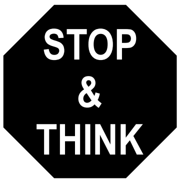
CHAPTER-4
SECTION-A

The embryonic development of the gastrointestinal system

Objectives



A. To provide the background knowledge to enable understanding of the embryological development of the gastrointestinal system.

B. To have a basic understanding of the major abnormalities of the gastrointestinal system.

In the following sections you are advised to make simple diagrams of the relevant structures discussed in the text.

Early development of the digestive system

The primitive gut tube extends from the buccopharyngeal membrane to the cloacal membrane and is divided into the:

A. Pharyngeal gut
B. Foregut
C. Midgut
D. Hindgut

The epithelium of the digestive system (the internal covering lining) and its derivatives are of endodermal origin; the muscular and peritoneal components are of mesodermal origin.

The foregut

The respiratory diverticulum appears attached to the pharyngeal opening of the foregut in the four-week embryo. The oesophagus is at cephalic end of the foregut, initially short, but then later is lengthened by the descend of the heart and developing lungs.

Other structures of the foregut include the liver, pancreas, biliary apparatus and proximal part of duodenum. The oesophagus (anteriorly) and trachea (posteriorly) are divided by the oesophagotracheal septum. The stomach develops as a fusiform dilation of the foregut and in its first few weeks it undergo a clockwise rotation and forms the greater and lesser curvatures.

The liver bud develops in a thick plate of mesodermal tissue known as the septum transversum (the future diaphragm) and then descends into the abdominal cavity suspended by the falciform ligament and lesser omentum.

The early intrauterine function of the liver is the formation of white and red cells (haemopoiesis) but this activity subsides gradually during the last two months of pregnancy.

The midgut

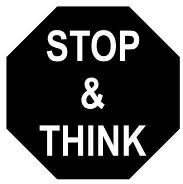
The midgut gives rise to the distal part of the duodenum, jejunum, ileum, appendix, ascending and proximal part of the transverse colon.
While the foregut and hindgut are established mainly as a result of the formation of the head and tail fold respectively, the midgut remains in communication with the yolk sac. Initially, this connection is wide, but as a result of the lateral folding it gradually becomes long and narrow, known as the **vitelline duct**. When later this connection is obliterated then the embryo obtains its freely suspended position in the abdominal cavity.

The hindgut

The hindgut gives rise to the distal third of the transverse colon, the descending colon, the sigmoid, the rectum and the upper part of the anal canal. The endoderm of the hindgut also gives rise to the internal lining of the bladder and urethra. The terminal portion of the hindgut enters into the cloaca, an endoderm-lined cavity which is in direct contact with the surface ectoderm. In the contact area between the endoderm and ectoderm, the cloacal membrane is formed. By a development of a transverse ridge, the urorectal septum arises in the angle betwen the allantois and the hindgut. This septum gradually grows in a caudal direction thereby dividing the cloaca into an anterior portion (the **urogenital sinus** and a posterior part, (the **urorectal canal**.) The terminal parts of these canals are lined by ectoderm, hence its sensitity to stimuli.

CLINICAL NOTES

Oesophageal Atresia



In its most common form the proximal part of the oesophagus ends in a blind sac, whereas the distal part is connected to the trachea by a narrow canal at a point just above the bifurcation.

Pyloric Stenosis

This is caused by a hypertrophy of the circular or longitudinal musculature of the stomach near the point of the pylorus. Depending on the degree of occlusion of the lumen of the oesophagus, the infant will have difficulty swallowing and vomiting is often severe.

Atresia of Gallbladder and Bile Ducts

Although the common bile duct initially develops as a solid structure the lumen develops by recanalisation of the epithelium. When this fails to occur, the gallbladder remains atretic and does not develop. A similar problem may present in the intra- and extrahepatic ducts if they fail to open.

Annular Pancreas

The pancreas develops from a primitive bud which consists of two components. As they develop they rotate around the duodenum and come to lie under the stomach. Occasionally, this rotating process results in the ventral part of pancreas to envelope the duodenum causing obstruction in the latter.

Duodenal Atresia.

This condition occurs when the lumen of the duodenum is occluded as a result of failed recanalization. This condition is associated with polyhydramnios, bile-containing vomitus and distension of the stomach.

Omphalocoele

Occurs when the midgut loops fails to return to the abdominal cavity. In the newborn, a light gay, shiny sac is visible at the base of the umbilical cord.

