INTRODUCTION

General

A. Concept

Continuous series of interconnected hollow tubes

B. Functions

1. Primary

a. Digestion

b. Absorption

2. Secondary

a. Ingestion -- receive food

b. Propulsion -- move food

c. Egestion -- elimination of unabsorbed residue

C. Extent & Components

1. Alimentary (gastrointestinal or G-I) tract (canal)

a. Comprises main tube

b. 29-30 feet (~29M) long -- only 1.5 feet(46 cm) superior to diaphragm

2. Principal organs

a. Mouth

b. Pharynx

c. Esophagus

d. Stomach

e. Small intestine

f. Large intestine

3. Accessory (secondary) organs

a. Teeth

b. Tongue

c. Salivary glands

d. Liver

e. Gallbladder

f. Pancreas

g. Nose -- olfactory receptors

D. Basic Wall Layers *[except mouth & pharynx]*

1. Mucosa

a. Epithelium

- Lines lumen of tube
- Stratified squamous, simple columnar or pseudostratified
- Protection, secretion & absorption

b. Connective tissue (basement membrane)

- Loose (areolar) basically
- Binds epithelium
- Vascular -- nourishment & absorption

c. Glands

- Mucus producing
  - Goblet & multicellular
  - Lubrication & moistening
- Chemical digestive substances

- Both mucus and chemical digestive substances

d. Muscularis mucosa

- Outermost portion
- Causes wrinkling to alter lumen surface area

2. Submucosa

a. Connective tissue

- Loose -- vascular
- Flexible binding of mucosa to muscularis externa, permitting separate movements

b. Glands

- Not present in all organs
- Mucous producing

c. Submucosal (Meissner's) plexus

- Nervous tissue
- Controls glandular secretions and blood flow

3. **Muscularis externa**

a. General

- Thickest layer
- Smooth, skeletal or a combination
- 2 or 3 component layers

b. Component layers

- Circular
  - Innermost (if only 2 layers)
  - Always present

- Constricts food in lumen

- Longitudinal
  - Outermost
  - Always present
  - Pushes along food in lumen
- Oblique
  - Only in stomach -- innermost
  - Pushes food in different direction from longitudinal

c. Myenteric (Auerbach's) plexus

- Nervous tissue -- between circular & longitudinal
- Coordinates muscular contractions

4. **Serosa or adventitia**

a. General

- Outer covering
- Interface between organ & surroundings

b. Serosa

- Covers abdominal organs
- Serous membrane -- simple squamous
- Part of visceral peritoneum
- Secretes serous fluid -- lubrication

c. Adventitia

- Covers thoracic & pelvic organs
- Connective tissue

- Variable thickness & composition

Digestion

A. Concept

1. All changes in & processing of ingested food which render it absorbable

2. Both physical & chemical aspects

B. Physical

1. Meaning -- changes & processing which do not involve chemical reactions

2. Examples

   a. Chewing

   b. Mixing

   c. Lubrication & moistening

   d. Movement (e.g. peristalsis)

   e. Egestion

   f. Release of secretions

   g. Ingestion

C. Chemical

1. Hydrolysis

   a. Meaning

   - Enzymatic splitting of compound molecule via water addition

   - Restores H_2O (H^+ & OH^-) lost during dehydration (condensation) bonding to form compound molecule (e.g. polymer) from smaller components (e.g. monomers)

b. Significance -- most common reaction type

2. Non-hydrolytic reactions

a. Account for very few reactions

b. E.g. -- fat emulsification

D. Control

1. Nervous

a. Local -- enteric

- Submucosal & myenteric plexuses
- Can function independently of CNS

b. Central -- via visceral (autonomic) nervous system

- General
  - Via visceral (autonomic) nervous system
  - Modifies inherent enteric control
- Parasympathetic -- stimulatory
- Sympathetic -- inhibitory

2. Hormonal *[most details later]*

a. Local – enteroendocrine

b. Typical distant source

3. Food itself

a. Chemical -- e.g. pH effect on enzyme activity; fats

b. Mechanical -- e.g. pressure effect on muscular action

Absorption

A. Concept – transport of fully chemically digested nutrient molecules/ions from the lumen of the digestive tract through the lining epithelium into blood and lymphatic vessels

B. Locations & Relative Amounts

1. Mouth -- none
2. Pharynx -- none
3. Esophagus -- none
4. Stomach -- slight
5. Small intestine -- overwhelming majority
6. Large intestine -- moderate
7. Accessory organs -- none

