor. For example, hummingbirds and bees carry pollen when they visit flowers in search of nectar.

*** Ingestion in bulk**

Most animals, especially humans, feed by ingestion in bulk. They consume relatively large pieces of food, or even whole prey. Various anatomical parts are used to kill prey, tear flesh or tear out plant materials: tentacles, pincers, claws, poisonous hooks, jaws and teeth.

1.3.Food processing

1.3.1. Stages of food processing

The four main stages of processing food are : ► ingestion, ► digestion, ► absorption, ►elimination.

• Ingestion

Ingestion is the first step in food processing. Almost all animals, including many consumers of liquid food, have to cope with food presented in bulk, in the form of extremely complex sets of molecules. Animals cannot use these macromolecules directly, for two reasons :

✓ **The polymers** : are too large to pass through the membranes and enter the cells of the animals.

✓ **The macromolecules** : that make up an animal are not similar to those that make up food. However, all organisms use common monomers to make macromolecules. For example, soybeans, drosophila and humans assemble their proteins from the same 20 amino acids.

*** Digestion**

Digestion is the second stage of food processing. It consists of breaking down food into molecules small enough to be absorbed by the body. It has two components :

✓ mechanical digestion, which is the fragmentation of food, and - chemical digestion, which is the transformation of macromolecules contained in food fragments into monomers. The animals

are then able to use these to assemble their own molecules or to use them as an energy source for the production of ATP.

The digestion of macromolecules breaks each bond by adding a water molecule using specific enzymes. This process of decomposition of macromolecules is called **enzymatic hydrolysis**

Certain varieties of hydrolytic enzymes catalyze the digestion of each of the categories of macromolecules found in food. This chemical decomposition is generally preceded by a mechanical fragmentation of the food, by means of chewing for example. A food that is fragmented into smaller pieces has a larger surface area exposed to digestive juices containing the hydrolytic enzymes.

The last two stages of food processing occur after digestion. During **absorption**, the cells constituting the wall of the digestive cavity of an animal allow the small molecules and the monomers present in this cavity to cross their plasma membrane. During **elimination,** the materials that have not undergone digestion or absorption leave the body.

1.3.2. The compartments of digestion

Most animals reduce the risk of self-management by processing food in specialized compartments.

Intracellular digestion :

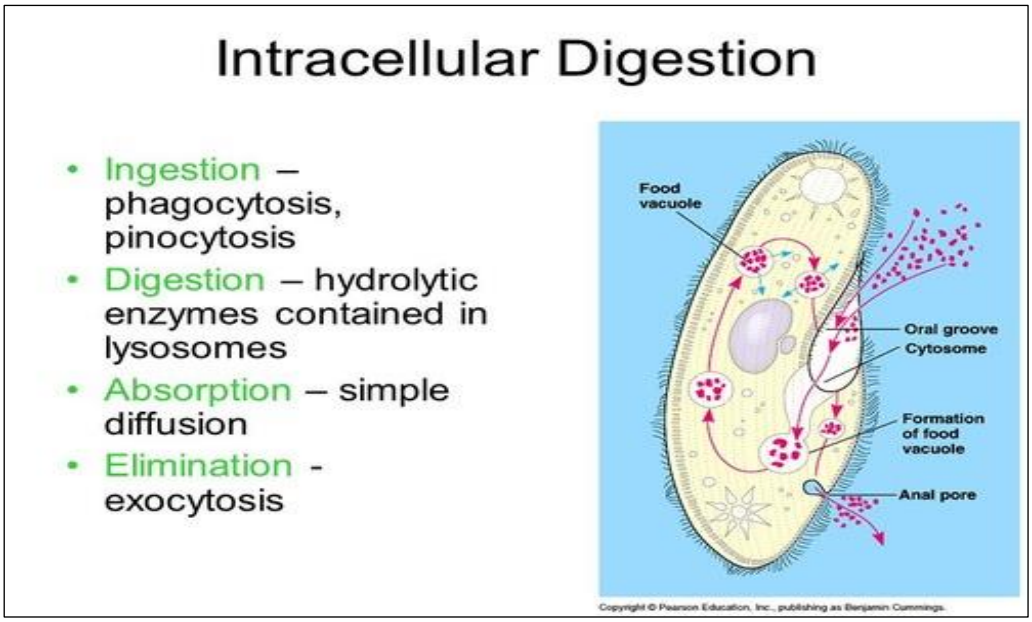


Figure 1 : Intracellular digestion in Paramecia

Digestive vacuoles are organelles used to break down food without the hydrolytic enzymes they contain degrading the cytoplasm of the cell. This is the simplest kind of digestive cavity. Heterotrophic Protists digest their food in digestive vacuoles, usually after incorporating the food by phagocytosis or by pinocytosis. The newly formed digestive vacuoles fuse with lysosomes, organelles containing hydrolytic enzymes. The food is therefore in contact with the enzymes.

