Digestive System

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1 Introduction

1.1 Summary/Significance of Diet

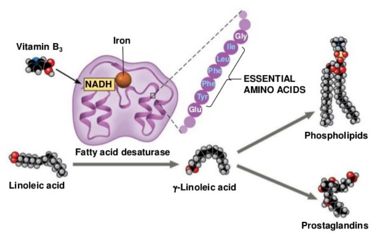
Our discussion starts off with a brief overview of nutrition before we dive into the details.

Essential Nutrients
Animals require 20 amino acids to make proteins. Most animal species have the enzymes to synthesize about half of these amino acids, as long as their diet includes sulfur and organic nitrogen. The remaining amino acids must be obtained from food in prefabricated form and are therefore called essential amino acids. Many animals, including adult humans, require eight amino acids in their diet: *isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.* Foods that provide all the essential amino acids are "complete" but foods that don't are thus called "incomplete."

Animals require fatty acids to synthesize a variety of cellular components, including membrane phospholipids, signaling molecules, and storage fats. Although animals can synthesize many fatty acids, they lack the enzymes to form the double bonds found in certain required fatty acids. Instead, these molecules must be obtained from the diet and are considered *essential fatty acids.*

This can be summarized below:

Figure 1: Overview of Essential Nutrients



Vitamins/Minerals are important to familiarize yourself with as they often appear either directly or indirectly. A full comprehensive list can be found in Campbell, but a few are listed below.

Vitamin	Dietary Sources	Major Functions	Dietary Symptoms
B_1	Pork, legumes, peanuts, whole grains	Coenzyme used in removing CO2 from organic compounds	Beriberi (tingling, poor coordination, reduced heart function)
B_2	Dairy products, meats, enriched grains, vegetables	Component of coenzymes FAD and FMN	Skin lesions, such as cracks at corners of mouth
A	Dark green and orange vegetables and fruits, dairy products	Component of visual pigments; maintenance of epithelial tissues	Blindness, skin disorders, impaired immunity
...	...	...	...
Na	Table Salt	Acid-base balance, water balance, nerve function	Muscle cramps, reduced appetite

1.2 Simple Digestive Systems

1. **Ingestion:** The act of feeding or eating.
2. **Digestion:** Food is broken down into molecules small enough for the body to absorb
3. **Absorption:** The animal's cells take up (absorb) small molecules such as amino acids and simple sugars
4. **Elimination:** Completes the process as undigested material passes out of the digestive system

Animals first evolved to have the same opening for both feeding and elimination, and digestion occurred in a space called the **gastrovascular cavity**. More advanced than the gastrovascular cavity is the **alimentary canal**

Figure 2: Gastrovascular Cavity in a Hydra

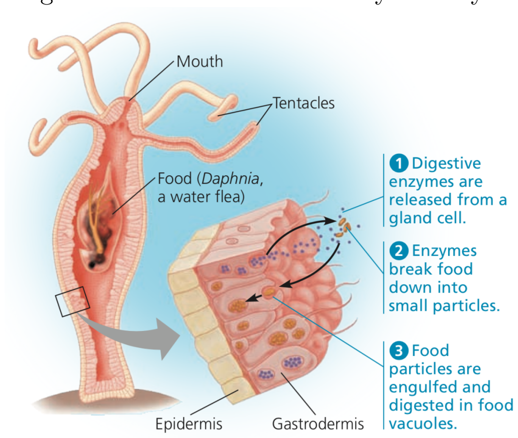
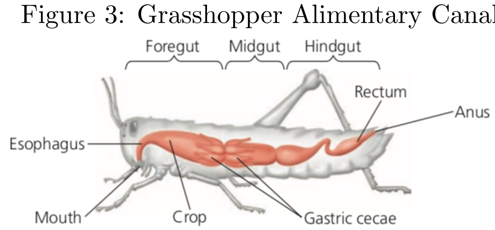


Figure 3: Grasshopper Alimentary Canal



1.3 More Advanced Digestive Systems

I will keep the diagrams limited as the necessary ones are included in the presentation, and repeating them would be redundant. (Yeah, and I'm kinda lazy)

Food is pushed along the alimentary canal by **peristalsis**, alternating waves of contraction and relaxation in the smooth muscles lining the canal. At some of the junctions between specialized compartments, the muscular layer forms ringlike valves called **sphincters**. Acting like draw- strings to close off the alimentary canal, sphincters regulate the passage of material between compartments (as you will later see, these are similar to ones in the circulatory system).

Oral Cavity, Pharynx, and Esophagus

1. Ingestion and the initial steps of digestion occur in the mouth, or *oral cavity*. Teeth grind the food. Meanwhile, the *salivary glands* deliver saliva through ducts to the oral cavity. The release of saliva when food enters the mouth is an automatic reaction mediated by the nervous system
2. Elements like *amylase* in saliva break down carbohydrates in the mouth, and saliva protects oral cavity through *mucus*.
3. Tongue movements form a *bolus*.