B. Mechanisms

1. Passive
    a. Diffusion
    b. Facilitated diffusion
2. Active transport

MOUTH

Boundaries

1. Teeth & lips -- anterior & lateral
2. Palate -- superior & lateral (partial)

3. Tongue -- inferior

4. Fauces

    a. Posterior

    b. Opening into pharynx

5. Buccal (cheeks) lateral

Palate

A. Hard

1. Location & relations

    a. Anterior palatal portion -- roof of mouth

    b. Anterior floor of nasal passages

2. Structure

    a. Bone

    b. Stratified squamous epithelium -- some keratinized

3. Function -- keeps nasal passages open, despite pressures from chewing & other mouth movements

B. Soft

1. Location & relations

    a. Posterior portion -- roof of mouth

    b. Posterior floor of nasal passages

2. Structure

    a. Mucosa -- non-keratinized stratified squamous

    b. Muscle -- skeletal

    c. Connective -- various

3. Function -- moves up during swallowing to close off posterior nares

4. Uvula

    a. Hangs from mid-posterior edge

    b. Core of skeletal muscle

    c. Function -- initiate swallowing reflex & nasal closure

C. Glands *[later]*

Tongue

A. General

1. Oral portion

    a. Within mouth cavity

    b. Anterior two-thirds

2. Pharyngeal portion

    a. Within oropharynx

    c. Posterior one-third

B. Structure

1. Mostly skeletal muscle -- bundles in many directions

2. Mucous membrane covering

    a. Non-keratinized stratified squamous -- most

    b. Keratinized stratified squamous -- tip

3. Papillae

    a. Bumps & projections

b. 4 kinds (shapes)

- Unevenly distributed
- Increase surface area

4. Frenulum

a. Mid-inferior membrane

b. Attaches tongue to floor of mouth

5. Glands *[later]*

6. Taste buds

a. Embedded in mucosa -- dorsal & lateral

b. Also in soft palate and epiglottis

C. Functions

1. Taste -- smell involved, also
2. Chewing -- positions food between teeth
3. Mixing food

a. With saliva

b. With mucus

c. Some breakup from pushing against surfaces

4. Lubrication of food -- mucous glands
5. Hydrolysis -- salivary glands
6. Deglutition -- swallowing
7. Speech
8. Immunity -- lymphatic tissue *[details late]*
9. Touch – tactile receptors

Lymphatic Tissue

A. General

1. Extent -- extensive compared with rest of body
2. Purpose -- first line of defense

B. Tonsils

1. Macroscopic -- actually within oropharynx
    a. Lingual
    b. Palatine
2. Microscopic -- thousands, embedded in mucosa
    a. Lingual
    b. Palatine
    c. Buccal
    d. Gingival
    e. Labial

Salivary Glands

A. Macroscopic

1. Parotid
    a. Largest
    b. Duct -- opens at 2nd upper molar
2. Submandibular (submaxillary)

a. Medium-size

b. Duct -- opens beside base of frenulum

3. Sublingual

a. Smallest

b. Ducts

- 10-20
- Open floor of mouth separately or join submandibular duct

B. Microscopic

1. Thousands -- embedded in mucosa

2. Locations

a. Lingual

b. Palatine

c. Buccal

d. Gingival

e. Labial

C. Functional Structure

1. Acini (alveoli)

a. Secretory units

b. Ovoid, hollow, thick-walled

c. Lining cells produce secretion

d. Myoepitheliocytes -- release & move secretion

e. Organization

- Only a few in microscopic
- Macroscopic -- lobular subdivisions

2. Ducts

a. Intercalated -- from each acinus

b. Others

- Junction of two or more intercalated
- Larger glands have tree-like structure with several to many branching levels, following lobular structure
- Secretory duct cells – some

3. Variations -- whole gland or individual acini

a. Mucus-secreting

- Glycoproteins + water + electrolytes
- Lubricates, moisturizes, protects

b. Serous

- Chief (zymogenic) cells – more granular
- Water, ions (e.g. pH buffering) & enzymes

c. Sero-mucous

- Intermediate chief cell type
- Both mucous & serous secretions

D. Secretion -- saliva *[details later]*

E. Control

1. Nervous -- parasympathetic

a. Salivatory center -- medulla

b. Satiety center -- hypothalamus

2. Causes (stimuli)
    a. Mechanical -- anything in mouth
    b. Smell
    c. Taste
    d. Visual
    e. Hearing
    e. Thoughts

Teeth

A. Location

1. Embedded in maxilla & mandible
2. Alveoli -- sockets
3. Gingiva -- gums
    a. Covers bone & joins tooth
    b. Continuous with general oral mucosal lining