Digestion can take place safely in a cavity delimited by a protective membrane. This phenomenon is called intracellular digestion (fig. 1).

Extracellular digestion :

In most animals, at least part of the hydrolysis takes place during extracellular digestion. Extracellular digestion takes place in compartments communicating with the outside of the animals' body.

Many animals characterized by a simple body organization plan have a digestive cavity with a single opening. This bag-like structure, called a cavity enzy gastrovascular, serves both for the digestion of nutrients and for their circulation throughout the body (hence the ***vascular*** qualifier). The Hydra (*Hydra sp.*), a Cnidarian, illustrates well the functioning of the gastrovascular cavity (fig. 2).

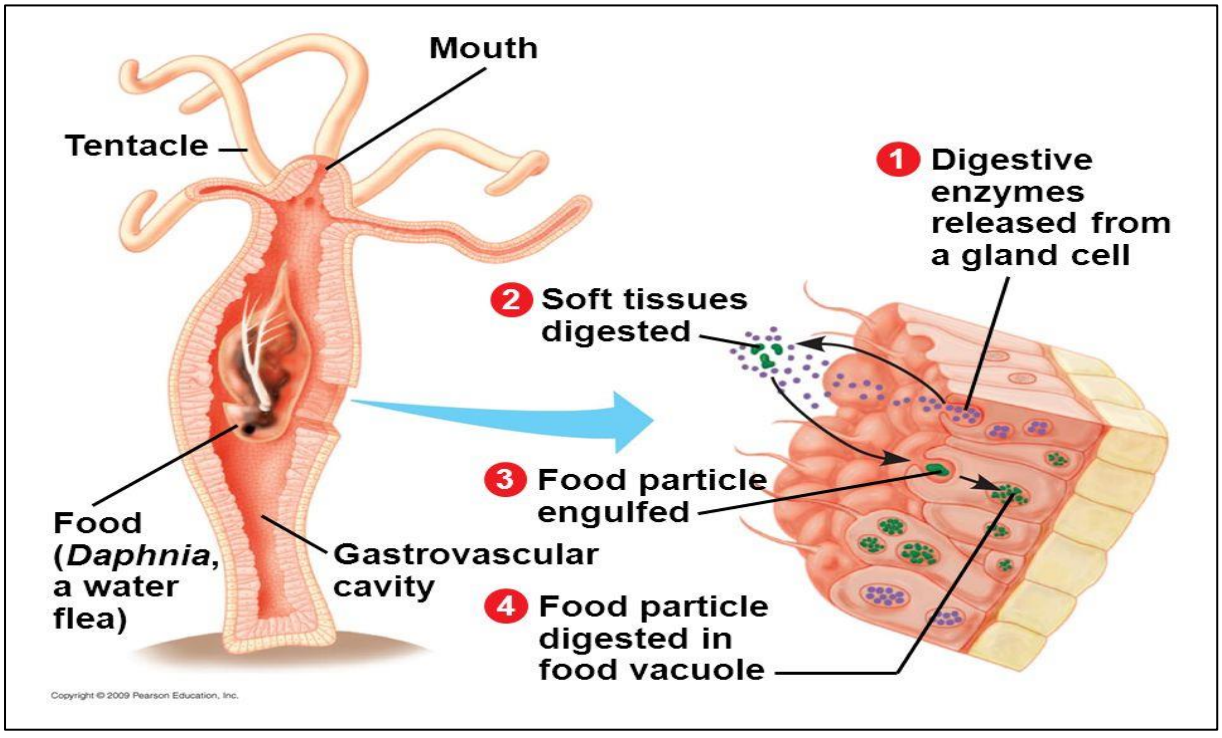
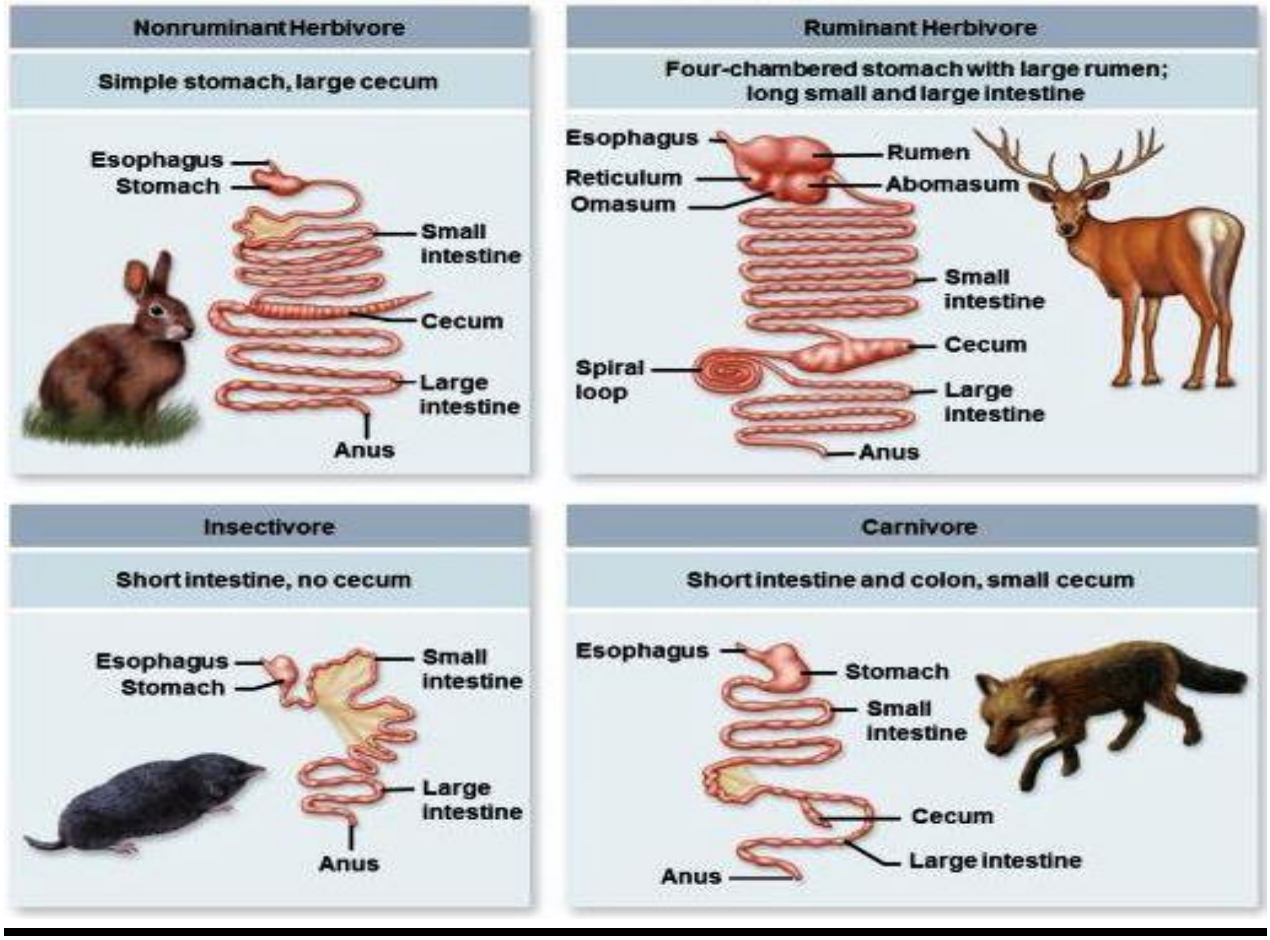


Figure 2 : Extracellular digestion in a gastrovascular cavity (in hydra)

