HUMAN ANATOMY AND PHYSIOLOGY-II - BP201(T)

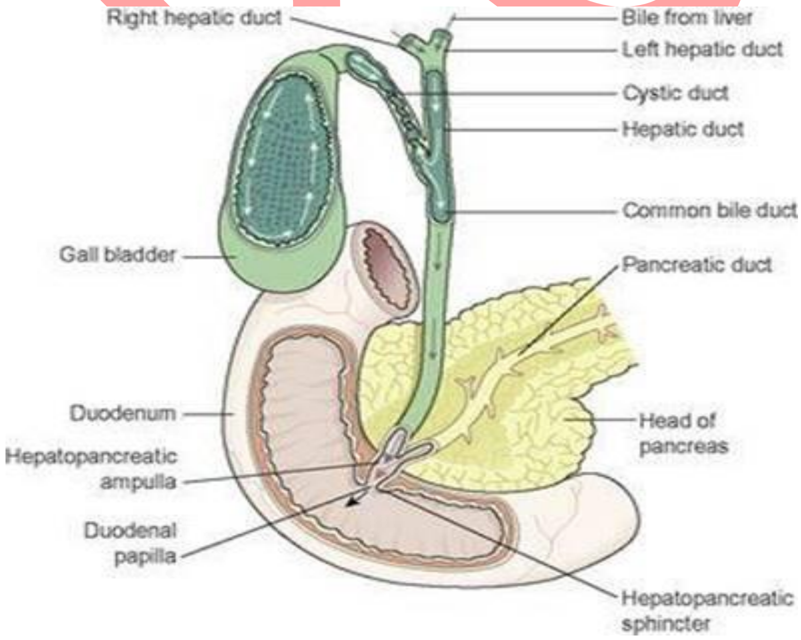
UNIT-II (Digestive System)

CLASS:4

TOPIC – Anatomy of GI Tract with special reference to anatomy and functions of stomach

SMALL INTESTINE

- The small intestine is continuous with the stomach at the pyloric sphincter. The small intestine is a little over 5 metres long and leads into the large intestine at the ileocecal valve.
- It lies in the abdominal cavity surrounded by the large intestine. In the small intestine the chemical digestion of food is completed and absorption of most nutrients takes place.
- The small intestine comprises three continuous parts.
- The duodenum is about 25 cm long and curves around the head of the pancreas.
- Secretions from the gall bladder and pancreas merge in a common structure – the hepatopancreatic ampulla – and enter the duodenum at the duodenal papilla.
- The duodenal papilla is guarded by a ring of smooth muscle, the hepatopancreatic sphincter (of Oddi).



Flow of Bile from the liver to the duodenum

- The jejunum is the middle section of the small intestine and is about 2 metres long.

- The ileum, or terminal section, is about 3 metres long and ends at the ileocaecal valve, which controls the flow of material from the ileum to the caecum, the first part of the large intestine, and prevents regurgitation.

Structure of the small intestine

- The walls of the small intestine are composed of the four layers of tissue. Some modifications of the peritoneum and mucosa (mucous membrane lining) are described below.

Peritoneum

A double layer of peritoneum called the mesentery attaches the jejunum and ileum to the posterior abdominal wall. The attachment is quite short in comparison with the length of the small intestine, therefore it is fan shaped. The large blood vessels and nerves lie on the posterior abdominal wall and the branches to the small intestine pass between the two layers of the mesentery.

