Bio Factsheet

Number 24

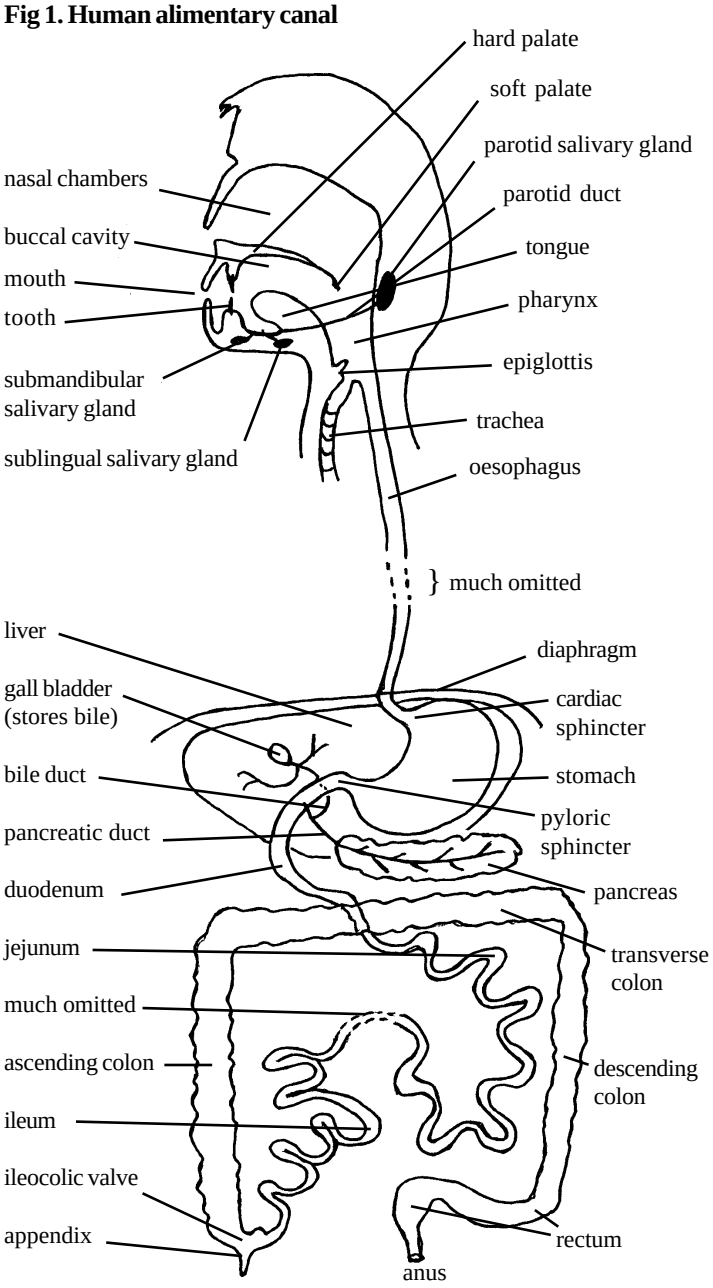
Human digestion

This Factsheet summarises the key aspects of human digestion:

1. **The gross anatomy of the human alimentary canal in relation to the processes of mastication, digestion and absorption.**
2. **The generalised histology of the gut wall and the histological structure of the oesophagus, stomach, ileum and colon in relation to the specific functions of these parts.**
3. **The sources and effects of secretions concerned with carbohydrate, protein and fat digestion.**
4. **The hormonal and nervous control of digestive secretions including olfactory and taste chemoreceptors and salivation.**
5. **The effects of alcohol on the gut.**

Examination questions on this topic often test recall knowledge of gut anatomy and histology, and of the mechanisms of digestion and absorption. Questions also often include tabular or graphical data for candidates to interpret or comment on.

Fig 1. Human alimentary canal



The gross anatomy of the human alimentary canal

The anatomy of the human digestive system can be seen in Fig 1.

