

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 long – only 1.5 feet 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

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

1. Mucosa

- a. Epithelium
 - Lines lumen of tube
 - Non-keratinized stratified squamous or simple columnar
 - Protection, secretion & absorption
- b. Connective tissue
 - Loose (areolar) basically
 - Binds epithelium
 - Vascular – nourishment & absorption
- c. Glands
 - Mucous producing
 - Goblet & multicellular

- Lubrication & moistening
 - Chemical digestive substances
 - d. Muscularis mucosae
 - 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
 - Submucosal (Meissner's) plexus
 - Nervous tissue
 - Controls glandular secretions
 - Controls 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. Egestion

C. Chemical

1. Hydrolysis
 - a. Meaning
 - Enzymatic splitting of compound molecule via water addition

- Restores H₂O (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 [all details later]

3. Chemical – e.g. pH effect on enzyme activity

4. Mechanical – e.g. pressure effect on muscular action

Absorption

A. 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

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 mucous
 - 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 later*]

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
3. Variations – whole gland or individual acini
- a. Mucous-secreting
 - Glycoproteins + water + electrolytes
 - Lubricates, moisturizes, protects
 - b. Serous
 - Cells more granular
 - Water, ions (e.g. pH buffering) & enzymes
 - c. Sero-mucous
 - Intermediate 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 (bicuspid) – 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. Mucous
 - 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
 - Proteolytic – e.g. lysozyme
- 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 – mucous-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
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
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. 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 esophagus
 - 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 mucous – non-goblet, though
 - c. Rugae
 - Prominent, irregular ridges
 - Provide increased surface area
 - Flatten out as stomach fills
 - 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
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

B. Cardiac Glands

1. Only in cardia
2. General lining cells continue relatively unchanged
3. Secrete mucous

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. Mucous-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. Mucous-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. Mucous

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 B₁₂ for later absorption
3. Stomach's only absolutely essential secretion (excepting mucous)

Absorption

1. Performed by general epithelial lining
2. Very restricted
 - a. Mucous layer & tight junctions between cells
 - b. Only alcohol & some drugs – lipid-soluble

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. Secretory cells are neuroendocrine type
- 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
- a. Intestinal
 - Secretin, cholecystokinin (CCK), gastric inhibitory peptide (GIP) & others
 - From small intestinal mucosa
 - 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
- 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
 - 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
 - b. Irregular coils free within abdominal cavity
3. Ileum
- a. Longest – over 12 feet long
 - b. Unpredictably coiled like jejunum
 - c. Ends at juncture with large intestine

C. Wall Modifications

1. General
 - a. To increase surface area – about 300 M²
 - b. If same surface, but smooth – 13,700 feet long
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
- 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
 - b. Duct cells – both intercalated & larger

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
 - Finishes what ptyalin started
- 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
- d. Chymotrypsin
 - Secreted as inactive trypsinogen
 - Activated by trypsin
 - Identical action with trypsin – less, though
- e. Carboxypeptidase

- Secreted as inactive procarboxypeptidase
 - Activated by trypsin
 - Splits some free amino acids from peptide ends
- f. Others
- More specialized
 - e.g. – collagenase & elastase
- g. 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 & taurocholic 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 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. Mucous
4. Enterokinase [*covered above*]

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. Sucrose – hydrolyses sucrose
 - c. Lactase – hydrolyses lactose
2. Aminopeptidases – finish splitting small peptides into 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 B₁₂ (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
 - B₁₂ – 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. Source – duodenal mucosa
- b. Stimulus – acidic chyme from stomach
- c. Effect
 - Water & bicarbonate from pancreatic ducts
 - Inhibits gastric secretion & motility

2. Cholecystokinin (CCK)

- 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. Enterokinin
- 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
- B. Regions & Openings
 - 1. Cecum

- a. Blind pouch for 2 inches 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.
4. Anal canal
- a. Terminal region of 1.5 in.
 - 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. En masse 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