Ilial (or Meckel's) Diverticulum

Occurs when a remnant of yolk sac (or vitelline duct) persists, forming an opening between the lumen of the ileum and the umbilicus. This condition is associated with drainage of meconium from the umbilicus.

Malrotation of the midgut.

Occurs when the midgut undergoes only partial rotation, resulting in abnormal positioning of the abnormal viscera. This condition may be associated with volvulus.

Intestinal atresia or stenosis.

Occurs as a result of failed recanalisation.

Colonic aganglionosis

Failure of the neural crest cells to form the myenteric plexus in the sigmoid colon and rectum. This condition is associated with loss of peristalsis, foetal retention, and abdominal distension.

Anorectal agenesis

Occurs when the rectum ends as a blind sac above the puborectalis muscle because of abnormal formation of the urorectal septum. This condition may be accompanied by a **rectovesical fistula, rectourethral fistula, or rectovaginal fistula**.

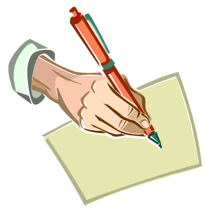
Anal agenesis

Occurs when the canal ends as a blind sac below the puborectal muscle as a result of abnormal formation of the urorectal septum. This condition may be accompanied by **a rectovesical fistula, rectourethral fistula, or rectovaginal fistula.**

SELF ASSESSMENT QUESTIONS

1. From which embryonic germ layer is the epithelial gut lining formed.
2. Describe three common developmental abnormalities of the gastroinestinal system.

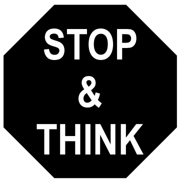
Please refer to your labelling supplement handbook and label any images associated with the above chapter.



SECTION-B

Anatomy and physiology of the gastrointestinal system

The digestive system is basically an open tube from mouth to anus, and is thus considered to be in direct contact with the external environment. As a result of its vulnerability to external pathogens, it is fiercely protected by lymphatic tissues in strategic points along the tract.



Learning Outcomes:

The student should be able to:

- Name the divisions of the tract, and the accessory organs
- Describe the structure and function of the divisions of the tract
- Describe the typical anatomy of the alimentary tract tube.
- Define retroperitoneal, and be able to give examples of such organs.
- Describe the anatomy of the alimentary canal, and the accessory organs of digestion.
- Demonstrate knowledge of the functions of the various areas of the digestive system.
- Demonstrate knowledge of the digestive enzymes, their actions and the substrates upon which they act.

Overview of the Digestive System

The digestive system can be roughly divided into two parts:

1) **The digestive tract** (or alimentary canal)-
   - Mouth
   - Pharynx
   - Oesophagus
   - Stomach
   - Small Intestine
   - Large Intestine
   - Rectum and anal canal

2) **The accessory organs**-
   - Salivary glands
   - Pancreas
   - Liver and gall bladder

The functions of the digestive tract

- Ingestion
- Secretion
- Mixing and propulsion
- Digestion
- Absorption
- Excretion

Anatomy and Histology of the Alimentary Canal

From oesophagus to anus, the canal is **generally** made up of the same four layers of tissue:

- Mucosa- The inner mucous membrane lining the GI tract
- Submucosa
- Muscular layer
- The superficial adventitia, or serosa

Throughout the tract, these layers are adapted to suit the functions of the various structures through which they progress.

The Mucosa

The lumen of the alimentary canal is lined with mucous membrane- the mucosa. The functions of the mucosa are protective, secretory and absorptive.
It is made up of three layers:

1. The **epithelial lining** which is in direct contact with the contents of the tract.
   - In the **mouth**, **oesophagus**, **pharynx** and **anal canal**, this layer is mainly made up of nonkeratinised stratified squamous epithelium, which serves to protect the tract.
   - The **stomach** and **intestines** are lined with simple columnar epithelium, which function in the secretory and absorptive actions of these organs. Among the absorptive epithelial cells, are exocrine cells, which secrete mucus and fluid into the lumen of the tract. There are also several endocrine cells, called enteroendocrine cells, which secrete hormones into the bloodstream.
2. The underlying **lamina propria** is made up of aereolar connective tissue, blood and lymphatic vessels. This layer supports the epithelium and binds it to the muscularis. It houses most of the mucosa-associated-lymphoid tissue (MALT). Other MALT is found in the tonsils, small intestine, appendix and large intestine, and mount immune responses against the microbes, which may penetrate the epithelium.
3. A thin layer of **smooth muscle** throws the mucosa into a series of folds, which contribute to increasing the surface area for digestion and absorption.

