

ORGANIZATION & FUNCTIONS OF THE DIGESTIVE SYSTEM

The *digestive system* (also called *gastrointestinal system*, *digestive tract*, or *digestive tube*) is basically a long tube open at both ends, making the lumen of the digestive system an extension of the external environment. Food enters from the oral end (mouth) and is broken down mechanically and chemically by the aid of a variety of digestive structures; next the lining of the digestive tube absorbs the usable nutrients, and leftover materials leave from the anal end as waste products.

FOODSTUFF UNDERGOES MECHANICAL & CHEMICAL DIGESTION

Humans ingest food, usually in forms unsuitable for uptake and use by body cells. The digestive system transforms the ingested foodstuff to simpler nutrients, capable of uptake by body cells. This is accomplished by *mechanical* and *chemical* digestive processes that occur in the oral (mouth), gastric (stomach), and intestinal stations, in an orderly manner, resembling a food-processing plant. During mechanical digestion, solid food masses are torn apart and ground by the teeth and mixed with juices from the digestive glands (salivary, gastric, and intestinal), in order to dissolve the food particles and form a rich soup. This mixture is vigorously shaken during various gastrointestinal movements generated by the gut's muscular wall. *Chemical digestion* transforms the dissolved food particles into simple, absorbable nutrients by the action of various *digestive enzymes*, secreted mainly by the pancreas and also by the stomach and intestinal glands. These enzymes *hydrolyze* the large and complex food molecules into simpler forms that are absorbable by the intestinal lining.

DIGESTION BEGINS IN THE MOUTH AND STOMACH

The *salivary glands* secrete *saliva* to aid in mechanical digestion and dissolving of the food in the mouth. The *pharynx* and *esophagus* aid in *swallowing* and transport of the food into the *stomach*, which acts as a reservoir to receive a meal at once while delivering it to the *intestine* in intervals. In the stomach, food is subjected to vigorous movements that mix it with the *gastric juices* to form *chyme*. Gastric juices, containing *mucus*, *acid*, and *enzymes*, are secreted by the stomach glands. Some chemical digestion of proteins, but no absorption of any significance (except for alcohol), occurs in the stomach.

THE LIVER AND PANCREAS AID IN INTESTINAL DIGESTION

In the *small intestine*, the dissolved food particles in the gastric chyme are subjected to further shaking and mixing movements that mix them with the alkaline *intestinal juice*. Intestinal juice also contains the secretions of the large accessory digestive glands (the *pancreas* and *liver*). The pancreatic juice is alkaline due to high bicarbonate content and also rich in a variety of hydrolytic enzymes that are essential for chemical digestion of all food substances. The liver secretes the *bile*, which facilitates fat digestion.

SMALL INTESTINE ABSORBS NUTRIENTS INTO THE BLOOD

The small intestine is the main site of absorption of nutrients. This occurs across the inner lining of the small intestine. Upon absorption, all water-soluble material enters the *intestinal-hepatic portal venous system* (hepatic portal vein) and is taken to the liver for processing. From the liver the nutrients are

transported by blood to the body cells, where they are taken up and consumed for energy and cellular metabolism. The absorbed fatty nutrients enter the lymph vessels, bypassing the liver, and enter the blood via the lymphatic circulation.

THE LARGE INTESTINE DEHYDRATES UNUSED CHYME

The last function of the digestive system, carried out by the *large intestine (colon)*, is to remove and absorb the water from the remaining and unused chyme and treat the non-absorbable remnants of absorption (e.g., fiber). Dehydration produces solid fecal masses (feces) that, along with bacterial debris, are moved by *peristalsis* and *mass action* to the *rectum* and *anus* where the feces are excreted (*defecation*). The useful intestinal bacteria play a major role in colon function and fecal formation. Salts (sodium) and some vitamins of bacterial origin (e.g., vitamin K) are also absorbed in the colon.

