10
Digestive System

Introduction

The gastrointestinal system is the portal through which nutritive substances, vitamins, minerals, and fluids enter the body. Proteins, fats, and complex carbohydrates are broken down into absorbable units ***(digested)***, principally in the small intestine. The products of digestion and the vitamins, minerals, and water cross the mucosa and enter the lymph or the blood ***(absorption)***.

Digestion of the major foodstuffs is an orderly process involving the action of a large number of digestive enzymes.
Enzymes from the :

1. *Salivary and lingual glands* attack carbohydrates and fats.
2. *Enzymes from the stomach* attack proteins and fats.
3. *Enzymes from the exocrine portion* of the pancreas attack carbohydrates, proteins, lipids, DNA and RNA.
4. Other *enzymes that complete the digestive process are found in the luminal membranes and the cytoplasm* of the cells that line the small intestine.

The action of the enzymes is aided by the hydrochloric acid secreted by the stomach and the bile secreted by the liver.

The mucosal cells in the small intestine are called ***enterocytes***. In the small intestine they have a ***brush border*** made up of numerous microvilli lining their apical surface. This border is rich in enzymes. It is lined on its luminal side by a layer that is rich in neutral and amino sugars, the ***glycocalyx***. The membranes of the mucosal cells contain glycoprotein enzymes that hydrolyze carbohydrates and peptides and the glycocalyx is made up in part of the carbohydrate portions of these glycoproteins that extend into the intestinal lumen. Next to the brush border and glycocalyx is an ***unstirred layer*** similar to the layer adjacent to other biologic membranes. Solutes must diffuse across this layer to reach the mucosal cells. The mucous coat overlying the cells also constitutes a significant barrier to diffusion.

Substances pass from the lumen of the gastrointestinal tract to the interstitial fluid and thence to the lymph and blood by-

i. diffusion, ii. facilitated diffusion, iii. osmosis, iv. solvent drag, v. active transport, vi. secondary active transport (coupled transport), and vii. endocytosis.

Most substances must pass from the intestinal lumen into the mucosal cells (enterocytes) and then out of the enterocytes to the interstitial fluid, and the processes responsible for movement across the luminal cell membrane are often quite different from those responsible for movement across the basal and lateral cell membranes to the interstitial fluid.

(Ref. Ganong 22th edition, Page 447)

Digestion

Difinition: Digestion may be defined as a physiological process by which complex food particles are broken down into simple form, suitable for absorption and subsequent utilization.

Purpose of digestion

i. Supply energy to the body for activity.
ii. For the growth of the body.
iii. For the repair of wear and tear.
iv. For the reproduction and lactation.

Parts of digestive system

i. Mouth or buccal cavity with tongue
ii. Oropharynx
iii. Oesophagous
iv. Stomach.
v. *Small intestine :*
   a. Duodenum
   b. Jejunum and ileum
vi. *Large intestine:*
   a. Caecum
   b. Ascending colon
   c. Transverse colon
   d. Descending colon
   e. Sigmoid colon
   f. Rectum
   g. Anal canal.

Accessory parts of digestive system :

i. Teeth
ii. Salivary glands : Parotid, submandibular, sublingual
iii. Liver
iv. Pancreas
v. Gall bladder
vi. Other digestive glands in the wall of the digestive tract.

Alimentary tract : Extend from mouth to anus with their associated glands.

Gastrointestinal tract (GIT) : Extend from stomach to anus.

Table 10-4. Mean lengths of various segments of the gastro intestinal tract as measured by intubation in living humans.

Pharynx, esophagus, and stomach	65 cm
Duodenum	25 cm
Jejunum and ileum	260 cm
(Ref. Ganong 22th Edition) Colon	110 cm

Table 10-1 : **Local hormones with their source, cause of secretion and functions :**

Name	*Source*	*Cause of secretion*	*Site of action*	*Function*
1. Gastrin.	Antral mucosa of stomach.	Presence of food in stomach.	Stomach, lower oesophageal sphincter, small intestine, G. bladder.	1. Stimulates gastric acid & pepsin secretion. 2. Increases stomach motility. 3. Contracts lower oesophageal sphincter.
2. Secretin.	Duodenal mucosa. ductal cell.	Presence of acidic chyme into duodenum.	Pancrease Stomach	1. Increases hydrolytic type of pancreatic secretion. 2. Decreases gastric secretion of acid.
3. Cholecys-tokinine.	Mucosa of upper small intestine.	Presence of fatty substance, protein in duodenum.	Gall bladder.	1. Increases bile secretion. 2. Contraction of G. bladder. 3. Contraction of sphincter of oddi.
4. Pancreo zymine.	Mucosa of upper small intestine.	Presence of fatty substance, protein in duodenum.	Pancreas.	1. Ecbolic type of pancreatic secretion. 2. Decreases stomach Motility.
5. Gastric inhibitory peptide (G.I.P)	Mucosa of duodenum and jejunum.	Presence of fat and glucose in duodenum.	Stomach.	1. Inhibits gastric secretion & motility. 2. Stimulate intestinal secretion of water & electrolytes.
6. Vaso-active intestinal peptide (VIP)	Mucosa of duodenum and jejunum.	Presence of chyme in the intestine.	Intestine	1. Stimulates intestinal secretion of water and electrolytes.
7. Villikinin.	Intestine.	Presence of chyme in the intestine.	Villi	1. Increases the motility of villi. 2. Constriction of blood vessel.
8. Enterocrinin	Mucosa of upper S. intestine.	Presence of chyme in the intestine.	Intestine	1. Increases intestinal secretion.
9. Entero gastrone.	Duodenal mucosa.	Presence of fat in duodenum.	Stomach mucosa.	1. Inhibit gastric secretion.
10. Motiline.	Duodenal mucosa.	Presence of fat in duodenum.	Stomach mucosa.	1. Stimulates gastric motility & intestinal juice secretion.
11. Bombesin.	GIT mucosa.	Immunoreactivity.	Small intestine.	1. Increase gastric secretion 2. Increase motility of small intestine and gall bladder.

Others :

12. Somatostatin
13. Neurotensin
14. Substance P
15. Serotonin; glucagon
16. Opoid peptides
17. GRP gastrinreleasing peptide.

Table 10-2 : **Principal digestive enzymes. The corresponding proenzymes are shown in parentheses.**

Source	Enzyme	Activator	Substrate	Catalytic Function or Products
Salivary glands	Salivary alpha amylase	Cl^-	Starch	Hydrolyzes 1 : 4α Act linkages, producing α-limit dextrins, maltotriose, and maltose
Lingual glands	Lingual lipase	-	Triglycerides	Fatty acids plus 1 ,2-diacylglycerols
Stomach	Pepsins (pepsinogens)	HCI	Proteins and polypeptides	Cleave peptide bonds adjacent to aromatic amino acids
	Gastric lipase	-	Triglycerides	Fatty acids and glycerol
Exocrine pancreas	Trypsin (trypsinogen)	Enteropep-tidase	Proteins and polypeptides	Cleave peptide bonds on carboxyl side of basic amino acids (arginine or lysine)
	Chymotrypsins (chymo-trypsinogens)	Trypsin	Proteins and polypeptides	Cleaves peptide bonds on carboxyl side of aromatic amino acids
	Elastase (proelastase)	Trypsin	Elastin, some other proteins	Cleaves bonds on carboxyl side of aliphatic amino
	Carboxypeptidase A (pro-carboxypeptidase A)	Trypsin	Proteins and polypeptides	Cleaves carboxyl terminal amino acids that have aromatic or branched aliphatic side chains
	Carboxypeptidase B (pro-carboxypeptidase B)	Trypsin	Proteins and polypeptides	Cleaves carboxyl terminal amino acids that have basic side chains
	Colipase (procolipase)	Trypsin	Fat droplets	Facilitates exposure of active site of pancreatic lipase
	Pancreatic lipase	...	Triglycerides	Monoglycerides and fatty acids
	Cholesteryl ester hydrolase	...	Cholesteryl esters	Cholesterol
	Pancreatic alpha-arnylase	Cl^-	Starch	Same as salivary alpha amylase
	Ribonuclease	...	RNA	Nucleotides
	Deoxyriibonuclease	...	DNA	Nucleotides
	Phospholipase A_2 (prophospholipase A_2)	Trypsin	Phospholipids	Fatty acids, lysophospholipids
Intestinal mucosa	Enteropeptidases	...	Trypsinogen	Trypsin
	Aminopeptidases	...	Polypeptides	Cleave amino terminal amino acid from peptide
	Carboxypeptidases	...	Polypeptides	Cleave carboxyl terminal amino acid from peptide
	Endopeptidases	...	Polypeptides	Cleave between residues in midportion of peptide
	Dipeptidases	...	Dipeptides	Two amino acids
	Maltase	...	Maltose, maltotriose, alpha-dextrins	Glucose
	Lactase	...	Lactose	Galactose and glucose
	Sucrase[1]	...	Sucrose: also malto-triose and maltose	Fructose and glucose
	alpha Dextrinase[1]	...	alpha-Dextrins, maltose, maltotriose	Glucose
	Trehalase	...	Trehalose	Glucose
	Noclease and related enzymes	...	Nucleic acids	Pentoses and purine and pyrimidine bases
Cytoplasm of mucosal cell	Various peptidases	...	Di-, Tri-, and tetrapeptides	Amino acids

[1] *Sucrase and alpha-dextrinase are separate subunits ot a single protein.*

(Ref. Ganong 22th Edition, Page 468, 469)

Function of digestive tract

1. Ingestion of food.
2. Digestion of food.
3. Secretion of various digestive juice.
4. Absorption of H_2O, vitamines, salt and end products of digestion.
5. Excretion of heavy metals, toxins etc.
6. Helps in movement of food through it.
7. Regulation of acid base balance.
8. Regulation of water balance.
9. Regulation of blood sugar level.
10. Helps in erythropoiesis.

Function of the different parts of GIT

Functions of oral cavity

1. It is the receiving chanel of the food staff.
2. It helps in breaking down the food staff into small fragments by mastication (Chewing).
3. It helps formation of bolus, by mixing the ground up food staff with saliva.
4. By formation of bolus, it helps swallowing.
5. It elps in conveying the sensation of taste of the food, by the test buds of tongue.
6. Some amount of salivary digestion may also occur in the buccal cavity.

Function of Stomach

1. *Mechanical function :*
   a. Stomach acts as reservior of food.
   b. The movement of the stomach helps in proper mixing of food with disgestive juice and also helps to propel the food into the duodenum.
2. *Digestive function :* Due to the presence of pepsin, stomach digests protein upto the stage of peptone. It also digest fats to a some extent with the help of gastric lipase. Gastric renin coagulates milk, HcI causes some hydrolysis of food staffs.
3. *Secretory function :* Stomach secretes gastric juice hormones like gastrin etc.
4. *Absorptive function :* Stomach absorbs small quantity of water, saliva, alcohol, glucose, certain drugs, vitamin B_{12} etc.
5. *Stimulatory function :* Stomach manufactures two chemical substances like hormone which are as follows :
   a. Gastrin : It acts as a stimulator for gastric juice secretion.
   b. Castle's intinsic factor : It is an enzyme like substances present in the gastric juice as well as in the gastric mucous membrane.

   The extrinsic factor is vit B_{12}. When it is taken in the mouth, the Castle's intrinsic factor interacts with extrinsic factor and helps in the absorption of Vit-B_{12}.

Function of large intestine (Colon)

1. *Absorptive function :* It helps in absorption of
   a. Water : 80% of H_2O.
   b. Salt : NaCI along with water.
   c. Sugar : Only glucose.
   d. Aminoacid : If amino acid escape absorption in the small intestine.
   e. Alcohol.
   f. Drug : Hypotonic drugs such as 5% paraldehyde, also sedative such as 40% magsulph.
   g. Anaesthetic agent.
   h. Steroid.
2. *Secretory function :* The chief secretion is mucus. Some amount of inorganic salts (chlorides) and HCO_3 along with some organic materials are also secreted.
3. *Excretory function :* Some heavy metals- Lead, bismuth, mercury and arsenic etc are excreted through the colon.
4. *Synthetic function :* Vit-K_1,Vit-K_2 and Vit B_{12}, folic acid etc are synthesized by the bacterial flora in the large intestine.
5. *Digestive function :* Large intestine is aboundant with bacterial flora. These bacterial flora helps in digestion.
6. *Expulsive or propulsive function :* Due to its mass peristaltic movement, it helps in the act of defecation.

***Integrated action of gastrointestinal hormones** in regulating digestion and utilization of absorbed nutrients.*

(The dashed arrow indicate inhibition.

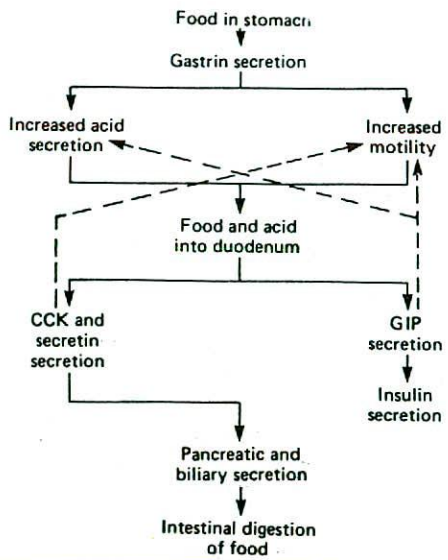


Table 10-3 : Integrated action of gastrointestinal hormones in regulating digestion & utilization of absorbed nutrients.

(Ref. Ganong 22th edition; Page-487)

Mucus

Mucus is a thick secretion composed mainly of water, electrolytes, and a mixture of several glycoproteins, which themselves are composed of large polysaccharides bound with much smaller quantities of protein.

Importance of mucus in the GIT :

1. It adhere tightly to the food or other particles and also to spread as a thin film over the surfaces.
2. It coats the wall of the gut and prevents actual contact of food particles with the mucosa.
3. Mucus has a low resistance to slipage so that the particles can slide along the epithelium with great ease.
4. Mucus causes fecal particles to adhere to each other to form the fecal masses.
5. Mucus is strongly resistant to digestion by the gastro-intestinal enzymes.
6. The glycoproteins of mucus have amphoretic properties and capable of buffering small amount of either acids or alkalies. Mucus also contains moderate amount of bicarbonate ions, which specifically neutralize acids.

(Ref. Guyton & Hall-11th Edition, Page 793)

Secretory functions of alimentary tract

Digestive juices

1. Saliva
2. Gastric juice
3. Pancreatic juice
4. Intestinal juice or succus intericus
5. Bile.

Daily secretion of intestinal juices :

Juice	*Daily Volume (ml)*	*PH*
Saliva	1000	6.0 - 7.0
Gastric secretion	*1500*	*1.0 - 3.5*
Pancreatic secretion	1000	8.0 - 8.3
Bile	*1000*	*7.8*
Small intestinal secretion	1800	7.5 - 8.0
Brunner's gland secretion	*200*	*8.0 - 8.9*
Large intestinal secretion	200	7.5 - 8.0
Total	*6700*	-

(Ref. Guyton & Hall-11th Edition, Page 794)

Q. **Why different digestive juice are necessary for digestion of food?**

Ans. Different digestive juices are necessary for digestion of food because-

i. One particular digestive juice does not contain all enzymes necessary for digestion of food staffs. e.g saliva contain only carbohydrate splitting enzyme.

ii. One particular digestive juice cannot even digest particular food upto its completion. E.g. Gastric juice digest protein upto the stage of peptone, pancreatic juice digest peptone upto the stage of peptide, peptide then completely digested upto amino acids by the succus intericus.

iii. Reaction of different digestive juice are different.

For this reasons, different digestive juice are required for digestion of food.

Saliva

Salivary glands

Salivary glands are mixed gland. There are mainly three pairs of salivary glands- parotid, submaxillary or submandibular and sublingul glands. In addition, there are many small buccal glands.

a. ***Parotid glands :*** Parotid glands secret entirely the serous type, containing ptyelin (an alpha-amylase). The gland opens upon the inner surface of the cheek opposite the second upper molar tooth, by a single duct called the duct of Stensen.

b. ***Submaxillary or submandibular glands :*** Secret both the serous type and mucous. The gland open upon the floor of the mouth on the side of the frenulum of the tongue, by Wharton's duct.

c. ***Sublingul gland :*** Secret both the serous types and mucous. The gland open by several fine ducts, upon the floor of the mouth by the side of the frenulum. These are called the ducts of Rivinus.

d. ***Buccal glands*** : There are small accessory buccal glands scattered throughout the mucous membrane and secret only mucous.

(Ref. Guyton & Hall-11th Edition, Page 793, 794)

Table 10-5. ***Characteristics of each pair of salivary glands in human*** :

Gland	*Parasympathetic nerve supply via*	*Histologic type*	*secretion*	*% ot*
Parotid	Glossopharyngeal	Serous	Watery	25%
Subman-dibular	Facial	Mucous & serous	Moderately viscus	70%
Sublingul	Facial	Mucous & serous	Viscus	05%

(Ref. Ganong 22th edition, Page 488)

Control of salivary secretion

Salivary secretion is under neural control.

1. *Parasympathetic nerve* : Stimulation of the parasym pathetic nerve supply causes profuse secretion of watery saliva with a relatively low content of organic material. Associated with this secretion is a pronounced vasodilation in the gland, which appears to be due to the local release of VIP. This polypeptide is a cotransmitter with acetylcholine in some of the postganglionic parasympathetic neurons. Atropine and other cholinergic blocking agents reduce salivary secretion.

2. *Sympathetic nerve* : Stimulation of the sympathetic nerve supply causes vasoconstriction and, in humans, secretion of small amounts of saliva rich in organic constituents from the submandibular glands.

Food in the mouth causes reflex secretion of saliva. and so does stimulation of the vagal afferent fibers at the gastric end of the esophagus. Salivary secretion is easily conditioned. In humans, the sight, smell, and even thought of food causes salivary secretion ("makes the mouth water").

(Ref. Ganong 22th edition, Page 489)

Q. **Salivation cannot be a process of excretion, it is chiefly a secretory process- *Explain*.**

Ans. Following observations prove that salivation is mainly a secretory phenomenon :

1. Saliva is extremly useful, hence, caot be an excretory product.
2. Evidence of work : During salivation the glands are found to be actively working.
   a. During salivation the glands inerease in size, become vascular and their temperature increases.
   b. Hydrostatic pressure in the salivary duct increases.
   c. The osmotic pressure. becomes higher than that of blood.
   d. The amount of oxygen used and CO_2 produced by the gland increase.
   e. Saliva contain certain substances, not present in blood e.g ptyalin.
3. The zymogen and mucinogen granules which are present in resting glandular cells, reduce to a much smaller number during activity.
4. Changes of electric potential takes place in the gland during secretion.

Saliva

Definition : Saliva is a viscus, colourless, oplacent fluid which is secreted by the three pairs of salivary glands- the parotid, submandibular, and sublingual glands. There are also many small buccal glands from which salivation occurs.

Characters :

1.	Total secretion	:	800 - 1500ml/day.
	Average	:	1000 ml/day.
2.	Reaction	:	Slightly acidic
3.	pH	:	6.0 - 7.0
4.	Specific gravity	:	1.002 - 1.012.

(Ref. Guyton & Hall-11th Edition, Page 793)

N.B. pH : 7.0-8.0; Total secretion : about 1500 ml. *(Ganong 20th,P-473)*

Composition of saliva :

A. Water : 99.5%

B. Solid : 0.5%
   i. *Organic* : 0.3%
      a. Enzyme : Ptyaline (salivary alpha-amylase), Lingual lipase, Carbonic anhydrase phosphatase, Lysozymes.
      b. Other organics : Mucin, urea, cholesterol, amino acids.
      c. Blood group substances : Antigen of ABO blood group.
   ii. *Inorganic* (0.2 %) : NaCl, KCl, acid and alkaline sodium phosphate, calcium phosphate, $CaCO_3$, $KHCO_3$ etc.
   iiii. *Cellular constituents :* Yeast cell, bacteria, protozoa etc.
   iv. *Gases :* O_2, N_2, CO_2.

(Ref. Ganong 22th edition, Page-489; Guyton & Hall-11th P-793 & Others)

Function of saliva

1. *Mechanical functions :*
   i. It keps the mouth moist and helps in speech
   ii. It facilates swallowing
   iii. It helps in preparing food staffs into a bolus, suitable for digestion
   iv. It dilutes hot and irritent food, thus prevents injury of the mucous membrane
   v. Saliva also acts as a lubricant
   vi. It washes down the food debris there by prevent bacterial growth.
2. *Helps in taste :* By dissolving food staffs saliva helps in taking the sensation of taste.
3. *Disgestive function :* It breaks down boil starch into maltose due to the presence of enzyme ptyalin.

   eg. Boiled starch $\xrightarrow{ptyalin}$ Erythrodextrin $\xrightarrow{ptyalin}$ Achrodextrin $\xrightarrow{ptyalin}$ Maltose.

4. *Excretory function :* It excrets urea, some heavy metals (Pb, Bi, As, etc.), thyocyanates, certain drugs like iodine, alkaloids such as morphine; antibiotics such as penicilin etc.
5. *Helps in water balance :* Saliva keeps the mouth moist, when moisture is reduced in the mouth, certain nerve ending at the back of the tongue are stimulated and the desire of thirst arises. The subject then take water and thus water balance is maintained.
6. *Buffering function :* Due to the presence of HCo_3^- and Po_4 in saliva it acts as bufter-$NOHCO_3$, H_2CO_3 and Na_2HPO_4, NaH_2PO_4.
7. *Bacteriolytic action :* Cell membrane of different varities

of bacteria contains polysaccharides, lysosome. The enzymes present in the saliva is a polysaccharide, thus it dissolves the cell wall of many bacteria and finally kills them.

Q. ***Why ptyalin can not act on unboiled starch?***

Ans. Ptyalin can not act on unboiled starch because it cannot penetrate the protective membrane of unboiled starch.

Mechanism of saliva secretion *(/Regulation)* :

Saliva secretion is purely a reflex processes. Two types of reflex are :

a. *Condition reflex (acquired reflex) :* Here salivation occurs in presence of food such as sight, vision & smell of food stimulate saliva secretion reflexly although no food is actually given in mouth.

b. *Unconditioned or inherent or inborn reflex :* When food is actually given to the mouth then the secretion of salivary gland occurs by uncondition reflex.

Salivation also occur in response to reflexes originating in the stomach and upper intestines-particularly when very irritating foods are swallowed or when a person is nauseated because of some gastro-intestinal abnormality.

