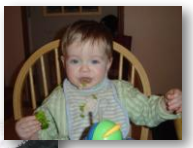
Chapter 50
Animal Nutrtion

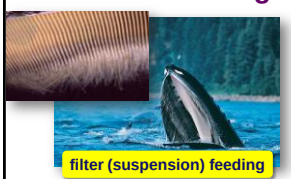


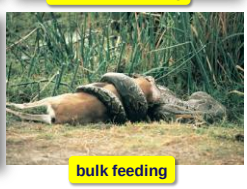

Nutritional Requirements

- 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.



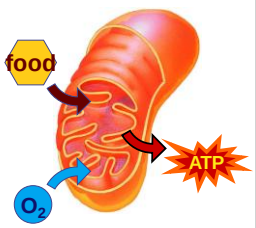
How do animals get their food?



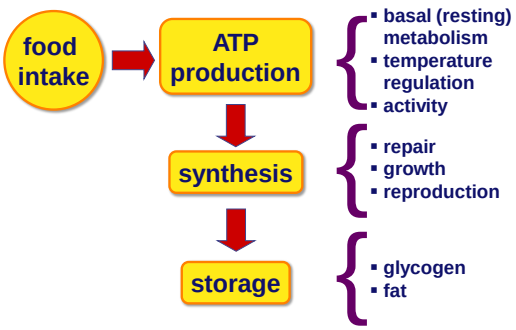


What do animals need to live?

- Animals make energy using:
  - food
  - oxygen
- Animals build bodies using:
  - food for raw materials
    - amino acids, sugars, fats, nucleotides
  - ATP energy for synthesis

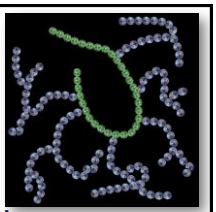
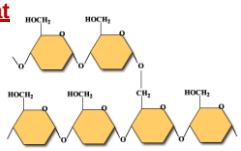


Energy Budget



Energy Storage

- In humans
  - glycogen storage
    - glucose polymer
  - in liver & muscle cells
- If glycogen stores are full & caloric intake still exceeds caloric expenditure
  - excess stored as fat
  - synthesis pathway from acetyl coA

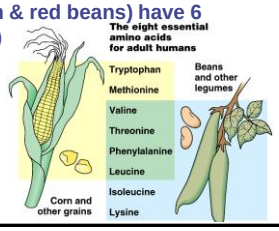



Balancing Calorie Needs with Intake

- When fewer calories are taken in than are expended, fuel is taken out of storage deposits & oxidized (digested)
  - breakdown (digest) glycogen from liver & muscle cells
  - metabolize (digest) fat

Vegetarian Diets

- Need to make sure you get enough protein
  - 20 amino acids to make protein
    - humans can synthesize 12 of the amino acids
    - 8 have to be eaten = "essential amino acids"
  - Grains (like corn) have 6 (missing 2)
  - Beans (like soybean & red beans) have 6 (missing different 2)
    - mix beans & grains for complete group of amino acids
      - rice & beans
      - taco/tortilla & beans
      - tofu & rice
      - peanut butter & bread



Eating a Balanced Diet

- What happens if an animal's diet is missing an essential nutrient?
  - deficiency diseases
    - scurvy — vitamin C (collagen production)
    - rickets — vitamin D (calcium absorption)
    - blindness — vitamin A (retinol production)
    - anemia — vitamin B_{12} (energy production)
    - kwashiorkor — protein