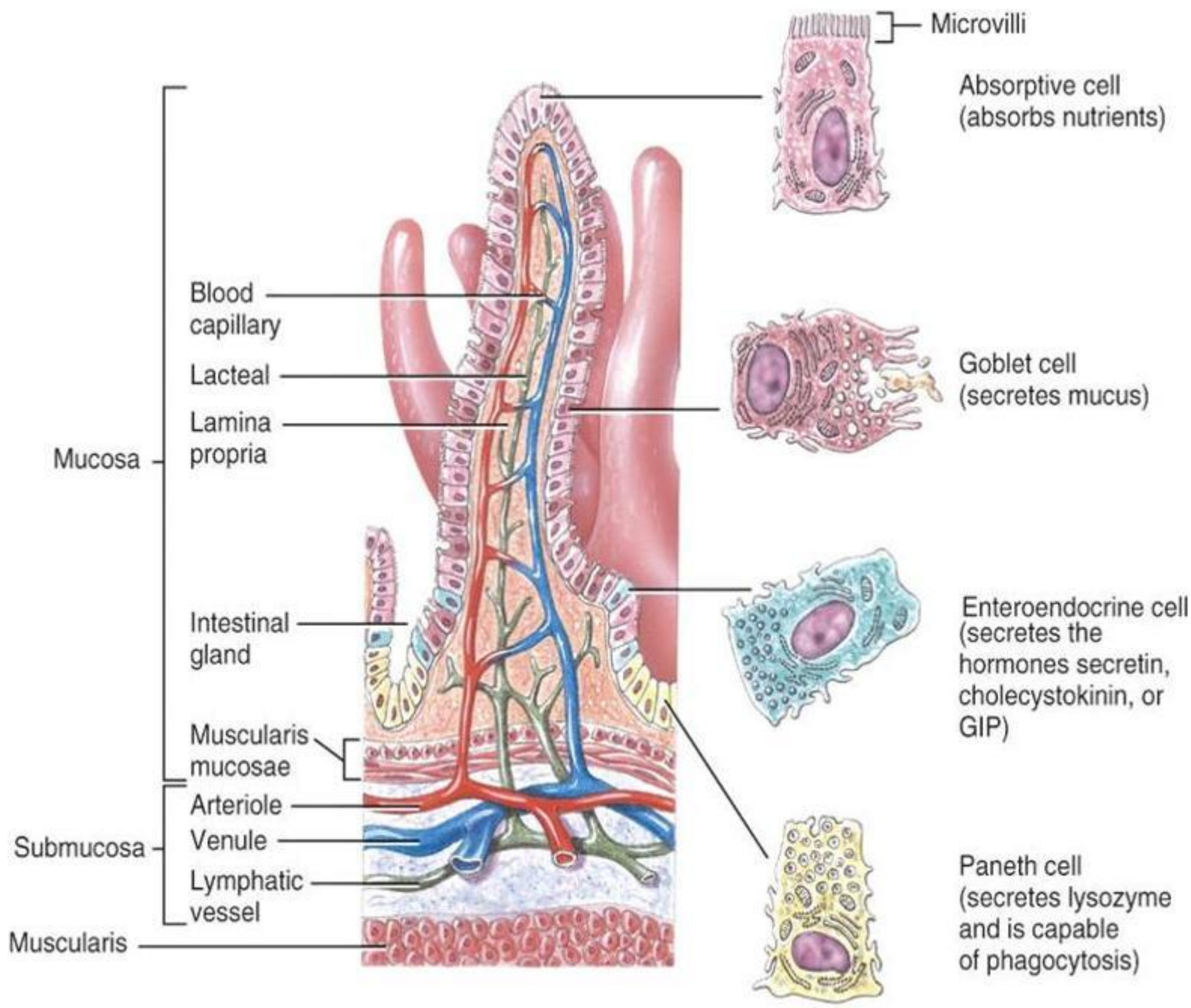
Mucosa

The surface area of the small intestine mucosa is greatly increased by permanent circular folds, villi and microvilli. The permanent circular folds, unlike the rugae of the stomach, are not smoothed out when the small intestine is distended. They promote mixing of chyme as it passes along.

The villi are tiny finger-like projections of the mucosal layer into the intestinal lumen, about 0.5 to 1 mm long. Their walls consist of columnar epithelial cells, or enterocytes, with tiny microvilli (1 μm long) on their free border. Goblet cells that secrete mucus are interspersed between the enterocytes. These epithelial cells enclose a network of blood and lymph capillaries. The lymph capillaries are called lacteals because absorbed fat gives the lymph a milky appearance. Absorption and some final stages of digestion of nutrients take place in the enterocytes before entering the blood and lymph capillaries.

The intestinal glands are simple tubular glands situated below the surface between the villi. The cells of the glands migrate upwards to form the walls of the villi replacing those at the tips as they are rubbed off by the intestinal contents. The entire epithelium is replaced every 3 to 5 days. During migration, the cells form digestive enzymes that lodge in the microvilli and, together with intestinal juice, complete the chemical digestion of carbohydrates, protein and fats.

Numerous lymph nodes are found in the mucosa at irregular intervals throughout the length of the small intestine. The smaller ones are known as solitary lymphatic follicles, and about 20 or 30 larger nodes situated towards the distal end of the ileum are called aggregated lymphatic follicles (Peyer's patches, These lymphatic tissues, packed with defensive cells, are strategically placed to neutralise ingested antigens.



(c) Enlarged villus showing lacteal, capillaries, intestinal glands, and cell types

Blood supply

The superior mesenteric artery supplies the whole of the small intestine, and venous drainage is by the superior mesenteric vein that joins other veins to form the portal vein. The portal vein contains a high concentration of absorbed nutrients and this blood passes through the liver before entering the hepatic veins and, ultimately, into the inferior vena cava.