B. Structure

1. Dentin
    a. Main substance
        - Calcified connective tissue
        - Gives overall shape
    b. Odontoblasts
        - Adjacent to pulp cavity
        - Secrete dentin

2. Enamel

    a. Covers dentin of crown

    b. Ameloblasts

        - Die before tooth erupts
        - Secrete enamel

    c. Structure

        - 98% mineralized -- very hard
        - Calcium salts
        - Arranged in parallel hexagonal prismatic rods

3. Cementum

    a. Thin mineralized connective tissue

    b. Tightly adhering layer around dentin of root

    c. Substrate for intimate attachment of surrounding periodontal ligaments

4. Periodontal ligaments

    a. Dense fibrous connective tissue

    b. Anchor tooth to surrounding bony alveolus

    c. Shock absorption -- give somewhat with stresses

C. Types & Age Changes

1. Four types

    a. Incisors -- biting & tearing

    b. Canines (cuspids) -- biting & tearing

    c. Premolars (bicuspids) -- grinding

d. Molars -- crushing & grinding

2. Two sets

a. First -- temporary

- 20 teeth -- 4-I/2-C/4-M @ jaw
- Erupt 7.5-24 months
- Shed 7-12 years

b. Second -- permanent

- 32 teeth -- 4-I/2-C/4-P/6-M @ jaw
- Erupt 7-24 years

Digestion

A. Physical

1. Mastication

a. Chewing

b. Increases surface area

2. Mixing with saliva

a. Softening

b. Lubrication

c. Exposure to chemical digestive substances

3. Deglutition -- swallowing

a. Reflex initiated -- continues in pharynx & esophagus

b. Bolus -- food/saliva mass

B. Chemical

1. Composition of saliva -- secreted by acini, unless otherwise noted

a. Water -- 99.5% volume

- Medium for other components
- Softening/physical breakup
- Excreted -- some

b. Mucus

- Lubrication & softening
- Protection
  - Physical -- coats surfaces
  - pH -- buffers against excess acid or base

c. Bicarbonate (HCO_3^-) -- buffers pH to 6-7

- Optimum pH for hydrolysis
- Very acidic pH would promote enamel erosion
- Secreted by duct cells -- exchanged for Cl^-

d. Potassium (K^+)

- Excreted
- Secreted by duct cells -- exchanged for Na^+

e. Bacteriostatic substances & action

- Washing action -- total saliva
- Antibodies
  - Specific for oral bacteria
  - From duct cells

- Proteolytic
  - E.g. lysozyme
  - From duct cells

f. Enzymes

- Ptyalin (salivary amylase)
  - Majority
  - Hydrolyses starches *[details below]*
- Others
  - Trace amounts -- disputed action
  - e.g. maltase, lipase, protease

2. Starch hydrolysis

a. Ptyalin hydrolyses starches

- Amylose, amylopectin, glycogen
- Progressive breakdown to smaller units
  - Dextrins -- oligosaccharides of 5-8 glucose residues
  - Maltose -- disaccharide

b. Efficiency of ptyalin

- Basically depends on time in mouth
- Remains active 30 min. (max.) in stomach, until bolus breaks up completely
- 70% of bread/potato starch hydrolyzed
- Other amylases finish process in small intestine

PHARYNX

Structure

A. Basic

1. Location -- base of skull
2. Shape
    a. Musculo-membranous tube
    b. Flattened anterior to posterior

B. Mucosa

1. Non-keratinized stratified squamous in digestive regions
2. Pseudostratified in respiratory regions

C. Muscles

1. Constrictors -- superior, middle, inferior
2. Others -- join with soft palate (e.g.)

D. Glands -- mucus-producing

E. Regions

1. Nasopharynx
    a. Entirely respiratory
    b. Openings
        - From posterior nares
        - Eustachian tubes

- Into oropharynx with fauces

2. Oropharynx

    a. Dual respiratory & digestive

    b. Continues inferiorly as laryngopharynx

3. Laryngopharynx

    a. Dual respiratory & digestive

    b. Adjacent to glottis

    c. Joins esophagus inferiorly

Function -- Deglutition (Swallowing)

A. First Phase

1. Voluntary -- conscious control

2. Tongue elevates & pushes bolus in tip to posterior wave through fauces into oropharynx

3. Hyoid elevated & moved forward

B. Second Phase

1. Involuntary -- unconscious, automatic control

2. Soft palate elevated & held against posterior wall, to block nasopharynx

3. Glottis blocked

    a. Larynx elevated & moved forward

    b. Epiglottis folded laterally

    c. Vocal folds come apposed (come together)