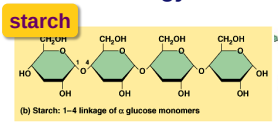
Different Diets; Different Lives

- 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

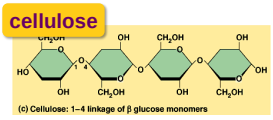
Digesting Cellulose

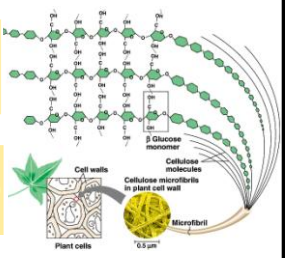
- How well you digest cellulose governs life strategy of herbivores

starch



cellulose



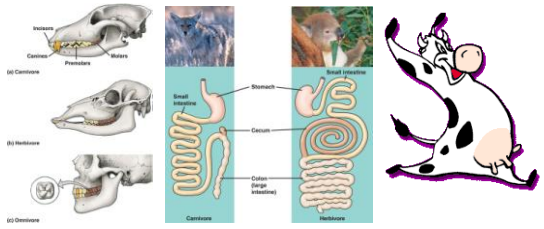


Cow
can digest cellulose well; no need to eat supplemental sugars

Gorilla
can NOT digest cellulose well; must supplement with sugar source, like fruit

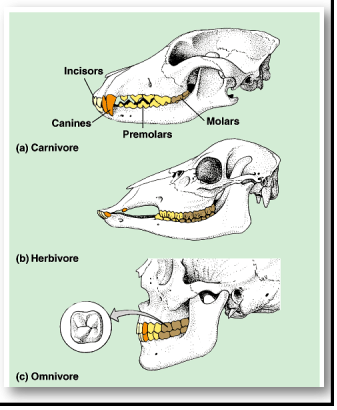
Different Diets; Different Bodies

- Adaptations of herbivore vs. carnivore
  - specialization in teeth
  - length of digestive system
  - number & size of stomachs



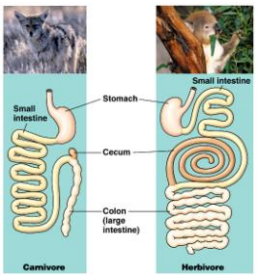
Teeth

- **Carnivore**
  - sharp ripping teeth
  - "canines"
- **Herbivore**
  - wide grinding teeth
  - molars
- **Omnivore**
  - both kinds of teeth



Length of Digestive System

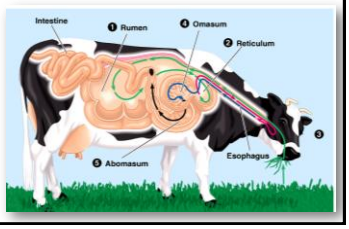
- Carnivores
  - short digestive system
    - protein easier to digest than cellulose
- Herbivores & omnivores
  - long digestive system
    - more time to digest cellulose
    - symbiotic bacteria in gut



Symbiotic Organisms

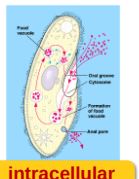
- How can cows digest cellulose efficiently?
  - symbiotic bacteria in stomachs help digest cellulose-rich meals
  - rabbit vs. cow adaptation: eat feces vs. chew cud

Ruminants additional mechanical digestion by chewing food multiple times after mixing it with enzymes