Unlike Cnidarians and Platelminths (flatworms), most animals (including Nematodes, Annelids, Molluscs, Arthropods, Echinoderms and Corded) have a succession of compartments connecting two openings: the mouth and the anus. This set is called *digestive tract, digestive tract or alimentary canal.* As the food moves there in a single direction, the digestive tract can comprise several specialized compartments carrying out the digestion and absorption of nutrients in stages (fig. 3). Food ingested through the mouth and pharynx passes through the esophagus, which leads to the crop, gizzard or stomach, depending on the species. The crop and the stomach are generally used to temporarily store food (even if part of the digestion can take place there); the gizzard, on the other hand, grinds and fragments the latter. The food then enters an intestine (more or less compartmentalized, depending on the species); there, the food molecules are hydrolyzed by digestive enzymes. The nutrients are absorbed by the wall of the digestive tract and make their way to the bloodstream. Indigestible residues are eliminated through the anus.



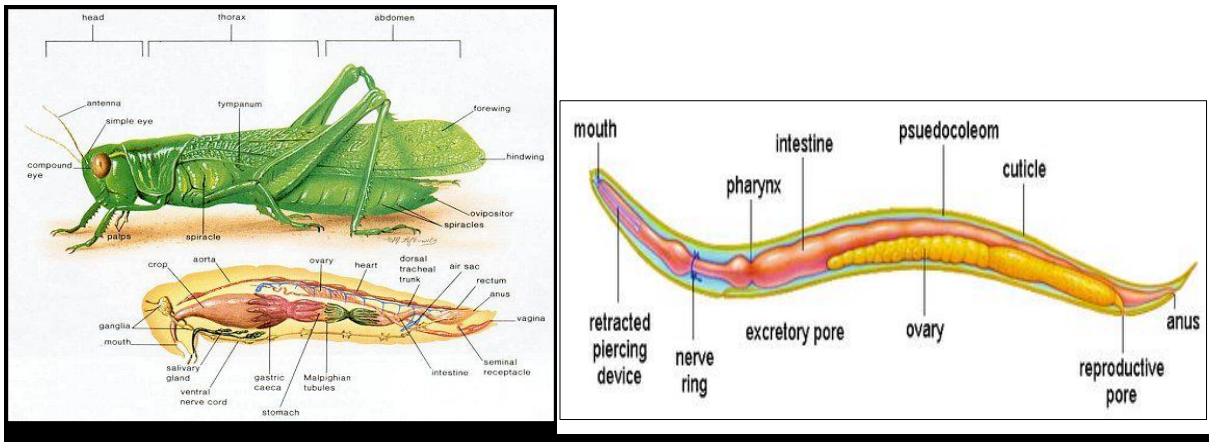


Figure 3 : Different digestive tracts in animals

1.3.3- The digestive system of mammals :

In mammals, the digestive system consists of a tube to which various accessory organs and glands are connected. Some of these glands discharge digestive juices into the tube via ducts (Fig. 4). The ancillary organs of the mammalian digestive system are the three pairs of salivary glands, the pancreas, the liver and the gallbladder.

