Animal Nutrition

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Nutrition Requirements

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

- Animals depend on a regular supply of food derived from other organisms.
- A balanced diet provides fuel for cellular work, as well as all the materials the body needs to construct its own organic molecules.

Homeostatic mechanisms manage an animal's fuel

- When an animal takes in more **calories** than it needs to produce ATP, the excess can be used for biosynthesis.
- Glycogen in liver and muscle of human: Glucose is a major fuel molecule.
  - If glycogen stores are full, the excess calories may be stored as fat.
  - The human body generally expends liver glycogen first, and then draws on muscle glycogen and fat.

- An **undernourished** animal is one whose diet is deficient in calories.
  - When starvation for calories persists, the body begins breaking down its own proteins for fuel.
  - **Anorexia nervosa**: an eating disorder associated with a compulsive aversion to body fat.
- **Over-nourishment** or **obesity** in the affluent nations:
  - The human body tends to hoard fat obtained from food instead of using them for fuel or biosynthesis. Human usually has enough fat to sustain them for several weeks. However, when we eat an excess of carbohydrates (CHOs), the body tends to increase its rate of CHO consumption.

- The human body seems to impose limits on weight gain (and loss): Most dieters return to their former weight soon after they stop dieting.
  - Complex feedback mechanisms regulate fat storage and use in mammals.
  - Hormone, **leptin**, produced by adipose cells: A high leptin level cues the brain to depress appetite and increase energy-consuming muscular activity and body-heat production.

An animal's diet must supply essential nutrients and carbon skeletons for biosynthesis

- To synthesize the molecules it needs to grow and replenish, an animal must obtain organic precursors (carbon skeletons) from its food.
- Besides fuel and carbon skeletons, an animal's diet must also supply **essential nutrient**s, which might be various for different animal species.
  - **Malnourished**: missing one or more essential nutrients in diet.
    - An over-nourished individual is possible to be malnourished.

- Four classes of essential nutrients - **essential amino acid**s, **essential fatty acid**s, **vitamin**s, and **mineral**s: Animals can't synthesize by themselves and must be obtained from food.
  - **Essential amino acids**: 8 amino acids are essential in the adult human diet.
    - The most reliable sources of essential amino acids are meat, eggs, cheese, and other animal products.
    - Most plant proteins are incomplete in essential amino acids: Corns are deficient in **lysine**, and beans are deficient in **methionine**. Vegetarians have to obtain sufficient quantities of all essential amino acids by eating a combination of plant foods during the same day, because the body can't store amino acids.

- **Essential fatty acids** are certain unsaturated fatty acids: Most diets furnish ample quantifies of essential fatty acids, and thus deficiencies are rare.

- **Vitamin**s: water-soluble and fat-soluble
  - 13 vitamins essential to humans:
  - Water-soluble vitamins:
    - **B complex** (B_1, B_2, B_6, B_{12}) as coenzymes
    - **Vitamin C** (ascorbic acid) is required for the synthesis of CNT.
  - Fat-soluble vitamins:
    - **Vitamin A** is incorporated into visual pigments of the eye.
    - **Vitamin D** aids in calcium absorption and bone formation
    - **Vitamin E** as antioxidant to protect the phospholipids from oxidation
    - **Vitamin K** is required for blood clotting.
  - Recommended daily allowances (RDAs):

- **Minerals** are inorganic nutrients, usually required in very small amount.
  - Calcium: construction of bone; functioning of nerves and muscles.
  - Phosphorus: ingredient of ATP and nucleic acid; construction of bone.
  - Iron in **cytochrome**s and hemoglobin: cellular respiration.
  - Magnesium, iron, zinc, copper, and selenium are cofactors of certain enzymes
  - Iodine to make thyroid hormones
  - Sodium, potassium, and chlorine: nerve function; osmotic balance.

- Ingesting an excess of salt and several other minerals can upset homeostatic balance and cause toxic side effects
  - Too much sodium is associated with high blood pressure.
  - Excess iron can cause liver damage.

Food Types and Feeding Mechanisms

Most animals are opportunistic feeders

- **Herbivore**s, **carnivore**s, and **omnivore**s

Diverse feeding adaptations have evolved among animals

- **Suspension-feeder**s: eating by filtration
- **Substrate-feeder**s: living in wood like termite
  - **Deposit-feeder**s (**detritus-feeder**s): living in soil or mud like earthworm
- **Fluid-feeder**s: drinking liquid food like butterfly
- **Bulk-feeder**s: swallowing prey like snake

Overview of Food Processing

The four main stages of food processing are ingest, digestion, absorption, and elimination

- Ingestion → digestion (enzymatic hydrolysis) → absorption → elimination

Digestion occurs in specialized compartments

- Intracellular digestion:
  - **Food vacuole**s of heterotrophic protists (*paramecium*) and sponge: **phagocytosis** or **pinocytosis**

- Extracellular digestion: in most animals
  - Single opening: **gastrovascular** cavity of hydra and flatworm
  - Two opening: **complete digestive tract** or **alimentary canal**
    - Mouth-pharynx-esophagus-crop-stomach-gizzard-intestine-rectum-anus

The Mammalian Digestive System

The oral cavity, pharynx, and esophagus initiate food processing

- The Oral Cavity
  - **Teeth**: physical digestion
  - **Saliva**: The presence of food in the oral cavity triggers a nervous reflex causing the **salivary gland**s to deliver saliva.
    - Buffer and antibacterial agents:
    - **Salivary amylase**: hydrolyze starch and glycogen
    - **Musin** protects the soft lining of mouth and lubricates the food.
  - **Tongue** shapes the food into a ball, **bolus**, and pushes a bolus into the pharynx.