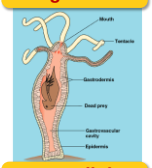


Getting & Using Food

- **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



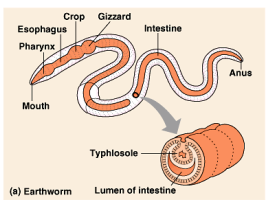
intracellular digestion

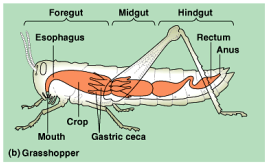


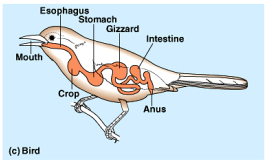
extracellular digestion

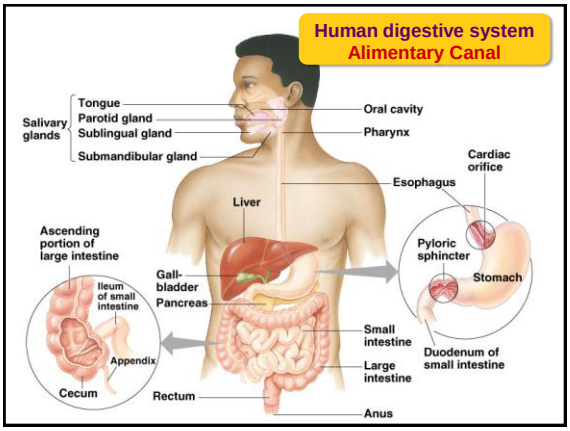
Digestive Systems

Everybody's got one!







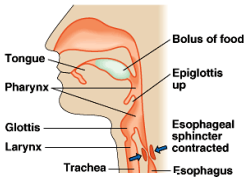


Common Processes & Structures

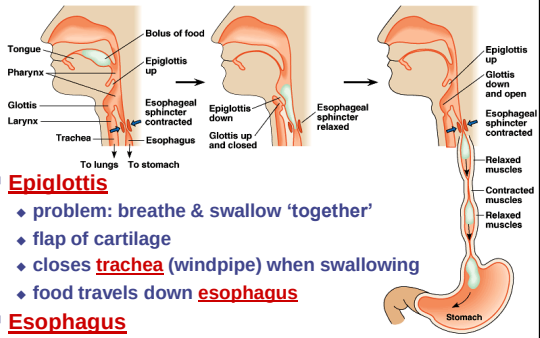
- Movement & Control
  - peristalsis
    - push food along by rhythmic waves of smooth muscle contraction in walls of digestive system
  - sphincters
    - muscular ring-like valves, regulate the passage of material between sections of digestive system
- Accessory glands
  - salivary glands, pancreas, liver & gall bladder
    - secrete digestive juices (enzymes & fluid)

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



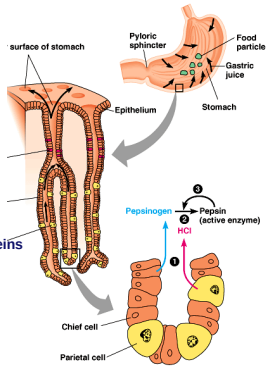
Swallowing (& not Choking)



- Epiglottis
  - problem: breathe & swallow 'together'
  - flap of cartilage
  - closes trachea (windpipe) when swallowing
  - food travels down esophagus
- Esophagus
  - move food along to stomach by peristalsis

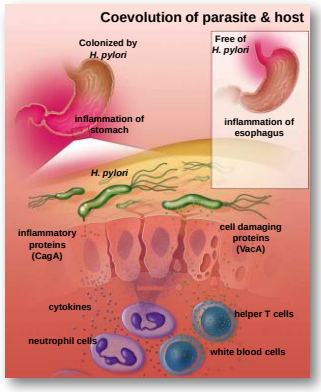
Stomach

- 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



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

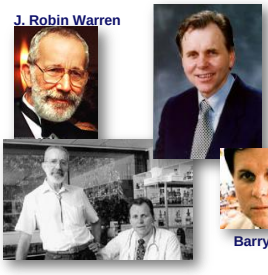


Revolutionizing Healthcare 1982 | 2005

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

Helicobacter pylori

J. Robin Warren



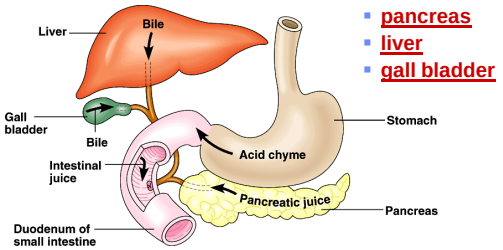
Barry Marshall

Small Intestine

- Function
  - chemical digestion
    - major organ of digestion & absorption
  - absorption through lining
    - over 6 meters!
    - small intestine has huge surface area = 300m^2 (~size of tennis court)
- Structure
  - 3 sections
    - duodenum = most digestion
    - jejunum = absorption of nutrients & water
    - ileum = absorption of nutrients & water