When a person smells or eats favourite food salivation is greater than when disliked food is smelled or eaten.

(Ref. Guyton & Hall-11th Edition & others)

Test for saliva

Collected saliva is taken into 4 test tube labelled with I, II, III, & IV.

1. A little unboiled starch is taken in a tubes no- I and I cc of saliva added to it → Iodine test → No change in colour → *Salivary amylase do not acts upon unboiled starch.*
2. A little boiled starch is taken in test tube no-II and I cc of saliva is added with it → Iodine test → Gradually the colour changes to purple red → *Salivary amylase acts upon boiled starch & hydrolyzed it.*
3. A little boiled starch taken in test tube no-III and I cc of boiled saliva is added to it → Iodine test → No change in colour → *Saliva is destroyed during boiling.*
4. A little HCI is taken in tube no-IV & I cc of saliva is added to it → Iodine test → No change of colour → *Saliva has no action on HCI.*

Applied :

Achalasia : It is a condition in which food accumulates in the esophagus and the organ becomes massively dilated.

Causes : It is due to increased resting lower oesophageal sphincter (LES) tone and incomplete relaxation upon swallowing. The myenteric plexus of the esophagus is deficient at the LES in this condition, and there is defective release of NO and VIP.

Treatment : It can be treated by pneumatic dilation of the sphincter or incision of the esophageal muscle (myotomy). Inhibition of acetylcholine release by injection of botulinum toxin into the LES is also effective and produces relief that lasts for several months.

(Ref. Ganong 22th edition, Page-490)

Gastroesophageal reflux disease : It is a condition of LES incompetence, which permits reflux of acid gastric contents into the esophagus. This common condition causes heartburn and esophagitis and can lead to ulceration and stricture of the esophagus due to scarring. In severe cases, there is weakness of the intrinsic sphincter, the extrinsic sphincter or both, but less severe cases are caused by intermittent periods of poorly understood decreases in the neural drive to both sphincters. The condition can be treated by inhibition of acid secretion with H_2 receptor blockers or omeprazole. Surgical treatment in which a portion of the fundus of the stomach is wrapped arround the lower esophagus so that the LES is inside a short tunnel of stomach is also effective.

(Ref. Ganong 22th edition, Page-490)

Aerophagia & Intestinal Gas : Nervous persons who hyperventilate sometimes swallow large amounts of air, and some air is unavoidably swallowed in the process of eating and dinking (***aerophagia***). Some of the swallowed air is regurgitated (***belching***), and some of the gases it contains are absorbed, but much of it passes on to the colon. Here, some of the oxygen is absorbed, and hydrogen, hydrogen sulfide, carbon dioxide, and methane formed by the colonic bacteria from carbohydrates and other substances are added to it. It is then expelled as ***flatus***. The smell is largely due to sulfides. The volume of gas normally found in the human gastrointestinal tract is about 200 ml, and the daily production is 500-1500 ml. In some individuals, gas in the intestines causes cramps, ***borborygmi*** (rumblng noises), and abdominal discomfort.

(Ref. Ganong 22th edition, Page-491)

Aptyalism : Aptyalism or Xerostomia is a condition of complete cessation of salivary secretion.

Causes :

i. Congenital Hypoplasia
ii. Abscence of salivary gland
iii. When mouth is dry
iv. Chewing is difficult
v. Speech is trouble some.

Temporary cessation occurs in Anxiety, worry, fear, shock,

Hyposalivation : Reduced salivation (less than normal) is called hyposalivation.

Cause :

i. Deep X-ray rodiation given to salivary gland.
ii. Surgical intervention.

Hypersalivation : Excessive salivation (more than normal) is called hypersalivation. It is also called *ptyalism or sialorrhoea.*

Causes :

i. During pregnancy.
ii. Ulcer tongue & mouth.
iii. Neoplasm of tongue, buccal cavity & oesophagus.
iv. Carious tooth or deformed tooth.
v. Gastric or Duodenal ulcer with pancreatic inflammation.
vi. Parkinsonism & psychoneurosis.

Sialolithiasis : Stone (calculi) in the salivary duct is called sialolithiasis.

Esophagial Secretion

The esophageal secretions are entirely mucoid in character and principally provide lubrication for swallowing. The main body of the esophagus is lined with many simple mucous glands, at the gastric end and to a lesser extent in the initial portion of the esophagus, there are many compound mucous glands. The mucus secreted by the compound glands in the upper esophagus prevents mucosal excoriation by newly entering food, whereas the compound glands located near the esophagogastric junction protect the esophageal wall from digestion by acidic gastric juices that often reflux from the stomach back into the lower esophagus. Despite this protection, a peptic ulcer at times may occur at the gastric end of the esophagus.

(Ref. Guyton & Hall-11th Edition, Page 795)

Gastric Secretion

Gastric glands with their secretion

There are three types of gland present in the stomach :

1. *Cardiac gland :* It contains mainly mucous secreting cells.
2. *Glands of body and fundus of stomach (Gastric glands or oxyntic glands)* : These glands are located on the inside surfaces of the body and fundus of the stomach, constituting the proximal 80% of the stomach.
   a. *Mucous neck cell :* Secrete mainly mucus but also some pepsinogen.
   b. *Peptic or chief or zymogenic cell :* Secrete large quantities of pepsinogen, gastric renin.
   c. *Oxyntic or parietal cell :* Secrete HCl and intrinsic factor of Castle.
   d. *Enterochromaffin cell :* Secrete gastrin and serotonin.
3. *Pyloric glands :* Mucus neck cell : secrete mucin & hormone gastrin. These glands are located in the antral portion of the stomach, constituting the distal 20% of the stomach.

(Ref. Guyton & Hall-11th Edition, Page 795 and others)

Intrinsic factor of castle : It is an enzyme like unidentified substance secreted by the stomach, sugested by Castle, called intinsic factor of castle. It is essential for the absorption of vitamin B_{12}.

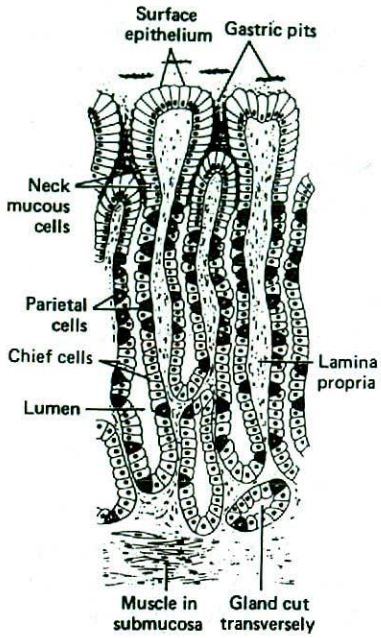


Fig. 10-1. *Diagram of glands in the mucosa of stomach.*

Characteristics of gastric juice :

1. *Quantity* : 500 - 1000 ml/meal
   or 1200-2500 ml/day
   or 1500 ml/day *(Guyton 11th)*
   or 2500 ml/day *(Ganong 22th, P-491)*
2. *Consistancy* : Cloudy and sticky due to presence of mucin and cells.
3. *Reaction* : Strongly acidic; P^H : 1.0 - 3.5
4. *Specific gravity* : 1.002-1.004.

(Ref. Ganong 22th Edition, Page 491, 492 & Others)

Composition of gastric juice :

A. *Water* : 99.5%
B. *Solid* : 0.5%
   a. *Inorganic :*
      i. Cations : Na^+, K^+, Mg^{++}, H^+
      ii. Anions : Cl^-, HPO_4^{2-}, SO_4^{2-},
      iii. HCl, $CaCl_2$, $Ca_3(PO_4)_2$
   b. *Organic :*
      i. Enzyme : Pepsins (Pepsinogens), gastric lipase.
      ii. Mucin.
      iii. Intrinsic factor of Castle.
      iv. Blood group substances : Antigen of ABO blood group found in gastric juice during stomach cancer.

(Ref. Ganong 22th edition, Page-492 & Others)

Function of gastric juice

1. *Digestive function :*
   a. The enzyme *pepsinogen* with the help of gastric HCI digests *protein* upto the stage of *peptone*.
   b. *Renin* coagulates casinogen of *milk* and converts it into *casein* and then into insoluble *calcium caseinate*.
   c. *Gastric lipase* digests fat to some extent.
2. *Excretory function :* Toxins, heavy metals, certain alkaloids etc are excreted through gastric juice.
3. *Function of HCl of Gastric juice :*
   a. Gastric HCl converts inactive pepsinogen into active pepsin.
   b. Gastric HCl acts as an antiseptic agent against bacteria.
   c. Gastric HCl causes hydrolysis of all the food staffs.
   d. It keeps iron in ferrous state for absorption.
   e. In presence of gastric HCl pepsinogen digest protein upto the stage of peptone.
   f. It provides suitable environment for the action of enzymes pepsin, renin & lipase.
   g. It helps in maintaining a proper environment for gastric emptying.
   h. It converts collagen protein into gelatin.
   i. It hydrolyzes cane sugar to glucose & fructose.
   j. It helps in the dissolution of the protoplasmic covering of the fat globules.
4. Antiseptic function : Gastric HCl acts an antiseptic agent against bacteria.
5. Haemopoietic function : The intrinsic factor of gastric juice helps absorption of extrinsic factor (Vit-B_{12}) essential for maturation of RBC.
6. Lubricating function : The mucin of gastric juice lubricates any irritant, which might have gained entry into the stomach.
7. Protective function : The mucin is responsible for protecting the gastric mucosa from the action of HCI. Thus stomach is not self digested.
8. Acid base regulation : It is responsible for the alkaline tide of blood, during secretion of HCl.

Secretion and activation of pepsinogen

Pepsinogen is secreted by the peptic and mucous cells of the gastric glands. When the pepsinogen is first secreted, they have no digestive activity. However, as soon as they come in contact with the hydrochloric acid and specially when they come in contact with previously formed pepsin and hydro chloric acid, they are immediately activated to form active pepsin.

In this process, the pepsinogen molecule, having a molecular weight of about 42,500 is split to form pepsin. Pepsin is an active proteolytic enzyme, molecular weight of about 35,000. Optimum pH 1.8 to 3.5, but above a pH of about 5 it has almost no proteolytic activity and even becomes completely inactivated in a short time.

(Ref. Guyton & Hall-11th Edition, Page 797)

Basic mechanism of secretion of gastric HCl

The *parietal (oxyntic)* cells contain a system of intracellular canaliculi. The hydrochloric acid is formed at the membranes of these canaliculi and then conducted through openings to the exterior. Mechanism of HCI secretion is consists of the following steps :

1. Chloride ion is actively transported from the cytoplasm of the parietal cell into the lumen of the canaliculus, and sodium ions are actively transported out of the lumen. These two effects together create a negative potential of -40 to -70 millivolts in the canaliculus, which inturn causes passive diffusion of positively charged potassium ions and a small number of sodium ions from the cell cytoplasm also into the canaliculus. Thus, in effect, mainly potassium chloride and much smaller amounts of sodium chloride enter the canaliculus.

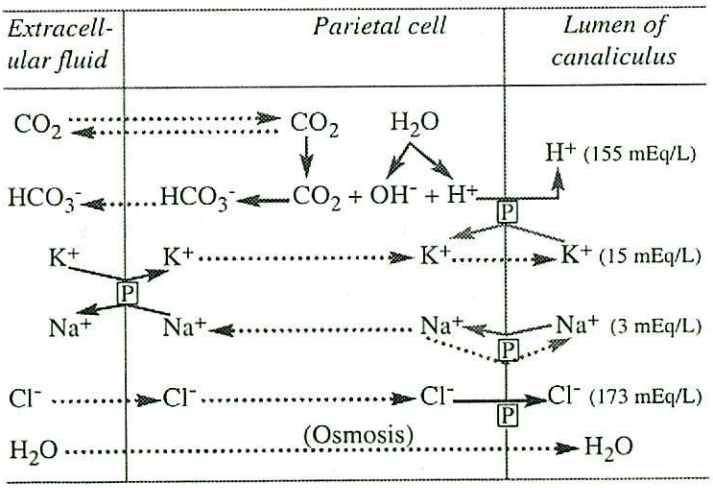


Fig.10-2. *HCl secretion by parietal cells in the stomach. Source: Guyton 10th.*

2. Water becomes dissociated into hydrogen ions and hydroxyl ions in the cell cytoplasm. The hydrogen ion is then actively secreted into the canaliculus in exchange for potassium ions, catalyzed by H^+-K^+ ATPase. In addition, the sodium ions are actively reabsorbed by a seperate sodium pump. Thus, most of the potassium and sodium ions that had diffused into the canaliculus are reabsorbed into the cell cytoplasm, and hydrogen ions take their place in the canaliculus, giving a strong solution of hydrochloric acid in the canaliculus, which is then secreted outward through the open end of the canaliculus into the lumen of the gland.
3. Water passes into the canaliculus by osmosis because of the secretion of the ions into the canaliculus. Thus, the final secretion from the canaliculus contains approximately hydrochloric acid at a concentration of 150 to 160 mEq/L, potassium chloride at a concentration of 15 mEq/L, and a small amount of sodium chloride.

4. Finally, carbon dioxide, either formed during metabolism in the cell or entering the cell from the blood, combines under the influence of carbonic anhydrase with the hydroxyl ions (formed in step 2 when water was dissociated) to form bicarbonate ions. This then diffuses out of the cell cytoplasm into the extracellular fluid in exchange for chloride ions that enter the cell from the extracellular fluid and are later secreted into the canaliculus.

(Ref. Guyton & Hall-11th Edition, Page 796)

Q. **For peptic digestion HCl is must- explain.**

Ans. For peptic digestion HCl is must because :

1. HCl of gastric juice converts inactive pepsinogen into active pepsin, by loss of about 15% of the nitrogen content of the pepsinogen molecule.
2. Pepsin is inactive in neutral or alkaline medium but it is highly proteolytic in strong acid solutions.

Q. **Lack of peptic activity causes poor meat digestion- Explain.**

Ans. Meat contain protein. Proteins are absorbed in the form of amino acids, so proteins are digested to amino acid prior to their absorption.

1. Pepsin is the proteolytic enzyme, which helps in protein digestion.
2. It converts 10 -15% protein to amino acid.
3. With the help of HCl; pepsin converts protein upto the stage of peptone.

   Protein → Acid metaprotein → Primary proteoses → Secondary proteoses → Peptone → Amino acid.

   As meat is protein, in the absence of proteolytic (peptic) activity meat is poorly digested.

Regulation of gastric secretion

Gastric motility and secretion are regulated by neural and humoral mechanisms. The neural components are local autonomic reflexes, involving cholinergic neurons, and impulses from the CNS by way of the vagus nerves. The humoral components are gastrin, enterogastrone.

Vagal stimulation increases gastrin secretion by release of gastrin-releasing peptide. Other vagal fibers release acetylcholine, which acts directly on the cells in the glands in the body and the fundus to increase acid and pepsin secretion. Stimulation of the vagus nerve in the chest or neck increases acid and pepsin secretion but vagotomy does not abolish the secretory response to local stimuli.

For convenience, the physiologic regulation of gastric secretion is usually discussed in terms of *cephalic, gastric, and intestinal influences, although these overlap*. The *cephalic influences* are vagally mediated responses induced by activity in the CNS. The *gastric influences* are primarily local reflex responses and responses to gastrin. The *intestinal influences* are the reflex and hormonal feedback effects on gastric secretion initiated from the mucosa of the small intestine.

(Ref. Ganong 22th edition, Page-494)

Phases of gastric secretion

Gastric secretion is said to occur in three phases : a cephalic phase, a gastric phase, and an intestinal phase. As will be apparent in the following discussion, these three phases fuse together.

i. ***Cephalic phase*** : The cephalic phase of gastric secretion occurs even before food enters the stomach, especially while it is being eaten. It results from the sight, smell, thought or taste of food, and the greater the appetite, the more intense is the stimulation. Neurogenic signals that cause the cephalic phase of gastric secretion can originate in the cerebral cortex or in the appetite centers of the amygdala or hypothalamus. They are transmitted through the dorsal motor nuclei of the vagi and thence through the vagus nerves to the stomach. This phase of secretion normally accounts for about *20 per cent of the gastric secretion* associated with eating a meal.

ii. ***Gastric phase*** : Once food enters the stomach, it excites- i. long vagovagal reflexes, ii. local enteric reflexes, and iii. the gastrin mechanism, all of which in turn cause secretion of gastric juice during several hours while the food remains in the stomach.

   The gastric phase of secretion accounts for about *70 per cent of the total gastric secretion* associated with eating a meal and therefore accounts for most of the total daily gastric secretion of about 1500 milliliters.

iii. ***Intestinal phase*** : The presence of food in the upper portion

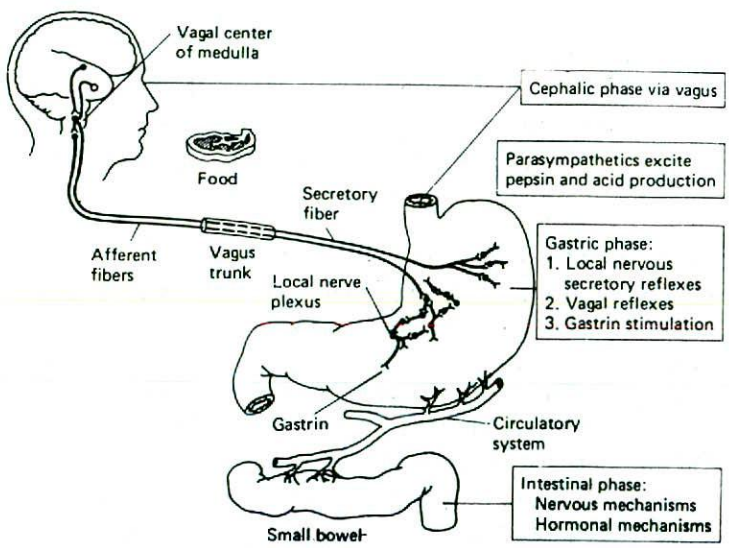


Fig. 10-3. Phase of gastric secretion & their regulation

of the small intestine, particularly in the duodenum, will continue to cause the stomach to secrete small amounts of gastric juice, probably partly because of small amounts of gastrin that are released by the duodenal mucosa in response to distention or partly because of chemical stimuli of the same type as those that also stimulate the stomach gastrin mechanism.

(Ref. Guyton & Hall-11th Edition, Page798)

Appetite juice *(Cephalic phass of gastric juice secretion)*

Cephalic phass of gastric juice secretion is refered to as appetite juice by Pavlov.

i. *Characteristics of cephalic phase of gastric juice secretion* :
   1. It is rich in HcI and pepsinogen and copious in amount.
   2. It is abolished by cutting the vagus nerves or by administration of blocking agents.
   3. It has two reflex elements : Both conditioned and uncondition reflexes.
   4. Hunger profoundly influences the secretion.
   5. Food, agreeably flavoured, attractive in appearance also helps in the secretion of the juice.
   6. Congenial surroundings and friendly company in the dining table also helps in this phase.
   7. Disagreable food, disgusting appearance and foul odor, all depress it.

ii. *Importance of cephalic phase of gastric juice secretion* :
   1. The acidity of the juice maintain the acid media and PH of the stomach & destroy the foreign particles comes with food particles.
   2. The acidity converts the pepsinogen into active pepsin and maintain a suitable environment for the action of pepsin.
   3. Pepsin of the juice begins to hydrolysis of protein food particles.
   4. It helps to initiate the second phase of gastric secretion.

Factors affecting gastric secretion

1. *Emotions :*
   a. Pleasant surroundings, elevated mood increase secretion.
   b. Unpleasant surroundings, fear, grief, shock depress it.
2. *Food :*
   a. Palatable food stimulates secretion.
   b. Disagreeable food depress it.
3. *Drink :* Pre-lunch drinks (alcoholic) stimulate gastric secretion.
4. *Alkalies :*
   a. In large doses - depress secretion.
   b. In small doses- stimulates secretion.
5. *Biters :* Unless the bitters contain alcohol, they have hardly any effect on gastric secretion.
6. *Acids :* HCI (1%) depress secretion when directly put inside the stomach.
7. *Drugs :* Like Histamine, Histalog, Caffine & alcohol and Insulin stimulate gastric secretion.
8. Tobacco smoking : Stimulate secretion.
9. *Vitamins :* Deficiency of Vit-B_{12} & Vit B_1 depress gastic secretion and respectively causes- Achylia gastrica and achlorhydria. Administration of Vit-D sometimes depress secretion.
10. *Electrolytes :* Changed blood calcium level depress secretion.
11. Hormones :
    a. ACTH, Steroid and Gastrin increase secretion.
    b. Serotonine, Enterogastrone depress it.

Factors increasing gastric juice secretion

Certain factors inhibits acid sceretion. These are :

i. Distension of the stomach.
ii. Sight, smell, taste of food.
iii. Low blood sugar level through hypothalamus.
iv. Gastrin.
v. *Insulin* : By lowering blood sugar level.
vi. *Cortisol* : Increase gastric secretion which is rich in acid pepsin but poor in mucin.

Factors inhibits gastric HCl secretion

Certain factors inhibits acid sceretion. These are :

i. Emotion, fear, grief and sensation of nausea.
ii. The presence of fat in the duodenum.
iii. High levels of (H^+) in the pyloric antrum or proximal duodenum.
iv. The presence of hyperosmolar concentration in the duodenum.

Alkaline tide

After a heavy meal, the HCI secretion will increase which also increases the production of HCO_3^-. This HCO_3^- then enters in the plasma and increases the pH of blood. As a result, alkalinity occurs, known as alkaline tide.

Post parandal alkaline tide

At the sametime, the alkalinity of urine will also be increased. All these condition are called post parandal alkaline tide.

Important constitent of gastric juice

i. Pepsin
ii. Gastric HCI
iii. Casle's intrinsic factor.
iv. Mucin.

Stimuli that affect gastrin secretion

i. *Stimuli that increase gastrin secretion.*
   1. *Luminal* :

a. Peptides and amino acids
b. Distention

2. *Neural* : Increased vagal discharge via GRP
3. *Blood borne* : Calcium, Epinephrine.

ii. *Stimuli that inhibit gastrin secretion*

1. *Luminal* :
   Acid
   Somatostatin
2. *Blood borne* : Secretin, GIP, VIP, glucagon, calcitonin.