- The **Pharynx**: **Epiglottis** down to cover **glottis** during swallow.

- The **Esophagus**
  - **Peristalsis** squeezes a bolus along the narrow esophagus.
  - Salivary amylase continues to hydrolyze starch and glycogen as the bolus passes through the esophagus.

The stomach stores food and performs preliminary digestion

- Secretion of stomach wall cells: **gastric juice**
  - **chief cell**s → **pepsinogen** (zymogen) → **pepsin :** positive feedback
  - **mucous cell**s → mucous with HCO_3^-
  - **parietal cell**s → HCl for pepsinogen activation
- The epithelia generate enough cells to replace the stomach lining every 3 days.

- **Gastric ulcers**: lesions in the stomach lining are caused by the acid-tolerant bacteria, *Helicobacter pylori*.

- **Acid chyme: cardiac orifice** → stomach → **pyloric sphincter**
  - **Heartburn**: the occasional backflow of acid chyme from the stomach into the lower end of the esophagus.

<u>The small intestine is the major organ of digestion and absorption</u>

- Small intestine: **duodenum** → **jejunum** → **ileum**
- Bicarbonate: buffer
- **Bile**:
  - Bile salts act as detergents for fat **emulsification.**
  - Bile pigments are by-products of RBC destruction in liver.
- Enzymatic action in the small intestine: **duodenum**
  - Carbohydrate digestion:
    - Pancreatic amylase:
    - Disaccharidases: **maltase** - maltose, **sucrase** - sucrose, l**actase** - lactose
  - Protein digestion: protease
    - Secretion from pancreas in inactive form:
      - **Trypsinogen** is converted to **trypsin** by one of membrane-bound **enteropeptidase** or trypsin (positive feedback)
      - **Chymotrypsinogen** and **procarboxypeptidase** are converted to **chymotrypsin** and **carboxypeptidase** respectively by trypsin.
    - Secretion by the intestine epithelium: **aminopeptidase**
  - Nucleic acid digestion:
    - **Nucleases** hydrolyze DNA (DNase) and RNA (RNase) into nucleotides.
  - Fat digestion: lipase – fatty acid and glycerol

- Absorption of nutrients:
  - Most absorption occurs in the **jejunum** and **ileum**
  - **Villi**: epithelial cells with **microvilli** (brush border) and a small lymphatic vessel, **lacteal**, surrounded by a net of capillary.
    - Passive diffusion or active transport
    - Water-soluble nutrients pass through the epithelium and enter capillaries.
    - Glycerol and fatty acid are recombined within the epithelia to form fats. The fats are mixed with cholesterol and coated with special proteins to form **chylomicrons**, which exocytose out of the epithelia and into lacteal.
  - **Hepatic portal vessel**: lead directly to liver
    - Liver is important in regulating the level of glucose in the blood.

- People eating the typical diets consumed in developed countries usually absorb 80-90 percent of the organic matter in their food. Much of the remaining undigestible material is cellulose from plant cell walls.

<u>Hormones help regulate digestion</u>

- **Gastrin** releasing from stomach to promote gastric juice secretion is stimulated by food, and is inhibited when the pH of stomach content is too low.
- **Enterogastrone**: secretion from duodenum by fat-rich chyme stimulation to inhibit peristalsis in stomach.
- **Secretin**: secretion from duodenum by fat-rich chyme stimulation to promote bicarbonate and enzymes releasing from pancreas.
- **Cholecystokinin** (**CCK**) causes the gallbladder to release bile, and pancreas to release enzymes.

Reclaiming water is the major function of the large intestine

- Large intestine (**colon**) includes **c**(**a**)**ecum**, **appendix** and **rectum.**
  - Diarrhea or constipation:
  - Harmless bacteria: *Escherichia coli*

- Two sphincters, one voluntary and the other involuntary, are located between anus and rectum.

Evolutionary adaptations of vertebrate digestive systems

Structural adaptations of the digestive system are often associated with diet

- **Dentition**, an animal's assortment of teeth, is reflecting its diet: **incisor**s, **canine**s, **premolar**s and **molar**s.

- The length of the digestive system: cecum and colon

Symbiotic microorganisms help nourish many vertebrates

- Animals do not produce enzymes that hydrolyze cellulose.
  - The alimentary canals of herbivorous vertebrates: fermentation chamber of symbiotic bacteria and protists.

- **Reingestion** - feces eating: symbiotic bacteria of rabbit and some rodents live in the large intestine as well as in the cecum.

- **Ruminant**s: