**BLY122**
**Chapter 43 Animal Nutrition**

I. Nutritional Requirements

A. Meeting Basic Needs
1. A nutrient is any substance that an organism needs to remain alive.
2. Two general types of nutrients are required:
   a. Reduced carbon compounds that can be oxidized to produce ATP
   b. Elements and molecules that are needed to synthesize body components and sustain cells
3. Recommended daily allowances (RDAs) were devised to identify the daily needs of healthy people.
   a. Humans must obtain the eight essential amino acids that we cannot synthesize.
   b. Vitamins are compounds that often function as coenzymes in metabolic reactions, and are needed only in minute amounts.
   c. Essential elements are used in a wide variety of ways by the body.
4. Chemical energy in foods
   a. The Calorie is the unit of measurement for food energy.
   b. On a food label, 1 Calorie corresponds to 1 kilocalorie of energy that is released when the food is oxidized by cells.
   c. Most food energy is in the form of carbohydrates and fats.
5. RDAs are subject to change as new research becomes available.
   a. A balanced diet generally fulfills all nutritional requirements.
   b. Supplements are not normally needed and can cause problems if abused.
   c. Women may need to take iron supplements due to the loss of iron in hemoglobin during menstruation.

B. Nutrition and Athletic Performance
1. Bergström et al. (1967) studied the performance of endurance athletes.
   a. An earlier hypothesis held that fatty acids provided the fuel for extended exertion.
   b. Bergström hypothesized that glycogen provides the immediate fuel for extended exertion.
   c. Experiment: Researchers gave nine students diets that varied in levels of carbohydrates and fats, and tested students' stored glycogen and physical endurance.
   d. Results:
   e. Conclusion: The data support the hypothesis that a diet rich in carbohydrates supports optimal performance.
2. Subsequent experiments confirmed the Bergström hypothesis.
   a. Carbohydrate loading is now a standard part of endurance training.
   b. Ingesting carbohydrates immediately before a race reduces performance.

II. Obtaining Food: The Structure and Function of Beaks, Teeth, and Mouthparts

A. Across animal groups there is a strong correlation between the size and shape of mouthparts with the size and shape of food sources.
1. Some lack extensive mouthparts; instead, they ingest food whole (maggots, snakes) .
2. Insects have a variety of mouthparts, from pinching mandibles of leaf-eaters to needlelike proboscis for sucking blood or nectar.
3. Humans eat plants and animals, and have molars for grinding and canines for tearing.
4. Other mammals eat only meat and have only sharp teeth designed for tearing.

B. Cichlid Fishes of Africa
1. As a group, they consume all types of food in the lakes, from plant to animal.
2. They diversified by adaptive radiation; 300 species appear to have evolved from a single common ancestor in less than 10,000 years.
3. Cichlids diversified because they have an extra set of jaws.
   a. Pharyngeal (throat) jaws are located well behind the normal oral jaws.
   b. Pharyngeal jaws are capable of biting, crushing, tearing, or compacting food, unlike the pharyngeal jaws of other fish, which function only in transporting food.
4. How did cichlid pharyngeal jaws originate?

a. A researcher compared the unique features cichlid pharyngeal jaws as compared to the pharyngeal jaws of non-cichlids.
b. Cichlids have toothlike protuberances on their pharyngeal jaws.
c. Conclusion: The data support the hypothesis that diverse animal mouthparts are an adaptive response to a diversity of food sources.

III. Digestion

A. The alimentary canal is the structure in which digestion takes place.
1. It begins at the mouth and ends at the anus.
a. The teeth begin digestion by tearing and chewing.
b. In humans, the use of knives and cooking is implicated in the decline in average tooth size over the last several million years.
c. Chemical breakdown of carbohydrates by enzymes begins in the mouth.
2. Food passes through the esophagus to the stomach.
3. Mechanical and chemical processing occurs in the stomach.
4. All types of food molecules are digested by enzymes and absorbed in the small intestine.
5. Water absorption and feces formation occurs in the large intestine.