(Ref. Ganong 22th edition, Page-485)

Q. **Why normal gastric juice secretion is essential for erythropoiesis?**

Ans. Extrinsic haemopoietic factor vit. B_{12} is essential for maturation of RBC and its deficiency leads to pernicious anaemia. One of the constituents of gastric juice, *intrinsic factor of Castle's* helps in absortption of vit-B_{12} which is released from the pyloric mucosa. Gastric mucosal atrophy, partial or total gastectomy or gastoejunostomy may leads to decreased gastric intrinsic factor secretion which causes pernicious anaemia. So, gastric secretion is essential for erythropoiesis.

Q. **Stomach does not digest itself- *Explain***

Ans. Stomach does not digest itself because :

1. Gastric mucosal glands of the stomach secret mucus which form a protective gastric mucosal barrier. For this barrier HCl and pepsin does not come in contact with the mucous membrane of the stomach.
2. Greater HCO_3^- ion concentration of blood flowing through gastric mucosa to counter act effect of HCl.
3. Presence of Antipepsin to counteract peptic digestion.
4. Production of NH_3 by urease locally, another doubtful neutralizer of HCl.

So stomach does not digest itself.

(Ref. Ganong 22th edition, Page-491 & others)

Applied :

Achylia Gastrica : It is a condition in which neither any HCl nor any pepsin is found in gastric juice. It is found in about 2-5% of normal individual.

This is a congenital error due to non-development of oxyntic and peptic cells. This condition dose not affect health, because pancreatic enzymes can digest all the ingested food staffs.

Hypochlorhydria : In certain pathological condition (pernicious anaemia; cancer of the stomach etc) the acidity of the gastric juice is very low, called hypochlorhydria.

Achlorhydria : When the acidity of the gastric juice is absent.

Hyperchlorhydria : Some people may have higher acidity in the gastric juice, called hyperchlorhydria.

Peptic Ulcer

a. *Definition* : Ulceration of any part of GIT due to action of excessive acid pepsin secretion.

b. *Cause of peptic ulcer* :

i. Excess acid and pepsin secretion by gastic mucosa.
ii. Irritation.
iii. Poor blood supply.
iv. Poor secretion of mucus.
v. Diminished capability of the gastro duodenal mucosal barrier to protect against the digestive properties of the acid-pepsin complex.

c. *Treatment of peptic ulcer :*

i. *Medical treatment :*

1. Reduction of stressful situations that might lead to excessive acid secretion.
2. Administration of antacid drugs and cimitidine or Ranitidine.
3. Interdiction of smoking
4. Removal of such ulcer causing factors as alcohol, aspirin, etc.

ii. *Surgical treatment :*

1. Vagotomy.
2. Removal of portion of stomach.

(Ref. Guyton & Hall-11th Edition, Page 820)

Ryles tube

It is a thin flexible rubber tube, of small bore, 12 french gauge (8mm) with an expanding perforated end and enclosing a metal bead (Ryle) is used for swallowing it into the stomach, other end is open.

i. *Markings* : It has three markings.
When swallowed up :

a. First marking coincides with incisor teeth (about 30 cm or 12 inches from the end), the end is near the cardiac end of oesophagus :
b. If upto the second mark, the end is within the stomach.
c. When upto the third mark, the end has entered the duodenum.

ii. *Uses of Ryles tube :*

a. Gastric juice analysis.
b. Gastric juice aspiration.
c. Nasogastric feeding.
d. As torniquet.

Gastric juice analysis

Method of gastric juice analysis :

1. Functional gastric analysis or Functional test meal method by ryles tube.
2. Histamin tests of gastric secretion.
3. Insulin test of gastric secretion.

Functional test meal method : It is the commonly used method for gastric juice analysis.

a. *Procedure :* The subject is kept in fasting condition since previous evening. In the morning, during gastric analysis, the subject is swallows the tube upto the second mark. The fasting contents of the stomach is withdrawn completely, by a syringe and preserved.

Then 10ml of samples are drawn every 15 minutes for analysis after half an hour of swallowing a pint of thin gruel, which acts as test meal for stimulating gastric secretion. This drawing of samples goes on for 2.5 hours.

The samples including resting stomach contents are then tested for:

1. Free acidity (HCI).
2. Combined acidity.
3. Total acidity.
4. Total chloride.
5. Starch and sugar.
6. Bile.
7. Blood.
8. Lactic acid.
9. Mucous & resence of pepsin.

b. *Importance :* This test not only gives an idea of the secreting capacity of stomach but the degree ofmotility, opening time of pylorus & duodenal regurgitation.

Pancreatic juice

Characteristics of pancreatic juice

1. *Quantity* : 800-1500 ml/day, average 1500ml/day.
2. *Consistancy* : Colourless, odorless and low viscosity.
3. *Reaction* : Strongly alkaline, P^H: 8.0 (Ganong 20th)
4. *Specific gravity* : 1.010-1.030.

(Ref. Ganong 22th edition, Page 497 & others)

Composition of pancreatic juice

A. Water : 98.5%

B. Solid : 1.5%.

a. *Organic :*

Enzymes : Pancreatic secretion contains enzymes for digesting all three major types of food : proteins, carbohydrates, and fats.

i. *Proteolytic* : *Trypsin* (Trypsinogen), *chymotrypsin* (chymotrypsinogen), *carboxypolypeptidase* (procarboxypolypeptidase), elastase (proelas tases), and nucleasea- ribonucleas (RNA ase), deoxyribo nuclease (DNA ase).

ii. *Carbohydrate splitting enzyme* : Pancreatic alpha amylase, which hydrolyzes starches, glycogen, and most other carbohydrates (except cellulose) to form disaccharides and a few trisaccharides.

iii. *Fat spliting enzyme* : Pancreatic lipase, colipase (procolipase), cholesterol enterase and phospholipase A_2 (phospholipase A_2).

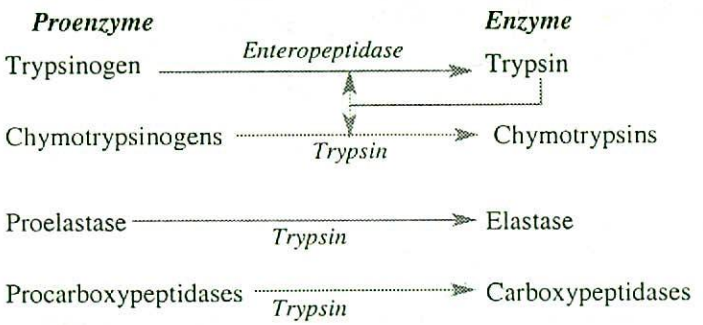
b. *Inorganic* :

i. Cations : Na^+, K^+, Ca^{++}, Mg^{++}.

ii. Anions : Large quantity of HCO_3^- (approximately 113 meq/L; *in plasma it is about 24 meq/L*), Cl^-, SO_4^{2-}, HPO_4^{2-}.

(Ref. Ganong 22th edition, Page 497; Guyton & Hall-11th Edition, Page 799 & others)

Activation of the pancretic proteases in the duodenal lumen



(Ref. Ganong 22th edition, Page 498)

Functions of pancereatic juice

A. ***Digestive action*** : Due to the presence of high concentration of different enzymes, pancreatic juice digest all three types of food- proteins, carborhydrates and fats.

1. *Proteolytic activity :* Proteoses, peptones and polypeptides are coverted into polypeptides and amino acids by the action of trypsin, chymotrypsin, carboxypolypeptidase and proteases.

RNA ase and DNA ase split two types of nuclic acid (RNA and DNA) into nucleo tides.

2. *Amylolytic activity :* Pancreatic amylase acts both on boiled and unboiled starch, glycogen and most other carbohydrates except cellulose to form disaccharides (maltose, isomaltose, multotriose) and few trisaccharides.

3. *Lipolytic activity :* Pancreatic lipase hydrolyzes neutral fat into fatty acids and monoglycerides; Cholesterol esterase hydrolyzes cholesterol esters; Phospholipase splits fatty acids from phospholipids with the help of some factor as - a. bile salt, b. alkaline media, in which pancreatic lipase acts best.

B. ***Neutralizing action*** : Pancreatic juice contains large quantities of HCO_3^-, which plays an important role in neutralizing the acid chyme emptied by the stomach into the duodenum.

(Ref. Guyton & Hall-11th Edition, Page799)

Trypsin inhibitor

(Why pancreas does not digested by its own proteolytic enzymes?)

Ans. Secretion of trypsin inhibitor prevents digestion of the pancreas itself. It is important that the proteolytic enzymes of the pancreatic juice not become activated until after they have been secreted into the intestine because the trypsin and other enzymes would digest the pancreas itself. Fortunately, the same cells that secrete the proteolytic enzymes into the acini of the pancreas secrete simultaneously another substance called trypsin inhibitor. This substance is formed in the cytoplasm of the glandular cells, and it prevents activation of trypsin both inside the secretory cells and in the acini and ducts of the pancreas. Because it is trypsin that activates the other pancreatic proteolytic enzymes, trypsin inhibitor prevents the subsequent activation of the others as well.

When the pancreas becomes severely damaged or when a duct becomes blocked, large quantities of pancreatic secretion sometimes become pooled in the damaged areas of the pancreas. Under these conditions, the effect of trypsin inhibitor is sometimes overwhelmed, in which ease the pancreatic secretions rapidly become activated and can literally digest the entire pancreas within a few hours, giving rise to the condition called *acute pancreatitis*. This often is lethal because of accompanying circulatory shock; even if not lethal, it usually leads to a subsequent lifetime of pancreatic insufficiency.

(Ref. Guyton & Hall-11th Edition, Page800)

Secretion of bicarbonate ions (HCO_3^-)

Although the enzymes of the pancreatic juice are secreted entirely by the acini of the pancreatic glands, the other two important components of pancreatic juice, bicarbonate ions and water, are secreted mainly by the epithelial cells of the ductules and ducts that lead from the acini. The stimulatory mechanisms for enzyme production and production of bicarbonate ions and water are also quite different. When the pancreas is stimulated to secrete copious quantities of pancreatic juice, the bicarbonate ion concentration can rise to as high as 145 mEq/L, a value about five times that of bicarbonate ions in the plasma. This provides a large quantity of alkali in the pancreatic juice that serves to neutralize the hydrochloric acid emptied into the duodenum from the stomach.

The basic steps in the cellular mechanism for secreting sodium bicarbonate solution into the pancreatic ductules and ducts are the following :

1. Carbon dioxide diffuses to the interior of the cell from the blood and combines with water under the influence of carbonic anhydrase to form carbonic acid (H_2CO_3). The carbonic acid in turn dissociates into bicarbonate ions and hydrogen ions (HCO_3^- and H^+).

   Then the bicarbonate ions are actively transported in association with sodium ions (Na^+) through the luminal border of the cell into the lumen of the duct.

2. The hydrogen ions formed by dissociation of carbonic acid inside the cell are exchanged for sodium ions through the *blood* border of the cell by a secondary active transport process. This supplies the sodium ions (Na^+) that are transported through the luminal border into the pancreatic duct lumen to provide electrical neutrality for the secreted bicarbonate ions.
3. The movement of sodium and bicarbonate ions from the blood into the duct lumen creates an osmotic gradient that causes osmosis of water also into the pancreatic duct, thus forming an almost completely isosmotic bicarbonate solution.

(Ref. Guyton & Hall-11th Edition, Page800)

Regulation of the secretion of pancreatic juice

Three basic stimuli are important in causing pancreatic secretion :

1. *Secretin* : Secretion of pancreatic juice is primarily under hormonal control. Secretin acts on the pancreatic ducts to cause copious secretion of a very alkaline pancreatic juice that is rich in HCO_3^- and poor in enzymes. The effect on duct cells is due to an increase in intracellular cAMP. Secretin also stimulates bile secretion.
2. *Pancreozymine* : It acts on the acinar cells to cause the release of zymogen granules and production of pancreatic juice rich in enzymes but low in volume, its effect is mediated by phospholipase C.
3. *Acetylcholine* : It acts on acinar cells via phospholipase C to cause discharge of zymogen granules, and stimulation of vagi causes secretion of a small amount of pancreatic juice rich in enzymes. There is evidence for vagally mediated conditioned reflex secretion of pancreatic juice in response to the sight or smell of food.

Note that as the volume of pancreatic secretion increases, its Cl^- concentration falls and its HCO_3^- concentration increases. Although HCO_3^- is secreted in the small ducts, it is reabsorbed in the large ducts in exchange for Cl^-. The magnitude of the exchange is inversely proportionate to the rate of flow.

The epithelium of the small pancreatic ducts contains many CFTRs. The relation of CFTRs to HCO_3^- secretion is unsettled, but in cystic fibrosis, the HCO_3^- content and the volume of pancreatic juice are reduced and there is an increased incidence of chronic pancreatitis.

(Ref. Ganong 22th edition, Page 498)

Phases of pancreatic secretion

Pancreatic secretion occurs in three phases, the same as for gastric secretion : the cephalic phase, the gastric phase, and the intestinal phase. Their characteristics are as follows :

1. ***Cephalic phases*** : During the cephalic phase of pancreatic secretion, the same nervous signals that cause secretion in the stomach also cause acetylcholine release by the vagal

nerve endings in the pancreas. This causes moderate amounts of enzymes to be secreted into the pancreatic acini and ducts, accounting for about 20 per cent of the total secretion of pancreatic enzymes after a meal. Little of the secretion flows immediately out the pancreatic ducts into the intestine because only small amounts of water and electrolytes are secreted along with the enzymes.

2. ***Gastric phase*** : During the gastric phase, the nervous stimulation of enzyme secretion continues, accounting for another 5 to 10 per cent of the enzymes secreted after a meal. Still only small amounts reach the duodenum because of continued lack of significant quantities of fluid secretion.
3. ***Intestinal phase*** : After chyme enters the small intestine, pancreatic secretion becomes copious, mainly in response to the hormone secretin. In addition, cholecystokinin causes still more increase in the secretion of enzymes.
   a. ***Secretin stimulates secretion of copious quantities of bicarbonate- neutralization of the acidic stomach chyme*** : Secretin is present in an inactive form, prosecretin, in so-called *S cells* in the mucosa of the duodenum and jejunum. The secretin mechanism is especially important for two reasons :

   First, secretin begins to be released from the mucosa of the small intestine when the pH of the duodenal contents falls below 4.5 to 5, and its release increases greatly as the pH falls to 3.0. This immediately causes copious quantities of pancreatic juice containing abundant amounts of sodium bicarbonate to be secreted. The net result is then the following reaction in the contents of the duodenum :

   $$HCl + NaHCO_3 \longrightarrow NaCl + H_2CO_3$$

   Then the carbonic acid immediately dissociates into carbon dioxide and water. The carbon dioxide is absorbed into the blood and expired through the lungs, thus leaving a neutral solution of sodium chloride in the duodenum. In this way the acid contents emptied into the duodenum from the stomach become neutralized, and further peptic activity by the gastric juices in the duodenum is immediately blocked. Because the mucosa of the small intestine cannot withstand the digestive action of acid gastric juice, this is an essential protective mechanism to prevent development of duodenal ulcers.

   Second. bicarbonate ion secretion by the pancreas also provides an appropriate pH for action of the pancreatic enzymes, which function optimally in a slightly alkaline or neutral medium, at a pH of 7.0 to 8.0. Fortunately, the pH of the sodium bicarbonate secretion averages 8.0.

   b. ***Cholecystokinin- control of digestive enzyme secretion by the pancreas*** : The presence of food in the upper small intestine also causes a second hormone cholecystokinin, to be released from *I cells*, in the mucosa of the duodenum and upper jejunum. This release of cholecystokinin results especially from the presence of *proteoses* and peptones (which are products of partial protein digestion and of long-chain *fatty acids; h*ydrochloric acid from the stomach juices also causes its release in smaller quantities.

   Cholecystokinin causes mainly secretion of large quantities of digestive enzymes by the acinar cells. This effect is similar to that of vagal stimulation but even more pronounced, accounting for 70 to 80 per cent of the total secretion of the pancreatic digestive enzymes after a meal.

(Ref. Guyton & Hall-11th Edition, Page 801)

Hydrolytic type of secretion : When the acid-chyme enters in the duodenum causes the release of secretin by its mucosa which then passes through blood and enters pancreas and stimulate it to release pancreatic juice rich in HCO_3^- and water but poor in enzyme. This is called "*hydrolytic type*" of secretion.

(Ref. Guyton & Hall-11th Edition)

Ecbolic type of secretion : Entering of fatty food in the duodenum causes release of PZ-CCK by its mucosa which then passes through blood and enters in the pancreas and stimulate it to release pancreatic juice rich in enzyme but poor in HCO_3^-. This is called *"ecbolic type"* of secretion.

(Ref. Guyton & Hall-11th Edition)

Diference between hydrolytic and Ecbolic type of secretion

Hydrolytic	*Ecbolic*
1. Poor in enzyme but rich in HCO_3^-	1. Rich in enzyme but poor in HCO_3^-
2. It is thin and watery.	2. It is thick.
3. It is secreted by secretin.	3. It is secreted by PZ-CCK.
4. It is secreted in response to acid chyme in the duodenum.	4. It is secreted in response to fatty food in duodenum.
5. It mainly neutralizes the pH of chyme.	5. It is disgetive in function.

Secretions of the small intestine

Brunner's gland : In the duodenum there are small, coiled acinotubular duodenal glands called Brunner's glands.

Crypts of Lieberkhan : Throughout the small intestine there are simple tubular intestinal glands called crypts of Lieberkuhn.

Valvulae conniventes : These are valve-like folds in the mucous membrane in the small intestine. These are various kinds of enteroendocrine cells.

Paneth cells : Endocrine cells located in the depths of the crypts of Lieberkuhn-secrete defensins, naturally occurring peptide antibiotics that are also secreted elsewhere in the body. The migrating enterocytes are exposed to a high concentrate of the defenses, and this may protect them as they move to the tops of the villi. Paneth cells may also secret guanylin.

(Ref. Ganong 22th Edition; page-505, 506)

Secretions of the small intestine

1. ***Secretion of mucus by Brunner's glands in the duodenum*** : An extensive array of compound mucous glands, called *Brunner's glands*, is located in the first few centimeters of the duodenum, mainly between the pylorus and the papilla of Vater where the pancreatic juices and bile empty into the duodenum.

   a. *Secretions of these glands* : These glands secrete large amounts of alkaline mucus in response to- i. *tactile stimuli or irritating stimuli* of the overlying mucosa, ii. *vagal stimulation*, which causes increased Brunner's glands secretion concurrently with increase in stomach secretion; and iii. gastrointestinal hormones, especially *secretin*.

   b. *Function of the mucus secreted by Brunner's glands* :
      i. It protect the duodenal wall from digestion by the highly acid gastric juice.
      ii. The mucus contains a large excess of bicarbonate ions, which add to the bicarbonate ions from pancreatic secretion and liver bile in neutralizing the hydrochloric acid entering the duodenum from the stomach.

   c. *Sympathetic stimulation* : Brunner's glands are inhibited by sympathetic stimulation : therefore, such stimulation is likely to leave the duodenal bulb unprotected and is perhaps one of the factors that cause this area of the gastrointestinal tract to be the site of peptic ulcers in about 50 per cent of ulcer patients.

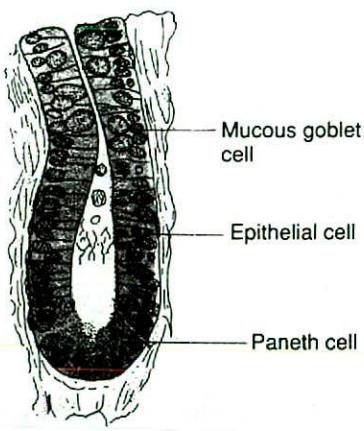


Figure10-6. *Crypt of Lieberkuhn, found in all parts of the small intestine between the villi, which secretes almost pure extracellular fluid.*

2. ***Secretion of the intestinal digestive juices by the Crypts of Lieberkuhn*** : Located over the entire surface of the small intestine are small pits called *crypts of Lieberkuhn*. These crypts lie between th intestinal villi. The intestinal surfaces of both the crypts and the villi are covered by an epithelium cornposed of two types of cells-

   a. a moderate number of *goblet cells*, which secrete mucus that lubricates and protects the intestinal surfaces.

   b. a large number of *enterocytes*, which, in the crypts secrete large quantities of water and electrolytes and, over the surfaces of the villi, reabsorb the water and electrolytes along with the end products of digestion.

The intestinal secretions are formed by the enterocytes of the crypts at a rate of about 1800 ml/day.

The secretions are almost pure cxtracellular fluid and have a slightly alkaline pH in the range of 7.5 to 8.0.

The secretions also are rapidly reabsorbed by the villi. This circulation of fluid from the crypts to the villi supplies a watery vehicle for absorption of substances from the chyme as it comes in contact with the villi. Thus, the primary function of the small intestine is to absorb the nutrients and their digestive products into the blood.

(Ref. Guyton & Hall-11th Edition, Page 805)

Mechanism of secretion of the watery fluid : The exact mechanism that causes the marked secretion of watery fluid by the crypts of Lieberkuhn is not known. It is believed to involve at least two active secretory processes : i. active secretion of chloride ions into the crypts and ii. active secretion of bicarbonate ions. The secretion of these ions causes electrical drag of sodium ions through the membrane and into the secreted fluid as well. Finally, all these ions together cause osmotic movement of water.

(Ref. Guyton & Hall-11th Edition, Page 805)

Digestive enzymes in the small intestinal secretion

When secretions of the small intestine are collected without cellular debris, they have almost no enzymes. However, the *enterocytes of the mucosa*, especially those that cover the villi, do contain digestive enzymes that digest specific food substances while they are being absorbed through the epithelium.

These enzymes are the following :

i. Several peptidases for splitting small peptides into amino acids i.e enteropeptidase, aminopeptidases, carboxypeptidases, endopeptidases, dipeptidases

ii. Four enzymes for splitting disaccharides into monosaccharides - sucrose, maltose. isomaltase, and lactase.

iii. Small amounts of *intestinal lipase* for splitting neutral fats into glycerol and fatty acids.

Most if not all of these digestive enzymes are located mainly in the *brush border of the enterocytes*. They are believed to

catalyze hydrolysis of the foods on the outside surfaces of the microvilli before absorption of the end products.

The epithelial cells deep in the crypts of Lieberkflhn continually undergo mitosis, and the new cells migrate along the basement membrane upward out of the crypts toward the tips of the villi, thus continually replacing the villus epithelium. As the villus cells age, they are finally shed into the intestinal secretions. The *life cycle of an intestinal epithelial cell is about 5 days.* This rapid growth of new cells also allows rapid repair of excoriations that occur in the mucosa.

