Animal Nutrition
What do animals need to live?

- **Animals make energy using:**
  - food
  - oxygen

- **Animals build bodies using:**
  - food for raw materials
    - amino acids, sugars, fats, nucleotides
  - ATP energy for synthesis
Nutritional requirements

- Animals are **heterotrophs**
  - need to take in food
  - Why? fulfills 3 needs…
    - **fuel** = chemical energy for production of ATP
    - **raw materials** = carbon source for synthesis
    - **essential nutrients** = animals cannot make
      - elements (N, P, K, Fe, Na, K, Ca...), NAD, FAD, etc.
How do animals get their food?

- Filter (suspension) feeding
- Substrate feeding
- Fluid feeding
- Bulk feeding
Different diets; different lives

- All animals eat other organisms
  - **Herbivores**
    - eat mainly **plants**
      - gorillas, cows, rabbits, snails
  - **Carnivores**
    - eat other **animals**
      - sharks, hawks, spiders, snakes
  - **Omnivores**
    - eat **animals & plants**
      - cockroaches, bears, raccoons, humans
      - humans evolved as hunters, scavengers & gatherers
Getting & Using Food

- **Ingest**
  - taking in food

- **Digest**
  - mechanical digestion
    - breaking up food into smaller pieces
  - chemical digestion
    - breaking down food into molecules small enough to be absorbed into cells
    - enzymes (hydrolysis)

- **Absorb**
  - absorb across cell membrane
    - diffusion
    - active transport

- **Eliminate**
  - undigested extracellular material passes out of digestive system
Digestive systems

Everybody’s got one!

(a) Earthworm

(b) Grasshopper

(c) Bird
Common processes & structures

- Movement & Control
  - **peristalsis**
    - push food along by rhythmic waves of smooth muscle contraction in walls of digestive system
  - **sphincters**
    - muscular ring-like valves, regulate the passage of material between sections of digestive system

- Accessory glands
  - salivary glands, pancreas, liver & gall bladder
    - secrete digestive juices (enzymes & fluid)
Swallowing (& not choking)

- **Epiglottis**
  - problem: breathe & swallow through same orifice
  - flap of cartilage
  - closes trachea (windpipe) when swallowing
  - food travels down esophagus

- **Esophagus**
  - move food along to stomach by peristalsis
Ingestion

- **Mouth**
  - **mechanical digestion**
    - **teeth**
      - breaking up food
  - **chemical digestion**
    - **saliva**
      - **amylase**
        - enzyme digests starch
      - **mucin**
        - slippery protein (mucus)
        - protects soft lining of digestive system
        - lubricates food for easier swallowing
      - **buffers**
        - neutralizes acid to prevent tooth decay
      - **anti-bacterial chemicals**
        - kill bacteria that enter mouth with food
mouth
- break up food
- moisten food
- digest starch
- kill germs
Stomach

**Functions**

- **food storage**
  - can stretch to fit ~2L food

- **disinfect food**
  - HCl = pH 2
    - kills bacteria
    - breaks apart cells

- **chemical digestion**
  - **pepsin**
    - enzyme breaks down proteins
    - secreted as **pepsinogen**
      - activated by HCl

But the stomach is made out of protein! What stops the stomach from digesting itself?

mucus secreted by stomach cells protects stomach lining
mouth
- break up food
- moisten food
- digest starch
- kill germs

stomach
- kills germs
- store food
- break up food
- digest proteins

cardiac sphincter

pyloric sphincter
Ulcers

- Used to think ulcers were caused by stress
  - tried to control with antacids

- Now know ulcers caused by bacterial infection of stomach
  - **Helicobacter pylori**
  - now cure with antibiotics
Revolutionizing healthcare

"for their discovery of the bacterium Helicobacter pylori and its role in gastritis and peptic ulcer disease"

*Helicobacter pylori*

J. Robin Warren

Barry Marshall
Small intestine

**Function**
- **major organ of digestion & absorption**
- **chemical digestion**
  - digestive enzymes
- **absorption through lining**
  - over 6 meters!
  - small intestine has huge surface area = 300m² (~size of tennis court)

**Structure**
- 3 sections
  - duodenum = most digestion
  - jejenum = absorption of nutrients & water
  - ileum = absorption of nutrients & water
Duodenum

- 1st section of small intestines
  - acid food from stomach mixes with digestive juices from accessory glands:
    - pancreas
    - liver
    - gall bladder
Pancreas

- **Digestive enzymes**
  - peptidases
    - trypsin
      - trypsinogen
    - chymotrypsin
      - chymotrypsinogen
    - carboxypeptidase
      - procarboxypeptidase
  - pancreatic amylase

- **Buffers**
  - reduces acidity
    - alkaline solution rich in bicarbonate (HCO$_3^-$)
    - buffers acidity of material from stomach

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**What stops pancreas from digesting itself**