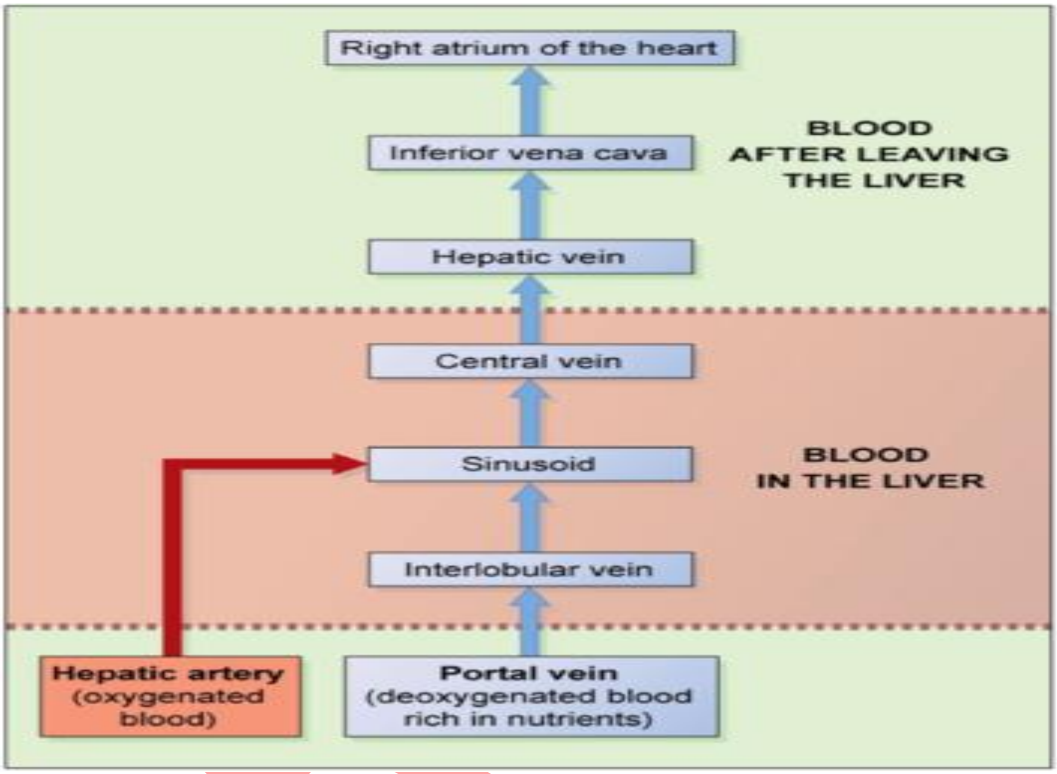
Intestinal juice

About 1500 ml of intestinal juice are secreted daily by the glands of the small intestine. It consists of: water, mucus and mineral salts. The pH of intestinal juice is usually between 7.8 and 8.0.

Functions of the small intestine:

- The functions are: onward movement of its contents by peristalsis, which is increased by parasympathetic stimulation secretion of intestinal juice, also increased by parasympathetic stimulation.

- Completion of chemical digestion of carbohydrates, protein and fats in the enterocytes of the villi
- Protection against infection by microbes that have survived the antimicrobial action of the hydrochloric acid in the stomach, by the solitary lymph follicles and aggregated lymph follicles.
- Secretion of the hormones cholecystokinin (CCK) and secretin absorption of nutrients.



Blood flow through the liver

CHEMICAL DIGESTION IN SMALL INTESTINE

- When acid chyme passes into the small intestine it is mixed with pancreatic juice, bile and intestinal juice, and is in contact with the enterocytes of the villi. In the small intestine digestion of all the nutrients is completed:
- Carbohydrates are broken down to monosaccharides.
- Proteins are broken down to amino acids.
- Fats are broken down to fatty acids and glycerol.

Pancreatic juice

Pancreatic juice is secreted by the exocrine pancreas and enters the duodenum at the duodenal papilla.

It consists of: water, mineral salts and enzymes:

– Amylase

– Lipase

– Nucleases that digest DNA and RNA

Inactive enzyme precursors including:

– Trypsinogen

– Chymotrypsinogen.

Pancreatic juice is alkaline (pH 8) because it contains significant quantities of bicarbonate ions, which are alkaline in solution. When acid stomach contents enter the duodenum they are mixed with pancreatic juice and bile and the pH is raised to between 6 and 8. This is the pH at which the pancreatic enzymes, amylase and lipase, act most effectively.

Functions:

Digestion of proteins:

Trypsinogen and chymotrypsinogen are inactive enzyme precursors activated by enterokinase, an enzyme in the microvilli, which converts them into the active proteolytic enzymes trypsin and chymotrypsin. These enzymes convert polypeptides to tripeptides, dipeptides and amino acids. It is important that they are produced as inactive precursors and are activated only upon arrival in the duodenum, otherwise they would digest the pancreas.

Digestion of carbohydrates:

Pancreatic amylase converts all digestible polysaccharides (starches) not acted upon by salivary amylase to disaccharides.

Digestion of fats:

Lipase converts fats to fatty acids and glycerol. To aid the action of lipase, bile salts emulsify fats, i.e. reduce the size of the globules, increasing their surface area. Control of secretion The secretion of pancreatic juice is stimulated by secretin and CCK, produced by endocrine cells in the walls of the duodenum. The presence in the duodenum of acid chyme from the stomach stimulates the production of these hormones.

Bile:

Bile, secreted by the liver, is unable to enter the duodenum when the hepatopancreatic sphincter is closed; therefore it passes from the hepatic duct along the cystic duct to the gall bladder where it is stored.
Bile has a pH of around 8 and between 500 and 1000 ml are secreted daily. It consists of: water, mineral salts, mucus, bile salts, bile pigments, mainly bilirubin and cholesterol.

Functions:

- The bile salts emulsify fats in the small intestine.
- Fatty acids are insoluble in water, which makes them very difficult to absorb through the intestinal wall. Bile salts make cholesterol and fatty acids soluble, enabling both these and fat-soluble vitamins (i.e. vitamins A, D, E and K) to be readily absorbed.
- The bile pigment, bilirubin, is a waste product of the breakdown of erythrocytes and is excreted in the bile rather than in the urine because of its low solubility in water.
- Bilirubin is altered by microbes in the large intestine. Some of the resultant urobilinogen, which is highly water-soluble, is reabsorbed and then excreted in the urine, but most is converted to stercobilin and excreted in the faeces. Stercobilin colours and deodorises the faeces.