4. In humans, the *pharynx* connects to the *trachea* and the *esophagus*. At most times, a contracted sphincter seals off the esophagus while the trachea remains open. When a food bolus arrives at the pharynx, the swallowing reflex is triggered. Movement of the *larynx*, the upper part of the airway, tips a flap of tissue called the *epiglottis* down, preventing food from entering the trachea. At the same time, the esophageal sphincter relaxes, allowing the bolus to pass into the esophagus. The trachea then reopens, and peristaltic contractions of the esophagus move the bolus to the stomach.

Digestion in the Stomach

1. The stomach is where digestion starts; gastric juices are released and *chyme* is formed.

2. In the interior of the cell, *chief cells* secrete inactive pepsinogen, and parietal cells release H^+ and Cl^-, creating HCl which activates pepsinogens resulting in positive feedback (side note: *Helicobacter pylori* was found to be resistant to the harsh environment and a Nobel Prize was awarded to those determined it could be cured by antibiotics).

3. *Mucus cells* secrete mucus to protect the cell lining from the acid .

4. Chyme passes to the *duodenum* where it combines with digestive juices from the pancreas, liver, and gallbladder.

5. The *pancreas* releases bicarbonate to neutralize the acid and proteases like *trypsin and chymotrypsin*.

6. *Bile* aids in fat emulsification. It is produced in the *liver* and stored in the *gallbladder*. (No-longer-functional blood cells are recycled to make bile)

Absorption in the Small Intestine

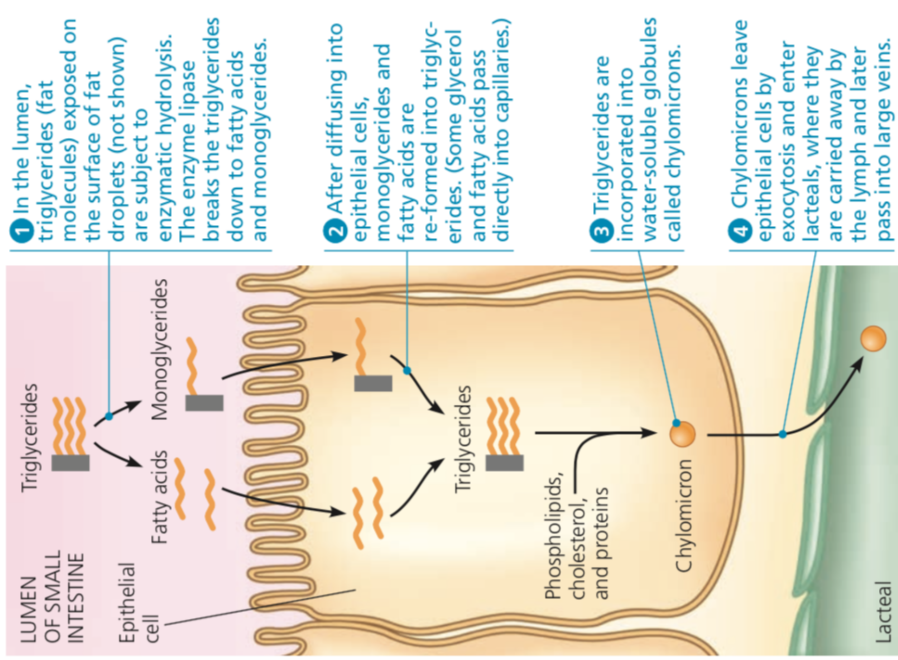
1. Large folds in the lining encircle the intestine and are studded with finger-like projections called *villi*. In turn, each epithelial cell of a villus has on its apical surface many microscopic projections, or *microvilli*, that are exposed to the intestinal lumen. These increase the surface area.

2. Active or passive diffusion in epithelial cells deposits nutrients in capillaries.

3. The capillaries and veins that carry nutrient-rich blood away from the villi converge into the hepatic portal vein, a blood vessel that leads directly to the liver (removes toxic substances and manages concentrations).

4. Some fats (triglycerides formed from monoglycerides that were formed from cleaving fats via lipase) take an alternate route. This is most simply explained by a diagram.

Figure 4: Absorption



Processing in Large Intenstine

1. The small intestine connects to the large intestine at a T-shaped junction. One arm of the T is the 1.5-m-long *colon*, which leads to the rectum and anus.
2. The other arm is a pouch called the *cecum*. The cecum is important for fermenting ingested material, especially in animals that eat large amounts of plant material. Compared with many other mammals, humans have a small cecum. The *appendix*, a finger-like extension of the human cecum, has a minor and dispensable role in immunity.