4. Superior & middle constrictors push bolus down past glottis

C. Third Phase

1. Involuntary

2. Inferior constrictor squeezes bolus into esophagus

D. Control

1. Deglutition center in lower pons & medulla

2. Sensory input from tactile receptors in soft palate & oropharynx near fauces

ESOPHAGUS

Structure

A. Basic

1. 10 inches long (25cm)

2. Continuation of G-I tract from pharynx to stomach

3. Posterior to trachea, lungs & heart

4. Mostly in midline -- lower part passes slightly left

5. Runs through diaphragm to join stomach

B. Regions

1. Cervical

   a. Within neck

   b. Joins laryngopharynx

2. Thoracic

    a. Within mediastinum

    b. Longest

3. Abdominal

    a. Below diaphragm

    b. Joins cardiac stomach

C. Wall

1. Four basic layers *[previously covered]*

2. Specializations

    a. Mucosa -- non-keratinized stratified squamous

    b. Submucosa -- numerous alveolar-shaped mucous glands

    c. Muscularis externa -- circular & longitudinal

        - Skeletal in cervical region
        - Combination skeletal & smooth in thoracic
        - Smooth in abdominal

    d. Adventitia -- except abdominal region

Function

A. Concept

1. Peristalsis -- wave-like, rhythmic, sequential motion along organ's length to propel bolus down into stomach

2. Continuation of deglutition reflex from pharynx

3. Not limited to esophagus -- small & large intestines, also

B. Mechanism

1. Basic -- alternating coordinated contractions of circular & longitudinal muscle layers

    a. Circular

        - Precise narrow portion of layer first contracts just above bolus
        - Prevents bolus going wrong direction

    b. Longitudinal

        - Starts just below constriction from circular
        - Contracts around bolus to squeeze downward

2. Continuation

    a. From repeats of circular/longitudinal coordinated contractions

    b. Massaging action occurs lower each time, until stomach reached

3. Stomach entry

    a. Lower 1-2 in. (2.5-5cm) has sphincter-like thickened circular muscle

    b. Relaxation at appropriate time for bolus to enter

    c. Closure at other times helps protect from highly acidic stomach contents

4. Role of different muscle types

    a. Skeletal contracts faster than smooth

    b. Helps insure propulsion downwards

5. Role of gravity

    a. Swallowing can occur in any body position

    b. Gravity provides some assistance

C. Control

1. Local

a. Myenteric plexus

b. Produces basic mechanism

c. From physical detection of & responses to presence of bolus as it progresses downwards

2. Central

a. Nervous impulses from deglutition center

b. Overall control & coordination with pharyngeal stage of deglutition

STOMACH

Structure

A. General

1. Shape -- flattened J-shaped dilation of G-I tract

2. Orientation

a. Flat surfaces oriented obliquely

b. Lesser curvature to the right & turned superiorly

c. Greater curvature to the left & oriented inferiorly

3. Capacity -- about 1 L.

B. Regions & Openings

1. Cardia

a. Cardiac orifice opening from esophagu

b. Cardiac region very small adjacent area

2. Fundus

a. Bulge superior & to the left of cardia

b. Function & microscopic structure same as body

3. Body

a. Inferior to fundus

b. Majority of stomach

4. Pylorus

a. Inferior narrowed portion, joining duodenum

b. Pyloric orifice surrounded by pyloric sphincter

C. Wall Modifications

1. Mucosa

a. Simple columnar epithelium

b. All cells secrete mucus -- non-goblet, though

c. Rugae

- Prominent, irregular ridges
- Provide increased surface area
- Flatten out as stomach fills
- Involves submucosa as well

d. Gastric pits -- openings into gastric glands *[below]*

2. Submucosa

a. Thick & rather loose connective tissue

b. Permits extreme flexibility to give during filling expansion, providing gliding surface for flattening of rugae

c. Involves mucosa as well

3. Muscularis externa -- extra, innermost oblique layer

4. Serosa

a. Greater omentum

b. Lesser omentum

Glands

A. General

1. Gastric pits

a. Mucosal surface pock-marks

b. Deeper in mucosa change into gastric glands

c. General epithelial lining continues until glands

2. Gastric glands

a. Run through rest of mucosa up to muscularis mucosae

b. Tubulo-acinar in shape

c. 3 types *[below]*

3. Gastric juice -- collective secretions of all glands and from general lining (including pit cells)

B. Cardiac Glands

1. Only in cardia

2. General lining cells continue relatively unchanged

3. Secrete mucus

C. Fundic Glands

1. In fundus & body -- most numerous

2. Relation to gastric pits

    a. Each pit has up to 3 smaller branches -- secondary pits

    b. Each secondary pit has up to 3 actual fundic glands

3. Cell types

    a. Mucus-secreting -- in upper portions & pits

    b. Parietal (oxyntic)