(Ref. Guyton & Hall-11th Edition, Page 805)

Regulation of Small Intestinal Secretion

1. *Local stimuli* : By far the most important means for regulating small intestinal secretion are various local nervous reflexes, especially reflexes initiated by tactile or irritative stimuli and by the increase in enteric nervous activity associate with the gastrointestinal movements. Therefore, for the most part, secretion in the small intestine occurs simply in response to the presence of chyme in the intestine- the greater the amount of chyme, the greater the secretion.
2. *Hormonal regulation* : Some of the same hormones that promote secretion elsewhere in the gastrointestinal tract also increase small intestinal secretion, especially secretin and cholecystokinin. Also, some experiments suggest that other hormonal substances extracted from the small intestinal mucosa by the chyme might help to control secretion. In general, the local enteric reflex mehanisms almost certainly play by far the dominant role.

(Ref. Guyton & Hall-11th Edition, Page 806)

Enteropeptidase

i. *Source* : This enzyme is secreted by the brush border when the pancreatic juice enters the duodenum.

ii. *Content* : Enteropeptidase contains 41% polysaccharide, and this high polysaccharide content apparently prevents it from being digested itself before it can exert its effect.

iii. *Function* : The powerful protein-splitting enzymes of the pancreatic juice are secreted as inactive proenzymes. Trypsinogen is converted to the active enzyme trypsin by the enzyme enteropeptidase (enterokinase) when the pancreatic juice enters the duodenum.

Substrate : Trypsinogen

Product : Trypsin.

iv. *Deficiency symptoms* : Enteropeptidase deficiency occurs as a congenital abnormality and leads to *protein malnutrition.*

(Ref. Ganong 22th Edition; page 497)

(Q. 10. Write short notes on- Enteropeptidase)

Secretions of the large intestine

Large intestinal secretions are :

1. ***Mucus Secretion*** : The mucosa of the large intestine, like that of the small intestine, has many crypts of Lieberkuhn, but in this mucosa, unlike that of the small intestine, there are no villi. Also, the epithelial cells contain almost no enzymes. Instead, they consist mainly of mucous cells that secrete only mucus.

   Therefore, the great preponderance of secretion in the large intestine is mucus. This mucus contains large amounts of bicarbonate ions caused by active transport through other epithelial cells that lie between the mucus-secreting epithelial cells.

   Function of mucus : Mucus in the large intestine protects the wall against excoriation, but in addition, it provides the adherent medium for holding fecal matter together. Furthermore, it protects the intestinal wall from the great amount of bacterial activity that takes place inside the feces, and it plus the alkalinity of the secretion (pH of 8.0 caused by large amounts of sodium bicarbonate) provides a barrier to keep acids formed deep in the feces from attacking the intestinal wall.

   Regulation of secretion of mucus : The rate of secretion of mucus is regulated principally by direct, tactile stimulation of the mucous cells on the surface of the mucosa and by local nervous reflexes to the mucous cells in the crypts of Lieberkuhn. Stimulation of the pelvic nerves, which carry the parasympathetic innnervation to the distal one half to two thirds of the large intestine, also causes marked increase in the secretion of mucus. This occurs alnong with an increase in motility. Therefore, during extreme parasympathetic stimulation, often caused by emotional disturbances, so much mucus may be secreted into the large intestine that the person has a bowel movement of ropy mucus as often as every 30minutes; this mucus contains little or no fecal material.

2. ***Secretion of water and electrolytes in response to irritation*** : Whenever a segment of the large intestine becomes intensely irritated, as occurs when bacterial infection becomes rampant during enteritis, the mucosa secretes large quantities of water and electrolytes in addition to the normal viscid solution of alkaline mucus. This acts to dilute the irritating factors and to cause rapid movement of the feces toward the anus. The usual result is diarrhea, with loss of large quanitites of water and electrolytes. But the diarrhea also washes away the irritant factor, which promotes earlier recovery from the disease than would otherwise occur.

(Ref. Guyton & Hall-11th Edition, Page 806)

Liver and Biliary System

Principal functions of the liver

1. *Formation and secretion of bile*
2. *Nutrient and vitamin metabolism :*
   - Glucose and other sugars
   - Amino acids
   - Lipids
     - Fatty acids
     - Cholesterol
     - Lipoproteins
   - Fat soluble vitamins
   - Water soluble vitamins
2. *Inactivation of various substances :*
   - Toxins
   - Steroids
   - Other hormones
3. *Synthesis of plasma proteins :*
   - Acute phase proteins
   - Albumin
   - Clotting factors
   - Steroid binding and other hormone binding proteins
4. *Immunity*
   - Kupffer cells.

(Ref. Ganong 22th Edition, Page 500)

Storage function of liver

Liver is the storage house of the body. It can storage carbohydrate, protein and fat as glycogen. It also storage certain vitamins, iron. Liver is the one of the major blood reserviors.

1. *Storage of glycogen :* When blood glucose level rises liver converts all the glucose into glycogen by the glycongenesis and stored them. It also converts the fat and protein into glucose by the process of neoglucogenesis and then stored them as glycogne.
2. *Storage of vitamins :* Liver has a particular propensity for storing vitamins and act as a excellent source of certain vitamins during their deficiency. It can stored vitamin-A to a greatest extent but large quantity of vit-D and vit-B_{12} are normally stored.
3. *Storage of irons :* The greater portion of iron in the body is stored in the liver in the form of ferritin. The hepatic cell contain a protein called apoferritin which combines with iron and convert them into ferritin and stored until needed.
4. *Storage of blood :* An icrease in pressure in the veins draining the liver dams blood in the liver sinosoids and there by causes the entire liver to swell. In this way liver stored about 200 ml to 400 ml of blood.

Liver function tests

A. Biochemical tests :

1. *Synthetic function tests* :
   - i. Total protein concentration
   - ii. Serum albumin & globulin level
   - iii. Albumin-globulin ratio (Normal- 1.7 : 1)
   - iv. Prothrombin time (Normal : 12-16 second)
2. *Excretory function test* :
   - i. Serum bilirubin level
   - ii. Urine bilirubin
   - iii. Urine urobilinogen
   - iv. Stool stercobilinogen
3. *Metabolic function test* :
   - i. Glucose tolerance test
   - ii. Galactose tolerance test
   - iii. Serum cholesterol level
4. *Serum enzymes* :
   - i. Alanine aminotransferase (ALT) / Serum glutamate pyruvate test (SGPT)
   - ii. Aspertate aminotransferase (AST) / Serum glutamate oxaloacetate test (SGOT)
   - iii. Alkaline phosphatase
   - iv. γ-glutamyl transferase
5. Bromsulphthaline clearance test - very rarejy done.
6. Other determination : Ferritin
   - i. Iron binding.c~pacity saturation
   - ii. Alpha 1 -antitrypsin

     α-fetoprotein : normaly produced by fetal liver.
   - iii. Ceruloplasmin
   - iv. Copper

B. Serological test :
   - i. Viral antigens and antibodies
   - ii. Autoantibodies.

Use of liver function test

1. Differential diagnosis of jaundice.
2. Diagnosis of liver damage.
3. To asses the extent of liver damage.
4. To follow the progress of liver.

Galactose tolerance test :

Procedure : Normally galactose is absorbed from the intestine and converted into glucose in the liver. 40 gm of galactose in 400 ml of water is given to a fasting subject and blood galactose level is determined at 40, 60, 90, 120 minutes interval. In healthy individual, there is hardly any rise of blood glucose. The normal galactose index: 68-160. Galactose index above 160 indicates hepatic damage.

Oral glucose tolerance test- OGTT

a. *Procedure* : The individual should be on a normal diet at least for 3 days and is to fast overnight (10-16 hours).

Test :

1. Fasting venous blood for plasma and urine samples are collected.
2. 75 gm glucose in 250-300 ml water is given by mouth.
3. Venous blood and urine samples are collected either at the end of 2 hours or at half hourly intervals for 2 to 2 hours 30 minutes
4. Plasma glucose on each sample is estimated. Sugar on each sample is examined.

b. *Result* :

	Normal	*Diabetes mellitus*
i. Fasting	Less than 5.5	7.8 or more
ii. 2 hours after 75 gm glucose	Less than 7.8	1.11 or more

Normal renal threshold of glucose is usually 180 mgldl. Diabetes of long standing often have elevated renal threshold.

Thus, a patient can be diagnosed as diabetic on the basis of OGTT & fasting blood glucose concentration.

Bile

Characteristics :

1. Quantity : 600 - 1000 ml/day (Guyton 10th, P-749)
   500 ml/day (Ganong 20th, P-485)
2. Colour : Yellowish green
3. Consistancy : Viscid, mucoid liquid
4. Reaction : Alkaline
5. PH : a. *Liver bile* : 7.6 - 8.6
   b. *Gall bladder bile* : 6.8 - 7.8
6. Taste : Bitter.

(Ref. Ganong 22th, P-501; Guyton 11th, P-803 & others)

Formation of bile

Bile is made up of the bile salts, bile pigments, and other substances dissolved in an alkaline electrolyte solution that resembles pancreatic juice.

About 500 ml is secreted per day. Some of the components of the bile are reabsorbed in the intestine and then excreted again by the liver (enterohepatic circulation).

Bile pigments : The glucuronides of the *bile pigments*, bilirubin and biliverdin, are responsible for the golden-yellow color of bile. These are the breakdown products of hemoglobin.

Bile salts : The bile salts are sodium and potassium salts of bile acids, and all those secreted into the bile are conjugated to glycine or taurine, a derivative of cysteine.

Bile acids : The bile acids are synthesized from cholesterol. The four found in humans are listed in Figure 26-22. In common with vitamin D, cholesterol, a variery of steroid hormones, and the digitalis glycosides, the bile acids contain the cyclopentanoperhydroPhenanthrene nucleus. The two principal (primary) bile acids formed in the liver are *cholic acid* and *chenodeoxycholic acid*. In the colon, bacteria convert cholic acid to deoxycholic acid and chenodeoxycholic acid to lithocholic acid. Since they are formed by bacterial action deoxycholic acid and chenodeoxycholic acid are called secondary biles acids.

(Ref. Ganong 22th Edition; page 504, 505)

Composition of liver and gall bladder bile

Costituents	*Liver bile*	*Gall bladder bile*
Water	97.5 g/dl	92 g/dl
Bile salts	1.1 g/dl	6 g/dl
Bilirubin	0.04 g/dl	0.3 g/dl
Cholesterol	0.1 g/dl	0.3 to 0.9 g/dl
Fatty acids	0.12 g/dl	0.3 to 1.2 g/dl
Lecithin	0.04 g/dl	0.3 g/dl
Na^+	145 mEq/L	130 mEq/L
K^+	5 mEq/L	12 mEq/L
Ca^{++}	5 mEq/L	23 mEq/L
Cl^-	100 mEq/L	25 mEq/L
HCO_3^-	28 mEq/L	10 mEq/L

(Ref. Guyton & Hall-11th Edition, Page 803)

Pathway of bile secretion

Hepatic cell → Bile canaliculi → Intralobular bile ductule → Inter lobular bile ductule → Right and left hepatic duct → Common hepatic duct → Cystic duct → Gall bladder → Cystic duct → Bile duct → Hepato pancreatic ampulla → Duodenum.

Function of bile

1. *Digestive function :*
   Bile helps in the digestion of fat and to a lesser extent of proteins and carbohydrates with the help of bile salt which acts in the following way -
   i. *By reducing surface tension :* By this fat is converted into emultion by broken down into samller molecules and increases the surfac area. So the process of digestion is quickened.
   ii. *By activating the action of lipase :* It is due to cholic acid.
   iii. *By solvent action :* It acts as a good solvent, so enzyme acts on aqueous solution.
2. *Absorptive function :* With the help of bile salts, bile help in the absorption of fat and other substances like fat soluble vitamins, iron, calcium etc.

3. *Cholagogue action :* Increases the secretion of bile from liver.
4. *Laxative function :* Bile salts increases peristalsis and thereby help in daefecation.
5. *Excretory function :* Certain substances are excreted through bile :
   i. Heavy metals : Cu, Zn, Hg, etc.
   ii. Certain drugs
   iii. Bile pigments- bilirubin etc.
   iv. Cholesterol
   v. Toxin, Bacteria.
6. *Mucin of bile acts as buffer and lubricant.*

(Ref. Guyton & Hall-11th Edition, page 802 & others)

Bile salts

Name of bile salts :

1. Na tauro-cholate, K tauro-cholate.
2. Na glycholate, K glycholate.

Synthesis of bile salt :

1. Taurine + Cholic acid → Taurocholic acid
   Taurocholic acid + Na → Na taurocholate
   Taurine is the derivatives of cystin.
2. Glycin + Enolic acid → Glycholic acid
   Glycholic acid + Na → Na Glycholate.

Function of the bile salt :

1. *Emulsifying or detergent function :* Bile salts decreases the surface tention of the particle and allows the intentional agitation to break the fat glubules into minute sizes.
2. *Absorptive function :* Bile salts help in the absorption of fatty acids, monoglycerides, cholesterol and other lipids from the intestinal tract by forming minute complexs with these lipid called micelles. It also help in the absorption of fat soluble vitamins, iron, calcium etc.

(Ref. Guyton & Hall-11th Edition, page 804)

Entero-hepatic circulation of bile salts

After secretion into the intestine from gallbladder, 94% of bile salt are reabsorbed into the blood fromthe small intestine, about one half of this by *diffusion* through the mucosa in the early portions of the small intestine and the remainder by an active transport process through the intestinal mucosa in the distal ileum. They then enter the portal blood and pass back to the liver.

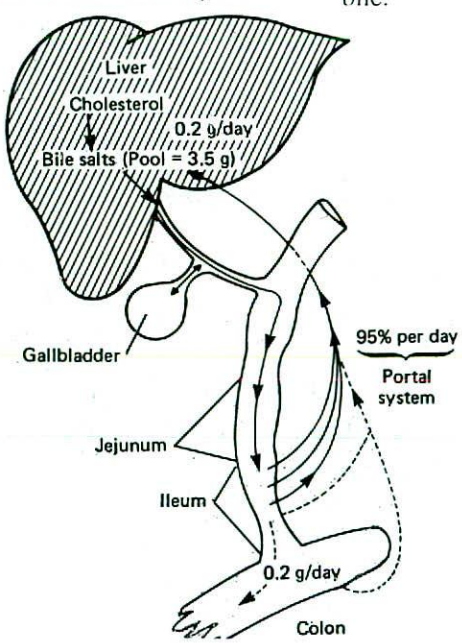


Fig. 10-5. *Entero Hepatic Circulation of Bile Salt.*

On reaching the liver, the bile salts are reabsorbed from the venous sinusoids into the hepatic cells and thus resecreted into the bile. In this way about 94% of all the bile salts are recirculated into the bile. So that on the average, these salts make the entire circuit some, 18 times before being carried out in the feces. These recirculation of bile salts is called entero-hepatic circulation of bile salts.

(Ref. Guyton & Hall-11th Edition, page 804)

Bile Acids

1. Cholic acid.
2. Deoxycholic acid.
3. Cheno-deoxycholic acid.
4. Lethocholic acid.
5. Enolic acid.

Bile pigment

1. Bilirubin
2. Biliverdin.

Gall Bladder

Functions of gall bladder :

1. Gall bladder absorbs H_2O and concentrates bile about 10-20 times.
2. It acts as a store house of bile.
3. It helps in the intermittent flow of bile.
4. It absorbs inorganic salts from bile to some extent and reduced the alkalinity of liver bile.
5. It excretes cholesterol to some extent.
6. It secretes mucous which is the main source of mucin in bile.

Mechanism of emptying of Gall bladder

Two basic conditions are required for the emptying of gall bladder-

i. Contraction of gall bladder.
ii. Simultaneous relaxation of sphincter of oddi.

Both this effect takes place in the following ways :

1. *Presence of fat and partially digested protein* in the upper part of small intestine causes release of hormone cholecystokinin from the intestinal mucosa passes to gall bladder via blood causes specific contraction of gall bladder that provides the pressure required to move bile towards duodenum.
2. *Vagal stimulation :* Stimulation of vagus nerve during cephalic phase of gastric secretion or during various intestino-

intestinal reflexes causes additional weak contraction of gall bladder and emptying of it occurs.

3. *Cholecystokinin :* Directly acts on the sphincter of oddi causing relaxation of it. In addition during contraction of gall bladder a neurogenic signal also inhibit the sphincter of oddi that causes flow of bile from the common bile duct into duodenum.
4. *The presence of food in the duodneum* - Causes the degree of peristalsis in the duodenal wall to increase. Each time a peristaltic wave travels toward the sphincter of oddi, causes relaxation of it, by the phenomenon receptive relaxtion. Causes flow of bile from the bile duct in to the duodenum.

(Ref. Guyton & Hall-11th Edition, Page 803)

Cholagogue : Any agent which increases the flow of bile from gall bladder into the intestine is known as cholagogue.

Choleratic : Any agent which increases the output of bile from liver, without changing its necessary constituentse. g - Bile salts, fat etc.

Hydrocholcratic : Any agent which increases the volume of bile without corresponding increases in bile solids.

Mechanism of gall stone formation

Under abnormal conditions the cholesterol may precipitate, resulting in the formation of gall stones.

The different conditions that can cause cholesterol precipitation are :

1. Too much absorption of water from the bile.
2. Too much absorption of bile salts and lecithin from the bile.
3. Too much secretion of cholesterol in the bile.
4. Inflammation of epithelium of the gall bladder.

The latter two of these require the following special explanation : The amount of ***cholesterol*** in the bile is determined partly by the quantity of fat that the person eat, for the hepatic cells synthesize cholesterol as one of the products of fat metabolism in the body. For this reason, persons on a high fat diet over a period of many years are prone to the development of gall stones.

Inflammation of the gall bladder epithelium often results from low grade chronic infection; this changes the absorptive characteristics of the gall bladder mucosa, sometimes allowing excessive absorption of bile salts, or other substances that are necessary to keep the cholesterol in solution. As a result, cholesterol begins to precipitate, usually forming many small crystals of cholesterol on the surface of the inflammed mucosa. These, in turn, act as nidi for further precipitation of cholesterol, and the crystals grow larger and larger. Occasionally tremendous numbers of sandlike stones develop, but much more frequently these coalesce to form a few large galls tones, or even a single stone that fills the entire gall bladder. Also, calcium ions, which are usually concentrated five or more fold in the gall bladder, often precipitate in the gall stones, making them x-ray opaque so that they can be seen in radiographs of the abdomen.

(Ref. Guyton & Hall-11th Edition, page 804)

Digestion & Absorption

Digestion

Basic mechanism of digestion : The basic mechanism of disgestion is hydrolysis. Almost all the carohydrates of the diet are large poly-saccharides or disaccharides, which are the combination of many mono saccharides bind to each other by the process of condensation. This mean that a H^+ is removed from one of the mono saccharide while $OH^-$is removed from the next one, this two mono saccharides then combines with each other at the sites of removal and the H^+ and OH combines to from water. When carbohydrates are digested back into mono saccharides, specific enzymes return the H^+ & OH^- to the polysaccha- rides and thereby seperate the monosaccharides from each other. This process is known as hydrolysis.

$$R_1 + R_2 + H_2O \xrightarrow{\text{Digestive Enzymes}} R_1OH + R_2H$$

(Ref. Guyton & Hall-11th Edition, page 808)

Absorption

Definition : Absorption is the process by which the end products of digestion pass through the intestinal epithelium and enter the blood stream.

Anatomical basis of absorption : The stomach is a poor absorptive area of the gastrointestinal tract because it lacks the typical villus type of absorptive membrane and because the junctions between the epithelial cells are tight junctions, only a few highly lipid soluble substances, such as *alcohol*,and some drugs like *aspirin*, can be absorbed in small quantities.

(Ref. Guyton & Hall-11th Edition, page 812)

Absorptive surface of the small intestinal mucosa- *The villi* :

1. *Valvulae conniventes or folds of Kercking* : These folds extend circularly most of the way arround the intestine specially in duodenum and jejunum which increase the surface area of absorptive mucosa about 3 fold.
2. *Villi (millions in number)* : These project about 1 mm from the surface of the mucosa and enhances the absorptive area another 10 fold.
3. *Brush border consisting of microvilli (1 micro meter in length, 0.1 micro meter in diameter)* : These increases the absorptive area another 20 fold.

Thus the combination of folds of Kercking, the villi and

the micro vill increases the absorptive area of the mucosa about 1000 fold, making tremendous total area of about 250 square meters for the entire intestine.

(Ref Guyton & Hall-11th Edition, page 812, 813)

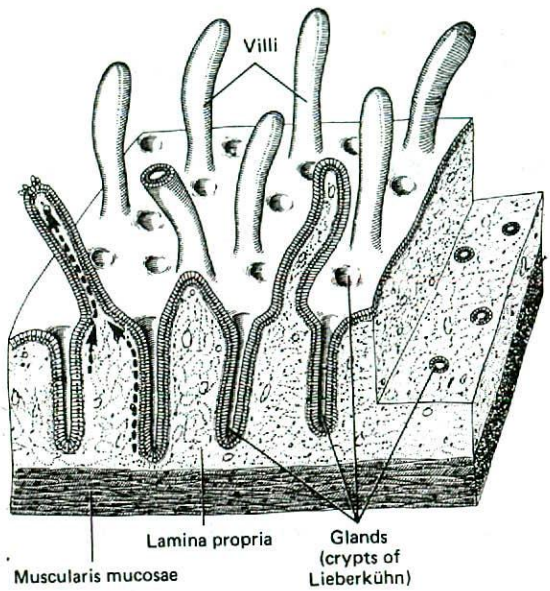


Fig. 10-7. *Structure of the small intestine. The epithelium linning the glands continues over the villi. Mucosal cells are formed in the glands and migrate up to the tips of the villi, where they are shed into the intestinal lumen.*

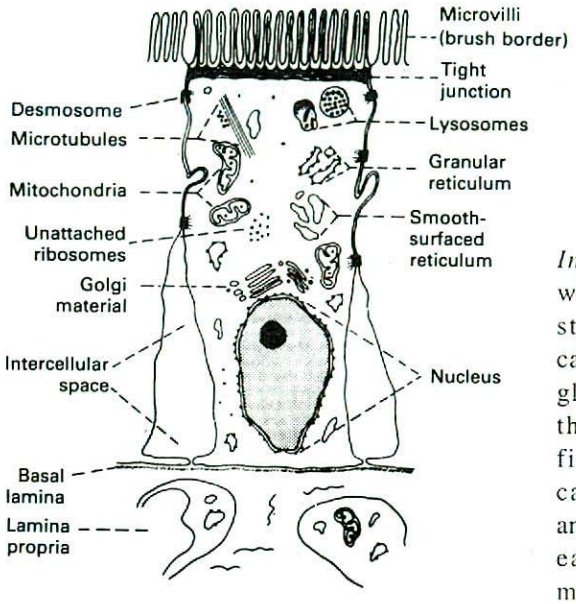


Fig. 10-8. *Diagram of enterocytes; the microvilli, the tight connections of cells at the mucosal edge (desmosomes), and the space between the cells at base (intercellular space).*

Basic mechenisms of absorption : Most substances must pass from the intestinal lumen into the mucosal cells (enterocytes) and then out of the enterocytes to the interstitial fluid, and the processes responsible for movement across the luminal cell membrane are often quite different from those responsible for movement across the basal and lateral cell membranes to the interstitial fluid.

