Animals are heterotrophs that require food for fuel, carbon skeletons, and essential nutrients

- A nutritionally adequate diet satisfies three needs:
  - ***fuel*** (chemical energy) for all the cellular work of the body;
  - ***the organic raw materials*** animals use in biosynthesis (carbon skeletons to make many of their own molecules);
  - ***essential nutrients***, substances that the animals cannot make for themselves
- Let's look closer….
- In addition to fuel for ATP production, an animal's diet must supply all the raw materials for biosynthesis.
  - This requires organic precursors (carbon skeletons) from its food.
  - Given a source of organic carbon (such as sugar) and a source of organic nitrogen (usually in amino acids from the digestion of proteins), animals can fabricate a great variety of organic molecules - carbohydrates, proteins, and lipids.
- Besides fuel and carbon skeletons, an animal's diet must also supply **essential nutrients**.
  - These are materials that must be obtained in ***preassembled form*** because the animal's cells cannot make them from *any* raw material.
- An animal whose diet is missing one or more essential nutrients is said to be **malnourished**.
- Animals require ***20 amino acids*** to make proteins.
- Most animals can synthesize half of these if their diet includes organic nitrogen.
- **Essential amino acids** must be obtained from food in prefabricated form.
  - Eight amino acids are essential in the adult human with a ninth, histidine, essential for infants.
  - The same amino acids are essential for most animals.

- While animals can synthesize most of the fatty acids they need, they cannot synthesize **essential fatty acids**.
  - These are certain unsaturated fatty acids, including linoleic acids required by humans.
  - Most diets furnish ample quantities of essential fatty acids, and thus deficiencies are rare.
- **Vitamins** are organic molecules required in the diet in quantities that are quite small compared with the relatively large quantities of essential amino acids and fatty acids animals need.
  - While vitamins are required in tiny amounts - from about 0.01 mg to 100 mg per day - depending on the vitamin, vitamin deficiency (or overdose in some cases) can cause serious problems.
- So far ***13*** vitamins essential to humans have been identified ***(see chart on pg. 854).***
  - These can be grouped into ***water-soluble vitamins*** and ***fat-soluble vitamins***, with extremely diverse physiological functions.
- Many vitamins act a coenzymes
- **Minerals** are simple inorganic nutrients, usually required in small amounts - from less than 1 mg to about 2,500 mg per day ***(see chart on pg. 855).***
  - Mineral requirements vary with animal species.
  - Humans and other vertebrates require relatively large quantities of ***calcium*** and ***phosphorus*** for the construction and maintenance of bone among other uses.
  - ***Iron*** is a component of the cytochromes (protein complexes) that function in cellular respiration and of hemoglobin, the oxygen binding protein of red blood cells.
- While ***sodium***, ***potassium***, and ***chloride*** have a major influence on the osmotic balance between cells and the interstitial fluids, excess consumption of salt (sodium chloride) is harmful.

Overview of Food Processing: Ingestion, Digestion, Absorption, and Elimination

- **Ingestion**, the act of eating, is the first stage of food processing.
  - Food comes "packaged" in bulk form - contains large polymers and various substances that may be difficult to process.
  - Animals cannot use macromolecules like proteins, fats, and carbohydrates in the form of starch or other polysaccharides – they need to break these large molecules down.
- **Digestion**, the second stage of food processing, is the process of breaking food down into molecules small enough for the body to absorb.
  - Digestion cleaves ***macromolecules*** into their component ***monomers***, which the animal then uses to make its own molecules or as fuel for ATP production ***(what are these monomers?)***
- Digestion reverses the process that a cell uses to link together monomers to form macromolecules.
  - Rather than removing a molecule of water for each new covalent bond formed, digestion breaks bonds with the addition of water via ***enzymatic hydrolysis***.
- Chemical digestion is usually preceded by mechanical fragmentation of the food - by chewing, for instance.
  - Breaking food into smaller pieces increases the surface area exposed to digestive juices containing hydrolytic enzymes.
- After the food is digested, the animal's cells take up small molecules such as amino acids and simple sugars from the digestive compartment, a process called **absorption**.
- During **elimination**, undigested material passes out of the digestive compartment.

Evolutionary Trends in Digestion

- The simplest digestive compartments are ***food vacuoles***, organelles in which hydrolytic enzymes break down food without digesting the cell's own cytoplasm, a process termed **intracellular digestion**.
  - This is the sole digestive strategy in heterotrophic protists and in sponges, the only animals that digest their food this way.
- In most animals, at least some hydrolysis occurs by **extracellular digestion**, the breakdown of food outside cells.
  - Extracellular digestion occurs within compartments that are continuous with the outside of the animal's body.
  - This enables organisms to devour much larger prey than can be ingested by phagocytosis and digested intracellularly.
- Many animals with simple body plans, such as cnidarians and flatworms, have digestive sacs with single openings, called **gastrovascular cavities**.
- Many animals with simple body plans, such as cnidarians and flatworms, have digestive sacs with single openings, called **gastrovascular cavities**.
- In contrast to cnidarians and flatworms, most animals have **complete digestive tracts** or **alimentary canals** with a mouth, digestive tube, and an anus.
  - Because food moves in one direction, the tube can be organized into special regions that carry out digestion and nutrient absorption in a stepwise fashion.
- Food ingested through the mouth and pharynx passes through an esophagus that leads to a crop, gizzard, or stomach, depending on the species.
  - Crops and stomachs usually serve as food storage organs, although some digestion occurs there too.
  - Gizzards grind and fragment food.
  - In the intestine, digestive enzymes hydrolyze the food molecules, and nutrients are absorbed across the lining of the tube into the blood.
  - Undigested wastes are eliminated through the anus.
- This system enables organisms to ingest additional food before earlier meals are completely digested.