    c. Chief (zymogenic or peptic) -- secrete most gastric juice components

D. Pyloric Glands

1. Within pylorus

2. Appear similar to cardiac glands

3. Cell types

    a. Mucus-secreting

    b. Chief

Gastric Juice & Digestion

A. Water

1. 99.5%

2. From chief cells

3. Same functions as in saliva

B. Hydrochloric Acid

1. Secreted by parietal cells

2. pH

    a. Upon secretion -- 0.9

    b. When diluted within lumen -- 2.5

    c. Thick mucous layer protects stomach wall

3. Functions

    a. Activation of enzymes

    b. Proper environment for enzyme action

    c. Denature ingested proteins -- they swell to increase surface area, exposing more peptide bonds for hydrolysis

    d. Bacteriostatic -- very effective

C. Pepsinogen

1. Secreted by chief cells

2. Inactive form of enzyme -- zymogen form, generically

3. Activation

    a. HCl converts to active pepsin

    b. Protective mechanism to protect chief cells

4. Action

    a. A protease (proteinase)

    b. Hydrolyses proteins to various forms

        - Mostly smaller polypeptides
        - Some small peptides
        - Very little free amino acids

5. Importance

    a. Not essential -- small intestinal proteases are varied &

abundant

b. Does initiate complicated protein digestion

D. Lipase

1. Secreted by chief cells
2. A tributylase -- hydrolyses tributin (butterfat)
3. Weak & not essential in this organ

E. Gastric Amylase

1. Secreted by chief cells
2. Identical in structure & function with ptyalin
3. Little or no importance -- inhospitable pH

F. Mucus

1. Secreted by all glands & general lining epithelium
2. More viscous than usual

3. Functions

a. Protection

- From acidity
- Forms thick coating on wall

b. Lubrication

G. Intrinsic Factor

1. Secreted by parietal cells

2. Binds with vitamin B_{12} for later absorption

3. Stomach's only absolutely essential secretion [conceptually speaking]

Absorption

1. Performed by general epithelial lining

2. Very restricted

   a. Mucous layer & tight junctions between cells

   b. Only alcohol and some drugs -- lipid-soluble

   c. Some water

Regulation of Secretion

A. Nervous

1. Sources

   a. Brain -- parasympathetic stimulation

   b. Enteric -- local

2. Stimuli

   a. Brain -- same as salivary

   b. Enteric

      - Distention
      - Tactile
      - Chemical -- especially protein in food & acid secretion

3. Effects

    a. Gastric juice secretion -- all components

    b. Hormone release *[details below]*

    c. Movements *[details later]*

B. Hormonal

1. General

    a. Part of very complicated & interrelated gastro-entero-pancreatic (GEP or just entero-) endocrine system

    b. Recepto-secretory cells are neuroendocrine type – also termed enteroendocrine

    c. Polypeptides, peptides or amines

2. Gastrin

    a. From G-cells of pyloric glands & duodenal glands

    b. Stimuli for secretion

        - Nervous
        - Presence of food in stomach
        - Small intestinal -- e.g. undigested proteins

    c. Effects

        - Release of gastric juice -- mostly acid
        - Muscular movements -- general churning

3. Histamine

    a. From mucosal mast cells (?)

    b. Stimulus -- acidity

    c. Effect -- reinforces gastrin & nervous effects

4. Inhibitory hormones

   Intestinal origin

   - Secretin, cholecystokinin (CCK), gastric inhibitory peptide (GIP), and others – from mucosa
   - Urogastrone – from duodenal glands – inhibits HCl
   - Stimuli -- food with acidity, fats, digested proteins or general irritation
   - Effects
     - Inhibit gastrin secretion
     - Slow stomach emptying

Phases of Gastric Secretion & Motility

A. Cephalic

1. Timing
   a. Before food reaches stomach
   b. Lasts only several minutes
2. Stimuli
   a. Before eating -- sight, smell & thoughts
   b. During eating -- tactile & taste
3. Cause -- parasympathetic impulses
4. Effects -- some secretion of gastric juice & gastrin