(Ref. Ganong 22th edition, Page-467)

Carbohydrate

Carbogydrate digestion

Carbohydrate foods of the diet : Only three major sources of carbohydrates exist in the normal human diet.

They are :

i. *Sucrose*, which is the *disaccharide* known popularly as cane sugar.

ii. *Lactose*, which is a *disaccharide* in milk.

iii. *Starches*, which are large *polysaccharides* present in almost all nonanimal foods and particularly in the grains.

iv. *Other carbohydrates* ingested to a slight extent are amylose, glycogen, alcohol, lactic acid, pyruvic acid, pectins, dextrins, and minor quantities of carbohydrate derivatives in meats.

v. *Cellulose* : The diet also contains a large amount of cellulose, which is a carbohydrate.

However, no enzymes capable of hydrolyzing cellulose are secreted in the human digestive tract. Consequently, cellulose cannot be considered a food for the human being.

In the ordinary diet, which contains far more starches than all other carbohydrates combined, glucose represents more than 80 percent of the final products of carbohydrate digestion, and galactose and fructose each seldom represent more than 10 percent of the products of carbohydrate digestion.

(Ref. Guyton & Hall 11-th Edition, Page 809)

The digestion of carbohydrate in different part of GI tract occurs as follows :

1. *In the mouth* : When food is chewed, it is mixed with saliva, which contains the enzyme ptyalin (an α-amylase) secreted mainly by the parotid glands. This enzyme hydrolyzes starch into the disaccharide maltose and other small polymers of glucose that contain three to nine glucose molecules. But the food remains in the mouth only a short time, and probably not more than 5% of all the startches that are eaten will have hydrolyzed by the time the food is swallowed.

$$\text{Starches} \xrightarrow{ptyalin} \text{Maltose and 3 to 9 glucose polymers}$$

2. *In the stomach* : However, starch digestion continues in the body and fundus of the stomach for as long as 1 hour before the food becomes mixed with the stomach secretions. Then the acidity of the salivary amylase is blocked by the acid of the gastric secretions because it is essentially nonactive as an enzyme once the pH of the medium falls below about 4.0. Nevertheless, on the average, before the food and its accomaining saliva do become completely mixed with the gastric secretions, as much as 30 to 40 per cent of the starches will have been hydrolyzed mainly to maltose.

3. *In the small intestine (Luminal digestion)* : Within 15 to 30

minutes after the empties from the stomach into the duodenum and mixes with pancreatic juice, vartually all the starches will have been digested. In general starches are almost totally converted into *maltose and other very small glucose polymers* before they have passed beyond the duodenum and upper jejunum.

Starch and dextrins —*Pancreatic α-amylase*→ Maltose and other very small glucose polymers.

4. *Membrane digestion (Digestion by enterocytes enzymes)* : The carbohydrate splitting enzymes of small intestine (maltase, lactase, alpha-dextrinase, sucrase, trehalase) are secreted from the enterocytes lining the villi of the small intestine and digest all the disaccharide in the following way

   a. Maltose —*Maltase 25 %, α-Dextrinase 50% , Sucrase 25%*→ Glucose + Glucose

   b. α-Dextrins —*α-Dextrinase 95% , Maltase 25%*→ Glucose + Glucose

   c. Maltotriose —*α-Dextrinase 95% , Maltase 25% , Sucrase 25%*→ Glucose + Glucose

   d. Lactose —*Lactase 100%*→ Glucose + Galactose

   e. Sucrose —*Sucrase 100%*→ Glucose + Fructose

   f. Trehalose —*Trehalase 100%*→ Glucose.

(Ref. Guyton & Hall-11th Edition, Page 809; Ganong 22th Edition; page 467)

N.B. Deficiency of one or more of the brush border *oligosaccharidases* may cause *diarrhea, bloating, and flatulence* after ingestion of sugar. The ***diarrhea*** is due to the increased number of osmotically active oligosaccharide molecules that remain in the intestinal lumen, causing the volume of the intestinal contents to increase. In the colon, bacteria break down some of the oligosaccharides, further increasing the number of osmotically active particles. The ***bloating*** and ***flatulance*** are due to the production of gas (CO_2 and H^+) from disaccharide reduces in the lower small intestine and colon.

Lactase is of interest because, in most mammals and in many races of humans, intestinal lactase activity is high at birth, then declines to low levels during childhood and adulthood. The low lactase levels are associated with intolerance to milk (***lactose intolerance***). Most Europeans and their American descendants retain their intestinal lactase activity in adulthood; the incidence of lactase deficiency in northern and western Europeans is only about 15%. However, The incidence in the blacks, American Indians, Orientals, and Mediterranean populations is 70-100%. Milk intolarence can be ameliorated by administration of commercial lactase preperations, but this is expensive. Yogurt is better tolerated than milk in intolerant individuals because it contains its own bacterial lactase.

(Ganong 21th edition, Page-471-474)

Absorption of carbohydrate

The end product of carbohydrate digestion are monosaccharide, disacchride. About 80% of monosaccharides are absorbed in the form of glucose and other in the form of galactose, fructose etc.

Absorption of glucose & galactose : Glucose and galactose are absorbed by the active process with the help of carrier by a process called sodium co-transport theory for glucose transport.

It is known that the carrier protein for transport of glucose present in the brush border of the epithelial cell. It is believed that the carrier protein has receptor sites for both a glucose molecule and a sodium ion. Glucose is transported whenever Na^+ is transported. The sodium binds with the receptor and transported with the help of energy from intestine to the interior of the intestinal epithelial cell and at the same time it pulls the glusose along with it. Then from the cell, glucose is transported into blood stream by the facilated diffusion.

Absorption of fructose : It is transported by facilated diffusion all the way through the intestinal epithelium but not coupled with sodium transport. On entering the cell, much of the fructose becomes phosphorylated, then converted to glucose

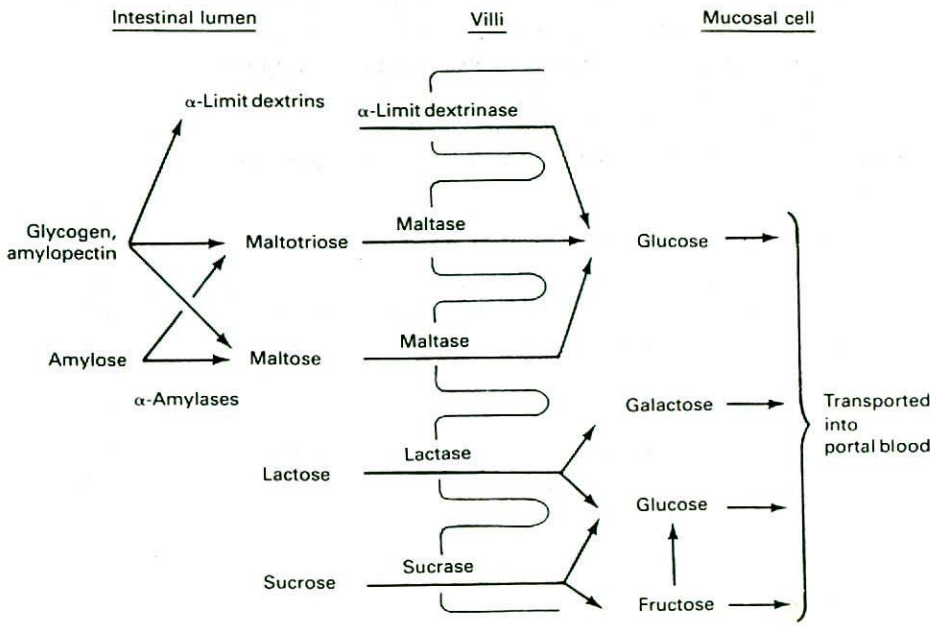


Table 10-9. *Outline of carohydrate digestion and adsorption.*

and finally transported in the from of glucose the rest of the way into the paracellular space.

(Ref. Guyton & Hall-11th Edition, Page 815, 816)

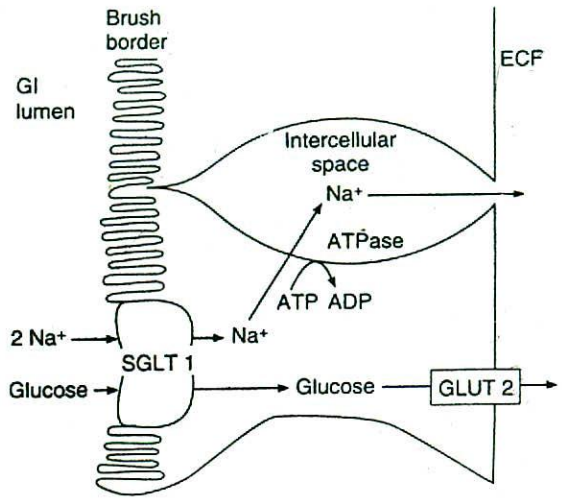


Figure 10-10. *Mechanism for glucose transport across intestinal epithelium. Glucose transport into the intestinal cell is coupled to Na^+ transport, utilizing the cotransporter SGLT 1. Na^+ is then actively transported out of the cell, and glucose enters the interstitium by facilitated diffusion via GLUT 2. From there, it diffuses into the blood.*

Protein

Digestion of protein

Proteins of the diet : The dietary proteins are formed of long chains of amino acids bound together by *peptide linkages*. The characteristics of each type of protein are determined by the types of amino acids in the protein molecule and by the arrangement of these amino acids.

The digestion of protein in different parts of GI tract occurs as follows :

1. *In the mouth :* No digestion of protein in the mouth.
2. *In the stomach :* In presence of pepsin and gastric HCl protein is converted into proteoses, peptones and a few polypeptides. Providing only 10-20 % of total protein digestion. A *gelatinase* that liquifies gelatin is also found in the stomach. *Chymosin*, a milk-clotting gastric enzyme also known as *renin*, is found in the stomachs of young animals but is probably absent in humans *(Ref. Ganong 22th, p-457).*

Protein —(*Pepsin*, *HCl*)→ Proteoses / Peptone / Polypeptides

3. *In the duodenum (Digestion of proteins by pancreatic secretions) :* Here trypsin and chymotrypsin of pancreatic juice act on broken and unbroken peptone and converts it into poly peptide.

Proteoses / Peptones —(*Trypsin, Chymotrypsi, Carboxy polypeptidase, Proelastase*)→ Poly peptides / Amino acids / Polypeptides

Carboxypolypeptidase then cleaves individual amino acids from the carboxyl ends of the polypeptides. *Proelastase* gives rise to elastase that in turn digests the elastin fibers that hold meats together.

Only a small percentage of the proteins are digested all the way to their constituent amino acids by the pancreatic juices. Most remains as dipeptides, tripeptides, and some even larger.

4. *Digestion of peptides by peptidases in the enterocytes that line the small intestinal villi mainly in the deudenum and jejunum :* The last digestion of the proteins in the intestinal lumen is achieved by the enterocytes that line the villi of the small intestine, mainly in the duodenum and jejunum. These cells have a brush border that consists literally of hundreds of microvilli projecting from the surface of each cell. In the cell membrane of each of these microvilli are multiple *peptidases* that protrude through the membranes to the exterior, where they come in contact with the intestinal fluids. Two types of peptidase enzymes are especially important, *aminopoly-peptidase* and several *dipeptidases*. They succeed in splitting the remaining larger polypeptides into tripeptides and dipeptides and a few all the way to amino acids. Both the amino acids and the dipeptides and tripeptides are easily transported through the microvillar membrane to the interior of the enterocyte.

Polypeptides / Amino acids —(*Peptidase*)→ Amino acids

Finally, inside the cytosol of the enterocyte are multiple other peptidases that are specific for the remaining types of linkages between the amino acids. Within minutes, virtually all the last dipeptides and tripeptides are digested to the final stage of single amino acids; they then pass on through the opposite side of the enterocyte into the blood. More than 99 percent of the final protein digestive products that are absorbed are individual amino acids, with only rare absorption of peptides, and very, very rare absorption of whole protein molecules. Even these very few molecules of protein can sometimes cause serious allergic or immunological disturbances.

(Ref. Guyton & Hall-11th Edition, Page 810)

Nucleic acids : Nucleic acids are split into nucleotides in the intestine by the *pancreatic nueleases*, and the nueleotides are split into the nucleosides and phosphoric acid by

enzymes that appear to be located on the luminal surfaces of the mucosal cells. The nucleosides are then split into their constituent sugars and purine and pyrimidine bases. The bases are absorbed by active transport.

(Ganong 22th edition, Page-473)

Absorption of protein

At least seven different transport systems transport amino acids into enterocytes. Five of these require Na^+ and cotransport amino acids and Na^+ in a fashion similar to the cotransport of Na^+ and glucose (Figure 13-9). Two of these four also require Cl^-. In two systems transport is independent of Na^+.

Di- and tripeptides are transported into enterocytes by a system that requires H^+ instead of Na^+. There is very little absorption of larger peptides. In the enterocytes, amino acids released from the peptides by intracellular hydrolysis plus the amino acids absorbed from the intestinal lumen and brush border are transported out of the enterocytes along their basolateral borders by at least five transport systems. From there, they enter the hepatic portal blood. Two of these systems are dependent on Na^+, and three are not. Significant amounts of small peptides also enter the portal blood.

(Ganong 22th edition, Page-472)

N.B. Absorption of amino acids is rapid in the duodenum and jejunum but slow in the ileum. Approxiniately 50% of the digested protein comes from ingested food, 25% from proteins in digestive juices, and 25% from desquamated mucosal cells. Only 2-5% of the protein in the small intestine escapes digestion and absorption. Some of the *ingested protein enters the colon* and is eventually digested by bacterial action. The protein in the stools is not of dietary origin but comes from bacteria and cellular debris. There is evidence that the peptidase activities of the brush border and the mucosal cell cytoplasm are increased by resection of part of the ileum and that they are independently altered in starvation. Thus. these enzymes appear to be subject to homeostatic regulation. In humans, a congenital defect in the mechanism that transports neutral amino acids in the intestine and renal tubules causes ***Hartnup disease***. A congenital defect in the transport of basic amino acids causes ***cystinuria***.

In infants, moderate amounts of undigested protems are also absorbed. The protein antibodies in maternal colostrum are largely secretory immunoglobulins (IgAs), the production of which is increased in the breast in late pregnancy. They cross the mammary epithelium by transcytosis and enter the circulation of the infant from the intestine, providing passive immunity against infections. Absorption is by endocytosis and subsequent exocytosis.

Protein absorption declines with age, but adults still absorb small quantities. Foreign proteins that enter the circulation provoke the formation of antibodies, and the antigen-antibody reaction occurring upon subsequent entry of more of the same protein may cause allergic symptoms. Thus, absorption of proteins from the intestine may explain the occurrence of allergic symptoms after eating certain foods. The incidence of food allergy in children is said to be as high as 8%. Certain foods are more allergenic than others. Crustaceans, mollusks, and fish are common offenders, and allergic responses to legumes, cows milk, and egg white are also relatively frequent.

Absorption of protein antigens, particularly bacterial and viral proteins, takes place in large *microfold cells* or ***M cells***, specialized intestinal epithelial cells that overlie aggregates of lymphoid tissue (Peyer's patches). These cells pass the antigens to the lymphoid cells, and lymphoblasts are activated. The activated lymphoblasts enter the circulation, but they later return to the intestinal mucosa and other epithelia, where they secrete IgA in response to subsequent exposures to the same antigen. This ***secretory immunity*** is an important defense mechanism.

(Ganong 22th edition, Page-472)

N.B. The blood of fasting animals contain 3-6 mgm of amino acid/100ml. After meal the amount rises to 8-10 m gm/100 ml of blood.

Fat (Lipids)

Digestion of fat

Fats of the diet : By far the most abundant fats of the diet are the *neutral fats*, also known as *triglycerides*, each molecule of which is composed of a glycerol nucleus and three fatty acids. Neutral fat is a major constituent in food of animal origin and much less so in food of plant origin.

In the usual diet are also small quantities of *phospholipids, cholesterol, and cholesterol esters*. The phospholipids and cholesterol esters contain fatty acid and therefore can be considered fats themselves. Cholesterol, on the other hand, is a sterol compound that contains no fatty acid, but it does exhibit some of the physical and chemical characteristics of fat; it is derived from fats, and it is metabolized similarly to fats. Therefore, cholesterol is considered, from a dietary point of view, a fat.

The digestion of fat in different parts of the GI tract occurs as follows :

1. *In the mouth* : No digestion of fat occurs in the mouth cavity.
2. *In the stomach* : Fat digestion may occur in the stomach because the fat splitting enzyme (gastric lipase) is present in the gastric juice but this enzyme is inactive in acid media.

   A small amount of triglycerides is digested in the stomach by *lingual lipase* that is secreted by lingual glands in the mouth and swallowed with the saliva. The amount of digestion is less than 10 percent and generally unimportant. Instead, essentially all fat digestion occurs in the small intestine.

3. *Digestion of fat in the intestine :* The main digestion of fat occurs in the duodenum and small intestine by *pancreatic lipase* with the help of bile salts. Bile salts at first emulsified the fat globules and broken them into simple form and increases the surface area of fat globules. Then the enzyme lipase act on the surface of fat globules and splits into free fatty acids and monoglycerides.

Emulcification of fat by bile acids and lecithin : Emulsifi cation is the process by which fat globules are broken down into simple form by the bile salts.

Bile salts have two parts-carboxyl or polar part which is highly soluble in water and a sterol part which is highly soluble in fat. Therefore, bile salts aggregate at surfaces of the fat globules in the intestinal contents with the carboxyl portion of bile salt, while the sterol portion is dissolves in the fat itself. These effect greatly decreases the interfacial tension of the fat. When the interfacial tension of a globule of non miscible fluid is low, this fluid on aggitation, can be broken up into may minute particles. As a result each time the diameter of the fat globules are decreased and the total surface area of the fat increases two times. This process is called emulsification. The lipase are water soluble compound and can attack the fat globules only on their surfaces.

$$\text{Fat} \xrightarrow{\textit{Bile + aggitation}} \text{Emulsified fat}$$

$$\xrightarrow{\textit{Pancreatic lipase}} \text{Fatty acid \& 2-monoglycerides.}$$

Digestion of triglycerides by pancreatic lipase : By far the most important enzyme for the digestion of triglycerides is pancreatic lipase in the pancreatic juice. This is present in enormous quantities in pancreatic juice, enough to digest all triglycerides that it can reach within a few minutes. In addition, the enterocytes of the small intestine contain a minute quantity of lipase known as enteric lipase, but this is usually unimportant.

End products of fat digestion : Most of the triglycerides of the diet are split by pancreatic lipase into free fatty acids and 2-monoglycerides, Minute portions remain in the diglyceride state.

(Ref. Guyton & Hall-11th Edition, Page811, 812)

Role of bile salts in accelerating fat digestion, formation of Micelles : Micelles are spherical globules about 3-4 nano meter in diameter and composed of 20 to 40 molecules of bile salts. The sterol nuclei of 20 to 40 bile salt molecules of the micelles aggregate together to form a small fat globules in the middle of micelles. This aggregation causes pollar group of the micelle to project outwards to cover the micelle. Since this pollar group are negatively charges, they allow the entire micelle globule to become dissolved in the water of the digestive fluid.

During triglycerides digestion, as rapidly as the monoglycerides and fatty acids are formed they become dissolved in the fatty portion of the micelles and transported to the surface of the epithelial cell.

(Ref. Guyton & Hall-11th Edition, Page 812)

Digestion of cholesterol esters and phospholipids : Most of the cholesterol in the diet is in the form of cholesterol esters, which are combinations of free cholesterol and one molecule of fatty acid. Phospholipids also contain fatty acid chains within their molecules. Both the cholesterol esters and the phospholipids are hydrolyzed by two other lipases in the pancreatic secretion that free the fatty acids-the enzyme cholesterol ester hydrolase to hydrolyze the cholesterol ester and phospholi -pase A_2 to hydrolyze the phospholipid.

The bile salt micelles play the same role in *"ferrying"* free cholesterol and the remaining portions of the digested phospho lipid molecules as they play in *"ferrying"* mono glycerides and free fatty acids. Indeed, this role of the micelles is essential to the absorption of cho -lesterol becasues essentially no cholesterol can be absobed without the function of the micelles. On the other hand, as much as 60 percent of the triglycerides can be digested and absorbed even in the absence of the bile salt micelles.

(Ref. Guyton & Hall-11th Edition, Page 812)

Absorption of fat

Fats are digested to form *monoglycerides* and *free fatty acids*, both of these digestive end products become dissolved in the central lipid portion of the *bile micelles*. Because of the molecular dimensions of these micelles, only 3 to 6 nanometers in diameter, and because of their highly charged exterior, they are soluble in the chyme. In this form, the monoglycerides and the fatty acids are carried to the surfaces of the microvilli of the intestinal cell brush border and then penetrate into the recesses among the moving, agitating microvilli. Here, both the monoglycerides and the fatty acids diffuse immediately from the micelle and then through the membrane of the microvillii to the interior of the cell; this is possible because these lipids are also soluble in the epithelial cell membrane. This leaves the bile micelles still in the chyme, where they function again and again to help absorb still more monoglycerides and fatty acids. Thus, the micelles perform a *'ferrying'* function that is highly important for fat absorption. In the presence of an abundance of bile micelles, about 97 per cent of the fat is absorbed; in the absence of the bile micelles, only 40 to 50 per cent is normally absorbed.

