Comparative Digestive Physiology

Gastrointestinal Anatomical Adaptations

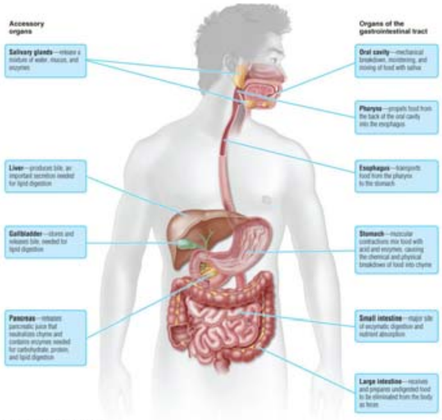
- Why important to nutrition?
  - The type of GI structure affects the type, rate and form of nutrients absorbed
  - Certain foods or feedstuffs are preferred
- Animals have evolved to accommodate a certain food supply (adaptation)
- The manner in which food is digested and absorbed drastically affects metabolism and nutrient requirements

GI Adaptations

- Distinctions are not always clear
- Classification by types of diets (i.e., carnivores, omnivores, herbivores, etc.) is not necessarily an accurate depiction of GI tract function
  - Many overlapping features such as significant hind-gut fermentation

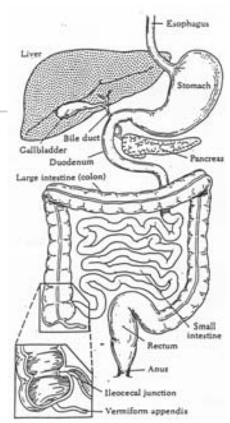
Symbiotic Relationship with Microbes

- All animals have microbes within their GI tract
- Importance to digestion depends on type of diet (form of nutrients) consumed
- Allows use of food and feed high in dietary fiber

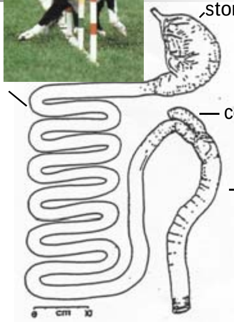


Human Digestive Tract

Simple gastric pouch & intestinal tract with small amounts of microbial digestion in large intestine



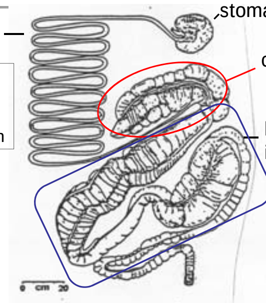
Dog



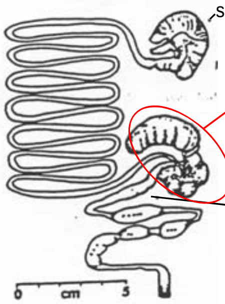
Simple gastric pouch & intestinal tract with small amounts of microbial digestion in large intestine

Horse

Simple gastric pouch but large intestine has substantial microbial digestion; cecum contributes to microbial digestion

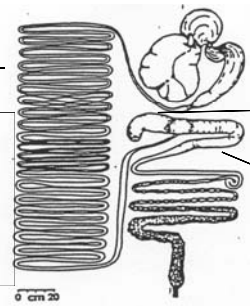


Rat



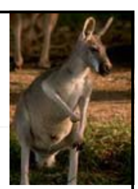
Simple gastric pouch but substantial microbial digestion in cecum

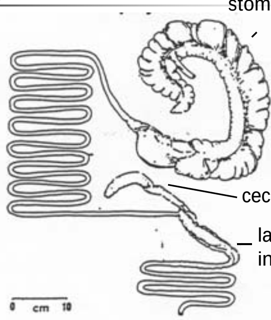
Sheep



Substantial pregastric fermentation; some potential for microbial digestion in large intestine and cecum

Kangaroo





Substantial pregastric fermentation; some potential for microbial digestion in large intestine and cecum

Capacity of Digestive Tracts

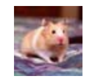
	Human	Pig	Horse	Sheep	Cattle
BW, kg	75	190	450	80	575
Rumen, liters	...	...	...	17	125
Omasum	...	...	...	1	20
Abomasum	1	8	8	2	15
Total stomach	1	8	8	20	160
Small intestine	4	9	27	6	65
Cecum	...	1	14	1	10
Large intestine	1	9	41	3	25
Total GI	6	27	90	30	260

Anatomical Classification

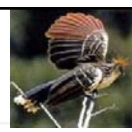
- Significance of fermentative digestion
  - All mammals have some fermentative capacity
  - Importance is directly related to fiber consumption

Anatomical Classification

- Pregastric fermentors
  - Importance of domestic ruminants in animal production
    - Cattle, sheep
  - Other well-known pregastric fermentors include macropod marsupials (e.g., kangaroo), hippopotamus and hamster



Pregastric Fermenters



Class	Species	Dietary habit
Ruminants	Cattle, sheep	Grazing herbivores
	Deer, antelope, camel	Selective herbivores, including folivores and frugivores
Nonruminants	Colobine monkey, hamster, vole	Selective herbivores
	Kangaroo, hippo	Grazing and selective herbivores
	Hoatzin	Folivore

Anatomical Classification

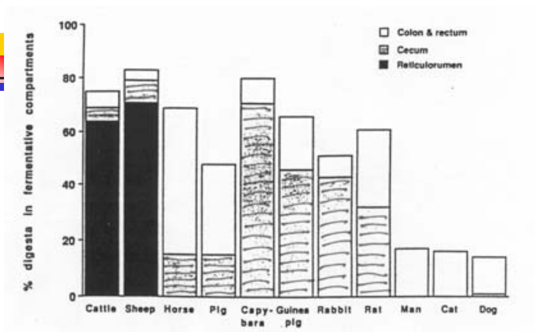
- Postgastric fermentors
  - Cecal fermentors
    - Mainly rodents and other small herbivores
    - Often associated with coprophagy
  - Colonic fermentors
    - Includes true herbiovores (e.g., horse) and elephant, omnivores (e.g., pig and human), and carnivores (e.g., cat and dog)
    - Degree of colonic sacculation is related to importance of fiber digestion and fermentative capacity

Postgastric Fermenters

Class	Species	Dietary habit
Cecal digesters	Capybara	Grazer
	Rabbit	Selective herbivores
	Rat, mouse	Omnivores
Colonic digesters		
Sacculated	Elephant, horse, zebra	Grazers
	New World monkeys	Folivores
	Pig, human	Omnivores
Unsacculated	Panda	Herbivores
	Dog, cat	Carnivore

Anatomical Classification

- The comparative importance of fermentation is related to the fraction of total digesta contained in fermentative compartments of the gastrointestinal (GI) tract



Adaptations to Feed Sources

- Gastric capacity and structure
  - Capacity is greatest in pregastric fermentors
    - Stomachs act as reservoir
  - Small stomach in carnivores is related to high nutrient density of the diet
  - Distribution and composition of epithelial lining varies between species and dietary adaptations

Adaptations to Feed Sources

- Intestinal length and functions
  - Small intestine
    - Less variable among species than stomach and hind gut, but generally shorter in carnivores than in herbivores
  - Large intestine
    - Importance of hind gut fermentation dictates variation in structure and size
    - Some hind gut fermentation occurs in most species

Fiber Digestion

- Ruminants vs Nonruminants

In general, pregastric fermentation increases the efficiency of fiber digestion.

Larger nonruminants offset their digestive efficiency by eating and passing more.

Smaller nonruminants select more digestible forage components and/or practice coprophagy

Pregastric Functions

- Prehension
  - Mechanisms vary with behavior and diet
    - Forelimbs
      - Primates, raccoon
    - Snout
      - Elephant, tapir
    - Tongue
      - Anteater, cow
    - Lips
      - Horse, sheep

Pregastric Functions

- Mastication
  - Physical reduction of feed
  - Especially important in nonruminant herbivores
  - Adaptations
    - Carnivores
      - Large canines and incisors
    - Herbivores
      - Specialized molars
    - Edentates (sloths, armadilloes, anteater)
      - Relative toothlessness

Pregastric Functions

- Salivation
  - 3 types of salivary glands based upon secretion
    - Serous – water and electrolyte rich (good buffer)
    - Mucous – protein and enzyme rich
    - Mixed – produces both serous and mucous secretions

Salivary Glands

Gland	Type of secretion	Main constituents
Parotid	Serous	Water, enzymes, ions
Submaxillary	Mucous or mixed	Mucin (mucous), mucin plus enzymes (mixed), water
Sublingual	Mucous or mixed	Mucin (mucous), mucin plus enzymes (mixed), water

Pregastric Functions

- Salivation
  - Varies little with diet but quantity and composition of saliva varies considerably
  - Amount of secretion
    - Human 1 liter/d
    - Sheep 4-8 liters/d
    - Horse 10-12 liters/d
    - Steer 40 liters/d
    - Cow 130-180 liters/d

Saliva

- Functions
  - Main role is to lubricate and moisten feed
  - Minor role in starch digestion (salivary amylase in humans and rodents)
  - Significant role in rumen buffering
  - N recycling (urea)
  - Contains many GI regulatory hormones such as EGF, IGF, and peptide YY

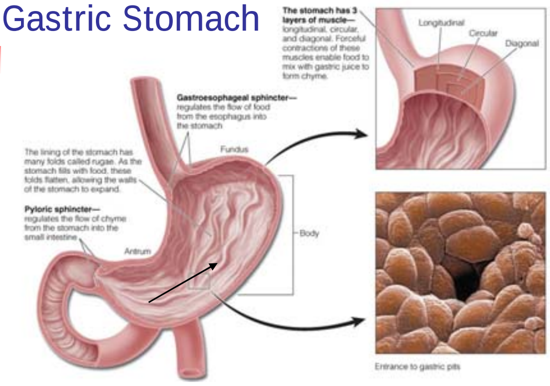
Pregastric Functions

- Deglutition (swallowing)
  - Reflex initiated by presence of food in pharnyx
  - Propulsion of food to stomach by esophageal peristalsis

Gastric Digestion

- Functions
  - Reservoir for controlled release of digesta to small intestine
  - Mechanical breakdown of food/feed
  - Hydrolytic digestion by acid and enzymes
    - Mainly protein

Gastric Stomach



1. Temporary Storage for Food

- Rugae
  - Convoluted pleats in interior lining of stomach
- Mechanoreceptors used to trigger feeling of fullness
  - Brain causes hunger to diminish

2. Production of Gastric Secretions

- Gastric pits contain:
  - Exocrine cells (parietal, chief, mucus cells)
    - Release secretions of water, hydrochloric acid (HCl), digestive enzymes, mucus, intrinsic factor
    - Forms gastric mucosal barrier
  - Endocrine cells (G cells)
    - Release hormones into blood

Gastrin

- Hormone
- Regulates gastric juice
- Released by G cells
- Stimulates release of HCl, intrinsic factor, & pepsinogen

HCl

- Dissolves food particles
- Destroys bacteria
- Provides acidic environment (pH 2-3) in which digestive enzymes function
- Converts pepsinogen to pepsin
  - Pepsin begins breakdown of protein

Nursing Neonate

- Rennin is produced by the gastric mucosa in calf, lamb and kid
  - coagulates milk proteins

Gastric Digestion

- Chief cells produce pepsinogen and gastric lipase found mainly in human infants, rabbits, horses, dogs and pigs
- Parietal cells produce HCl and intrinsic factor
  - HCl denatures protein and assists in the activation of pepsinogen to pepsin
  - Intrinsic factor is a protein important for the binding and absorption of vitamin B_{12}