Herbivoral Adaptations
Mutualistic symbiosis is particularly important in herbivores. Much of the chemical energy in herbivore diets comes from the cellulose of plant cell walls, but animals do not produce enzymes that hydrolyze cellulose. Instead, many vertebrates (as well as termites, whose wooden diets consist largely of cellulose) host large populations of mutualistic bacteria and protists in fermentation chambers in their alimentary canals. These microorganisms have enzymes that can digest cellulose to simple sugars and other compounds that the animal can absorb. In many cases, the microorganisms also use the sugars from digested cellulose in the production of a variety of nutrients essential to the animal, such as vitamins and amino acids.

Case Study: Cow Ruminant

1. Chewed food first enters the *rumen* and *reticulum*, where mutualistic microorganisms digest cellulose in the plant material.
2. Periodically, the cow regurgitates and rechews "cud" from the reticulum, further breaking down fibers and thereby enhancing microbial action.
3. The reswallowed cud passes to the *omasum*, where some water is removed.
4. It then passes to the *abomasum*, for digestion by the cow's enzymes. In this way, the cow obtains significant nutrients from both the grass and the mutualistic microorganisms, which maintain a stable population in the rumen.

*See Campbell for more information

Feedback mechanisms
A branch of the nervous system called the enteric division, which is dedicated to the digestive organs, regulates these events as well as peristalsis in the small and large intestines. The endocrine system also plays a critical role in controlling digestion. These mechanisms are best described with the following diagrams:

2 Questions

1. Explain how the digestion of fats is different from that of proteins and carbohydrates?

(a) Fat digestion occurs in the small intestine, and the digestion of proteins and carbohydrates occurs in the stomach.

(b) Fats are absorbed into cells as fatty acids and monoglycerides but are then modified for absorption; amino acids and glucose are not modified further.

(c) Fats enter the hepatic portal circulation, but digested proteins and carbohydrates enter the lymphatic system.

(d) Digested fats are absorbed in the large intestine, and digested proteins and carbohydrates are absorbed in the small intestine.

2. After being absorbed through the intestinal mucosa, glucose and amino acids are ...

(a) absorbed directly into the systemic circulation.

(b) used to build glycogen and peptides before being released to the body cells.

(c) transported directly to the liver by the hepatic portal vein.

(d) further digested by bile before release into the circulation.

3.The small intestine is specialized for absorption because it ...

(a) is the last section of the digestive tract and retains food the longest.

(b) has saclike extensions along its length that collect food.

(c) has no outlet so food remains within it for longer periods of time.

(d) has an extremely large surface area that allows extended exposure to food.

4.Obese humans probably have high levels of leptin because

(a) leptin stimulates eating.

(b) something is wrong with the leptin receptors in their brain, leading to increased leptin production to make up for the apparent shortage.

(c) weight gain leads to the production of leptin.

(d) leptin responds to mechanical stimulation in the adrenal cortex.

How could a drop in plasma proteins and a decrease in bile production be related to alcohol and drug abuse?

Erica's baby, Justin, has had a severe bout of diarrhea and is now dehydrated. Is his blood more likely to be acidotic or alkalotic? Why?

Mary Littlefeather arrives in her physician's office complaining of severe, steady pain in the upper right quadrant of her abdomen. The pain began shortly after she ate a meal of fried chicken, French fries, and peas. Lab tests and an ultrasound reveal the presence of gall- stones in the common bile duct running from the liver, gallbladder, and pancreas into the small intestine.
(a) Why was Mary's pain precipitated by the meal she ate?
(b) Which of the following processes will be affected by the gall stones: micelle formation in the intestine, carbohydrate digestion in the in- testine, protein absorption in the intestine. Explain your reasoning.

Context: Mineral absorption usually occurs by active transport. Iron is one of the few substances whose intestinal absorption is actively regulated. For the mineral, a decrease in body concentrations of it leads to enhanced uptake at the intestine. Dietary iron is ingested as heme iron in meat and as ionized iron in some plant products. Heme iron is absorbed by an apical transporter on the enterocyte. Ionized iron ($Fe2+$) is actively absorbed by apical cotransport with $H+$ on a protein called the divalent metal transporter 1 (DMT1). Inside the cell, enzymes convert heme iron to $Fe2+$, and both pools of ionized iron leave the cell on a transporter called ferroportin. Iron uptake by the body is regulated by a peptide hormone called hepcidin. When body stores of iron are high, the liver secretes hepcidin, which binds to ferroportin. The hepcidin-bound transporter is targeted for destruction by the enterocyte, which results in decreased iron uptake across the intestine.

In the disease state called hemochromatosis, the hormone hepcidin is either absent or not functional. Use your understanding of iron homeostasis to predict what would happen to intestinal iron uptake and plasma levels of iron in this disease.