Release from the gall bladder:

- After a meal, the duodenum secretes the hormones secretin and CCK during the intestinal phase of gastric secretion.
- They stimulate contraction of the gall bladder and relaxation of the hepatopancreatic sphincter, enabling the bile and pancreatic juice to pass through the duodenal papilla into the duodenum together.
- Secretion is markedly increased when chyme entering the duodenum contains a high proportion of fat.

Intestinal secretions:

- The principal constituents of intestinal secretions are water, mucus and mineral salts. Most of the digestive enzymes in the small intestine are contained in the enterocytes of the walls of the villi.
- Digestion of carbohydrate, protein and fat is completed by direct contact between these nutrients and the microvilli and within the enterocytes. The enzymes that complete chemical digestion of food at the surface of the enterocytes are: peptidases, lipase, sucrose, maltase and lactase.

Chemical digestion associated with enterocytes:

- Alkaline intestinal juice (pH 7.8 to 8.0) assists in raising the pH of the intestinal contents to between 6.5 and 7.5. Enterokinase activates pancreatic peptidases such as trypsin which convert some polypeptides to amino acids and some to smaller peptides. The final stage of breakdown of all peptides to amino acids takes place at the surface of the enterocytes.
- Lipase completes the digestion of emulsified fats to fatty acids and glycerol in the intestine.
- Sucrase, maltase and lactase complete the digestion of carbohydrates by converting disaccharides such as sucrose, maltose and lactose to monosaccharides at the surface of the enterocytes.

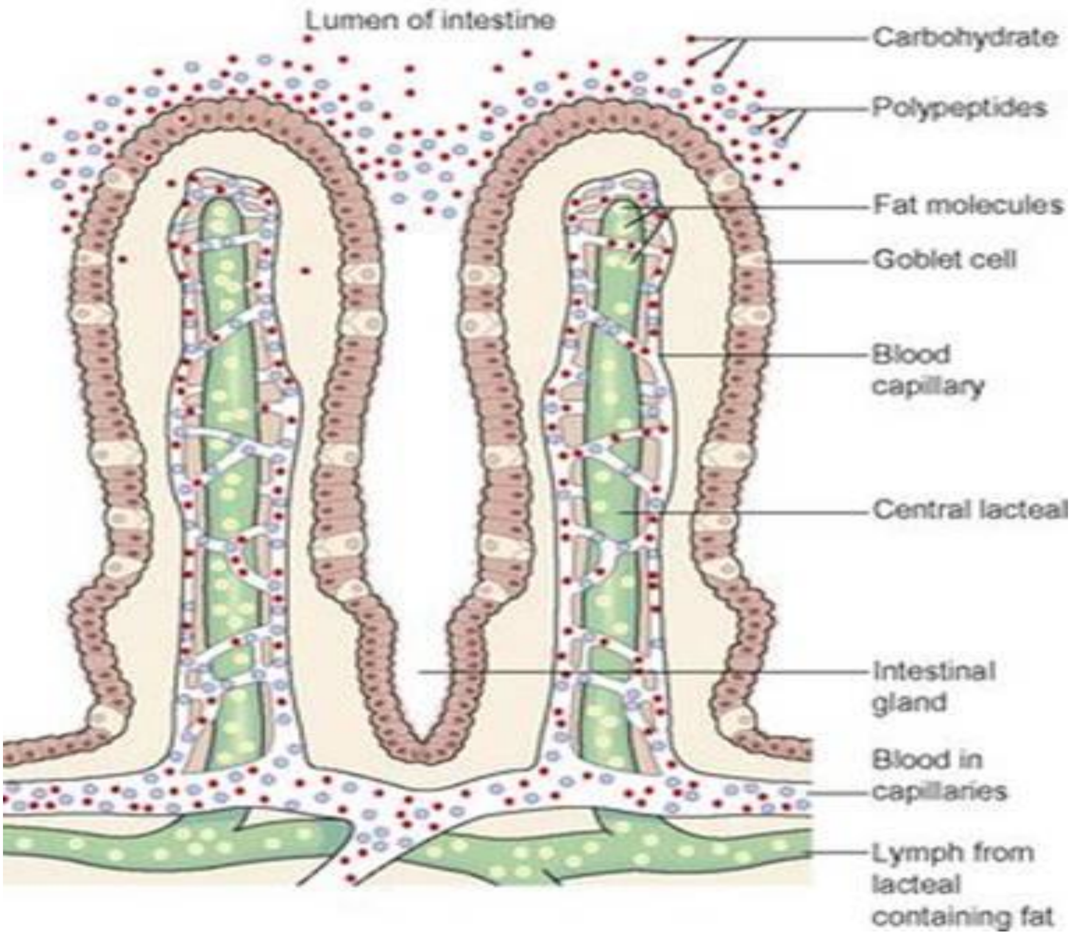
Control of secretion:

Mechanical stimulation of the intestinal glands by chyme is believed to be the main stimulus for the secretion of intestinal juice, although the hormone secretin may also be involved.

