Chapter 41: Animal Nutrition

Animals are heterotrophs that require food for:
1) Fuel
2) Carbon Skeletons
3) Essential Nutrients

Nutritional Requirement #1: Fuel for all cellular work of the body

Bioenergetics:
Flow of energy through an organism
- Sets upper / lower limits

Metabolic Rate:
Sum of all chemical reactions during set time interval
- Measured in calories (cal)

Bioenergetic Strategies:
1) Endothermic: Animal warmed by heat generated via metabolism
2) Exothermic: Metabolism does not have effect on body temperature (requires ↓ energy than endotherm)

Similar to Campbell et al. -- Figure 40.17
Metabolic rate per gram is inversely related to body size among similar animals:

**Mouse** (compared to elephant):
- 20x more calories / gram
- ↑ food consumption
- ↑ heart rate
- ↑ oxygen delivery

**Hypothesis:**
- The smaller the animal, the greater the energy cost to maintain stable body temperature (surface area / volume issue...)

**Problem:** Same relationship observed in ectotherms...

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**Nutritional Requirement #1:** Fuel for all cellular work of the body

Animals adjust their metabolic rates as conditions change:

**Basal Metabolic Rate:** Metabolic rate of a non-growing endotherm at rest
- BMR of humans = 1300 – 1800 kcal / day

**Standard Metabolic Rate:** Metabolic rate of a non-growing ectotherm at rest
- Temperature-dependent

Factors influencing metabolic rate:
- age, sex, size
- environmental temperature
- food / oxygen availability
- time of day

Average metabolic rate of animals
- 2 – 4 times BMR / SMR

An animal's maximum metabolic rate is inversely related to duration of activity.
Nutritional Requirement #1: Fuel for all cellular work of the body

Homeostatic mechanisms manage an animal's fuel:

**Fuel** = Organic molecules used in cellular respiration (e.g., fats, carbohydrates)

Excess energy stored as:
1) Glycogen
2) Fat (~ 2 weeks)

**Undernourishment:**
Animal diet chronically deficient in calories

**Overnourishment:**
Animal diet chronically excessive in calories

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Nutritional Requirement #2: Carbon skeletons for biosynthesis

Nutritional Requirement #3: Supply of essential nutrients

**Essential Nutrients** = Materials that the body can not synthesis from raw materials

- **Malnourished:** Missing one or more essential nutrients

**Classes of Essential Nutrients:**
1) **Essential Amino Acids**:
   - Animal products are “complete”
   - Plant products are “incomplete”
     - Protein deficiency

2) **Essential Fatty Acids**:
   - Unsaturated fatty acids
     - e.g., linoleic acid (phospholipids)
Nutritional Requirement #3: Supply of essential nutrients

Classes of Essential Nutrients:

3) **Vitamins:**
   - Organic molecules required in small quantities (compared to a.a. / fatty acids)
   - 13 essential vitamins required for humans (Table 41.1 – Campbell et al.)
     - **Water-soluble Vitamins** (excreted in urine; overdose = no problem)
       - B-complex – coenzymes in metabolic reactions
       - Vitamin C – connective tissue production (e.g., scurvy)
     - **Fat-soluble Vitamins** (deposited in body fat; overdose ~ toxic)
       - Vitamin A – visual pigments of eye
       - Vitamin D – calcium absorption / bone formation

4) **Minerals:**
   - Inorganic nutrients required in small quantities (Table 41.2 – Campbell et al.)
     - Calcium – bone formation; nerve / muscle function
     - Iron – cellular respiration (ETC); oxygen-carrying in blood
     - Zinc / Manganese / Selenium – enzyme cofactors

Dietary Categories of Animals:

- **Herbivores:** Animals that eat autotrophs
- **Carnivores:** Animals that eat other animals
- **Omnivores:** Animals that eat both plants and animals

Note: Most animals are opportunistic and will eat outside category

Food Ingestion Categories:

- **Suspension-feeders:** Sift small food particles from water (e.g., whales)
- **Substrate-feeders:** Live in / on the food source (e.g., larvae)
- **Deposit-feeders:** Eat partially decayed organic material in soil (e.g., worm)
- **Fluid-feeders:** Suck nutrient-rich fluids from a living host (e.g., mosquito)
- **Bulk-feeders:** Eat relatively large pieces of food (e.g., birds)
Main Stages of Food Processing:
1) Ingestion: The act of eating
   - Animals cannot use macromolecules immediately (too big / wrong structure)
2) Digestion: Process of breaking down food into small enough molecules
   - Mechanical Fragmentation (e.g., chewing)
   - Chemical Digestion (via enzymes)
     - Hydrolysis: The breaking of bonds with the addition of water
3) Absorption: Cellular uptake of small molecules
4) Elimination: Undigested material released from digestive system

Digestion occurs in specialized compartments:

Intracellular Digestion:
- **Food vacuole**: Food phagocytosed and fused with lysosome (e.g., sponge)

Extracellular Digestion (larger prey):
- **Gastrovascular cavity**: Digestive sacs with single opening
  - Enzymes secreted into sac
- **Alimentary Canal**: Uni-directional movement of food
  - Increased efficiency
The Mammalian Digestive System:

1) **Alimentary Canal**
   - **Peristalsis**
     - Rhythmic waves of contractions pushing food through canal

2) **Accessory Glands**
   - **Sphincters**
     - Ring-like valves regulating passage between chambers

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**Frolicking with Food:**

- **Mechanical Digestion** = Mastication
- **Chemical Digestion** = **Salivary Amylase**
  - Carbohydrates $\rightarrow$ Polysaccharides
  - Contained in saliva:
    - Released via reflex arc (~ 1 L / day)
    - Contains mucin, antibiotics, buffers
Oral Cavity
- Mechanical Digestion = Churning of stomach
  - 3 layers of muscle (cir. / long. / oblique)
- Chemical Digestion = Pepsin
  - Proteins → Small Peptides
  - Contained in gastric juices (pH ~ 2)
    - Hydrochloric acid:
      1) Disrupt extracellular matrix
      2) Kill bacteria
      3) Activate pepsin
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- Mucus coating protects stomach from HCl
  (failure = ulcer)
- Absorption = Water, alcohol, drugs (aspirin)

Chapter 41: Animal Nutrition
Frolicking with Food:
- Oral Cavity
- Esophagus
- Stomach
- Mechanical Digestion = Churning of stomach
- Chemical Digestion = Pepsin
- Contained in gastric juices (pH ~ 2)
- Hydrochloric acid:
  1) Disrupt extracellular matrix
  2) Kill bacteria
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Esophagus
Bolus
Stomach

Chapter 41: Animal Nutrition
Frolicking with Food:
- Stomach
- Chyme
- Small Intestine
- Chemical Digestion (duodenum):
  - Work with aid of accessory glands:
    1) Pancreas:
      - Alkaline solution (bicarbonate)
      - Digestive Enzymes
    2) Liver:
      - Bile = Fat emulsifier (bile salts)
        - Stored in gallbladder
        - Contains RBC wastes
Chemical Digestion in Small Intestine:

<table>
<thead>
<tr>
<th>Oral cavity, pharynx, esophagus</th>
<th>Polysaccharides (starch, glycogen) (\rightarrow) Salivary amylase (\rightarrow) Smaller polysaccharides, maltose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>Proteins (\rightarrow) Pepsin (\rightarrow) Small polypeptides</td>
</tr>
<tr>
<td>Lumen of small intestine</td>
<td>Polysaccharides (\rightarrow) Pancreatic amylases (\rightarrow) Maltose and other disaccharides</td>
</tr>
<tr>
<td>Epithelium of small intestine (brush border)</td>
<td>Disaccharidases (\rightarrow) Monosaccharides</td>
</tr>
<tr>
<td></td>
<td>Polypeptides (\rightarrow) Trypsin, Chymotrypsin (\rightarrow) Smaller polypeptides</td>
</tr>
<tr>
<td></td>
<td>Aminopeptidase, Carboxypeptidase (\rightarrow) Amino acids</td>
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<td></td>
<td>Small peptides (\rightarrow) Dipeptidases (\rightarrow) Amino acids</td>
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<tr>
<td></td>
<td>Nucleotidases (\rightarrow) Nucleosides (\rightarrow) Nucleosides</td>
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<tr>
<td></td>
<td>Fats converted into chylomicrons for transport in lymph system</td>
</tr>
<tr>
<td></td>
<td>Enters blood near heart</td>
</tr>
</tbody>
</table>

**Chapter 41: Animal Nutrition**

**Frolicking with Food:**

- **Absorption** (jejunum / ileum):
  - Large surface area (~ 300 m²)
    - Villi: Finger-like projections
    - Microvilli: Cytoplasmic projections
  - Lacteals / blood vessels penetrate villi
    - Active transport (e.g. glucose)
    - Passive transport (e.g. fructose)
  - Capillaries carry nutrients to liver via hepatic portal vein
  - Fats converted into chylomicrons for transport in lymph system
  - Enters blood near heart
Chapter 41: Animal Nutrition

Frolicking with Food:

- **Absorption** = Water
  - ~ 90% of water captured by SI & LI
  - Food waste = Feces
  - Diarrhea / Constipation

- Also absorbs vitamins produced by symbiotic bacteria (e.g., *E. coli*) in lumen
  - Vitamin K, B vitamins, folic acid

- **Rectum**: Terminal portion storing feces
  - 2 sphincters (invol. / vol.)

**Cecum**: Fermentation chamber containing symbiotic bacteria