The ***fate of the fatty acids in enterocytes*** depends on their size. Fatty acids containing less than 10-12 carbon atoms pass from the mucosal cells directly into the portal blood, where they are transported as free (unesterified) fatty acids. The fatty acids containing more than 10-12 carbon atoms are reesterified to

triglycerides in the mucosal cells. In addition, some of the absorbed cholesterol is esterifled. The triglycerides and cholesteryl esters are then coated with a layer of protein, cholesterol, and phospholipid to form ***chylomicrons***. These leave the cell and enter the lymphatics.

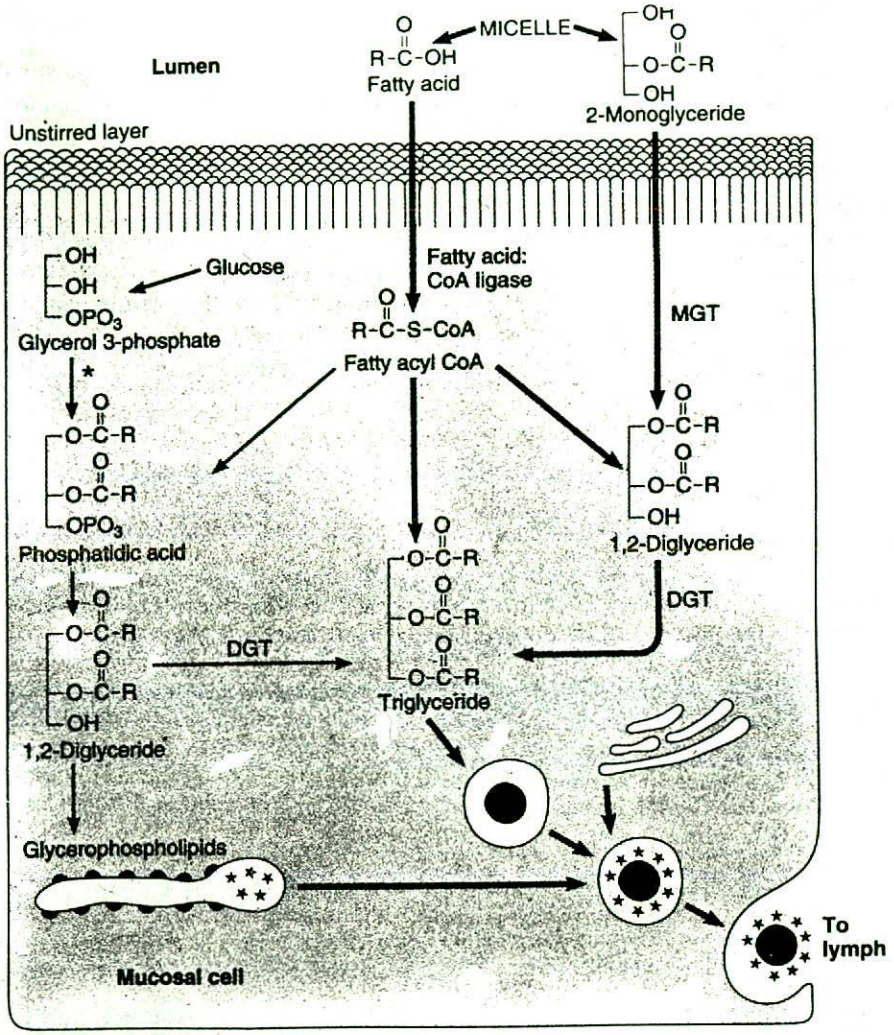


Figure 10-11. *Lipid absorption. Triglycerides are formed in the mucosal cells from monoglycerides and fatty acids. Some of the glycerides also come from glucose via phosphatidic acid. The triglycerides are then converted to chylomicrons and released by exocytosis. From the extracellular space, they enter the lymph. Heavy arrows indicated major pathways.*, reaction inhibited by monoglyceride; MGT, monoacylglycerol acyltransferase; DGT, diacylglycerol acyltransferase.*

In mucosal cells, most of the triglyceride is formed by the acylation of the absorbed 2-monoglycerides, primarily in the smooth endoplasmic reticulum. However, some of the triglyceride is formed from glycerophosphate, which in turn is a product of glucose catabolism. Glycerophosphate is also converted into glycerophospholipids that participate in chylomicron formation. The acylation of glycerophosphate and the formation of lipoproteins occur in the rough endoplasmic reticulum. Carbohydrate moieties are added to the proteins in the Golgi apparatus, and the finished *chylomicrons are extruded by exoeytosis* from the basal or lateral aspects of the cell.

Absorption of long-chain fatty acids is greatest in the upper parts of the small intestine, but appreciable amounts are also absorbed in the ileum.

The processes involved in fat absorption are not fully mature at birth, and infants fail to absorb l0-15% of ingested fat. Thus, they are more susceptible to the ill effects of disease processes that reduce fat absorption.

(Ganong 22th edition, Page-474, 475)

Short-chain fatty acids in the colon : Increasing attention is being focused on short-chain fatty acids (SCFAs) that are produced in the colon and absorbed from it. SCFAs are two-to five-carbon weak acids that have an average normal concentration of about 80 mmol/L in the lumen. About 60% of this total is acetate, 25% proprionate, and 15% butyrate. They are formed by the action of colonic bacteria on complex carbohydrates, resistant starches, and other components of the dietary fiber, ie, the material that escapes digestion in the upper gastrointestinal tract and enters the colon.

Absorbed SCFAs are metabolized and make a significant contribution to the total caloric intake, in addition, they exert a trophic effect on the colonic epithehal cells, combat inflammation, and are absorbed in part by exchange for H^+, helping to maintain acid-base equilibrium. There are a family of anion exchangers in the colonic epithelial cells. SCFAs also promote the absorption of Na^+, although the exact mechanism for coupled Na^+-SCFA absorption is unsettled.

(Ganong 22th edition, Page 475)

Absorption of cholesterol & other sterols : Cholesterol is readily absorbed from the small intestine if bile, fatty acids, and pancreatic juice are present. Closely related sterols of plant origin are poorly absorbed. Almost all the absorbed cholesterol is incorporated into chylomicrons that enter the circulation via the lymphatics, as noted above. Nonabsorbable plant sterols such as those found in *soybeans reduce the absorption of cholesterol*, probably by competing with cholesterol for esterification with fatty acids.

(Ganong 22th edition, Page 475)

Absorption of water & electrolytes

Water : The intestines are presented each day with about 2000 ml of ingested fluid plus 7000 ml of secretions from the mucosa of the gastrointestinal tract and associated glands.

Ninety eight percent of this fluid is reabsorbed, with a daily fluid loss of only 200 ml in the stools. Only small amounts of water move across the gastric mucosa, but water moves in both directions across the mucosa of the small and large intestines in response to osmotic gradients.

Water moves into or out of the intestine until the osmotic pressure of the intestinal contents equals that of the plasma. The osmolality of the duodenal contents may be hypertonic or hypotonic, depending on the meal ingested but by the time the meal enters the jejunum, its osmolality is close to that of plasma. This osmolality is maintained throughout the rest of the small intestine ; the osmotically active particles produced by digestion are removed by absorption, and water moves passively out of the gut alone the osmotic gradient thus generated.

In the colon ; Na^+ is pumped out and water moves passively with it, again along the osmotic gradient. Saline cathartics such as magnesium sulfate are poorly absorbed salts that retain their osmotic equivalent of water in the intestine, thus increasing intestinal volume and consequently exerting a laxative effect.

(Ganong 22th Edition; page 475)

Daily water turnover (ml) in the gastrointestinal tract

Ingested		***2000***
Endogenous secretions		***7000***
Salivary glands	1500	
Stomach	2500	
Bile	500	
Pancreas	1500	
Intestine	1000	
	7000	
Total Input		***9000***
Reabsorbed		***8800***
Jejunum	5500	
Ileum	2000	
Colon	1300	
	8800	
Balance in stool		***200***

Data from Moore EW ; Physiology of Intestinal Water and Electrolyte Absorption. American Gastroenteorological Society. 1976.

(Ganong 22th edition, Page-476)

Sodium : Some Na^+ diffuses into or out of the small intestine depending on the concentration gradient. Because the luminal membranes of all enterocytes in the small intestine and colon are permeable to Na^+, and their basolateral membranes contain Na^+-K^+ ATPase. Na^+ is also actively absorbed throughout the small and large intestines.

In the small intestine, active transport of Na^+ is important in bringing about absorption of glucose, some amino acids and other substances. Conversely, the presence of glucose in the intestinal lumen facilitates the reabsorpton of Na^+.

(Ganong 22th edition, Page-476)

Potassium : There is some seeretion of K^+ into the intestinal lumen, especially as a component of mucus, but for the most part, the movement of K^+ across the gastrointestinal mucosa is due to diffusion. On the other hand, there are K^+ channels in luminal as well as the basolateral membrane of the enterocytes of the colon, so K^+ is secreted into the colon. In addition, K^+ moves passively down its electrochemical gradient. The accumulation of K^+ in the colon is partially offset by H^+-K^+ ATPase in the luminal membrane of cells in the distal colon, with resulting active transport of K^+ into the cells. Nevertheless, loss of ileal or colonic fluids in chronic diarrhoea can lead to severe hypokalemia.

(Ganong 22th edition, Page-476)

Chloride : Cl^+ normally enters enterocytes from the interstitial fluid via Na^+-K^+-$2Cl^-$ co-transporters in their basolateral membranes and the Cl^- is then secreted into the intestinal lumen via channels that are regulated by various protein kinases. One of these is activated by protein kinase A and hence by cAMP.

(Ganong 22th edition, Page-476)

Chloride & Bicarbonate : In the ileum and the colon, it appears that Cl^- is actively reabsorbed in a one-for-one exchange for HCO_3^-. This tends to make the intestinal contents more alkaline. However, the physiologic significance of this exchange is uncertain.

Absorption of Vitamins & Minerals

Vitamins : Absorption of water-soluble vitamins is rapid, but absorption of the fat-soluble vitamins A, D, E and K is deficient if fat absorption is depressed because of lack of pancreatic enzymes or if bile is excluded from the intestine by obstruction of the bile duct. Most vitamins are absorbed in the upper small intestine, but vitamin B_{12} is absorbed in the ileum. This vitamin binds to intrinsic factor, a protein secreted by the stomach, and the complex is absorbed across the ileal mucosa.

Vitamin B_{12} absorption and folate absorption are Na^+ independent, but all seven of the remaining water-soluble vitamins- thiamine, riboflavin, niacin, pyridoxine, pantothenate, biotin and ascorbic acid are absorbed by carriers that are Na^+ cotransporters.

(Ganong 22th edition, Page-477)

Calcium : From 30 to 80% of ingested calcium is absorbed .

Active transport of Ca^{++} out of the intestinal lumen occurs primarily in the upper small intestine, and there is also some absorption by passive diffusion. Active transport is facilitated by 1, 25 dihydroxycholecalciferol, the metabolite of vitamin D that is produced in the kidneys. The metabolite induces the synthesis of two forms of a Ca^{+}-binding protein in the mucosal cells and several forms of Ca^{+}-H^{+} ATPase. However, the details of the way the metabolite stimulates absorption remain unsettled. The rate of production of 1, 25 dihydroxycholecalci-ferol is increased when the plasma calcium level is decreased and reduced when the plasma calcium level is elevated . Consequently, Ca^{++} absorption is adjusted to body needs ; absorption is increased in the presence of Ca^{++} deficiency and decreased in the presence of Ca^{++} excess. Ca^{++} absorption is also facilitated by protein. It is inhibited by phosphates and oxalates because these anions form isoluble salts with Ca^{++} in the intestine. Magnesium absorption is facilitated by protein.

(Ganong 22th edition, Page-477)

Action of Bacterial Flora on Food

1. ***Carbohydrate*** *:* The changes brought about on carbohydrate are known as fermentation. A group of bacteria (bacillus cellulose dissolvens-BCD) also break down the cellulose.

   Carbohydrate $\xrightarrow{Bacteria}$ i. Lower fatty acids (Lactic, acetic, propionic, butyric and benzoic).
   ii. Gases-CO_2, CH_4, and H_2.

   Cellulose $\xrightarrow{BCD}$ i. Acid- butyric acid.
   ii. Alcohol-ethyl alcohol.
   iii. Gases - CO_2, H_2 .

2. *Fat* : Bacteria hydrolyzes fat into glycerol and fatty acids.
   i. Fat $\xrightarrow{Bacteria}$ Glycerol & fatty acids.
   ii. Phospholipid $\xrightarrow{Bacteria}$ Choline $\rightarrow$ toxic neurine.
   iii. Cholesterol $\rightarrow$ Coprosterol.

3. *Proteins* :
   i. Changes brought about on proteins are known as putrefaction.
   ii. Hydrolysis of protein
   iii. Further changes are deamination, decarboxi lation, oxidation, reduction and demethylation takes place on the liberated amino acids.

Table 10-10 *:* **Normal transport of substances by the intestine and location of maximum absorption or secretion.**[1]

Absorption of :	*Small Intestine*			*Colon*
	Upper[2]	*Mid*	*Lower*	
Sugars (glucose, galactose, etc)	++	+++	++	0
Amino acids	++	+++	++	*0*
Water-soluble and fat-soluble vitamins except vitamin B12	+++	++	0	0
Betaine, dimethylglycine, sarcosine	+	++	++	*?*
Antibodies in newborns	+	++	+++	?
Pyrimidines (thymine and uracil)	+	+	*?*	*?*
Fatty acid absorption and conversion to triglyceride	+++	++	+	0
Bile salts	+	+	+++	*0*
Vitamin B_{12}	0	+	+++	0
Na^{+}	+++	++	+++	+++
K^{+}	+	+	+	Sec
Ca^{++}	+++	++	+	*?*
Fe^{++}	+++	++	+	?
Cl^{-}	+++	++	+	+
SO_4^{++}	++	+	0	?

Ref. Ganong 22th Edition

Mastication

Definition : As soon as food is taken into the mouth, it is ground under the teeth by a process known as mastication of chewings.

Mechanism : It is due to alternate contraction and relaxation of the muscles concerned in the movement of lower jaw, aided by muscles of tongue, lips and cheks. It is a reffex act.

Steps : Mastication process consists of-

1. Crushing movement or biting with closed mouth (upward movement of the lower jaw) : Carried out by combined action of masseter, temporalis and pterygoids.
2. Opening of mouth (downward movement of lower jaw) : By digastrics and mylohyoids and help by gravity.
3. Rotatory movement of the molars : By pterygoids. It is essential for grinding.

   Apart from these, the jaw moves side to side and also forward and backward.

Purpose of mastication :

1. It helps in digestion.
2. It helps in swallowing.
3. During chewing, secretion of saliva helps dissolution of food materials, needed to stimulate taste sensation, so increases palatability of the food.
4. It imparts the sensation of pleasure in taking food and leads to satisfaction and contentment.
5. Prolonged chewing with pleasantness of taste leads to initiate the cephalic phase of digestive juice.

Deglutition or Swallowing

Definition : It is the process by which the bolus of food, formed during chewing is propelled backward and pass into stomach through oesophagus is called deglutition. It takes only 9 -12 seconds.

Mechenism : Swallowing (deglutition) is a reflex response that is triggered by afferent impulses in the trigeminal, glossopharyngeal, and vagus nerves. These impulses are integrated in the nucleus of the tractus solitarius and the nucleus ambiguus. The efferent fibers pass to the pharyngeal musculature and the tongue via the trigeminal, facial, and hypoglossal nerves. Swallowing as initiated by the voluntary action of collecting the oral contents on the tongue and propelling them backward into the pharynx. This starts a wave of involuntary contraction in the pharyngeal muscles that pushes the material into the esophagus. Inhibition of respiration and glottic closure are part of the reflex response. Swallowing is difficult if not impossible when the mouth is open, as anyone who has spent time in the dentist's chair feeling saliva collect in the throat is well aware. A normal adult swallows frequcntly while eating, but swallowing also continues between meals. The total number of swallows per day is about 600 : 200 while eating and drinking, 350 while awake without food, and 50 while sleeping.

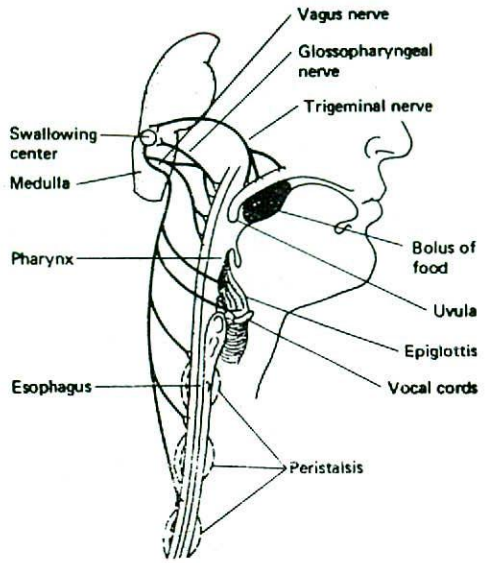


Fig. 10-11. *Mechanism of swallowing.*

At the pharyngoesophageal junction, there is a 3 cm segment of esophagus in which the resting wall tension is high. This segment relaxes reflexly upon swallowing, permitting the swallowed material to enter the body of the esophagus. A peristaltic ring contraction of the esophageal muscle forms behind the material, which is then swept down the esophagus at a speed of approximately 4 cm/s. When humans are in an upright position, liquids and semisolid foods generally fall by gravity to the lower esophagus ahead of the peristaltic wave.

(Ref. Ganong 22th Edition; page 489)

Low of gut

An electrical stimulus to any point of a gut causes a contractile ring to appear near the point of stimulus but at the same time causes a relaxation- receptive relaxation several cm down the gut towards the anus.

Movement of GI tract

Basic movement of GI tract

There are two basic type of movements :

1. Mixing movement.
2. Propulsive movement.

Mixing movement

i. *Definition* : It is the movement which mixes intestinal contents.

ii. *Type :* Fixed.

iii. *Pattern :* Contraction and relaxation.

iv. *Cause :*

   a. Peristaltic contraction.

b. Local constrictive contractions of small segment of gut wall.

v. *Purpose :*
   a. Mixes the food particles with digestive juices.
   b. Helps in absorption by constant bringing of chyme with absorptive surface.

Propulsive movement *(Peristalsis)*

i. *Definition* : It is the movement that propels intestinal content in aboral direction that is from mouth to anus.

ii. *Type :* Translatory; moves the food paticle anal wards.

iii. *Pattern :* Proximal contraction and distal relaxation.

iv. *Cause :* Distension of gut wall.

v. *Purpose :*
   a. To travel the food in aboral direction.
   b. Helps in the partial mixing of food with digestive juices.

Cause of anal ward movement

i. Receptive relaxation and low of gut

ii. Gradient theory for analward movement.

Movements of different part of GIT

1. *In stomach* :
   i. Mixing movement.
   ii. Propulsive or peristalsis movement.
   iii. Hunger contraction.
2. *In small intestine :*
   i. Mixing movement or segmentation (1 cm at a time).
   ii. Propulsive or peristalsis (velocity 0.5-2 cm/sec).
   iii. Pendular movement.
3. *In large intestine* :
   i. Mixing movement or Haustration (2.5 cm at a time)
   ii. Propulsive movement or Mass movement (20 cm at a time).
4. *Movement of villi* :
   i. Side to side movement
   ii. Pumping movement.

Segmentation contraction *(mixing contractions)*

When a portion of the small intestine becomes distended with chyme, the stretching of the intestinal wall elicits localized concentric contractions spaced at intervals along the intestine and lasting a fraction of a minute. The contractions cause 'segmentation' of the samll intestine. That is they divide the intestine into spaced segments that have the appearance of a chain of sausages. As one set of segmentation contractions relaxes, a new set often begins, but the contractions this time occur mainly at new points between the previous contrctions. Therefore, it is clear that the segmentation contractions can 'chop' the chyme about 2 to 3 times per minute, in this way promoting progressive mixing of the solid food paticles with the secretions of the small intestine. This frequency is about 12 per minute in the duodenum, and proximal jejunum, the maximum

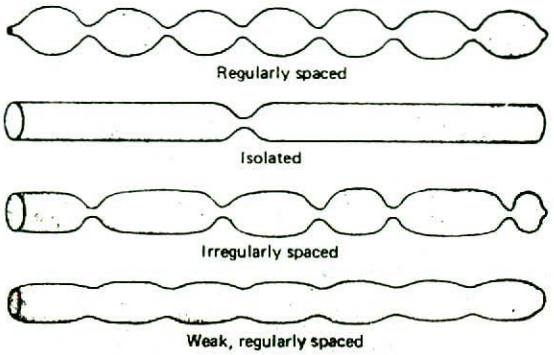


Fig. 10-12. *Segmentation contraction.*

frequency of the segmentation contractions in these areas is also about 12 per minute. However, in the terminal ileum, the maximum frequency is usually 8 to 9 contractions per minute.

The segmentation contractions become exceedingly weak when the excitatory activity of the enteric nervoous system is blocked by atropine.

(Ref. Guyton & Hall-11th Edition, Page 787)

Propulsive or peristalsis movement

Peristalsis in the small intestine : Chyme is propelled through the small instestine by peristatic waves. These can occur in any part of the small intestine, and they move anal ward at a velocity of 0.5 to 2 cm per second, much faster in the proximal intestine and much slower in the terminal intestine. However, they are normally very weak and usually die out after travelling only 3 to 5 cms, very rarely farther than 10 cms, so that the movement of the chyme is also very slow, so slow in fact that the net movement of the chyme along the small intestine averages only 1 cm per minute. This means that normally 3 to 5 hours are required for passage of chyme from the pylorus to the ileocecal valve.

Control of peristalsis by nervous and hormonal signals : Peristaltic activity of the small intestine is greatly increased after a meal. This is caused partly by the beginning entry of chyme into the duodenum but also by the so called gastroenteric reflex that is initiated by distension of the stomach and conducted principally through the myenteric plexus from the stomach down along the wall of the small intestine. This reflex increases the over all degree of excitability of the small intestine, including both increased motility and secretion. The function of the peristaltic waves in the small intestine is not only to cause progression of the chyme toward the ileocecal valve but also to spread out the chyme along the intestinal mucosa.

(Ref. Guyton 10th Edition, Page-734)

The peristaltic rush : Though peristalsis in the small intestine

is normally very weak, intense irritation of the intestinal mucosa, as occurs in some severe cases of infectious diarrhoea, can cause both very powerful and rapid peristalsis called the *peristaltic rush*. This is initiated mainly by extrinsic nervous reflexes to the brain stem and back again to the gut. The powerful peristaltic contractions then tavel long distances in the small intestine within minutes, sweeping the contents of the intestine into the colon and thereby relieving the small intestine of either irritative chyme or excessive distension.