Absorption of nutrients:

- Absorption of nutrients from the small intestine through the enterocytes occurs by several processes, including diffusion, osmosis, facilitated diffusion and active transport. Water moves by osmosis, small fat-soluble substances, e.g. fatty acids and glycerol, are able to diffuse through cell membranes while others are generally transported inside the villi by other mechanisms.
- Monosaccharides and amino acids pass into the capillaries in the villi. Fatty acids and glycerol enter into the lacteals where they are transported along lymphatic vessels and enter the circulation at the thoracic duct.
- Some proteins are absorbed unchanged, e.g. antibodies present in breast milk and oral vaccines, such as poliomyelitis vaccine. The extent of protein absorption is believed to be limited.
- Other nutrients such as vitamins, mineral salts and water are also absorbed from the small intestine into the blood capillaries. Fat-soluble vitamins are absorbed into the lacteals along with fatty acids and glycerol. Vitamin B12 combines with intrinsic factor in the stomach and is actively absorbed in the terminal ileum.
- The surface area through which absorption takes place in the small intestine is greatly increased by the circular folds of mucous membrane and by the very large number of villi and microvilli present. It has been calculated that the surface area of the small intestine is about five times that of the whole body.

- Large amounts of fluid enter the alimentary tract each day. Of this, only about 1500 ml is not absorbed by the small intestine, and passes into the large intestine.



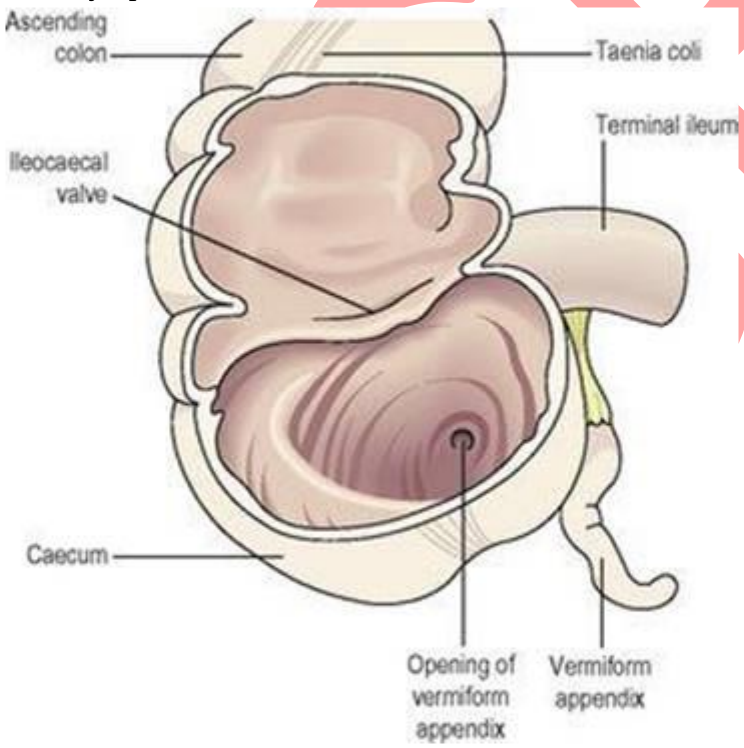
<u>The absorption of Nutrients into the Villi</u>

LARGE INTESTINE

- The large intestine is about 1.5 metres long, beginning at the caecum in the right iliac fossa and terminating at the rectum and anal canal deep in the pelvis. Its lumen is about 6.5 cm in diameter, larger than that of the small intestine. It forms an arch round the coiled-up small intestine.
- The large intestine is divided into the caecum, colon, sigmoid colon, rectum and anal canal.

Caecum

- This is the first part of the large intestine. It is a dilated region which has a blind end inferiorly and is continuous with the ascending colon superiorly. Just below the junction of the two the ileocecal valve opens from the ileum. The vermiform appendix is a fine tube, closed at one end, which leads from the caecum. It is usually about 8 to 9 cm long and has the same structure as the walls of the large intestine but contains more lymphoid tissue.



Colon

- The colon has four parts which have the same structure and functions.

Ascending colon

This passes upwards from the caecum to the level of the liver where it curves acutely to the left at the hepatic flexure to become the transverse colon.

Transverse colon

- This is a loop of colon that extends across the abdominal cavity in front of the duodenum and the stomach to the area of the spleen where it forms the splenic flexure and curves acutely downwards to become the descending colon.

Descending colon

- This passes down the left side of the abdominal cavity then curves towards the midline. After it enters the true pelvis it is known as the sigmoid colon.