The Submucosa

This layer is made up of aereolar connective tissue, which binds the mucosa to the muscularis. It is highly vascular, and also contains the **enteric nervous system** (plexus of Meissner), considered part of the autonomic nervous system, which regulates the movement of the mucosa, vasoconstriction of blood vessels, and innervates the secretory cells.

Muscularis

The muscular layer of the gut is made up basically of two layers- an outer longitudinal layer, and an inner circular layer.
Skeletal muscle is found in association with the mouth, pharynx, superior and middle portion of the oesophagus, and the external anal sphincter. The rest of the GI tract is made up of involuntary smooth muscle, and is innervated by the myenteric plexus of the autonomic (**enteric**) nervous system. This plexus is mainly concerned with the gastrointestinal tract motility.

Serosa

This is the superficial outer layer, which is made up of loose connective tissue and some elastic fibres. Inferior to the diaphragm, the serosa is referred to as the peritoneum.

NOTE- the enteric nervous system communicates with the central nervous system parasympathetically via the vagus nerve, and sympathetically via the prevertibral ganglia. It is considered by many as a second brain as it can operate autonomously. Within enteric plexuses three types of neurone are found- sensory, motor and interneurones. It is an area of much current research.

Peristalsis

The method by which the contents of the gastrointestinal tract are moved from one end to another is termed peristalsis. Peristalsis occurs throughout the gastrointestinal tract, and in the ureters, bile ducts and uterine tubes. In the gastrointestinal tract, peristaltic movement is caused by the circular smooth muscles of the muscularis contracting behind the contents preventing backflow, followed by a contraction of the longitudinal smooth muscles which pushes the digested food forward.

The Peritoneum

The peritoneum is an enclosed sac, made up of simple squamous epithelium, and is found within the abdominal cavity. It is made up of two layers:

- The parietal layer- lines the abdominal wall.
- The visceral layer- in contact with the visceral organs within the abdominal and pelvic cavities.

Between these layers is the potential space, called the peritoneal cavity, which contains a thin layer of serous fluid, which prevents friction.

Some organs lie within the invaginations of this closed sac, whilst others lie posterior to the peritoneum, and are said to be retroperitoneal. Retroperitoneal organs include the kidneys & adrenal glands, the spleen and the pancreas, and have only their anterior surfaces covered by the peritoneum.

The pelvic organs have only their superior surfaces covered by the peritoneum.
The folds of the peritoneum function to bind the organs to each other, and to the walls of the abdominal cavity. The peritoneum supports the blood and lymphatic vessels, and the nerves, which supply the organs.

There are two important folds of the peritoneum- the lesser omentum, and the greater omentum.

- The lesser omentum suspends the stomach and the duodenum from the liver, and contains lymph nodes.
- The greater omentum is the largest peritoneal fold, and is likened to a 'fatty apron', lying over the transverse colon and small intestine. This layer contains a great deal of fatty tissue, as well as many lymph nodes, which contribute immune cells that help to combat infection of the gastrointestinal (GI) tract.

The Mouth (Oral/Buccal Cavity)

The process of digestion begins with ingestion of food into the mouth (also called the oral/buccal cavity) and the mastication of food by the teeth. Pulverised food is moistened and partly broken down by the chemical action of saliva. It is moulded into a bolus by the action of the tongue and the buccal cavity, and projected towards the oesophagus.

The borders of the mouth are:

- The bucca (cheeks)- laterally
- The hard and soft palates- superiorly
- The tongue- inferiorly
- The labia (lips)- anteriorly

The Tongue

The tongue is composed of skeletal muscle covered in mucous membrane. It is attached at the hyoid bone, styloid process of the temporal bone, and the mandible.
The extrinsic muscles originate outside of the tongue and are attached to the local bones. These muscles move the tongue laterally and forward and backward, for chewing food, shaping food into a bolus, swallowing. They also hold the tongue in place.
The intrinsic muscles originate in and insert into the connective tissue of the tongue. They alter the size and shape of the tongue for speech and swallowing.
The lingual frenulum limits the movement of the tongue posteriorly.
The dorsum and lateral surfaces are covered in papillae, of which many contain taste buds.

The Pharynx

The pharynx is a passage, which extends from the nasal cavity to the level of the 6th cervical vertebra. At this level it becomes differentiated into the **oesophagus** (for swallowing food) and the **trachea** (the major air passage).

The pharynx is lined with a mucous membrane, which differs depending on the region of the pharynx it is lining.

The pharynx is divided into three parts:
1) The uppermost region is the **nasopharynx**, housing the opening to the auditory (Eustatian) tube, and the pharyngeal tonsils. Lined with ciliated columnar epithelium.
2) The **oropharynx** lies behind the mouth, and extends to the level of the 3rd cervical vertebra. This region bears the palatine tonsil, and the uvula, which separates the oral pharynx from the nasal pharynx during swallowing. Lined with stratified columnar epithelium, which serves to protect the pharynx from the passage of rough or hot food particles.
3) The **laryngopharynx** continues from the oropharynx to become the oesophagus at the level of the 6th cervical vertebra.

The Oesophagus

The oesophagus is a long elastic-muscular tube beginning at the inferior end of the laryngopharynx. It transports the bolus through the oesophageal hiatus of the diaphragm, into the stomach of the abdominal cavity. Normally, food is prevented from returning to the oesophagus by the lower oesophageal sphincter. This is important, as the acid from the gastric secretions of the stomach can severely damage the oesophageal wall. The oesophagus does not contribute to digestion, and is merely a structure of transportation through the muscular peristaltic movements.

Histology

Mucosa: Stratified squamous epithelium. Near the stomach, the mucosa contains mucous glands

The **sub-mucosa**: Areolar connective tissue, blood vessels and mucous glands.

The **muscular layer** is divided into three parts:.
1. The superior third is made up of skeletal muscle
2. The mid-third is a mixture of skeletal & smooth muscle
3. The inferior third is smooth muscle

The Stomach

The stomach is a ‘J’-shaped enlargement of the digestive tube. It is located directly inferior to the diaphragm in the epigastric, umbilical and left hypochondriac regions of the abdominal cavity. When empty, the stomach is the size of a large sausage, and the mucosa falls into many large folds, known as rugae, but it can expand considerably to accommodate food. The stomach contributes to digestion through the mechanical churning the food, to break it down and mix it with the gastric juice to allow for a greater surface area of food to be in contact with the digestive juices. Minimal absorption takes place in the stomach. Only water, alcohol and some medications are

absorbed here. Many herbal constituents extracted in alcohol (tincture) or water (infusion), are often able to be quickly absorbed in the stomach.
The churning movements and chemical break down of food into smaller particles, renders the ingested material fairly liquid. Peristaltic contractions force the food towards the inferior (pyloric) sphincter, and squirts small quantities of the food into the duodenum. The secretions of the stomach make it an acid medium.

The stomach is divided into four regions:

1) The cardia.
2) The fundus
3) The body
4) The pylorus- the pyloric antrum and pyloric canal

The stomach has two orifices:

1) The cardiac sphincter/ lower oesophageal sphincter.
2) The pyloric sphincter.

Micro-anatomy of the stomach:

The Mucosa- simple columnar epithelial cells. The mucosa contains a lamina propria and muscularis mucosa of smooth muscle. Gastric glands line the gastric pits.
The gastric glands are made up of three types of exocrine glands to form the gastric juice

1) Mucous neck cells and mucous surface cells secrete mucus.
2) Chief cells secrete pepsinogen and gastric lipase
3) Parietal cells – secretes hydrochloric acid and intrinsic factor.

Enteroendocrine cells (the G-cell) in the pyloric antrum secrete the hormone gastrin into the bloodstream, which plays a role in the stimulation of the digestive process.

The sub-mucosa- Areolar connective tissue.
The muscularis- Outer longitudinal, middle circular and an inner oblique smooth muscle layer. The various directions of the smooth muscle layers aid the stomach in its function of churning and mixing food with the gastric juices.
The serosa- Part of the visceral peritoneum.

Functions of the stomach

As it can expand, the stomach serves to hold food, and then deliver it in small quantities to the duodenum of the small intestine for further digestion. The stomach functions are principally of digestion rather than absorption.

The Small Intestine

The small intestine extends from the pyloric sphincter to the ileocaecal valve of the large intestine. In the living person it averages about 3m long, and this long length is to provide adequate surface area for its functions in digestion and absorption. The area is further enlarged by the permanent deep folds in the tube, villi and microvilli, which encourage the passage of chyme to be of a spiral nature, thereby further increasing absorption.