(Ref. Guyton & Hall-11th Edition, Page 787)

Movements of the colon

1. ***Haustrations** (Mixing movements)* : It is the mixing movement of large intenstine. At each saculation of large intenstine, the circular muscles contract first and constricting the lumen of the colon almost to occlusion. This is immediately followed by the contraction of the longitudinal muscles which are aggregated to form three longitudinal strips known as *taenia coli*. These combined contraction of the circular and longitudinal muscles cause the unstimulated portion of the large intestine to bulge outward into bag like sacs called haustrations.

   In this movement all the faecal materials is gradually exposed to the surface of the large intestine and fluid is progressively absorbed.

   (Ref. Guyton & Hall-11th Edition, Page 788)

2. ***Mass Movements** (propulsive movements)* : A mass movement is a modified type of peristalsis characterized by the following sequence of events :
   i. *First*, a constrictive ring occurs in response to a distended or irritated point in the colon, usually in the transverse colon.
   ii. Then, rapidly thereafter the 20 or more centimeters of colon distal to the constriction lose their haustrations and instead contract as a unit, forcing the fecal material in this segment en masse further down the colon. The contraction develops progressively more force for about 30 seconds, and relaxation then occurs during the next 2 to 3 minutes. Then, another mass movement occurs, this time perhaps farther along the colon.

   A whole series of mass movements usually persists for 10 to 30 minutes. Then they cease but return perhaps a half day or even a day later. When they have forced a mass of feces into the rectum, the desire for defecation is felt.

   Initiation of mass movements by gastrocolic and duodenocolic reflexes : The appearance of mass movements after meals is facilitated by gastrocolic and duodenocolic reflexes. These reflexes result from distention of the stomach and duodenum. They occur either not at all or hardly at all when the extrinsic autonomic nerves to the colon have been removed; therefore, the reflexes almost certainly are initiated by way of the autonomic nervous system.

   Irritation in the colon can also initiate intense mass movements. For instance, a person who has an ulcerated condition of the colon mucosa (*ulcerative colitis*) frequently has mass movements that persist almost all the time.

   (Ref. Guyton & Hall-11th Edition, Page 789)

Pyloric pump : The pumping action of the antral portion of stomach that propels chyme from stomach to duodenum is called pyloric pump.

Kneading movements : These are contractions affecting a large segment with relaxation of the adjacent segment, which go on alternately shaking the content vigorously.

Antiperistaltic movements : It is the reverse peristalsis occurs in a part of the large intestine, especially in ascending and transverse colon. This usually alternates with normal peristalsis, so the contents have no chance to be moved into aboral direction. This movement prolongs the stay of the contents to help absorption of water. It is rarely seen in human beings.

Hunger : It is the some total of those process which leads to intake of food. Lateral nucli of hypothalamus acts as hunger centre.

Appetite : A desire to take a particular type of food.

Hunger pangs : When hunger contraction actually causes pain in stomach pit then it is called hunger pangs. Usually do not begins 12 to 24 hours after the last ingestion of food.

Hungar contraction : Beside the peristaltic contraction that occur when food is present in the stomach, another type of intense contraction, called hungar contraction, often occurs when the stomach has been empty for several hours or more.

(Ref. Guyton & Hall-11th Edition, Page 785)

Vomiting

a. *Definition* : It is the process by which the content of upper gastro intestinal tract is expelled out through mouth cavity.

b. *Cause :*
   i. It is due to irritation, distention or over excitation of stomach or doudenum.
   ii. Vomitting may also caused by stimulation of chemoreceptor trigger zone of medulla by some drugs (apomorphine, morphine) or by motion sicknes. It may also occur due to cortical excitation.

c. *Mechanism of vomitting :*
   i. A deep breath.
   ii. Rising of hyoid bone and larynx to pull the

cricoesophageal sphincture open.

iii. Closing of glotis.

iv. Lifting the soft palate to close the posterior naris.

v. Strong downward contraction of the diaphragm along with the simultaneous contaction of all the abdominal muscles & squeezing the stomach & rise of intragastric pressure.

vi. Relaxation of gastro-oesophageal sphincture and finally expulsion of gastric content.

Feces

Approximate composition of feces on an average diet

Component	*Percentage of total Weight*
Water	75
Solids	25
	Percentage of total Solids
Cellulose and other indigestible fiber	Variable
Bacteria	30
Inorganic material (mostly calcium andphosphates)	15
Fat and fat derivatives	5

Also desquamated mucosal cells, mucus and small amounts of digestive enzymes.

(Ref. Ganong 22th edition, Page 509)

Defecation

Most of the time, the rectum is empty of feces. This results partly from the fact that a weak functional sphincter exists about 20 centimeters from the anus at the juncture between the sigmoid colon and the rectum. There is also a sharp angulation here that contributes additonal resistance to filling of the rectum. When a mass movement forces feces into the rectum, the desire for defecation is normally initiated immediately, including reflex contraction of the rectum and relaxation of the anal sphincters.

Continual dribble of fecal matter through the anus is prevented by tonic constriction of-

i. The *internal anal sphincter*, a several-centimeters-long thickening of the circular smooth muscle that lies immediately inside the anus.

ii. The *external anal sphincter*, composed of striated voluntary muscle that both surrounds the internal sphincter and extends distal to it. The external sphincter is controlled by nerve fibers in the pudendal nerve, which is part of the somatic nervous system and therefore is under *voluntary, conscious* or at least *subconscious control*; subconsciously, it is usually kept continuously constricted unless conscious signals inhibit the constriction.

Defecation reflexes : Ordinarily, defecation is initiated by defecation reflexes.

1. *Intrinsic reflex* : One of these reflexes is an *intrinsic reflex* mediated by the local enteric nervous system in the rectal wall. This can be described as follows :

   When feces enter the rectum, distention of the rectal wall initiates afferent signals that spread through the myenteric plexus to initiate peristaltic waves in the descending colon, sigmoid, and rectum, forcing feces toward the anus. As the peristaltic wave approaches the anus, the internal anal sphincter is relaxed by inhibitory signals from the myenteric plexus; if the external anal sphincter is also consciously, voluntarily relaxed at the same time, defecation occurs.

   However, the intrinsic myenteric defecation reflex functioning by itself is relatively weak. To be effective in causing defecation, it usually must be fortified by another type of defecation reflex, a parasympathetic defecation reflex.

ii. *Parasympathetic defecation reflex* : It involves the sacral segments of the spinal cord. When the nerve endings in the rectum are stimulated, signals are transmitted first into the spinal cord and then reflexly back to the descending colon, sigmoid, rectum, and anus by way of parasympathetic nerve fibers in the pelvic nerves. These parasympathetic signals greatly intensify the penstaltic waves as well as relax the internal anal sphincter and thus convert the intrinsic myenteric defecation reflex from a weak effort into a powerful process of defecation that is sometimes effective in emptying the large bowel all at once all the way from the splenic flexure of the colon to the anus.

iii. Also, the afferent defecation signals entering the spinal cord initiate other effects, such as taking a deep breath, closure of the glottis, and contraction of the abdominal wall muscles to force the fecal contents of the colon downward and at the same time cause the pelvic floor to relax downward and pull outward on the anal ring to evaginate the feces.

(Ref. Guyton & Hall-11th Edition, Page 789)

Constipation

i. *Definition* : Constipation means slow movement of feces through the large intestine; it is often associated with large quantities of dry, hard feces in the descending colon that accumulate because of the long time available for absorption of fluid.

ii. *Cause* :

   a. Any pathology of the intestines that obstructs movement of intestinal contents, such as tumors, adhesions that constrict the intestines, and ulcers, can cause constipation.

b. A frequent functional cause of constipation is irregular bowel habits that have developed through a lifetime of inhibition of the normal defecation reflexes.
c. Infants are seldom constipated but part of their training in the early years of life requires that they learn to control defecation, and this control is effected by inhibiting the natural defecation reflexes.
d. Clinical experience shows that if one fails to allow defecation to occur when the defecation reflexes are excited or if one overuses laxatives to take the place of natural bowel function, the reflexes themselves become progressively less strong over a period of time and the colon becomes atonic.
e. Constipation can also result from spasm of a small segment of the sigmoid colon. It should be recalled that motility even normally is weak in the large intestine, so that even a slight degree of spasm is often capable of causing serious constipation.

iii. *Effects* : After the constipation has continued for several days and excessive feces have accumulated above the spastic sigmoid colon, excessive colonic secretions often lead to a day or so of diarrhoea. After this, the cycle begins again, with repeated bouts of alternating constipation and diarrhoea.

iv. *Management* :
a. Establishment of regular bowel habits early in life, usually defecating in the morning after breakfast when the gastrocolic and duodenocolic reflexes cause mass movements in the large intestine, the development of constipation in later life can generally be prevented.
b. Laxatives.

(Ref. Guyton & Hall-11th Edition; page 822)

(Q. 10. Write short notes on- constipation)

Flatus

i. *Definition* : Gases in the gastrointestinal tract called *flatus*.

ii. Sources : Gases, called flatus, can enter the gastrointestinal tract from three sources :
a. Swallowed air
b. Gases formed as a result of bacterial action
c. Gases that diffuse from the blood into the gastrointestinal tract.

iii. *Composition* :
a. *In the stomach* : Most gases in the stomach are mixtures of nitrogen and oxygen derived from swallowed air, and in the typical person most of these gases are expelled by belching.
b. *In the small intestine* :
* Only small amounts of gas are normally present in the small intestine, and much of this *gas is air* that passes from the stomach into the intestinal tract.
* In addition, considerable amounts of *carbon dioxide* occasionally accumulate because reaction between acidic gastric juice and bicarbonate in pancreatic juice sometimes liberates carbon dioxide too rapidly for all of this to be absorbed.

c. *In the large intestine* :
* A greater proportion of the gases is derived from *bacterial action*, including especially *carbon dioxide*, *methane* and *hydrogen*. They occur along with varying amounts of oxygen and nitrogen from swallowed air.
* When the methane and hydrogen become suitably mixed with oxygen from swallowed air, an actual *explosive mixture* is rarely formed; use of the electric cautery during sigmoidoscopy has been known to cause a mild explosion.

iv. *Foods cause greater expulsion of flatus* : Certain foods are known to cause greater expulsion of flatus through the anus than others- *beans, cabbage, onion, cauliflower, corn*, and *certain irritant foods such as vinegar.*

Some of these foods serve as a suitable medium for gas-forming bacteria, especially because of unabsorbed fermentable types of carbohydrates (for instance, beans contain an undigestible sugar that passes into the colon and becomes a superior food for the colonic bacteria. But in other instances, excess expulsion of gas results from irritation of the large intestine, which promotes rapid peristaltic expulsion of gases before they can be absorbed.

v. *Amount of gas formation* : The amount of gases entering or forming in the large intestine each day averages 7 to 10 liters.

vi. *Amount of gas expulsion and absorption* : The amount expelled through the anus is usually only liter. The remainder is normally absorbed into through the intestinal mucosa and expelled into the lung.

(Ref. Guyton & Hall-11th Edition; page 825)

(Q. 10. Write short notes on- Flatus)

Lactose intolerance

In most mammals and in many races of humans, *intestinal lactase* activity is high at birth, then declines to low levels during childhood and adulthood. The low lactase levels are associated with intolerance to milk (*lactse intolerance*).

Milk intolerance can be ameliorated by administration of commercial lactase preparations, but this is expensive. Yogurt is better tolerated than milk in intolerant individuals because it contains its own bacterial lactase.

(Ref. Ganong 22th Edition; page 469)

(Q. 09. Write short notes on- Lactose intolerance)

***Direction** : Write T for true & F for false against each of the following statement.*

Introduction

Q. 01. **Substances having antioxidant effects are**
- T a. vitamin E
- T b. selenium
- T c. vitamin A
- F d. vitamin K
- F e. thiamin.

Q. 02. **Function of the gastrointestinal tract are**
- T a. nervous and hormonal control.
- T b. absorption of digestive products
- T c. propultion of food through alimentary tract
- F d. absorption of digestive juice
- F e. circulation of hormone

Q. 03. **Regarding gastorintestinal blood flow**
- T a. PO_2 is high in the venules
- T b. it is increased by bradykinin
- T c. it is decreased by sympathetic stimulation.
- F d. PO_2 is high in the tips of the villi
- F e. it is increased by gastrin.

Q. 04. **Gastrointestinal smooth muscle**
- T e. spike potentials last for 10 to 20 milli seconds
- T a. functions as a syncytium
- T b. contracts rhythmically
- F c. spike potentials are not true action potentials
- F d. action potential are same as nerve fibers

Q. 05. **Salivary glands are activator of**
- T a. Cl^-
- F b. HCl
- F c. trypsin
- F d. enteropeptidase
- F e. H^+.

Q. 06. **Digestive activities of the pharynx are**
- T a. deglutition
- T b. closing the airway passage
- F c. relaxation of upper esophageal sphincter
- F d. permitting entry of bolus into stomach
- F e. lubrication of esophagus.

Q. 07. **Regarding stomach**
- T a. here HCl reduces ferric irons to ferrous irons.
- T b. motility is inhibited by enterogastrone
- F c. motility is increased when fats enter duodenum
- F d. absorbs vitamin B_{12}
- F e. secretion is inhibited by pentagastrin.

Q. 08. **Stomach**
- T a. stores food.
- T b. mixes food and gastric juice
- T c. secretes gastric juice
- F d. completes the digestion of proteins
- F e. absorbs 90% of all nutrients

Q. 09. **In the colon**
- T a. fecal transit time is inversely related to its fiber content
- T b. water absorbtion is more than in the small intestine
- T c. mucus lubricate the fecal contents
- F d. fecal transit time is about 7 days
- F e. bacteria amount to three quarters of the fecal weight.

Q. 10. **Appetite for food is increased**
- T a. if blood glucose level falls
- T b. by the type of food.
- T c. when lateral hypothalamic area is stimulated
- F d. if the stomach is distended
- F e. if posterior hypothalamic area is stimulated.

Q. 11. **Thirst sensation**
- T c. may be produced on stimulation of hypothalamus
- T d. is produced by rise in osmolarity of body fluid
- T a. increases in severe dehydration
- F b. decreases in severe dehydration
- F e. is produced by rise in blood volume.

Q. 12. **Dietary fiber includes one of following**
- T b. Pectins
- F a. Collagen
- F c. Keratin

F d. Elastin
F b. All.

Q. 13. **An increase in body fat increase**
T a. probability of increased morbidity and premature mortality.
T b. survival time during fasting
T c. survival time in cold weather
F d. percentage of water in the body
F e. specific gravity of the body

Q. 14. **Which of the following does not change with age**
T a. Glucose tolerance
F b. FEV_1
F c. GFR
F d. Hematocrit
F e. All.

Q. 15. **Energy for the brain in starvation is from**
T a. Glucose
T b. Ketones
F c. Fatty acids
F d. Amino acids
F e. All.

Gastric juice & Enzymes

Q. 16. **The feature of enzyme cascade systems is**
T a. Feed back regulation
F b. Amplification
F c. Allostearic inhibition
F d. Counter regulation
F e. None.

Q. 17. **Fastest acting enzyme is**
T a. Carbonic anhydrase
F b. Pepsin
F c. Trypsin
F d. Thrombin
F e. None.

Q. 18. **Mucus is secreted by**
T a. stomach
T b. duodenum
T c. ileum
T d. large intestine
F e. ear.

Saliva

Q. 19. **Saliva**
T a. contains high concentrations of potassumand bicarbonate ions.
T b. lubricates the mouth
T c. has antiseptic action
T d. helps in speech
F e. is required for complete digestion of starch

Q. 20. **Salivary secretion**
T a. contains low concentrations of sodium and chloride ions
T b. can be affected by higher centers.
F c. is decreased by parasympathetic stimulation
F d. is primarily under hormonal control
F e. increases during nervousness

Q. 21. **Saliva plays important role in**
T a. prevention of dental carries
T b. buffering action
T c. deglutition
F d. excretion of ammonia and salt
F e. water balance

Q. 22. **Characteristics of saliva include**
T a. more than twice the iodide level of plasma
F b. similar composition from different salivary gland.
F c. has no enzymic content
F d. less than half the ionic calcium level of plasma
F e. pH between 5 and 6.

Q. 23. **Saliva is necessary for**
T a. digestion of food
T b. swallowing of food
T c. taste sensation
T d. heat loss
T e. bacteriolytic action.

Q. 24. **The major enzyme of saliva is**
T a. amylase
F b. trypsin
F c. lipase
F d. pepsin
F e. gastrin.

Q. 25. **Hyposalivation occurs in**
T a. fever.
T b. sialolithiasis
T c. emotional state
F d. neoplasm of mouth
F e. pregnancy

Q. 26. **Hypersalivation occurs in**
T a. neurological disorder
T b. ulceration of esophagus
T c. pregnancy
F d. emotional state
F e. fever.

Q. 27. **Salivary secretions are abolished**
- T a. by the administration of anticholinergic agents
- F b. by activation of the sympathetic nerve
- F c. when weak acid are present in the mouth
- F d. at the one set of vomiting
- F e. by thinking of appetizing food.

Gastric juice

Q. 28. **Gastric hydrocholoric acid**
- T a. denatures proteins
- T b. sitmulates secretion of CCK
- T c. inhibits secretion of gastrin.
- F d. stimulates secretion of gastrin
- F e. inhibits secretion of secretin.

Q. 29. **Regarding reaction of digestive juices**
- T a. saliva usually slightly acidic
- T b. pancreatic juice alkaline
- F c. intestinal juice strongly alkaline
- F d. intestinal juice strongly acidic
- F e. gastric juice slightly acidic.

Q. 30. **The chief cells of the oxyntic glands**
- T a. secrete gelatinase.
- T b. are basophilic
- T c. secrete pepsinogen
- F d. secrete muc in
- F e. secrete HCI

Q. 31. **Pyloric glands of stomach secretes**
- T a. gastrin.
- T b. thick alkaline viscid mucous
- F c. both acid and pepsin
- F d. small amount of pepsinogen
- F e. alkaline thin watery mucus

Q. 32. **Which inhibits gastric secretion?**
- T a. Secretin
- F b. High gastric pH
- F c. Calcium
- F d. Insulin
- F e. All.

Q. 33. **Pepsin is an example of**
- T a. enzyme
- F b. hormone
- F c. nutrient
- F d. vitamin
- F e. lipid.

Q. 34. **Pepsin**
- T a. breaks certain peptide bonds
- T b. is the active form of pepsinogen
- F c. is secreted from zymogenic cells
- F d. splits short chain of triglycerides
- F e. kills microbes in a food.

Q. 35. **Pepsinogen is activated by**
- T a. Low pH
- F b. Enterokinase
- F c. Trypsin
- F d. Chymotrypsin
- F e. All.

Pancreatic juice

Q. 36. **Pancreatic secretion contain**
- T a. Trypsin
- T b. Lipase
- F c. Enteropeptidase
- F d. Pepsin
- F e. Renin

Q. 37. **Severe exocrine pancreatic deficiency causes**
- T a. undigested muscle fibres in the stool
- T b. bleeding tendency
- T c. steatorrhea
- F d. an abnormal mucous in the small intestine
- F e. normal glucose tolerance test

Q. 38. **Islets of Langerhans are found in**
- T a. pancreas
- F b. ovary
- F c. spleen
- F d. brain
- F e. liver.

Q. 39. **Pancreatic juice rich in water and electrolytes but poor in enzymes is secreted in response to**
- T a. Secretin
- F b. Pancreatozymin
- F c. Cholecystokinin
- F d. Proteins
- F e. All.

Small intestinal enzymes

Q. 40. **The brush border enzymes are**
- T a. invertase.
- T b. lactase
- T c. aminopeptidase
- F d. nuclease
- F e. chollagenase

Q. 41. **Small intestinal enzymes are**
- T a. enterokinase.
- T b. α-dextrinase

T c. maltase
F d. ribonuclease
F e. lipase

Q. 42. **Trypsinogen**
T a. is converted to trypsin by enterokinase
T b. remains as trypsinogen by trypsin inhibitor
T c. is secreted during cephalic phase of digestion.
T d. is the inactive form of trypsin
F e. is converted to trypsin by HCl

Q. 43. **Chymotrypsinogen is activated into chyrnotrypsin by**
T a. Trypsin
F b. Pepsin
F c. Fatty acids
F d. Bile salts
F e. All.

Q. 44. **Succus entericus is secreted by**
T a. crypts of leiberkuhn and brunner's gland
F b. islets of langerhans
F c. gastric glands
F d. goblet cell
F e. salivary glands.

Q. 45. **The following are decreased in proenzyme form**
T a. Trypsin
T b. Chymotrypsin
T c. Pepsin
F d. Ribonuclease
F e. All.

Q. 46. **Which secretion contributes to the maximum amount of potassium**
T a. Salivary
F b. Gastric
F c. Pancreatic
F d. Biliary
F e. None.

Q. 47. **The rate of basic electrical rhythm (BER) is high in**
T a. duodenum
F b. stomach
F c. jejunum
F d. ileum
F e. colon.

Gastro-intestinal hormones

Q. 48. **Following are local hormones**
F a. Insulin
T b. Heparin
T c. Bradykinin
T d. Acetyl choline
F e. All

Q. 49. **Following are gastrointestinal hormones**
T a. CCK - PZ
T b. GIP
T c. Motilin
F d. Chymotrypsin.
F e. All

Q. 50. **Following are gastrointèstinal hormones except**
F a. CCK - PZ
F b. GIP
F c. Motilin
T d. Chymotrypsin.

Q. 51. **Gastrointestinal hormones are**
T a. motilin
T b. CCK
T c. GIP
F d. enterokinase
F e. histamine

Q. 52. **The hormone mainly acting on stomach is**
T a. gastrin
T b. bombesin
F c. pancreozymin
F d. secretin
F e. VIP.

Q. 53. **The duodenum secretes a hormone which has following effects except**
T b. Increases gastric motility
F a. Causes copious pancretic juice rich in bicarbonate and poor in enzymes
F c. Causes gall bladder to contract and sphincter of Oddi to relax
F d. Leads to meagre flow of pancreatic juice rich in enzymes
F e. None.

Q. 54. **The duodenum secretes a hormone which has following effects**
T a. Causes gall bladder to contract and sphincter of Oddi to relax
T b. Leads to meagre flow of pancreatic juice rich in enzymes
T c. Causes copious pancretic juice rich in bicarbonate and poor in enzymes
F d. Increases gastric motility
F e. All.