Sigmoid colon

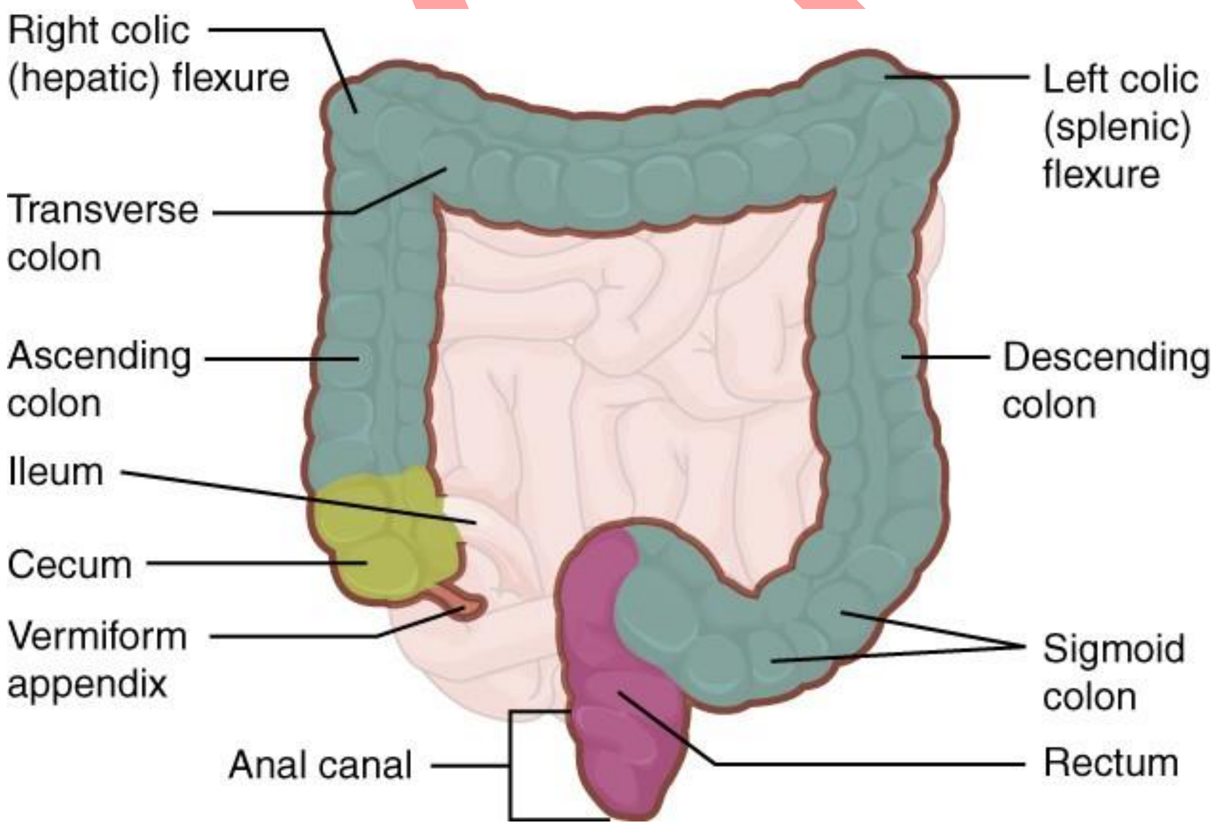
- This part describes an S-shaped curve in the pelvis that continues downwards to become the rectum.

Rectum

- This is a slightly dilated section of the large intestine about 13 cm long. It leads from the sigmoid colon and terminates in the anal canal.

Anal canal

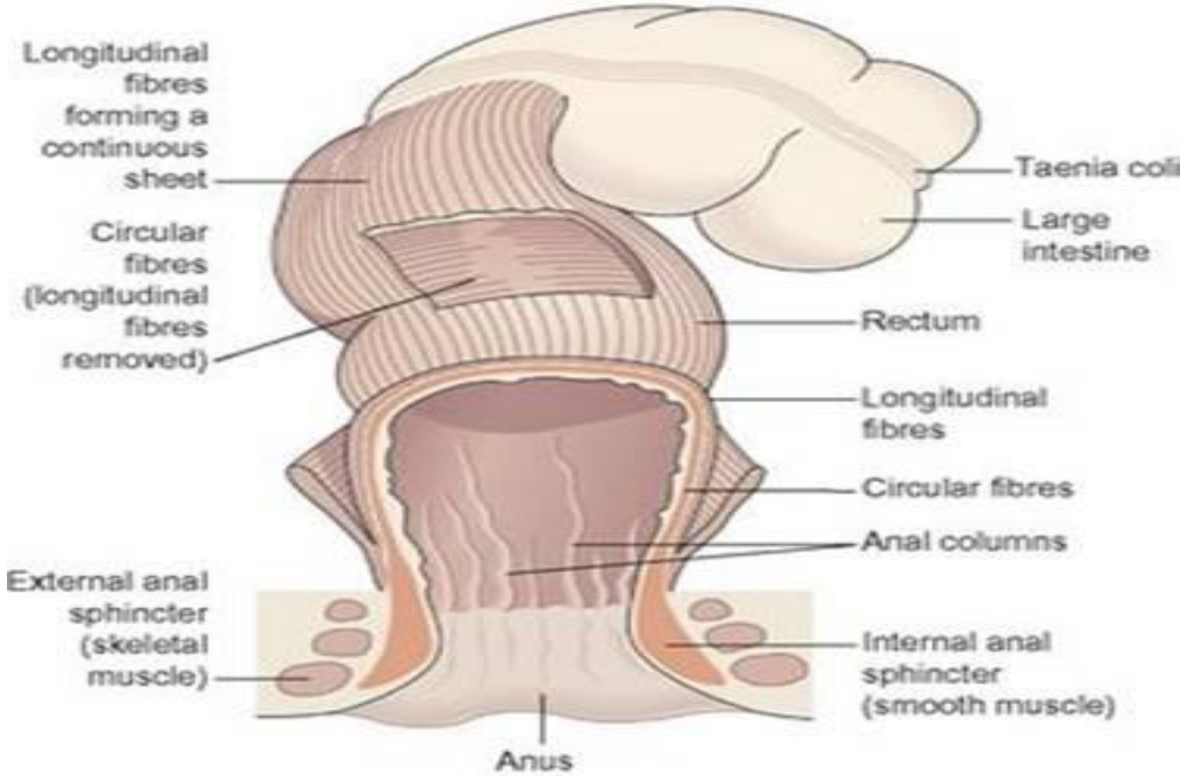
- This is a short passage about 3.8 cm long in the adult and leads from the rectum to the exterior. Two sphincter muscles control the anus; the internal sphincter, consisting of smooth muscle, is under the control of the autonomic nervous system and the external sphincter, formed by skeletal muscle, is under voluntary control.