B. The Mouth and Esophagus
1. Starch breakdown begins in the esophagus.
a. Starch breakdown was the first enzyme-catalyzed reaction discovered.
b. Amylase cleaves glycosidic bonds in starch, glycogen, and other polymers.
2. Cells in the tongue release lingual lipase that begins the digestion of lipids.
3. Saliva also contains water and glycoproteins called mucins.
a. Mucins plus water produce mucus.
b. Mucus makes food slippery, facilitating its passage to the stomach.
4. Peristalsis moves food from mouth to stomach in about six seconds.
a. The upper esophagus consists of skeletal muscle.
b. The lower esophagus is smooth muscle, and the middle third is a mixture of both types.
c. Peristalsis, a wave of reflexive contractions, in the upper third of the esophagus occurs in response to electrical signals from the base of the brain.
d. The mechanism of peristalsis in the lower third of the esophagus is not understood.

C. The Stomach
1. The stomach is a tough, muscular pouch bracketed on either end by sphincters.
a. When food enters, muscular contractions cause churning that mixes the contents.
b. Some mechanical breakdown of food occurs.
2. The stomach's most important function is digestion of proteins.
a. The stomach contains hydrochloric acid, therefore it is highly acidic.
b. By studying a man with a shotgun injury to the stomach, Beaumont established that digestion of meats occurs in the stomach.
3. Later, a researcher purified the stomach enzyme that digests protein.
a. The enzyme was named pepsin.
b. Hypothesis: Because the enzyme digests protein, it must be produced in an inactive form or else it would destroy the cells that produce it.

4. Which cells produce stomach acid?
a. Parietal cells are located along canals in the stomach lining that lead to the stomach lumen.
b. The shape and activity of the cells varies as digestion proceeds.
c. Hypothesis: Parietal cells are the source of HCl in gastric juice.
d. Fitzgerald stained the stomach lining of dogs with an acid dye that identified parietal cells as the source of HCl in the stomach.
e. Microscopic studies identified goblet cells as the source of mucus in gastric juice.
5. How do parietal cells secrete HCl?
a. A researcher (1930s) found a high concentration of carbonic anhydrase in parietal cells.
b. Later, transmission electron microscopy showed that parietal cells are packed with mitochondria.

6. The ruminant stomach
    a. Ruminants are grazing animals (cows, sheep, antelope, etc.) that have specialized stomachs for digesting plant matter.
    b. Ruminants can obtain glucose from cellulose because they have cellulose bacteria living in their digestive tract.
    c. Ruminants have a four-chambered stomach.
    d. Other plant eating, non-ruminant animals have a cecum that harbors microorganisms that ferment cellulose.

D. The Small Intestine
1. Peristalsis in the stomach wall sends food through a sphincter into the small intestine.
2. In the small intestine:
    a. Partially digested food mixes with secretions from the pancreas and liver.
    b. After passing through 20 feet of small intestine, food is completely digested and most nutrients have been absorbed.
3. Protein processing by pancreatic enzymes
    a. Proteins leaving the stomach are denatured and reduced by pepsin to small polypeptides.
    b. By the late 1800s, a series of digestive enzymes had been isolated from the pancreas.
    c. How is the secretion of enzymes from the pancreas regulated?
4. Digesting lipids: bile and transport
    a. Fats are insoluble in water, so fat tends to concentrate in globules as the stomach contents are churned.
    b. Bile salts in the small intestine emulsify the fat globules, breaking them up.
    c. Emulsified fats are digested to fatty acids by lipase enzymes secreted by the pancreas.
    d. Fatty acids bind to fatty-acid binding protein in the membrane of the epithelial cells lining the small intestine.
    e. After fatty acids enter these cells, they are packaged into protein-coated complexes, chylomicrons, and transported to fat storage cells and other tissues.
5. Carbohydrate digestion and the intestinal epithelium
    a. Pancreatic amylase completes the digestion of carbohydrates in the intestine; nuleases digest DNA ad RNA.
    b. Sugars released by amylase digestion are absorbed by intestinal epithelial cells.
    c. The intestinal epithelium has an enormous surface area for absorption.
6. How does nutrient absorption actually occur?
    a. Researchers (1980s) found that nutrient absorption depends on an electrochemical gradient that favors sodium entry into the epithelium.
    b. Hypothesis: The apical membrane of epithelial cells contains cotransporters.
    c. Investigators searched for a hypothesized glucose-sodium cotransporter.
    d. The current model for glucose absorption

E. The Large Intestine
1. The primary function of the large intestine is to compact remaining wastes and absorb enough water to form feces.
2. The mechanism of water absorption in the large intestine is not well understood.
    a. Aquaporins may be involved.
    b. The *AQP3* and *AQP4* genes are the best-studied aquaporin genes in the large intestine.
    c. Mice with mutations in other aquaporin genes are being tested, but water reabsorption in the colon is not well understood.