Q. 55. **Gastrin secretion is inhibited by**
T a. luminal acid
T b. somatostatin

T c. calcitonin.
F d. luminal distention
F e. peptides and amino acid

Q. 56. **Gastrin secretion**
T a. is enhanced by mere thought of food
T b. is stimulated by histamine secretion.
T c. contains factor which helps in vit B_{12} absorption.
F b. is decreased by eating food
F e. is stimulated by pancreozymin.

Q. 57. **Stimuli that increase gastrin secretion are**
T a. increased vagal discharge
T b. luminal peptides and aminoacid
T c. blood borne calcium and epinephrine
F d. somatostatin
F e. secretin

Q. 58. **Gastrin**
T a. promotes secretion of gastric juice
T b. increases gastric motility
T c. promotes growth of gastric mucosa
F d. stimulates release of insulin
F e. slows gastric emptying.

Q. 59. **Gastrin**
T a. causes contraction of lower esophageal sphincter
T b. inereases motility of the stomach
F c. inhibits parietal cells to secrete HC1
F d. inhibits chief cells to secrete pepsinogen
F e. causes contraction of pyloric sphincter.

Q. 60. **Gastrin secretion is**
T c. Increased by stomach distention
F a. Inhibited by curare
F b. Stimulated by nor adrenaline
F d. Stimulated by an increase in tonic activity
F a. None.

Q. 61. **Gastrin is produced by**
T a. Pancreas
T b. Gastricantral cells
T c. Pituitary
T d. All
F e. None.

Q. 62. **Gastrin secretion is stimulated by the following**
T a. Gastric distension
T b. Gastrin
T c. Vagal stimulus
F d. Secretin
F e. None.

Q. 63. **Secretin does not cause**
T a. Gastric secretion increase
F b. Bicarbonate secretion
F c. Auguments the action of CCK
F d. Contraction of pyloric sphincter
F e. None.

Q. 64. **Secretin cause**
T a. Bicarbonate secretion
T b. Auguments the action of CCK
T c. Contraction of pyloric sphincter
F d. Gastric secretion increase
F e. All

Q. 65. **Secretin**
T a. stimulates secretion of bile.
T b. inhibits secretion of gastric juice
T c. promotes normal growth and maintenance of pancreas
F d. inhibits secretion of pancreatic juice
F e. decreases effects of CCK

Q. 66. **Intrinsic factor**
T a. is secreted from oxyntic cells.
T b. is needed for absorption of vitamin B_{12}
T c. is required for erythropoiesis
F d. forms a protective barrier
F e. prevents digestion of stomach wall

Q. 67. **Cholecystokinin**
T a. causes ejection of bile from gallbladder
T b. causes opening of sphincter of oddi
T c. induces satiety
F d. stimulates gastric emptying
F e. decreases effects of secretin.

Q.68. **Gastric inhibitory peptides**
T a. inhibits sceretion of gastric juice
T b. slows gastric emptying
T c. stimulates release of insulin by pancreatic beta cells
F d. stimulate sceretion of gastric juice
F e. promotes gastric emptying.

Q. 69. **Actions of cholecystokinin include the following**
T a. Contraction of gall bladder
T b. Secretion of pancreatic juice rich in enzymes
T c. Increases the secretion of enterokinase
T d. Augments the action of secretion of gastrin
F e. Stimulated gastric emptying.

Q. 70. **Actions of cholecystokinin include all of the following except**
T e. Stimulated gastric emptying.
F a. Contraction of gall bladder
F b. Secretion of pancreatic juice rich in enzymes
F c. Increases the secretion of enterokinase
F d. Augments the action of secretion of gastrin

Q. 71. **D cells of pancreas secrete**
- T a. Somatostatin.
- F b. Insulin
- F c. Glucagon
- F d. VIP
- F e. None.

Hepato-billiary system

Q. 72. **Bile enters the gall bladder through the**
- T a. cystic duct
- F b. hepatie duct
- F c. common bile duct
- F d. thoracic duct
- F e. hepatopanereatic duct

Q. 73. **The liver stores**
- T a. glycogen
- T b. vitamin A
- F c. glucose
- F d. vitamin B_1, B_2, B_6 and C
- F e. bile salt.

Q. 74. **Bile is formed at the rate of how many ml/hour in liver**
- T a. 20
- F b. 40
- F c. 80
- F d. 100
- F c. 60.

Q. 75. **Maximum absorption of bile occurs at**
- T c. Ileum
- F a. Jejunum
- F b. Duodenum
- F d. Colon
- F c. Caecum.

Q. 76. **Liver is the only organ which normally**
- T a. Synthesizes heparin
- T b. Synthesizes urea
- T c. Degrades haemoglobin
- T d. Converts glycogen to glucose
- T e. All of the above.

Q. 77. **Most potent simulus for bile secretion is**
- T a. Bile salt
- F b. Cholecystokinin
- F c. Gastrin
- F d. Secretin
- F e. Bile acid

Q. 78. **Factors causing contraction of gall bladder include**
- T a. acetylcholine
- T b. fat in the small gut
- T c. CCK
- F d. Secretin
- F e. protein in the small gut.

Q. 79. **The liver is the principal site for**
- T a. storage of iron.
- T b. synthesis of plasma albumin
- F c. synthesis of plasma globulins
- F d. synthesis of vitamin B_{12}
- F e. storage of vitamin C

Q. 80. **Bile salts**
- T a. are derived from cholesterol
- T b. are essential for fat digestion
- T c. form micelles
- F d. are absorbed mainly in the upper small intestine
- F e. inhibit bile secretion by the liver.

Q. 81. **The liver**
- T a. inactivates gonadal steroid hormones.
- T b. maintains the normal blood glucose level
- T c. converts the NH_4 into urea.
- F d. synthesizes vitamin D_3.
- F e. manufactures immunoglobulins

Q. 82. **Urobilinogen is**
- T a. absorbed from the intestine
- T b. present in both urine and faeces.
- T c. excreated in bile
- F d. formed mostly in reticuloendothelial system
- F e. excreted mainly in the unne

Q. 83. **Enterohepatic circulation**
- T a. means recirculation of bile salt.
- T b. helps in conservation of bile salts
- F c. helps in excretion of bile salts
- F d. stimulates bile salt production in the liver
- F e. cause excreation of bile

Q. 84. **Bile salts assist in digestion of fats by**
- T a. breaking them into small fragement.
- T b. emulsification
- F c. contributing as lipolytic enzyme
- F d. stimulating secretion of a lipase
- F e. increasing the alkalinity of digestive medium

Q. 85. **Endogenous compounds excreted by the liver into the bile ducts are**
- T a. bile salt
- T b. cholesterol
- F c. albumin
- F d. ampicillin
- F e. sulfonamides.

Q. 86. **Exogenous compounds excreted by the liver are**
- T a. ampicillin
- T b. tetracycline.
- F c. urobilinogen
- F d. bilirubin
- F e. lecithin

Q. 87. **Hepatic protein synthesis leads to the production of**
- T a. albumin.
- T b. transport proteins
- T c. clotting factors
- F d. cholesterol
- F e. ketone bodies

Q. 88. **Lipid metabolic function of the liver results in**
- T a. synthesis of cholesterol
- T b. production of ketone bodies
- T c. excretion of cholesterol.
- F d. synthesis of clotting factors
- F e. synthesis of bile salts

Q. 89. **Composition of bile have**
- T a. sodium
- T b. potassium
- F c. magnesium
- F d. mucin
- F e. carbonic anhydrase.

Q. 90. **Lipoproteins are**
- T a. chylomicrons
- T b. VLDL
- T c. LDL
- T d. HDL
- F e. lacteal.

Digestion and absorption

Q. 91. **Digestion is chemically**
- T a. hydrolysis
- F b. hydrogenation
- F c. hydration
- F d. dehydration
- F e. condensation.

Q. 92. **Micelle formation is necessary for the intestinal absorption of**
- T a. vitamin D
- T b. fatty acids
- F c. bile acids
- F d. vitamin B_{12}
- F e. glycerol.

Q. 93. **Digestion of starch starts from**
- T a. mouth
- F b. esophagus
- F c. stomach
- F d. duodenum
- F e. jejunum.

Q. 94. **Intestinal absorption is faster for**
- T a. Hexoses
- F b. Dissacharides
- F c. Oligosaccharides
- F d. Polysaccharides
- F e. None.

Q. 95. **The final sugars in intestinal chyme are**
- T a. Glucose & fructose
- F b. Ribose & mannose
- F c. Ribose & xylulose
- F d. Xylulose & fructose
- F e. None.

Q. 96. **The only sugar normally absorbed in the intestine against a concentration gradient is**
- T a. Glucose
- F b. Xylose
- F c. Mannose
- F d. Ribose
- F e. Galactose.

Q. 97. **Active reabsorption of glucose occurs in the**
- T a. Proximal tubule
- F b. Distal tubule
- F c. Loop of henle
- F d. Collecting ducts
- F e. None.

Q. 98. **Gastric digestion is most important for**
- T a. proteins
- F b. fats
- F c. carbohydrates
- F d. vitamins
- F e. minerals.

Q. 99. **Fat absorption occurs in the**
- T a. duodenum
- T b. ileum
- F c. stomach
- F d. colon
- F e. rectum.

Q. 100. **Short chain fatty acid produced by bacteria are maximally absorbed in**
- T a. Colon
- F b. Duodenum
- F c. Ileum

F d. Jejunum
F d. Stomach.

Q. 101. **Fat is maximally absorbed in**
T a. Jejunum
F b. Ileum
F c. Colon
F d. Stomach
F e. Duodenum

Q. 102. **Elimination of terminal ileum is associated with malabsorption of**
T a. vitamin B_{12}
T b. fats
F c. protein
F d. carbohydrate
F e. vitamin C.

Q. 103. **Chylomicrons**
T a. supply dietary lipid to cell
T b. are lipid carrier proteins
F c. are originated from liver
F d. carry dietary protein
F e. deliver endogenous triglyceride to cell.

Q. 104. **Ingested vitamin B_{12}**
T a. is bound to protein R
T b. forms B_{12} intrinsic factor complex
T c. binds to parietal cells.
T d. binds to intrinsic factor in the stomach
F e. is absorbed in the stomach

Q. 105. **Physiology of digestion in large intestine include**
T a. synthesis of some vitamins
T b. chemical digestion through bacterial action.
F c. chylomicrons move into lymph
F d. chylomicrons are synthesized to triglycerides
F e. formation of chylomicrons

Q. 106. **Elimination of terminal ileum is associated with malabsorption of**
T a. vitamin B_{12}
T b. fats
F c. protein
F d. carbohydrate
F e. vitamin C.

Q. 107. **Potassium content in colonic secretion is**
T a. 30 meq/L
F b. 10 meq/L
F c. 15 meq/L
F d. 50 meq/L
F e. 45 meq/L.

Q. 108. **Which of the following is absorbed in the colon**
T a. Electrolytes
F b. Iron
F c. Proteins
F d. Bile salts
F e. Glucose.

Q. 109. **Which of the following is absorbed in the proximal intestine**
T a. Iron
F b. Electrolytes
F c. Bile salts
F d. Vitamin B_{12}
F e. Proteins

Q. 110. **Which of the following is the fastest to be absorbed from the stomach**
T a. Water
F b. Carbohydrate
F c. Proteins
F d. Fats
F e. Bile salts

Q. 111. **Which secretion contributes to the maximu amount of potassium**
T a. Salivary
F b. Gastric
F c. Pancreatic
F d. Intestinal
F e. Biliary.

Regulation of GIT activities

Q. 112. **Swallowing centre is situated in**
T a. Medulla
F b. Midbrain
F c. Pons
F d. Cerebellum
F e. Spinal cord.

Q. 113. **Satiety centre in hypothalamus is regulated by**
T a. Blood glucose levels
F b. Gastric dilatation
F c. All of the above
F d. Blood insulin levels
F e. None.

Q. 114. **Anabolic action on protein is mediated by**
T a. Testesterone
F b. ACTH
F c. Insulin
F d. TSH
F e. None.

Q. 115. **Vagal stimulation following intake of food affect the secretion of**
T a. Stomach
T b. Pancreas

T c. Gall bladder
F d. Parotid
F e. All.

Q. 116. **Vagal stimulation cause the following**
T a. Increase in intestinal secretion
T b. Constriction of intestinal musculature
T c. Fall in blood pressure
F d. Relaxation of bronchial musculature
F e. None.

Q. 117. **Vaso-vagal reflex is most dependent on**
T a. receptive relaxation
T b. gastric emptying
F c. chewing
F d. swallowing
F e. intestinal segmentation.

Q. 118. **Muscle tone in the lower esophagus is**
T a. increased by gastrin
T b. greater than that in the middle esophagus
T c. a major factor in preventing heart-burn
F d. increased in pregnancy
F e. increased by anticholinergic drugs.

Q. 119. **Factors that depolarize the membrane of gastrointestinal smooth muscle are**
T a. stimulation by parasympathetic nerves
T b. stimulation by gastrointestinal tract hormones
F c. shortening of the muscle
F d. inhibition by acetylcholine
F e. stimulation by epinephrine and norepinephrine.

Q. 120. **Factors that can excite the enterogastric reflexes are**
T a. osmolality of the chyme
T b. presence of irritation in duodenal mucosa
F c. contraction of the duodenum
F d. alkalinity of the duodenal chyme
F e. break down products of fats.

Q. 121. **Gastro-colic reflex is related to**
T a. Mass preistalsis
F b. Segmental movement
F c. Pendular movement
F d. Colonic disorder
F e. None.

Q. 122. **The following simulate enterogastric reflex?**
T a. Products of protein digestion in the duodenum
T b. Duodenal distension
T c. H^+ ions bathing duodenal mucosa
F d. Hormones
F e. None.

Q. 123. **Which of the following does not simulate enterogastric reflex?**
F a. Products of protein digestion in the duodenum
F b. Duodenal distension
F c. H^+ ions bathing duodenal mucosa
T d. Hormones.
F e. None.

Q. 124. **Enterogastric reflex is caused by**
T a. Duodenum distension
T b. Increased osmolality of chyme
T c. b and c
F d. Alkaline pH in duodenum
F e. All.

Q. 125. **Enterogastric reflex is caused by**
T a. Duodenum distension
T b. Increased osmolality of chyme
T c. b and c
F d. Alkaline pH in duodenum
F e. All.

Q. 126. **Stimulation for gastric emptying**
T a. Distension.
F b. Secretin
F c. CCK
F d. Gastrin
F e. None.

Q. 127. **Gastric phase of gastric secretion is caused by**
T a. chemical substances
T b. polypeptides
T c. natural substances
T d. hormones
F e. iron.

Q. 128. **Cephalic phase of gastric secretion is mediated by**
T a. Gastrin
F b. Neurohormones
F c. Parasympathetic
F d. Sympathetic
F e. None.

Q. 129. **Cephalic phase of gastric secretion**
T a. starts immediately after food enters the mouth
T b. is mediated by parasympathetic nerve
F c. is not influenced by mucus
F d. leads to 100% of gastric secretions
F e. is mediated by sympathetic nerve.

Q. 130. **Most potent stimulus for secretin is**
T a. Acid chyme
F b. Dilatation of intestine
F c. Protein
F d. Fat
F e. None.

Q. 131. **Gastric emptying is decreased by all except**
- T a. Hypoosmolarity in duodenum
- F b. Fatty meal
- F c. Hyperosmolarity in duodenum
- F d. Distension of duodenum
- F e. None.

Q. 132. **Gastric emptying is decreased by**
- T a. Fatty meal
- T b. Hyperosmolarity in duodenum
- T c. Distension of duodenum
- F d. Hypoosmolarity in duodenum
- F e. None.

Q. 133. **Gastric secretion is**
- T a. Increased by stomach distention
- F b. Inhibited by curare
- F c. Stimulated by nor adrenaline
- F d. Stimulated by an increase in tonic activity
- F e. None.

Q. 134. **The gastric phase of gastric secretion is brought about by**
- T a. Hormonal factors
- F b. Neural factors
- F c. Gastric distension
- F d. Presence of proteins in the stomach
- F e. All.

Q. 135. **Best stimuli for secretin secretion is**
- T a. Acid
- F b. Protein
- F c. Fat
- F d. Bile
- F e. None.

Q. 136. **Best stimuli for CCK secretion is**
- T a. Fat
- F b. Acid
- F c. Protein
- F d. Bile
- F e. None.

Q. 137. **Most potent simulus for bile secretion is**
- T a. Bile salt
- F b. Cholecystokinin
- F c. Gastrin
- F d. Secretin
- F e. Bile acid

Q. 138. **The role of chromium in the body is**
- T a. Facilitates action of insulin
- F b. Erythropoiesis
- F c. Growth and development
- F e. None.
- F d. Spermatogenesis

Movements of GIT

Q. 139. **Antiperistalsis**
- T a. helps in to and fro movement
- T b. causes vomiting.
- T c. serves to mix the chyme with digestive juice
- F d. causes movement of food bolus.
- F e. propels the intestinal contens towards ileocolic sphincter

Q. 140. **As the masticated food passes through the esophagus**
- T a. stomach receives food
- T b. stomach shows receptive relaxation
- F c. cardiac sphincter constricts
- F d. pyloric sphincter relaxes
- F e. duodenum constricts

Q. 141. **Pyloric sphincter**
- T a. regulates passage of chyme from stomach to duodenum
- T b. prevents back flow of chyme from duodenum to stomach
- F c. mixes food with gastric juice
- F d. forces chyme from stomach to duodenum
- F e. prevents digestion of stomach.

Q. 142. **Stomach reflexly**
- T a. stimulates bile expulsion
- T b. stimulates salivation
- T c. increases peristaltic movements in the last part of ileum
- F d. inhibits pancreatic secretion
- F e. decreases peristaltic movements in the colon.

Q. 143. **The passage of gastric contents to the dudenum may cause**
- T a. copious secretion of pancreatic juice rich in bicarbonate
- T b. decreased gastric motility
- T c. contraction of the gall bladder
- F d. contraction of the pyloric sphnicter
- F e. release of gastrin.

Q. 144. **Factors that inhibits stomach emptying include**
- T a. enterogastric reflex
- T b. CCK
- T c. increased acidity of duodenal chyme.
- F d. gastrocolic reflex
- F e. gastrin

Q. 145. **Hormones that inhibits gastric emptying are**
- T a. secretin
- T b. GIP
- T c. CCK

F d. gastrin
F e. motilin

Q. 146. **Gastric emptying is stimulated by**
T a. distention of stomach
T b. increased gastric motility.
F c. distention of duodenum
F d. presence of fatty acids
F e. decreased gastric motility

Q. 147. **Gastric emptying is inhibited by**
T a. decreased gastric motility.
T b. distention of doudenum
F c. presence of protein, alcohol in stomach
F d. increased secretion of gastrin
F e. relaxation of pyloric sphincter

Q. 148. **Gastric emptying is primarilly controlled**
T a. when chyme enters the intestine
F b. during chewing
F c. during swallowing
F d. when chyme enters the stomach
F e. during the interodigestive period.

Q. 149. **Small intestine has**
T a. four types of movement
T b. pendular movement
F c. three types of movement
F d. two types of movement
F e. retropulsive movement.

Q. 150. **Small intestinal motility is enhanced by**
T a. insulin.
T b. gastrin
T c. cholecystokinin
F d. glucagon
F e. secretin

Q. 151. **Small intestinal motility is inhibited by**
T a. secretin
T b. glucagon.
F c. insulin
F d. gastrin
F e. cholecystokinin

Q. 152. **Functions of the colon include**
T a. absorption of water
T b. absorption of electrolytes
T c. storage of fecal matter.
F d. emptying of food
F e. prevention of back flow of fecal matter

Q. 153. **Mechanical movements of the large intestine include**
T a. haustral churning
T b. mass peristalsis.
F c. mixing movement
F d. pendular movement
F e. retropulsive movement

Q. 154. **Peristaltic rush means**
T a. powerful peristalsis
T b. diarrhoea.
F c. mass movement
F d. rapid antiperistalsis
F e. weak peristalsis

Q. 155. **Regarding defecation reflex**
T a. the stretch receptors are in the rectal wall
T b. it is co-ordinated by reflex centres in the spinal cord
T c. it can be voluntarily inhibited
F d. its afferent limb carries impulses from stretch receptors
F e. its efferent limb travels through sympathetic nerve.

Q. 156. **Vomiting**
T a. starts with salivation and the sensation of nausea.
T b. is antiperistalsis
F c. is usually preceded by decreased heart rate
F d. center is present in the thalamus
F e. begins with a deep expiration.

Q. 157. **Adynamic ileus**
T a. may occur after abdominal operation.
T b. occurs when the intestine are traumatized
T c. can be relieved by aspirating the fluid and gas
F d. is a direct stimulation of smooth muscle
F e. causes increased intestinal motility

Applied

Q. 158. **Cholelithiasis**
T e. occurs due to bile stasis.
T b. incidence increases with age
T c. occurs in 20% of the woman and in 5% of the men
F a. is the absence of gall stones
F d. occurs between the ages of 20-30 years

Q. 159. **Gastroesophageal reflux disease**
T a. is caused by lower esophageal sphincter incompetence
T b. permits reflux of acid
T c. is due to regurgitation of food
T d. causes heart-burn
F e. is same as achalasia

Q. 160. **Hemorrhoids**
T a. are caused by improper bowel habit.
T b. develop when the veins are engorged with blood
T c. may be caused by constipation
F d. are saclike outpouching of the wall of the colon
F e. cause an inflammation within the diverticula

Q. 161. **Constipation**

T a. is caused by improper bowel habits.
T b. refers to infrequent or difficult defecation
F c. increased motility of the intestines
F d. is decreased water absorption
F e. is caused by lactose intolarance

Q. 162. **Causes of alkalosis are**

T a. complete water deprivation for 24 hours.
T b. severe persistent vomiting
T c. excessive sweating
F d. severe diarrhea
F e. drinking of sodium lactate solution

Q. 163. **Cause of acidosis is**

T a. severe diarrhoea
F b. severe persistent vomiting
F c. excessive sweating
F d. drinking of sodium lacate solution
F e. complete water deprivation for 24 hours.

Q. 164. **Total gastrectomy causes**

T a. malabsorption of protein
T b. impaired fat absorption
T c. vitamin B_{12} malabsorption
F d. haemodilution after meals
F e. grossly reduced iron absorption

Q. 165. **Surgical removal of about 90% of the ileum and jejunum tends to cause**

T a. An increase in fat content of stool
T b. Demineraiisation of bones
T c. Anaemia.
F d. A fall in extracellular fluid volume
F e. None.