Structure

- Arrangement of muscle fibres in the large intestine, rectum and anus

Arrangement of muscle fibres in the large intestine, rectum and anus



The four layers of tissue described in the basic structure of the gastrointestinal tract are present in the caecum, colon, the rectum and the anal canal. The arrangement of the longitudinal muscle fibres is modified in the caecum and colon. They do not form a smooth continuous layer of tissue but are instead collected into three bands, called taeniae coli, situated at regular intervals round the caecum and colon. They stop at the junction of the sigmoid colon and the rectum. As these bands of muscle tissue are slightly shorter than the total length of the caecum and colon they give it a sacculated or puckered appearance.

- The longitudinal muscle fibres spread out as in the basic structure and completely surround the rectum and the anal canal. The anal sphincters are formed by thickening of the circular muscle layer.
- In the submucosal layer there is more lymphoid tissue than in any other part of the alimentary tract, providing non-specific defence against invasion by resident and other potentially harmful microbes.
- In the mucosal lining of the colon and the upper region of the rectum are large numbers of mucus-secreting goblet cells within simple tubular glands. They are not present beyond the junction between the rectum and the anal canal.
- The lining membrane of the anal canal consists of stratified squamous epithelium continuous with the mucous membrane lining of the rectum above and which merges with the skin beyond the external anal sphincter. In the upper section of the anal canal

the mucous membrane is arranged in 6 to 10 vertical folds, the anal columns. Each column contains a terminal branch of the superior rectal artery and vein.

Blood supply

Arterial supply is mainly by the superior and inferior mesenteric arteries. The superior mesenteric artery supplies the caecum, ascending and most of the transverse colon. The inferior mesenteric artery supplies the remainder of the colon and the proximal part of the rectum. The middle and inferior rectal arteries, branches of the internal iliac arteries, supply the distal section of the rectum and the anus.

Venous drainage is mainly by the superior and inferior mesenteric veins which drain blood from the parts supplied by arteries of the same names. These veins join the splenic and gastric veins to form the portal vein. Veins draining the distal part of the rectum and the anus join the internal iliac veins, meaning that blood from this region returns directly to the inferior cava, bypassing the portal circulation.

Functions of the large intestine, rectum and anal canal

Absorption

The contents of the ileum which pass through the ileocaecal valve into the caecum are fluid, even though a large amount of water has been absorbed in the small intestine. In the large intestine absorption of water, by osmosis, continues until the familiar semisolid consistency of faeces is achieved. Mineral salts, vitamins and some drugs are also absorbed into the blood capillaries from the large intestine.

Microbial activity:

The large intestine is heavily colonised by certain types of bacteria, which synthesise vitamin K and folic acid. They include Escherichia coli, Enterobacter aerogenes, Streptococcus faecalis and Clostridium perfringens. These microbes are commensals, i.e. normally harmless, in humans. However, they may become pathogenic if transferred to another part of the body, e.g. E. coli may cause cystitis if it gains access to the urinary bladder. Gases in the bowel consist of some of the constituents of air, mainly nitrogen, swallowed with food and drink and as a feature of some anxiety states. Hydrogen, carbon dioxide and methane are produced by bacterial fermentation of unabsorbed nutrients, especially carbohydrate. Gases pass out of the bowel as flatus (wind). Large numbers of microbes are present in the faeces.

Mass movement:

The large intestine does not exhibit peristaltic movement as in other parts of the digestive tract. Only at fairly long intervals (about twice an hour) does a wave of strong peristalsis sweep along the transverse colon forcing its contents into the descending and sigmoid colons. This is known as mass movement and it is often precipitated by the entry of food into the stomach. This combination of stimulus and response is called the gastrocolic reflex.