Most of the chemical break-down and absorption of the food particles into smaller, components takes place in the small intestine. Once the food mixture has reached the duodenum, it is referred to as chyme.

The small intestine is made up of three portions:

- The duodenum – retroperitoneal. About 25 cm long.
- The jejunum – about 1 meter.
- The ileum – about 2 meters.

Two openings in the duodenum allow for digestive secretions of the pancreas and liver to enter, and contribute to the digestive process. Pancreatic enzymes are strongly alkaline, and therefore neutralise the acidity of the chyme, whilst breaking down proteins, starches and fats into their smallest components.
The liver secretes bile, which is stored and concentrated in the gall-bladder. The presence of acid chyme in the duodenum (derived from the gastric acid), stimulates the release of hormones in the pancreas, which in turn, is the signal for the gall-bladder to release its concentrated bile contents into the duodenum. Bile functions to emulsify fats, and facilitates the absorption of fat-soluble vitamins, amongst other functions.

The small intestine, itself, also secretes digestive enzymes, which contribute to the final phase of the digestion of carbohydrates, fats and proteins.
The process of digestion and absorption requires a large surface area. The length of the small intestine (3m) provides a large surface area for this process. Multiple circular folds within the small intestine further increase the surface area, and contribute to the absorption of nutrients, by causing the chyme to spiral and thereby allow for maximum contact with the wall of the intestine. Finger-like outgrowths, called villi, and even smaller projections on the villi, called micro-villi, still further expand on the surface area. The walls of the small intestine also contain glands, which secrete digestive enzymes, and are liberally scattered with mucosa-associated-lymphoid-tissue (MALT). Aggregation of lymphoid tissue, called Peyer's patches, are found in the ileum.

Movement through the small intestine

The chyme is mechanically digested and transported through the small intestine by two types of movements:

- **Segmentation-** occurs as a result of distension of the intestinal wall. This refers to localised contractions, which mix the chyme with the digestive juices and bring the particles of chyme into contact with the mucosa for absorption. They do not push the food forward.
- **Migrating motility complex-** once the food is largely absorbed, a peristaltic action takes over, which pushes the food along a short stretch of the intestine towards the large intestine.

Micro-anatomy of the small intestine

The walls of the small intestine are basically similar to that of the GI tract as a whole, but with a few variations.

1) The mucosa

- Contains villi – increases surface area for absorption.
- Each villus contains an arteriole, venule, blood capillary network and a lacteal.
- The nutrients pass through into the capillary or lacteal to enter the blood or lymph.

The epithelium of the mucosa is made up of simple columnar epithelium:

- Absorptive cells – with microvilli to form the brush border.
- Goblet cells
- Enteroendocrine cells: S cells Secretin CCK cells Cholecystokinin K cells Glucose-dependant insulinotropic peptide
- Paneth cells secrete Lysozyme Phagocytose foreign debris.

2) The lamina propria

Aggregations of MALT cells, referred to as Peyer's patches.

3) The submucosa

Contains Brunner's (duodenal) glands, which secrete alkaline mucus.

4) The muscularis

An outer longitudinal layer
An inner circular layer.

Intestinal Juices and the Brush Border Enzymes

The intestinal secretions are alkaline (pH 7.6), as compared to the acid medium of the stomach. The pancreatic and intestinal juices provide a liquid medium to aid digestion absorption of nutrients from the chyme.

The chyme comes into contact with the microvilli, which secretes brush-border enzymes.
These enzymes comprise of:

- Carbohydrate digesting enzymes: **dextrinase, maltase, sucrase, lactase**.
- Protein digesting enzymes: **peptidases**
- Nucleotide digesting enzymes: **neucleosidases, phosphatases**

As the cells are sloughed off into the lumen, they break apart to release the enzymes, whilst other digestion occurs at the brush border.

Functions of the small intestine

- Segmentation mixes chyme with digestive enzymes, and allows food to come into contact with the mucosa for absorption.
- Peristalsis propels chyme along the tract.
- Digestion is completed.

- Absorption of 90% of nutrients.

The Large Intestine

The large intestine is primarily involved in the final completion of absorption (mainly of water), production of certain vitamins, formation and expulsion of faeces. It is about 1.5m long, and extends from the ileocaecal valve to the anus.