The mouth is the opening to the **buccal** or oral cavity and is surrounded by muscular lips which close the mouth to retain food in the cavity. The buccal cavity is separated from the nasal chamber by the bony hard palate and cartilaginous soft palate. It contains :

1. the tongue which is made of striated voluntary muscle and this is used to mix the food with saliva and to push the food into the pharynx during swallowing.

2. the teeth which are used to masticate (chew) the food. This breaks the food up into small pieces, mixes it with saliva and breaks up the indigestible cellulose cell walls of plant material. Mastication is sometimes called mechanical digestion. The buccal cavity also receives saliva which is secreted through ducts from three pairs of salivary glands, the submandibular gland, the sublingual gland and the parotid glands (Fig 1).

The buccal cavity opens into the throat or pharynx which then continues into the food pipe or oesophagus (gullet). During swallowing, the glottis, which is the entrance to the airways, is closed by a fibrous flap of tissue known as the epiglottis. This prevents food from entering the airways.

The oesophagus carries food to the stomach by a muscular wave-like action called **peristalsis**. It joins the stomach at the cardiac sphincter. This ring of smooth muscle prevents food from regurgitating up the oesophagus when the stomach contracts. The stomach is a muscular sac which holds and churns the food with digestive gastric juice for about four hours before releasing it through the pyloric sphincter into the duodenum. The duodenum is a U-shaped tube about twelve inches long. It receives digestive secretions from the liver, called **bile**, from the pancreas, called **pancreatic juice**, and from glands in its own wall which produces a secretion called **succus entericus**.

The contents of the duodenum pass onwards into the jejunum (meaning empty, since at death the jejunus always empties into the ileum). The jejunum is about eight feet long, and the contents are held there for about twelve hours whilst digestion proceeds. The contents then pass into the ileum, which is about twelve feet long, where they remain for around twelve hours whilst absorption of nutrients into the blood and lymphatic systems occurs.

The contents are then released through the ileocolic valve into the colon. The colon is about five feet long and two and a half inches wide. It consists of the ascending, transverse and descending sections. In the colon the bulk of the remaining water and salts are absorbed into the blood, so that the contents become the consistency of faeces. Also in the colon are symbiotic bacteria, such as Escherischia coli. These are useful since they manufacture various B vitamins which are used by humans after absorption into the blood.

Eventually, the faecal material is passed into an S-shaped tube called the rectum. This is about eight inches long and when it contains faeces it causes the person to have the urge to defecate. The faecal material is evacuated to the exterior via a muscular sphincter called the anus.

The generalised histology of the gut wall

The gut wall has the same basic histological pattern throughout the alimentary canal, but the different regions of the canal have modifications in their histology related to their local functions.

The gut wall consists of distinct histological layers. Autonomic nerve plexuses lie in the base of the submucosa and in the muscularis mucosa. These are involved in regulating gut movements for moving and mixing food and digestive secretions.

Two basic types of gut movement occur, **peristalsis** and **segmentation.** Peristalsis is controlled by nervous reflex arcs from the medulla of the brain. In peristalsis, the circular muscle of the muscularis externa contracts behind the ball (bolus) of food whilst the longitudinal muscle contracts in front of the food. This constricts the gut behind the food and shortens it in front of the food. These contractions pass in waves along the gut and thus the food is forced along.

Segmentation occurs mainly in the small intestine (duodenum, jejunum, ileum) and large intestine (colon, rectum). It is a local contraction of the circular smooth muscle which divides the intestine into short segments. This helps to mix the foods and digestive juices, and to bring foods into contact with the absorptive surfaces. It is enhanced by parasympathetic stimulation and suppressed by sympathetic stimulation.

Histological specialisations of different gut regions

The oesophagus contains stratified squamous epithelium which allows it to withstand the friction of abrasive food materials passing along it. The muscles of the muscularis externa are well developed for peristalsis during swallowing. They also contain some voluntary striated muscle fibres which aid in regurgitation of food (these are particularly well developed in ruminant mammals which chew the cud).

The histology of the stomach can be seen in Fig 2. The surface epithelium is of columnar type with numerous mucous secreting goblet cells. The mucus coats the stomach wall, preventing attack by enzymes and acids. The epithelium is developed into simple tubular glands which stretch into the lamina propria. These glands contain: mucous goblet cells, chief (zymogen) cells, which secrete protein hydrolysing enzymes, oxyntic (parietal) cells which secrete hydrochloric acid and G-cells which secrete the hormone gastrin. The stomach also contains an extra layer of smooth muscle cells which run obliquely. These lie to the outside of the longitudinal muscle and give extra churning ability to enhance gastric digestion.

The histology of the ileum can be seen in Fig 3 and 4. The mucosa of the ileum is covered with millions of finger shaped projections called villi (about 0.5 to 1.0 mm high).

Exam hint - *Structure:function of the villus is an extremely common exam question!*

Fig 2. Stomach wall lining

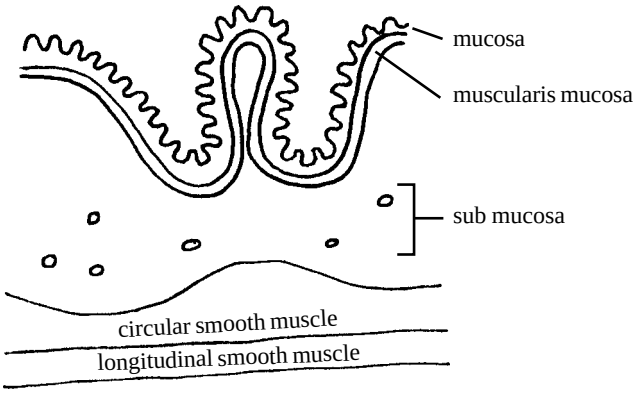


Fig 3. Epithelial cell of villus

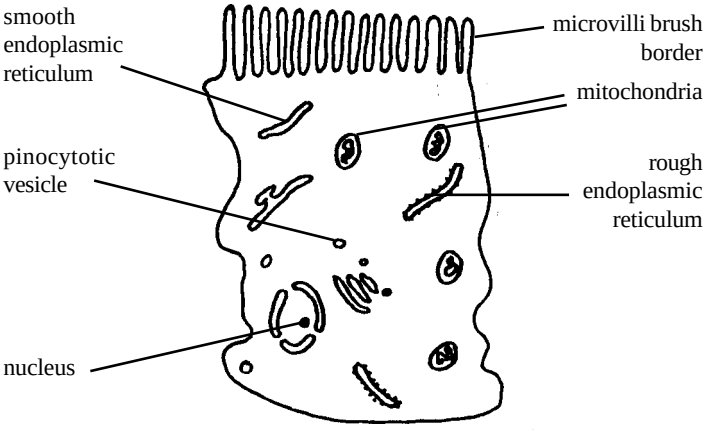
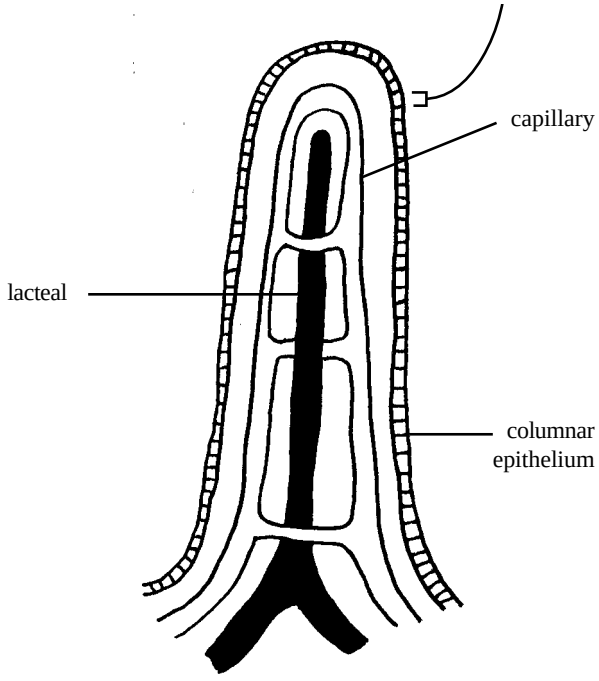