ENZYMES TRANSFORM FOOD INTO ABSORBABLE NUTRIENTS

Humans consume foods from a variety of animal and plant sources. In the fresh form, all these foods contain different amounts of the main classes of nutrients: *proteins*, *carbohydrates*, and *fats*. For example, meats contain a lot of protein, some fat, and a very small amount of carbohydrate while breads, pasta and potato contain a lot of carbohydrates, some proteins and very little fat. Apples contain fiber, some carbohydrates, smaller amounts of protein, and negligible fat.

During chemical digestion, with the aid of a variety of *protease enzymes*, dietary proteins are broken down first into *oligopeptides*, which are further digested into smaller *peptides* and finally into *amino acids*, the building blocks of all peptides and proteins. Free amino acids are then in the form suitable for absorption by the intestinal mucosa and delivery to the liver and other body cells.

Dietary sources of carbohydrates are plant starches (polysaccharides) and *disaccharides* such as sucrose (table sugar) and lactose (milk sugar). Polysaccharides are broken down to *oligo-* and *disaccharides* with the help of *amylase enzymes*; more specific enzymes (e.g., sucrase and lactase) work on disaccharides to form *monosaccharides* (simple sugars) like glucose, fructose, and galactose, absorbable forms of carbohydrates.

Dietary fats are available mainly as *triglycerides (triacylglycerols)*, which are broken down in the intestine by the action of lipases into their constituents—*glycerol* and *fatty acids*. Occasionally, *mono-* or *diglycerides* are also produced. The bile, an important digestive secretion of liver, plays an important role in fat chemical digestion. The simpler fats are then absorbed across the mucosa. Before entry into the blood, triglycerides are resynthesized and incorporated into lipoprotein particles called *chylomicrons*, which are then transported via the *lymphatic system* to the blood. Action of pancreatic nucleases (RNAase and DNAase) and related enzymes chemically digests the dietary nucleic acids to form nucleotides and then nucleosides and finally sugars, phosphoric acids, and pyrimidine and purine bases, which are absorbed. Dietary fiber is not absorbed; bacteria digest it in the large intestine.

CN: Use blue for L and light gray (or a single light color) for structures H-K. Notice the use of overlapping colors in the stomach region of the central illustration to suggest the presence of one organ in front of another.

1. Color the same structure in both the anatomic and the functional dia-

- grams before going on to the next structure. Color the titles along the right edge of the page.

2. Color the inner edge of the doughnut, which demonstrates that the digestive tract (the mouth to the anus) is essentially outside the body.

DIGESTIVE SYSTEM:

DIGESTIVE TRACT:

- ORAL CAVITY
- PHARYNX
- ESOPHAGUS
- STOMACH
- SMALL INTESTINE
- LARGE INTESTINE
- RECTUM

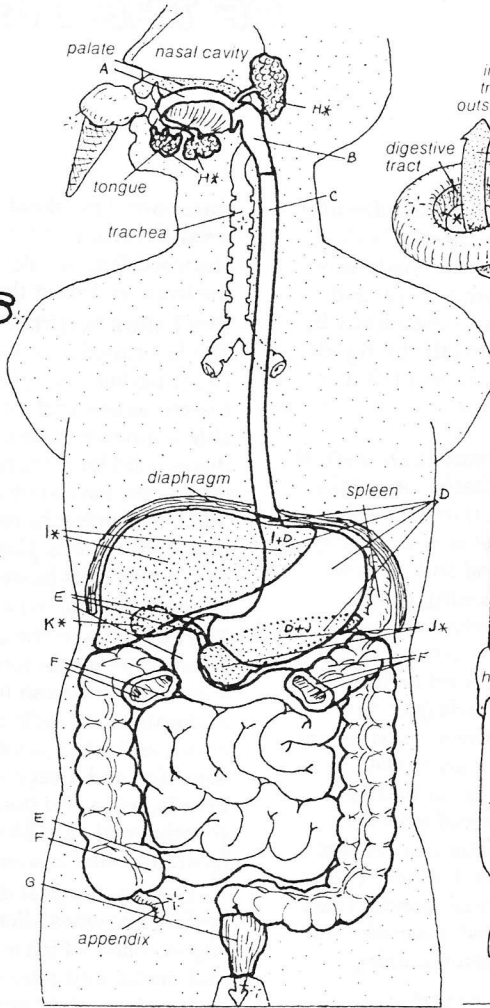
DIGESTIVE GLANDS:

- SALIVARY GLANDS
- LIVER
- PANCREAS
- GALL BLADDER

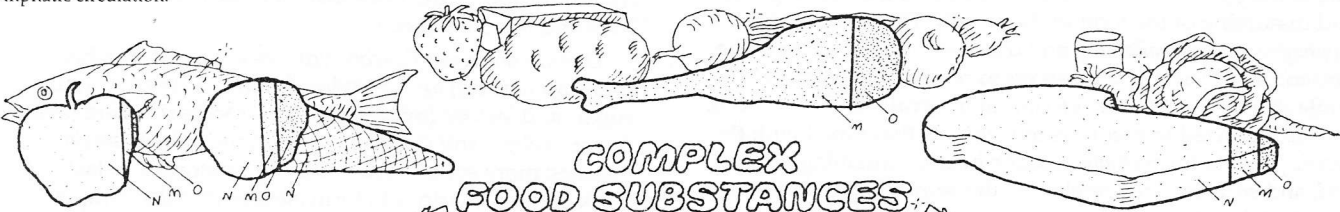
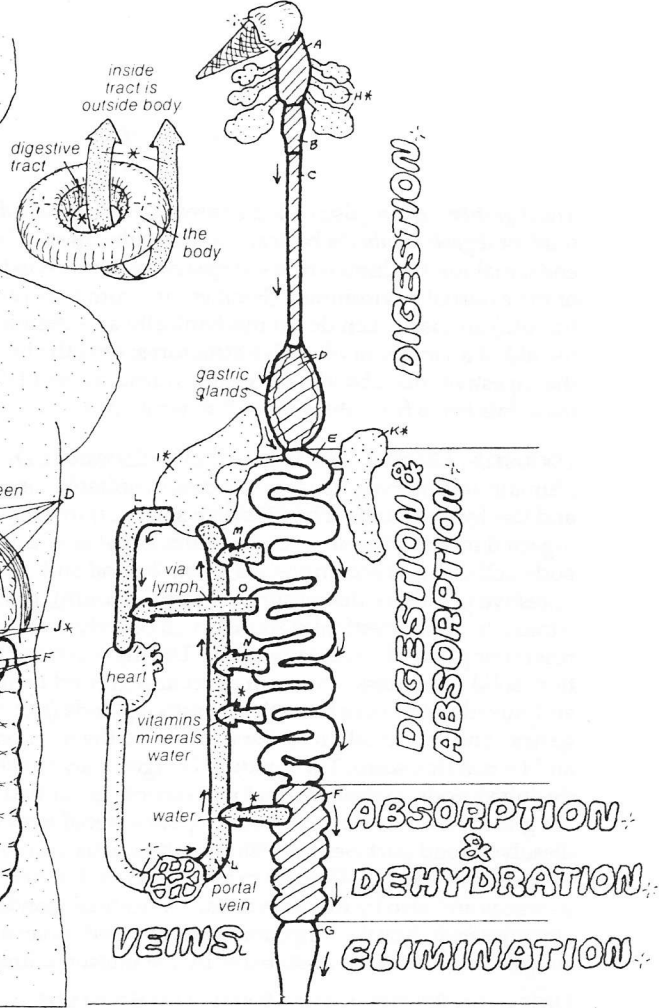
GALL BLADDER