The large intestine is the final part of the alimentary canal. It is divided into:

- The caecum
- The colon- ascending, transverse, and descending.
- Sigmoid colon
- The rectum
- The anal canal

The small intestine meets the large intestine at the ileocaecal valve. The caecum is a pouch-like expanded portion of the large intestine, attached to which is the vermiform (worm-like) appendix. The appendix is richly supplied with lymphoid tissue.

The ascending colon ascends superiorly towards the liver, and turns sharply towards the left. This bend is referred to as the hepatic flexure. As the large intestine moves across the abdomen, it is called the transverse colon. Beneath the left lower ribs, it again turns sharply at the splenic flexure, to descend as the descending colon. As the descending colon curves medially, it is called the sigmoid or pelvic colon. Inferior to this portion, it becomes the rectum, where the faeces are stored for expulsion through the anal sphincters.

The colon is inhabited by very large numbers of microbes such as bacteria and fungi. When kept in normal numbers, these bacteria are either harmless, or beneficial to their host, and are referred to as **commensals**. They participate in the synthesis of vitamins B, & vitamin K, folic acid, and convert the remaining proteins into amino acids. However, if their population is allowed to expand out of normal proportion (such as with the ingestion of antibiotics), or they are transferred to other parts of the body, they become pathogenic. A large part of the faeces produced is made up of dead bacteria.

There are three types of mechanical movements produced by the bowel:

- **Haustral churning-** the structure of the large intestine includes muscular pouch-like sacculations throughout its length, called haustra. The haustra remain relaxed and become distended, whilst they fill up, but when the distension reaches a certain point, it stimulated the contraction of the pouch, which propels the contents into the next haustra – thus slowly moving the bowel matter along the colon.
- **Peristalsis-** occurs primarily at the more proximal portions of the large intestine (that portion closest to the small intestine), and at a much slower rate than the small intestine.
- **Mass peristalsis** – this motion occurs only 2-3 times a day, and is stimulated by food in the stomach- **the gastrocolic reflex**. In this case,

there is a strong peristaltic contraction from the transverse colon, driving the colonic contents into the rectum. Nerve impulses in the rectum respond to stretch, and the urge to defecate ensues.

Micro-anatomy of the Large Intestine

The mucosa:

- The large intestine differs quite markedly from the mucosa of the small intestine - there is a noticeable lack of the villi, microvilli, and the circular folds of the small intestine.
- The mucosa is made up of simple columnar epithelium, with a lamina propria of areolar connective tissue, and muscularis mucosae.
- The epithelium contains mainly absorptive cells (which absorb primarily water), and goblet cells (which secrete mucus for lubrication of intestinal contents).
- Just before the anal opening, the epithelium changes abruptly to stratified squamous, this contains large modified sweat glands – the anal glands.

Solitary lymphatic nodules are found in the mucosa, but the appendix is abundant with lymphatic nodules in its mucosa and sub-mucosa.

The sub-mucosa
Similar to that of the rest of the GI tract.

The muscularis:
Differs from the small intestine:

- External layer of longitudinal smooth muscle, with portions of this layer thickened forming the taeniae coli, and contractions of these thickened bands of muscle, gather the intestine into haustra.
- Small pouches of fat filled visceral peritoneum are attached to the taeniae coli, and are referred to as epiploic appendages.

Faeces Formation
The chyme becomes solid as a result of the water absorption, which occurs mainly in the large intestine. Faeces are made up of water, inorganic salts, sloughed-off epithelial cells from the mucosa, bacteria and products of bacterial decomposition, and undigested food such as cellulose.
Much of the water taken in the form of food is reabsorbed (mainly via osmosis) in the small and large intestine, which makes them important organs in regulating the water balance of the body.

Functions of the Large Intestine

- Haustral churning and peristalsis which moves the contents along the colon to form faeces.
- Bacteria produce some vitamins B and Vitamin K.
- Absorption of water, ions and vitamins
- Defecation.
- Maintenance of water balance of the body.

The Accessory Organs of the Digestive Tract:

Now you shall be considering the contributions of the liver, gallbladder and pancreas to the digestive process. These organs contribute, not only to the body in terms of digestion, but more globally by affecting homeostasis as well.

The Salivary Glands

The major salivary glands are divided into three groups:
1) Parotid glands – Secretes saliva into the oral cavity via the parotid duct. These glands secrete a serous fluid, containing salivary amylase. Ducts open opposite to 2nd mandibular molar.
2) Submandibular glands –The secretions are more mucosal and also contain amylase.Ducts open onto floor of mouth.
3) Sublingual glands –These glands secrete mostly mucus with just a little amylase. Ducts open onto floor of mouth

Saliva is made up of 99.5% water – for dissolving foods to be tasted and digested. It is also contains amylase, lipase, bicarbonate, and phosphate urea and uric acid.