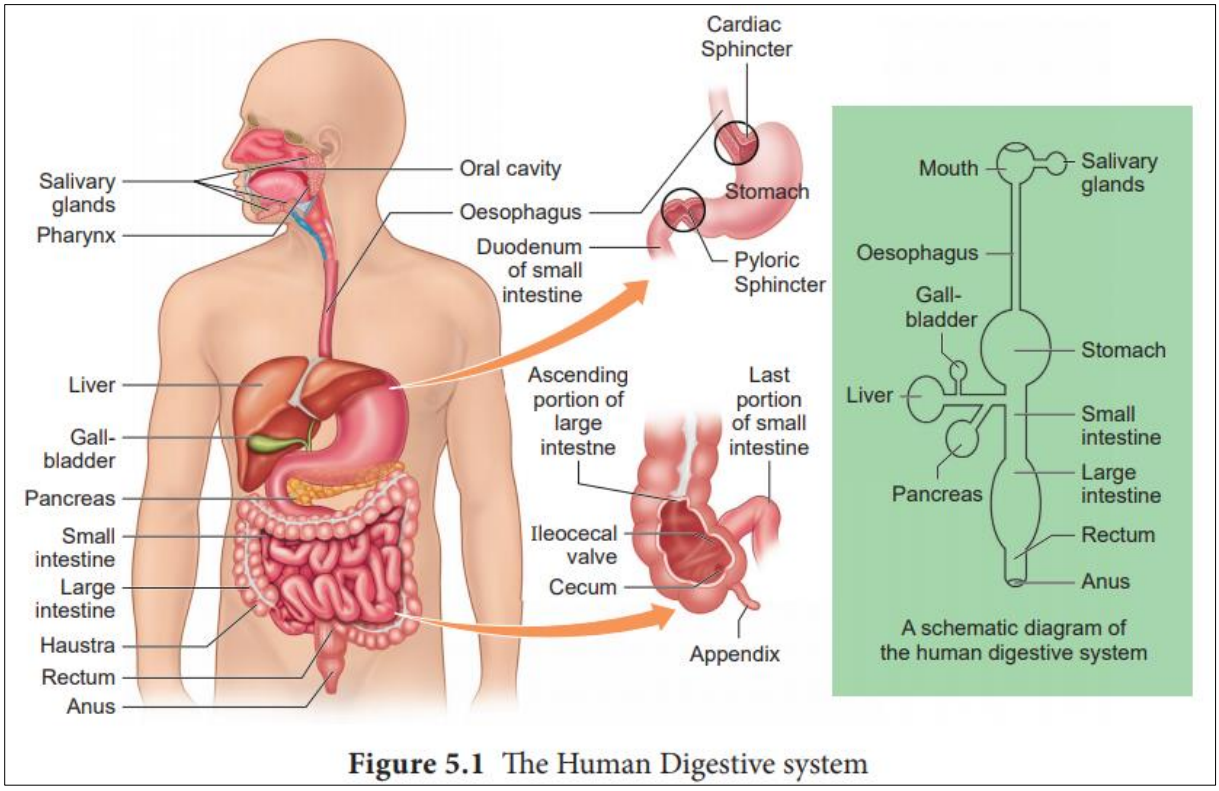


Figure 4 : The digestive system of human

Food moves through the alimentary canal thanks to peristalsis, that is to say a movement produced by a succession of rhythmic contractions resulting from the action of the smooth muscles of the wall of the digestive tract. At certain junction points of the specialized segments of the digestive tract, the muscle layer forms a ring called a sphincter (or sphincter muscle). This closes the tube in the manner of a noose and regulates the passage of food from one compartment to another.

It is in the oral cavity that food processing begins; these are then transported to the stomach through the pharynx and esophagus. The food is lubricated and its digestion begins in the oral cavity, where it is chewed by the teeth and fragmented into particles exposed to salivary amylase. This enzyme starts the decomposition of polysaccharides. In addition, the oral mucosa adds a lingual lipase to food that attacks lipids. However, it occurs especially in the stomach. The esophagus brings food from the pharynx to the stomach through the movement of involuntary muscles producing peristaltic waves.

Food stays in the stomach, the site of preliminary digestion and absorption of certain substances. The stomach stores food and secretes gastric juice, which converts the meal into an acidic chyme. Gastric juice includes hydrogen chloride as well as the enzymes pepsin and gastric lipase. The stomach absorbs certain amounts of neutral molecules, short fatty acids, alcohol, electrolytes and water.

The small intestine plays a major role in digestion and absorption. The acidic chyme from the stomach reaches the duodenum and mixes with intestinal juice, bile and pancreatic juice. Various enzymes complete the hydrolysis of food molecules and transform them into monomers. The latter are then absorbed into the blood by passing through the mucous membrane of the small intestine. The liver is an important organ, with multiple functions. Among other things, it produces bile, which mechanically intervenes in the digestion of fats (fig. 5).