Defaecation:

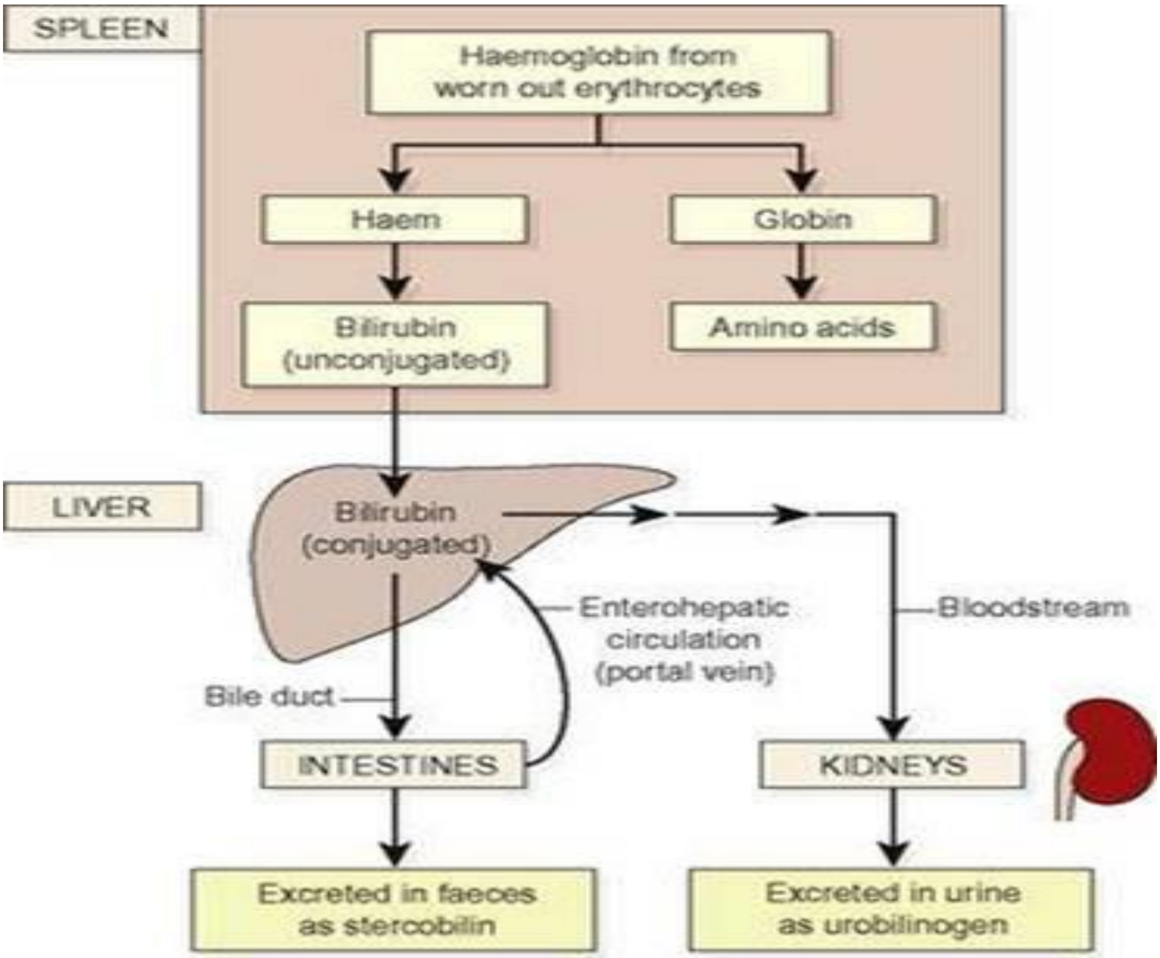
Usually the rectum is empty, but when a mass movement forces the contents of the sigmoid colon into the rectum the nerve endings in its walls are stimulated by stretch. In the infant, defaecation occurs by reflex (involuntary) action. However, during the second or third year of life the ability to override the defaecation reflex is learned. In practical terms this acquired voluntary control means that the brain can inhibit the reflex until such time as it is convenient to defaecate. The external anal sphincter is under conscious control through the pudendal nerve. Thus defaecation involves involuntary contraction of the muscle of the rectum and relaxation of the internal anal sphincter. Contraction of the abdominal muscles and lowering of the diaphragm increase the intra-abdominal pressure (Valsalva's manoeuvre) and so assist the process of defaecation. When defaecation is voluntarily postponed the need to defaecate tends to fade until the next mass movement occurs and the reflex is initiated again. Repeated suppression of the reflex may lead to constipation (hard faeces) as more water is absorbed.

Constituents of faeces :

The faeces consist of a semisolid brown mass. The brown colour is due to the presence of stercobilin.

Even though absorption of water takes place in the small and large intestines, water still makes up about 60 to 70% of the weight of the faeces. The remainder consists of: fibre (indigestible cellular plant and animal material), dead and live microbes, epithelial cells shed from the walls of the tract, fatty acids, mucus secreted by the epithelial lining of the large intestine.

Mucus helps to lubricate the faeces and an adequate amount of dietary non-starch polysaccharide (NSP, fibre and previously known as roughage) ensures that the contents of the large intestine are sufficiently bulky to stimulate defaecation.



Fate of bilirubin from breakdown of worn-out erythrocytes.