The Liver and Gallbladder:

The liver is the largest gland in the body, located in the upper right hypochondirac and the epigastric regions, fitting snugly against the diaphragm.

The liver is made up principally of two lobes – the large right and the small left. The right also has two small lobes associated with it, which are the inferiorly placed quadrate lobe, and the posterior caudate lobe. The falciform ligament - a fold of the parietal peritoneum, which also serves to attach the liver to the anterior abdominal wall and the diaphragm, attaches the right and left lobes to each other.

On the inferior surface of the liver between the quadrate and caudate lobes, is a transverse fissure, the porta, which transmits the hepatic portal vein, the hepatic artery and the nerves to the liver, and the hepatic duct and lymphatics from the liver.

The gallbladder is a small pear-shaped organ, about 7-10cm long, which is attached to the liver via the common bile duct, and associated with the liver both anatomically and functionally.
The gallbladder is broadly divided into the wide fundus, the body and neck, which comprise of the tapered portion, projecting upwards.

The wall of the gallbladder is made up of three coats:
1) The serous coat

2) The fibromuscular coat - dense fibrous tissue, with smooth muscle fibres on a longitudinal and transverse plane.
3) The mucosa is elevated into minute rugae – to allow for expansion.

The neck of the gallbladder leads into the cystic ducts, where the folds of the mucous coat become especially prominent and form a spiral fold.

The bile ducts:
The major bile ducts are made up of right and left hepatic ducts, which emanate from the major lobes of the liver, and join at the porta to form the common hepatic duct. The common hepatic duct enters the lesser omentum, where it unites with the cystic duct, of the gall bladder, to continue as the common bile duct.

Histology of the Liver and Gallbladder:
Beneath the peritoneal layer is a thin fibrous capsule encasing the liver and sending fibrous partitions into its substance – which divides the liver into units known as lobules.
Each lobule is about 1- 2.5mm in diameter, and is made up of specialized epithelial cells known as hepatocytes. These are arranged in irregular branching and interconnected sheets around a vein known as the central vein, which drains into the three hepatic veins. These in turn drain into the inferior vena cava.

Rather than capillaries, the liver has endothelial-lined sinusoids, through which the blood passes. Within these sinusoids are macrophage cells known as Kupffer's cells. These fixed phagocytes destroy decrepit leukocytes, RBC's, bacteria, toxins and other foreign matter in the venous blood draining from the GI tract (hence its reputation as a detoxifier).

Between adjacent lobules are tributaries from the hepatic portal vein, portal artery and the bile duct. This group is referred to as the 'portal triad'. The branches of the hepatic portal vein, drain into the sinusoids, and provide the cells with nutrients (and toxins) from the alimentary canal. The hepatic artery also drains into the sinusoids, supplying the hepatocytes with oxygen. These two blood vessels provide nutrients and oxygen to the hepatocytes. Metabolites from the hepatocytes drain into the central vein, and from there into one of the hepatic veins. The bile ducts drain the bile ductules.

Bile Secretion:
Bile is secreted by the hepatocytes, and enters bile canaliculi – narrow intercellular canals. Bile canaliculi empty into small bile ductules at the periphery of the lobules, which merge to form the right and left hepatic ducts. The right and left hepatic ducts unite to exit the liver as the common hepatic duct. The common hepatic duct units with the cystic duct from the gallbladder to form the common bile duct. Bile enters the cystic duct and is stored and concentrated in the gallbladder until required in the small intestine.

Thus, the gallbladder functions to store the bile. It also functions to concentrate the bile by absorbing water and ions from the fluid through the gallbladder mucosa.

Bile Composition and Role:
Bile is made up mainly of water, but also bile acids, bile salts, cholesterol, lecithin, bile pigment and ions.

It is partially an excretory product and partially a digestive secretion:

- The bile salts play a role in the emulsification of lipid globules into a suspension of easily absorbed droplets for transport, by the lymphatic vessels as chyle.
- Bile pigment is principally made up of conjugated bilirubin. Dead RBC's release iron, globin and heme – from which bilirubin is derived. The iron and globin are recycled for the formation of new RBCs. Some of the bilirubin is converted to conjugated bilirubin and secreted as a constituent of bile. This bile is broken down in the intestine and stercobilin.