B. Gastric

1. Timing
   a. When food reaches stomach
   b. Lasts for about 3 hours

2. Stimuli-- direct presence of food

3. Causes -- parasympathetic, enteric & gastrin

4. Effects

    a. More gastric juice than cephalic

    b. General motility for mixing

C. Intestinal

a. Timing

    a. When small intestine receives food -- now chyme

    b. Lasts longer than gastric phase

b. Stimuli -- duodenal distention & chemicals in food

c. Causes -- parasympathetic, enteric & hormonal

d. Effects

    a. Decreased gastric juice

    b. Decreased motility & emptying

SMALL INTESTINE

Structure

A. General

1. About 22 feet long x 1 inch diameter (6.8M x 40mm)

2. Suspended from posterior abdominal wall

    a. By mesentery -- extension of covering serosa

    b. Continuous with lining parietal peritoneum

B. Regions & Openings

1. Duodenum
    a. Shortest -- 10 inches long (25cm)
    b. C-shaped
    c. Retro-peritoneal -- against body wall
    d. Opening from pyloric stomach
    e. Opening from bile/pancreatic ducts -- papilla
2. Jejunum
    a. About 8 feet long (2.5M)
    b. Irregular coils free within abdominal cavity
3. Ileum
    a. Longest -- over 12 feet long (3.7M)
    b. Unpredictably coiled like jejunum
    c. Ends at juncture with large intestine

C. Wall Modifications

1. General
    a. To increase surface area -- about 300 M^2
    b. If same surface, but smooth -- 13,700 feet long (4.2Km)
2. Circular folds (plicae circulares)
    a. Like corrugations -- project about 8mm into lumen
    b. Permanent -- do not flatten out like rugae
    c. Decrease in number in jejunum & few in ileum
3. Villi

a. Finger-like projections -- 0.5-1.0 mm into lumen

b. Cover circular folds & low areas between

c. Different shapes in each region

d. Fewest in ileum

e. Covered with simple columnar epithelium

- Absorptive cells -- most numerous
- Goblet cells

f. Vascular

- Extensive capillaries
- Central lacteal

4. Microvilli (brush border)

   Several thousand submicroscopic projections from each absorptive cell

Glands

A. Intestinal (Crypts of Lieberkühn)

1. Open into lumen as gastric glands do -- at bases of villi

2. Single tubular glands which run through rest of thickness of mucosa

3. Cells

   a. Upper & most of length -- continuation of absorptive/goblet lining

   b. Lower -- chief (different from gastric)

B. Duodenal (Brunner's)

1. Only within submucosa of duodenum

2. Alveolar -- empty into crypts – mucus

3. Reason – acidic chime from stomach

C. Pancreatic Acini *[only included here for convenience]*

1. Compound gland -- similar layout to macro-salivary

2. Secretions from 2 sources

a. Acinar chief (zymogenic) type cells

c. Duct cells -- both intercalated & larger

D. Gallbladder/Liver -- Bile

Chemical Digestion

A. Pancreatic Juice

1. Water

a. 98% by volume

b. From duct cells

c. Functions

- Medium for other components
- Some excretion

2. Bicarbonate

a. From duct cells

b. Buffers pH to necessary 8.0

3. Pancreatic amylase

a. From chief cells -- amylopsin

b. Contrasts with ptyalin

- More & wider range of activity
- More time for hydrolysis

c. Functions

- Finishes what ptyalin started
- Can hydrolyze most carbohydrates
- Result
  - Disaccharides -- most
  - Trisaccharides

4. Lipases

a. From chief cells

b. All types of lipids hydrolyzed

c. Steapsin (pancreatic lipase) -- most general

- Secreted as inactive steapsinogen
- Activated by bile salts *[later]*
- Fats to fatty acids & monoglycerides

d. Cholesterol esterase

e. Phospholipase

5. Proteases

a. From chief cells

b. Trypsin

- Secreted as inactive trypsinogen
- Activated by enterokinase from intestinal glands & previously activated trypsin

- Most proteins & polypeptides hydrolyzed to very small peptides

c. Chymotrypsin

- Secreted as inactive chymotrypsinogen
- Activated by trypsin
- Identical action with trypsin -- less, though

d. Carboxypeptidase

- Secreted as inactive procarboxypeptidase
- Activated by trypsin
- Splits some free amino acids from peptide ends

e. Others

- More specialized
- e.g. -- collagenase & elastase

f. Trypsin inhibitor

- Formed within chief cells
- Further protection against activation of trypsin & others intracellularly & in ducts

6. Nucleases

a. From chief cells

b. Hydrolyze nucleic acids -- DNA & RNA

c. Deoxyribonuclease & ribonuclease -- depolymerize

d. Nucleotidases & phosphatases -- finish

Bile

A. Water

1. 85% of volume
2. Medium & excreted

B. Pigments

1. Bilirubin -- from heme destruction
2. Excreted

C. Cholesterol -- excretion of excess

D. Bile Salts

1. Glycocholic (cholic acid + glycine) & taurocholic (taurine + glycine) acids
2. Functions
   a. Buffer
   b. Emulsify fats
      - Not hydrolysis
      - Breakup of large insoluble particles
   c. Activate steapsinogen
   d. Enhance absorption of digested lipids -- micelles
   e. Permit vitamin K and D absorption -- colon
   f. Stimulate peristalsis

Intestinal Juice

A. Sources

1. Intestinal glands
2. Duodenal glands
3. Goblet cells of general lining epithelium

B. Components

1. Water
2. Intestinal amylase
3. Mucus
4. Enterokinase *[covered above]*
5. Lysozyme – from intestinal glands -- antibacterial

Final Hydrolysis

A. Location

1. Microvilli
    a. Enzymes within absorptive cell membrane on villi
    b. Technically not secreted
    c. Site of absorption as well -- efficient
2. Some authorities differ -- say enzymes are released free into lumen when cells normally die & slough off

B. Enzymes

1. Disaccharidases (saccharidases)
    a. Maltase -- hydrolyses maltose

b. Sucrase -- hydrolyses sucrose

c. Lactase -- hydrolyses lactose

2. Aminopeptidases -- finish splitting small peptides into dipeptides, tripeptides and some amino acids

3. Phosphatases -- split phosphate from many molecules

4. Intestinal lipase -- splits fatty acids from glycerol

5. Enterokinase -- trypsin activator *[previously covered]*

Absorption

A. Regional Differences

1. Digested proteins, carbohydrates, lipids & nucleic acids

a. Most absorbed in duodenum & first half of jejunum

b. Rest of jejunum & ileum sort of a reserve

3. Ileum has special absorptive roles

a. Vitamin B_{12} (bound with intrinsic factor)

b. Most water & electrolytes

c. Most bile salts

B. Absorption into Villus Capillaries

1. Monosaccharides

a. Most by active transport from lumen into absorptive cells -- indirect, co-transport (coupled) with Na^+

- Na^+ continually diffuses into cells, due to steep concentration gradient being maintained by outward active transport

- Monosaccharides follow inward moving Na^+

b. A few transported by facilitated diffusion

c. Diffusion from absorptive cells into capillaries

2. Peptides & amino acids

a. Most by co-transport with Na^+

b. Some by facilitated diffusion

3. Digested nucleic acids -- active transport

4. Vitamins

a. Fat-soluble *[with fats -- below]*

b. Water-soluble

- B_{12} -- active transport
- Rest of B complex & C -- diffusion

5. Water

a. Mechanism

- Diffusion
- Follows osmotic gradient created by loss of lumen solute from transport of other substances

b. Sources & 24 hr. amounts in chyme

- Ingested -- 1500 ml
- Saliva -- 1500 ml
- Gastric juice -- 2000 ml
- Pancreatic juice -- 1500 ml
- Bile -- 500 ml
- Intestinal juice -- 2000 ml

c. Amounts -- 24 hr.

- Total in small intestine -- 9000 ml
- Absorption -- 7500 ml
- Feces only has 150 ml -- colon absorption

6. Electrolytes

a. Sodium -- co-transport & active transport

b. Potassium -- diffusion, from gradient produced by active transport of other ions

c. Calcium -- active transport

d. Magnesium -- active transport

e. Chloride -- diffusion, following sodium

f. Bicarbonate -- diffusion & facilitated diffusion

g. Phosphate, sulfate & nitrate -- active transport

C. Absorption into Villus Lacteals

1. Substances absorbed

a. Digested fats

b. Fat-soluble vitamins -- A, D, E & K

2. Mechanism

a. Micelles -- complex of several substances

- Fatty acids
- Monoglycerides
- Vitamins
- Cholesterol -- fatty acids removed

- Bile salts

b. Absorption

- Micelles are water soluble
- Adhere to microvillus membrane
- All except bile salts diffuse into cell
- Bile salts reusable to form more micelles

c. Cyclomicrons -- a lipoprotein complex

- Reconstituted fats & cholesterol
- Phospholipids
- Protein

d. Passage into lacteals

- Cyclomicrons soluble in cell membranes
- Diffuse into lacteals

Regulation of Secretion

A. Nervous

1. Local

a. Mechanical & chemical presence of chyme

b. Stimulates intestinal juice

2. Central

a. Parasympathetic impulses

b. Targets

- Pancreas to stimulate enzyme release from acini
- Gallbladder help promote emptying