The Mammalian Digestive System

- When food is in the ***oral cavity*** (mouth) a nervous reflex occurs which causes ***saliva*** to be secreted into the mouth. Saliva lubricates the food and contains the enzyme ***salivary amylase***, which hydrolyzes starch and glycogen into smaller polysaccharides and the disaccharide maltose.
- During chewing, food is shaped into a ball called a ***bolus.***
  - After being swallowed, the bolus enters the ***pharynx*** – a junction that opens to the esophagus and trachea.
  - During swallowing, the ***epiglottis*** moves over the trachea – diverting food to the esophagus.
- The ***esophagus*** moves food from the pharynx down to the stomach through ***peristalis*** – rhythmic waves of contraction by smooth muscle in the walls of the esophagus.

- The ***stomach*** is in the upper abdominal cavity, and its functions include storing food and secreting gastric juice. ***Gastric juice*** contains hydrochloric acid, which is very acidic (pH of about 2). Gastric juice breaks down the extracellular matrix of meat and plant materials, and it also kills most of the bacteria ingested with food.
  - ***Pepsin*** is an enzyme in gastric juice that begins to hydrolyze proteins into smaller polypeptides.
  - Pepsin is secreted in an inactive form called ***pepsinogen***, which is activated by hydrochloric acid in the stomach.
- The result of digestion in the stomach is a substance called ***acid chyme***.
- The acid chyme is shunted from the end of the stomach into the beginning of the small intestine via the ***pyloric sphincter***.
- The ***small intestine*** is the longest section of the alimentary canal.
- The beginning of the small intestine is the site of most of the hydrolysis of macromolecules, and the rest of the small intestine is responsible for the absorption of nutrients into the blood.
- The first section of the small intestine is known as the ***duodenum***.
- In the duodenum, the acid chyme mixes with secretions from the pancreas (*bicarbonate*, which acts as a buffer against acid chyme), the liver (*bile*, which contains bile salts – detergents that aid in digestion), the gallbladder, and the intestinal wall itself.
- Let's take a look at how the 4 major classes of macromolecules are broken down in the small intestine.
- **Carbohydrates** – Breakdown of starch and glycogen begins with salivary amylase in the oral cavity.
- In the small intestine, ***pancreatic amylases*** break starch, glycogen, and small polysaccharides into disaccharides.
  - The breakdown of these disaccharides occurs at the wall of the intestinal epithelium, and then the monosaccharides are quickly abosorbed.
- **Proteins** – Pepsin begins to breakdown of proteins in the stomach.
  - In the small intestine, ***trypsin*** and ***chymotrypsin*** break polypeptides into smaller chains.
  - Two dipeptidases, ***carboxypeptidase*** and ***aminopeptidase*** break apart proteins into amino acids.
- **Nucleic acids** – Breakdown of nucleic acids is similar to that of proteins.
  - In the small intestine, nucleases break them down into nucleotides, nitrogenous bases, sugars, and phosphate groups.

- **<u>Fats</u>** – Digestion of fats starts in the small intestine.
  - Bile salts coat the fat droplets and keep them from coalescing (clumping together), a process called ***<u>emulsification</u>***, and ***<u>lipase</u>*** hydrolyzes them.
- Most absorption of nutrients occurs in the small intestine, and the epithelial lining of the small intestine has folds, called ***<u>villi</u>***, which in turn bear projections called ***<u>microvilli</u>*** – both of which radically increase the surface area available for absorption.
- In each villus is a set of tiny blood vessels called capillaries and a lymph vessel called a ***<u>lacteal</u>***.
- Monosaccharides, such as glucose, cross via ***passive diffusion***, whereas amino acids and dipeptides are pumped across in ***<u>active transport.</u>***
- The lacteal will also absorb small fatty acids.
- The capillaries and veins that drain the nutrients away from the villi all join the ***<u>hepatic portal vessel</u>***, which brings them to the ***<u>liver</u>***.
- The liver has the metabolic versatility to metabolize the various organic molecules present in food.
- Some hormones involved in digestion are ***<u>gastrin</u>***, which stimulates the secretion of gastric juice, and ***<u>enterogastrones</u>***, such as ***<u>secretin</u>*** and ***<u>cholescystokinin</u>*** (CCK), that are secreted by the walls of the duodenum and that prompt the digestion of various macromolecules.
- The ***<u>large intestine</u>***, also called the ***<u>colon</u>***, is connected to the small intestine by a sphincter (a ring-like valve).
- The point of the connection is the site of the ***<u>cecum</u>***, a small pouch with an extension called the ***<u>appendix</u>***.
- The main function of the large intestine is to compact waste and recover water from it that can be returned to the body.
- The wastes become more solid as they travel along and form feces.
- At the end of the colon is the ***<u>rectum</u>***, where feces are stored until they are eliminated.