The liver has metabolic, secretory, and immunological functions, and you will need to know them

<u>The Pancreas</u>

The pancreas is a retroperitoneal gland situated behind the greater curvature of the stomach.
It is divided anatomically and functionally:

Anatomically

- The **head**. The expanded portion, found near the curve of the duodenum
- The **body and tail**. Located superior and lateral to the head.

Functionally

- An exocrine portion, made up of glandular epithelial cells arranged in clusters called acini. The acini cells, which constitute 99% of the cells, secrete pancreatic juice – which is a mixture of fluid and digestive enzymes.
- An endocrine portion, made up of the pancreatic islet cells (islets of Langerhans), which make up the remaining 1% of the pancreas. The islets are composed of two main cell types – the large alpha cells, and the smaller beta cells. These cells secrete the hormones, glucagon, insulin, somatostatin and pancreatic polypeptide.

The capsule of the pancreas is thin, and composed of loose fibrous connective tissue. Septa of the capsule divide the gland into lobules, and serve to support the blood & lymph vessels, and nerves.

Pancreatic secretions pass from the secreting cells into small ducts, which unite to form two large ducts. The larger duct is known as the pancreatic duct (duct of Wirsung), and the smaller is the accessory duct **(**duct of Santorini).

The pancreatic duct runs the length of the gland from tail to head, receiving secretions from the branches of the various lobules. It joins the common bile duct, from the liver and gallbladder, and together, they enter the duodenum as the hepatopancreatic ampulla (ampulla of Vater).
The accessory duct empties into the duodenum about 2.5 cm superior to the hepatopancreatic ampulla.

Functions of the pancreas

The pancreas, as was mentioned before, is divided functionally into two parts:

The exocrine portion:
Produces the pancreatic juice, which contains digestive enzymes and is alkaline in reaction. Secretions are initiated by the hormone secretin, which is liberated by the intestinal epithelium after stimulation by the acid contents of the stomach. The pancreatic juice buffers the acidic chyme, stops the action of pepsin from the stomach and creates an ideal environment for the digestive enzymes in the small intestine.

Pancreatic juice is made up of:
Pancreatic amylase - Carbohydrate digestion
Trypsin, chymotrypsin, carboxypeptidase and elastase- Protein digestion.
Lipase- Triglyceride digestion
Ribonuclease and deoxyribonuclease- Nucleic acid-digestion.

The endocrine portion:
Produces glucose regulating hormones:

- Insulin (beta cells)
    - Cellular uptake of glucose
    - Synthesis of glycogen in the liver
- Glucagon (alpha cells)
    - Conversion of glycogen to glucose

The gastrointestinal system

SELF ASSESSMENT QUESTIONS

Question 1:
Write a descriptive account on the structure and function of the walls of the alimentary tract beginning with the oesophagus and end at the anus.

Question 2:
Identify the location of all the sphincters found within the alimentary tract and relate these to clinical significance.

Question 3:
The anal sphincter is made up of an external and internal sphincter - Describe the muscular arrangement of this orifice.

Question 4:
Describe how the large surface area is achieved in the small intestine

Question 5:
a) Define an exocrine gland
b) Define an endocrine gland
c) The pancreas has both types of glands. Look up in the text books which enzymes the exocrine glands secrete, and which two hormones the endocrine glands secrete.

Question 6:
True of False?
a) The gall-bladder is essential for bile production?
b) The oesophagus forms part of the trachea?
c) The stomach produces the only acid secretions of the digestive tract?
d) The hepatic flexure is on the right side of the body?
e) Many of the abdominal organs lie inside the peritoneal sac?
f) The large intestine functions in the digestive process?
The colon should be cleansed of bacteria?

Question 7:
What is the role that the uvula plays?

Question 8:
Draw a diagram to illustrate the regions of the stomach, the curvatures, and the two sphincters.

Question 9:

a) Write a list of the functions of the stomach.
b) List the contents of gastric juice, and the functions of the specific contents.

Question 10:

Describe the portal flow from the hepatic artery and hepatic portal vein, to the heart.

Question 11:

Write brief notes regarding the functions of the liver.

Question 12:

True or False?

a) The pancreatic secretions constitute the majority of the digestive enzymes?
b) The pancreas is entirely an organ of digestion?

Please refer to your labelling supplement handbook and label any images associated with the above chapter.