IV. Nutritional Homestasis—Glucose as a Case Study

A. Diabetes mellitus is a disease of glucose homeostasis.
1. Diabetics have abnormally high levels of glucose in the bloodstream.
    a. Glucose is excreted in the urine because the high levels present in the plasma prevent full reabsorption in the kidney.
    b. Chronic glucose imbalance eventually can lead to blindness, kidney failure, heart failure, and poor circulation in the legs.

2. Searching for the cause of diabetes
    a. In 1879, researchers removed the pancreas from a dog and observed that diabetes developed.
    b. Hypothesis: A compound secreted by the pancreas is involved in removal of glucose from the bloodstream.
    c. Efforts to find an extract of the pancreas that prevented diabetes were unsuccessful due to damage to the active agent by pancreatic digestive enzymes during extraction.
    d. Banting and Best eventually isolated the active agent by blocking the pancreatic duct until the tissue atrophied.

B. Insulin's Role in Homeostasis
1. Insulin is a hormone produced in the pancreas when blood-glucose levels are high.
2. Insulin binds to receptors on cells throughout the body and stimulates them to increase their uptake and processing of glucose.
    a. Liver cells produce more glycogen.
    b. Cells that store fats synthesize more fats from glucose precursors.
3. Result: Glucose levels in the blood decline.
4. When blood-glucose levels drop, such as after exercise, the pancreas secretes glucagon.
    a. In response to glucagon, liver cells break down glycogen and release glucose.
    b. Glucagon triggers fat breakdown and glucose release from fat-storing cells.
5. Result: Glucose levels in the blood rise.
6. Homeostasis of glucose in the blood is controlled by insulin and glucagon.

C. Types of Diabetes
1. Type I diabetes mellitus occurs in people who have a defect in insulin synthesis (insulin-dependent diabetes).
2. Type II diabetes mellitus occurs in people who have a defect in the insulin receptor (non-insulin-dependent diabetes).
3. Both types of diabetes lead to the production of large volumes of urine.
    a. The body attempts to clear the glucose from the bloodstream.
    b. The word *diabetes* means "to run through," and *mellitus* means "honeyed" or "sweet."

D. The Type II Diabetes Mellitus Epidemic
1. An epidemic of type II diabetes is currently under way in some human populations.
    a. In the United States, about 6% of people aged 20 to 74 have type II diabetes.
    b. African Americans, Hispanics, and Native Americans are much more prone to diabetes.
    c. The frequency among teenagers of all ethnic groups is increasing rapidly.
    d. The Pima Indians of the American Southwest have the highest frequency recorded: Almost 60% of adults over 35 years old are diabetic. (**Fig. 43.18a**)
2. Some families appear to have a genetic predisposition to diabetes.
3. Strong evidence exists that there is an environmental component to the disease.
    a. Diabetes is more prevalent in obese people. (**Fig. 43.18b**)
    b. Obesity is increasing due to increasing fat content of food and labor-saving devices that reduce physical activity.

**Chapter Vocabulary**

heterotroph

nutrient
food
nutritional balance
essential amino acids
vitamins
essential elements
electrolytes
recommended daily allowance (RDA)
Calorie
kilocalorie

glycogen
carbohydrate loading

proboscis
mandible
canines
molars
cichlid fish
endemic
adaptive radiation
pharyngeal jaws
oral jaws

digestion
absorption
alimentary canal
gastrointestinal tract (GI tract)

mouth
salivary glands
saliva
amylase
lingual lipase
glycoprotein
mucin
mucus
esophagus
peristalsis
skeletal muscle
smooth muscle
reflex

stomach
sphincter
goblet cells
gastric juice
pepsin
pepsinogen
chief cells
parietal cells
HCl
carbonic anhydrase
carbonic acid
bicarbonate ion
protein denaturation

ruminant
symbiosis
rumen
cud
reticulum
omasum
abomasums
cecum

small intestine
pancreas
pancreatic enzymes
trypsinogen
trypsin
enterokinase
hormone
secretin
cholecystokinin
gastrin
pancreatic lipase
emulsified
bile salts
bile
liver
gallbladder
fatty-acid binding protein
chylomicrons
nucleases
pancreatic amylase
villi
microvilli
lacteals
large intestine/colon
aquaporins
rectum
anus

diabetes mellitus
insulin
glucagon
gluconeogenesis
Type I diabetes
Type II diabetes
obese
body mass index