B. Hormonal

1. Secretin
    a. Part of entero-endocrine system
    b. Source -- receptosecretory cells of duodenal mucosa
    c. Stimulus -- acidic chyme from stomach
    d. Effect
        - Water & bicarbonate from pancreatic ducts
        - Inhibits gastric secretion & motility
2. Cholecystokinin (CCK) – or cholechystokinin-pancreozymin
    a. Source -- duodenal mucosa
    b. Stimulus -- lipids & partially digested proteins in chyme
    c. Effects
        - Enzymes from pancreatic acini
        - Bile from gallbladder
        - Inhibits gastric secretion & motility
3. Enterokrinin
    a. Source -- duodenal mucosa
    b. Stimulus -- acidic chyme
    c. Effect -- buffering mucus from intestinal glands
4. Gastric inhibitory peptide *[previously covered]*
5. Gastrin *[previously covered]*
6. Glucagon (enteroglucagon)
    a. Source -- duodenal mucosa

b. Stimulus -- high glucose concentration in chyme

c. Effect -- insulin release from pancreatic islets

Physical Mechanisms

A. Peristalsis *[previously covered]*

B. Enterogastric Reflexes

1. Concept

   a. Cooperative nervous signals between stomach & small intestine

   b. Both enteric & central

2. Purposes

   a. Regulate stomach emptying

   b. Stimulate intestinal peristalsis

3. Types

   a. Stimulation of stomach emptying

   b. Inhibition of stomach emptying

C. Segmentation

1. Concept -- compartmentalization of chyme within different segments along intestine

2. Purpose -- retain chyme for mixing contractions & digestion for adequate periods before being moved on

D. Emptying

1. Relaxation of ileocecal valve from pressure gradient

2. Can be inhibited by reflex from colon if it is full

LARGE INTESTINE

Structure

A. Size -- about 8 feet long x 2.5 inches diameter (2.5M x 6.25cm)

B. Regions & Openings

1. Cecum
    a. Blind pouch for 2 inches (5cm) inferior to ileocecal valve
    b. Appendix extends from this
2. Colon
    a. Most of large intestine's length
    b. Regions
        - Ascending
        - Transverse
        - Descending
        - Sigmoid (pelvic)
3. Rectum -- from sigmoid colon, posterior, about 6 in. (15cm)
4. Anal canal
    a. Terminal region of 1.5 in. (3.75cm)
    b. Ends with anus (anal opening)
    c. Two sphincters control anus

C. Wall Modifications

1. Mucosa
    a. Not smooth -- nothing like rugae or circular folds
    b. Lining epithelium

- Goblet cells -- more numerous
- Absorptive cells

c. Intestinal glands (crypts)

- Structurally like small intestinal
- General lining epithelium continued

2. MUscularis externa

a. Taeniae coli

- Three narrow bands of longitudinal layer
- Shorter than rest -- cause gathering to cause pouching out of haustrae

b. Plicae semilunares

- Periodic circular layer constrictions, like loose sphincters
- Define boundaries between haustrae

Functions

A. Normal Microflora

1. Concept -- beneficial microbial population

2. Benefits

a. Decomposition of indigestible materials for easier passage

b. Synthesis -- by-products of their metabolism

- Vitamins -- K & some B complex
- Some amino acids

c. Protection against noxious microorganisms

B. Secretions

1. Mucus -- more lubrication due to drier feces
2. Bicarbonate -- buffering

B. Absorption

1. Synthesized vitamins & amino acids
2. Water
    a. About 1350 ml in 24 hr.
    b. Only 150 ml lost in feces
3. Electrolytes
    a. Sodium -- active transport
    b. Chloride -- follows sodium passively
4. Most of bile salts not absorbed in small intestine

C. Movements

1. Peristalsis -- very slow
2. Segmentation
    a. Haustrae assist
    b. Slow kneading movements in each segment
3. Mass movement
    a. <u>En masse</u> movements from each segment to more distal segment
    b. Feces in rectum (final segment) will initiate defecation reflex
    c. Periodic -- few times per day

D. Defecation (Egestion)

1. Internal anal sphincter
    a. Smooth muscle
    b. Rectum reaches threshold level of fullness from mass movement
    c. Pressure receptors initiate reflex relaxation
    d. Constriction can return if external sphincter does not relax
2. External anal sphincter
    a. Skeletal muscle
    b. Conscious relaxation for defecation
    c. Constriction maintained if defecation not desired
3. Actual defecation
    a. Longitudinal layer of rectum contracts to increase pressure
    b. Intra-abdominal pressure increased by contraction of abdominal wall muscles