Explain how this is a molecular example of structure-function theme.
mouth
- break up food
- moisten food
- digest starch
- kill germs

pancreas
- produces enzymes to digest proteins & starch

stomach
- kills germs
- break up food
- digest proteins
- store food
Liver

- Digestive System Functions
  - produces **bile**
    - stored in **gallbladder** until needed
    - breaks up fats
      - act like detergents to breakup fats

Circulatory System Connection

*bile contains colors from old red blood cells collected in liver = iron in RBC rusts & makes feces brown*
**mouth**
- break up food
- moisten food
- digest starch
- kill germs

**stomach**
- kills germs
- break up food
- digest proteins
- store food

**liver**
- produces bile
  - stored in gall bladder
- break up fats

**pancreas**
- produces enzymes to digest proteins & starch
# Digestive Enzymes

<table>
<thead>
<tr>
<th>Location</th>
<th>Carbohydrate Digestion</th>
<th>Protein Digestion</th>
<th>Nucleic Acid Digestion</th>
<th>Fat Digestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral cavity, pharynx, esophagus</td>
<td>Polysaccharides (starch, glycogen)</td>
<td>Salivary amylase</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salivary amylase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smaller polysaccharides, maltose</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>Prokaryotes</td>
<td>Pepsin</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Small polypeptides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumen of small intestine</td>
<td>Polysaccharides</td>
<td>Trypsin, Chymotrypsin</td>
<td>Nucleases</td>
<td>Fat globules</td>
</tr>
<tr>
<td></td>
<td>Pancreatic amylases</td>
<td>Smaller polypeptides</td>
<td>DNA, RNA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maltose and other disaccharides</td>
<td>Aminopeptidase, Carboxypeptidase</td>
<td>Nucleotides</td>
<td></td>
</tr>
<tr>
<td>Epithelium of small intestine</td>
<td>Disaccharidases</td>
<td>Dipeptidases</td>
<td>Nucleotidases</td>
<td>Bile salts</td>
</tr>
<tr>
<td>(brush border)</td>
<td>Monosaccharides</td>
<td>Amino acids</td>
<td></td>
<td>Fat droplets</td>
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<td></td>
<td>(emulsified)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lipase</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Glycerol, fatty acids, glycerides</td>
</tr>
</tbody>
</table>

**Notes:**
- **Salivary amylase** acts on starch and glycogen in the oral cavity.
- **Pepsin** and **trypsin** are enzymes that break down proteins into smaller peptides.
- **Nucleases** and **lipase** are enzymes that break down nucleic acids and fats, respectively.
Absorption by Small Intestines

- Absorption through **villi & microvilli**
  - finger-like projections
    - increase surface area for absorption
Absorption of Nutrients

- **Passive transport**
  - fructose

- **Active (protein pumps) transport**
  - pump amino acids, vitamins & glucose
    - against concentration gradients across intestinal cell membranes
    - allows intestine to absorb much higher proportion of nutrients in the intestine than would be possible with passive diffusion
      - worth the cost of ATP!

nutrients are valuable... grab all you can get!
- **small intestines**: breakdown all foods - proteins, starch, fats, nucleic acids - absorb nutrients
- **mouth**: break up food, moisten food, digest starch, kill germs
- **stomach**: kills germs, break up food, digest proteins, store food
- **pancreas**: produces enzymes to digest proteins & starch
- **liver**: produces bile, stored in gall bladder, break up fats
Large intestines (colon)

- **Function**
  - re-absorb water
    - use ~9 liters of water every day in digestive juices
    - > 90% of water reabsorbed
      - not enough water absorbed back to body
        - diarrhea
      - too much water absorbed back to body
        - constipation
Flora of large intestines

- Living in the large intestine is a rich flora of harmless, helpful bacteria
  - *Escherichia coli (E. coli)*
    - a favorite research organism
  - bacteria produce vitamins
    - vitamin K; biotin, folic acid & other B vitamins
  - generate gases
    - by-product of bacterial metabolism
    - methane, hydrogen sulfide

You've got company!
Rectum

- Last section of colon (large intestines)
  - eliminate feces
    - undigested materials
      - extracellular waste
        - mainly cellulose from plants
        - roughage or fiber
  - salts
  - masses of bacteria

Tell them about the rabbits, George!
mouth
- break up food
- moisten food
- digest starch
- kill germs

stomach
- kills germs
- break up food
- digest proteins
- store food

liver
- produces bile
  - stored in gall bladder
- break up fats

pancreas
- produces enzymes to digest proteins & carbs

small intestines
- breakdown food
  - proteins
  - starch
  - fats
- absorb nutrients

large intestines
- absorb water
Appendix

Vestigial organ

Ascending portion of large intestine

Ileum of small intestine

Cecum

Appendix

Liver

Gall-bladder

Pancreas

Small intestine

Large intestine

Anus
Hungry for Information?
Ask Questions!