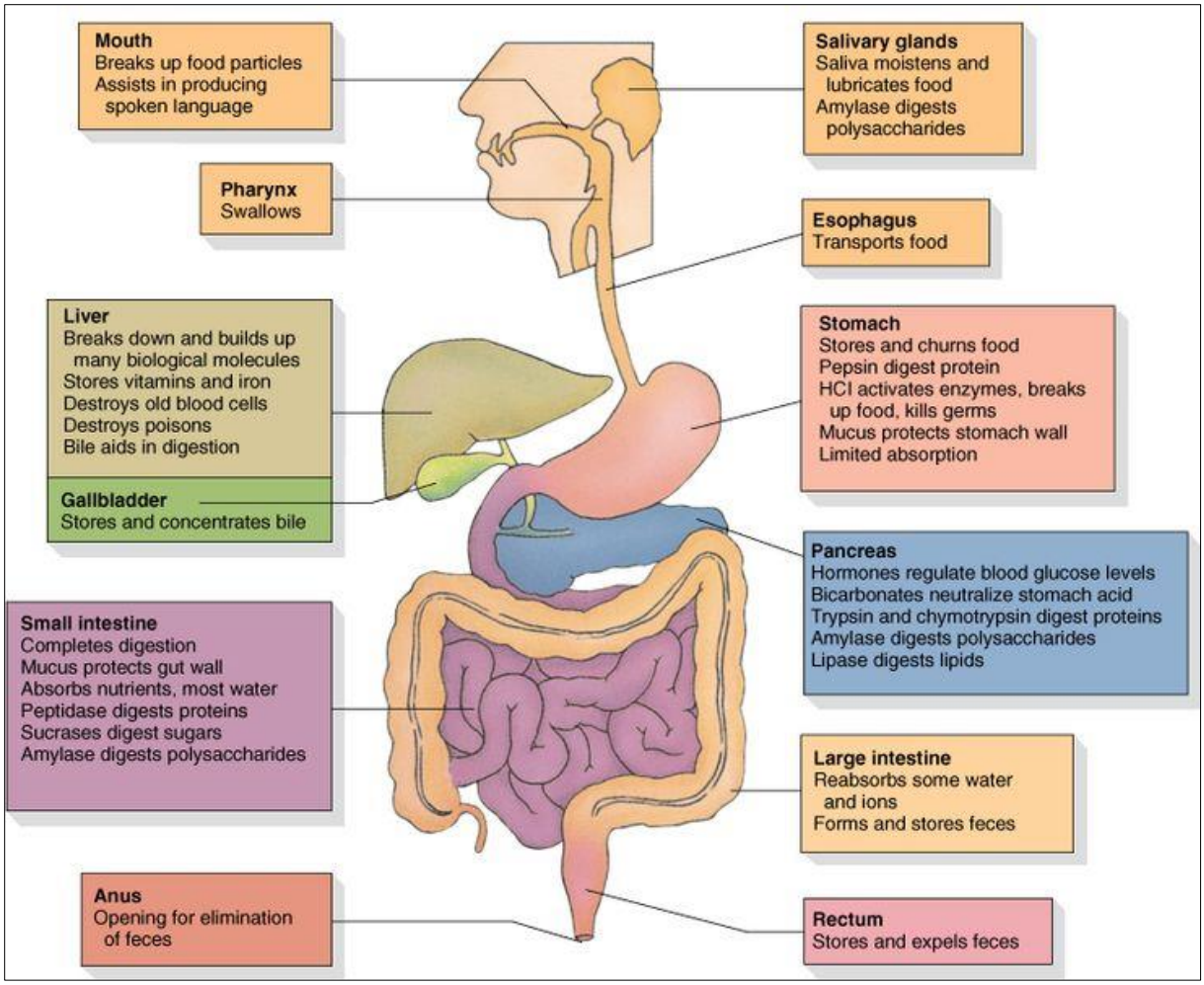


Figure05 : Schematic representation of enzymatic digestion in the human digestive system.

The regulation of digestion is carried out by the nervous and hormonal pathways (fig. 6). The nervous system controls peristalsis and secretions from the stomach, liver, salivary glands and pancreas. The gastrin hormone stimulates gastric motility and the secretion of gastric juices. A category of duodenal hormones, enterogastrones, regulates the activities of the pancreas, stomach, liver and gallbladder. The absorption of water and electrolytes constitutes one of the essential functions of the large intestine. The large intestine (mainly the colon) helps the small intestine to reabsorb water and electrolytes. It harbors bacteria, some of which synthesize vitamins (biotin, folic acid, vit. K and several B-complex vitamins). Feces pass through the rectum and are eliminated through the anus.

The adaptations of the digestive system of vertebrates during evolution

Structural adaptations of the digestive system are often associated with diet. Mammals have a dentition that usually corresponds to their diet. Herbivores usually have a longer digestive tract than other mammals, because it takes longer to digest plant matter than animal matter. Symbiotic microorganisms contribute to the nutrition of many vertebrates. Many herbivores have special fermentation chambers, in which mutualistic microorganisms digest cellulose.