The digestive system functions to ingest, digest, and absorb food substances into the bloodstream and to eliminate remaining wastes. The digestive structures in the mouth and stomach act primarily in the mechanical and chemical digestion of foods. The small intestine acts in chemical digestion of food substances and absorption of resultant nutrients. The large intestine (colon) absorbs remaining water and salts and excretes waste products of digestion (feces) through its exit end, the rectum and anus. To facilitate digestion, numerous exocrine glands secrete a variety of alkaline or acidic juices containing enzymes and mucus into the digestive lumen. The large and separately located pancreas, liver, and salivary glands constitute the accessory digestive glands, while the numerous small stomach and intestinal glands form an intrinsic part of the gut wall. During the absorption process, the breakdown products of proteins, carbohydrates, and nucleic acids, as well as water, minerals, and water-soluble vitamins, are transported across the intestinal mucosa into the hepatic portal circulation for delivery to liver and bloodstream. Fats and fat-soluble vitamins, however, are absorbed via the lacteals and lymph vessels for delivery to the blood via the lymphatic circulation.

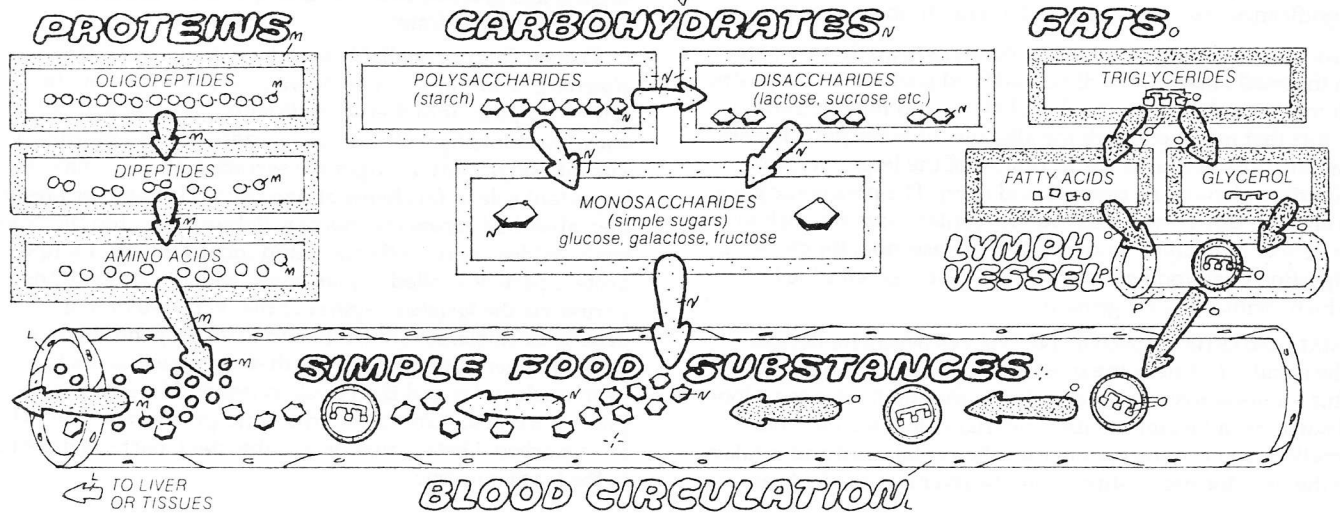
ANATOMIC ORGANIZATION:



FUNCTIONAL ORGANIZATION:



COMPLEX FOOD SUBSTANCES



Dietary foods such as meats, fruits, dairy products, bread, and vegetables are rarely found in readily absorbable form. The complex dietary substances are proteins (meat, egg white, beans), carbohydrates (bread, rice, potato), and fats (milk fat, egg yolk, butter, oils). Digestive enzymes (not shown) secreted by the pancreas and other digestive glands hydrolyze complex dietary substances into simpler and smaller molecules that can

be readily absorbed by the intestinal mucosa into the bloodstream. Proteins are digested into amino acids, complex carbohydrates (polysaccharides) into simple sugars (monosaccharides—e.g., glucose), fats (triglycerides = triacylglycerols) into fatty acids and glycerol, and nucleic acids (not shown) into purine and pyrimidine bases and ribose sugars. Dietary fibers facilitate digestion but are not absorbed.