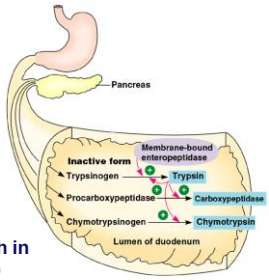
Duodenum

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



Pancreas

- Digestive enzymes
  - peptidases
    - trypsin
      - trypsinogen
    - chymotrypsin
      - chimotrypsinogen
    - carboxypeptidase
      - procarboxypeptidase
  - amylase
- Buffers
  - reduces acidity
    - alkaline solution rich in bicarbonate (HCO_3-)
    - buffers acidity of material from stomach



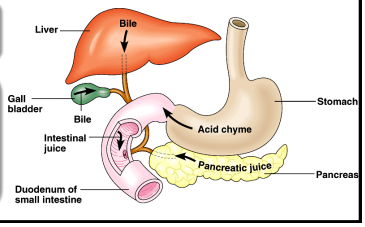
small intestines

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

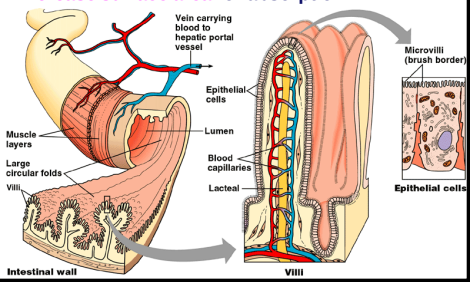


Digestive Enzymes

	(a) Carbohydrate digestion	(b) Protein digestion	(c) Nucleic acid digestion	(d) Fat digestion
Oral cavity, pharynx, esophagus	Polysaccharides (starch, glycogen) → Salivary amylase → Smaller polysaccharides, maltose			
Stomach		Proteins → Pepsin → Small polypeptides		
Lumen of small intestine	Polysaccharides → Pancreatic amylases → Maltose and other disaccharides	Polypeptides → Trypsin, Chymotrypsin → Smaller polypeptides → Aminopeptidase, Carboxypeptidase → Amino acids	DNA, RNA → Nucleases → Nucleotides	Fat globules → Bile salts → Fat droplets (emulsified) → Lipase → Glycerol, fatty acids, glycerides
Epithelium of small intestine (brush border)	Disaccharidases → Monosaccharides	Small peptides → Dipeptidases → Amino acids	Nucleotidases → Nucleosides → Nucleosidases → Nitrogenous bases, sugars, phosphates	

Absorption by Small Intestines

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

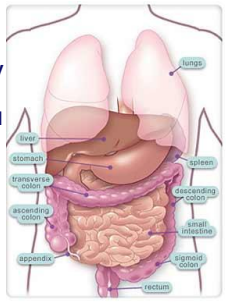


Absorption of Nutrients

- 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!

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

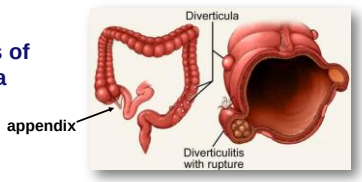


Flora of Large Intestines

- 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

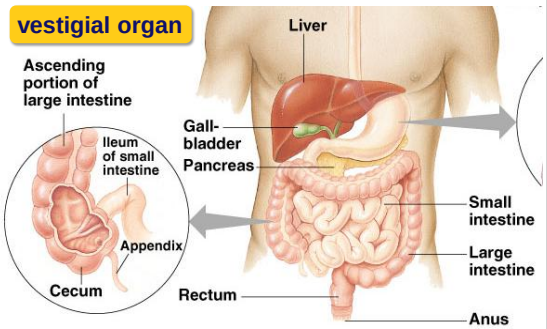
Rectum

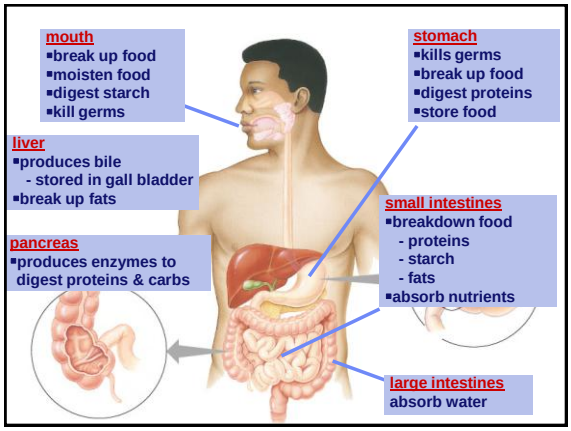
- Last section of colon (large intestines)
  - eliminate feces
    - undigested materials
      - extracellular waste
        - mainly cellulose from plants
        - roughage or fiber
    - salts
    - masses of bacteria

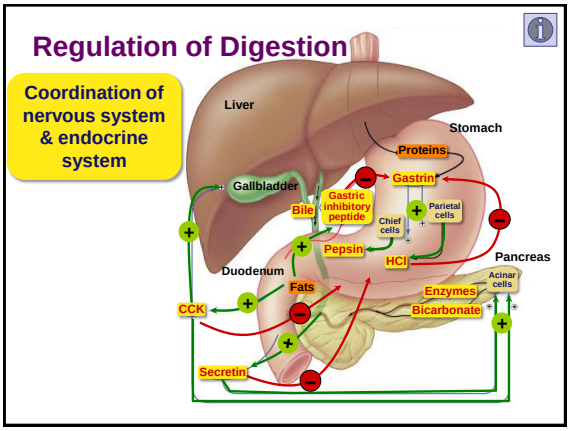


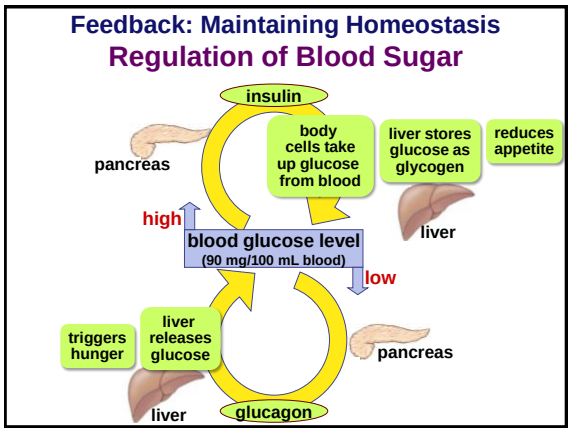
Appendix

vestigial organ









Managing Glucose Levels

- Mammals regulate use & storage of glucose
  - **insulin** reduces blood glucose levels
    - glucose levels rise above set point, pancreas secretes insulin
    - promotes transport of glucose into cells & storage of glucose (as glycogen) in liver & muscle cells
    - drops blood glucose levels
  - **glucagon** increases blood glucose levels
    - when glucose levels drop below set point, pancreas secretes glucagon
    - promotes breakdown of glycogen & release of glucose into the blood
    - raises blood glucose levels

Regulating Intake of Food

- Studies in mice…
  - **Ob allele**
    - wild type Ob/_ produces leptin (provides feedback to reduce appetite)
    - recessive mutation ob/ob does not
  - **Db allele**
    - wild type Db/_ produces leptin receptors
    - recessive mutation db/db does not
  - **Ghrelin**
    - hormone produced by stomach— works on hypothalamus
    - stimulates appetite (high before meals, low after)

This obese mouse (L) has defect in gene which normally produces leptin, an appetite-regulating protein.