Fig 4. Histological structure of the ileum, including a villus



The **columnar epithelium** lining the villi is itself covered with microvilli which provide a huge surface area for absorption. The villi also have a superb capillary network which feeds into the hepatic portal vein to take blood and absorbed foods to the liver for assimilation, and a good lymph supply (lacteals) for fat absorption. Between the villi, the epithelium is modified into simple tubular glands which stretch into the lamina propria. These glands are the crypts of Lieberkuhn and secrete the succus entericus (intestinal digestive juice). In the duodenum, the crypts extend into the submucosa and form the glands of Brunner which secrete an alkaline mucus to protect the small intestinal wall from enzyme attack.

There are no villi present in the colon and the surface columnar epithelium absorbs water. It is extended into the lamina propria as simple tubular glands, but these secrete only mucus and do not produce enzymes. (Remember that bacteria in the colon produce many digestive enzymes to continue digestion of carbohydrates, proteins and lipids - but they do not digest cellulose in the human.) Portions of the longitudial muscles are greatly thickened and form three cords, the taenia coli, which run the length of the colon. These aid in moving contents along and in pushing faeces into the rectum when defecation becomes necessary.

Sources and effects of digestive secretions

All the digestive secretions contain water which acts as a solvent and lubricant. Most secretions also contain mucus which acts as a lubricant and also forms a protective lining over the gut surface to prevent erosion by acids and enzymes. Over-indulgence in alcohol will precipitate the mucus lining of the stomach wall, thus leaving the wall prone to erosion. The alcohol also stimulates secretion of hydrochloric acid into the stomach which can then attack the wall since the acid is fairly concentrated at pH 1.5 to 2.5. This can lead to the formation of ulcers.

The sources and effects of the digestive secretions are summarised in Table 1.

Table 1. Digestive secretions

Source	Contents	Effects
Saliva from salivary glands	Amylase	Digests starch/glycogen to maltose
Gastric juice from stomach glands	Hydrochloric acid	Provides an optimum pH for stomach enzymes. Disinfects the food. Changes inactive pepsinogen to pepsin. Promotes absorption of ions.
	Pepsinogen	Activated to pepsin which digests proteins to peptides
	Rennin	Only in babies where, together with Ca^{2+}, it coagulates milk protein to curd, making it more digestible.
	Lipase	Digests fats to fatty acids and monoglycerides
	Intrinsic factor	Promotes vitamin B12 absorption which stimulates red blood cell formation
Pancreatic juice from pancreas	Amylase	Digests starch/glycogen to maltose
	Lipase	Digests fats to fatty acids and monoglycerides
	Trypsinogen	Activated to trypsin which digests proteins to peptides and which activates chymotrypsinogen
	Chymotrypsinogen	Forms chymotrypsin which digests proteins to peptides
	Carboxypeptidase	Digests peptides to amino acids
Bile from the liver	Bile salts	Emulsifies fats into 1 micrometre droplets which increase the surface area for lipase action. Also aids the absorption of fats.
	(Bile pigments) eg. bilirubin	Breakdown products of haemoglobin which will be excreted in the faeces
Succus entericus from the crypts and Brunner's glands	Aminopeptidase	Digests peptides to amino acids
	Maltase	Digests maltose to glucose
	Sucrase	Digests sucrose to glucose and fructose
	Lactase	Digests lactose to glucose and galactose
	Enterokinase	Activates trypsinogen to trypsin

Note that many of the enzymes are secreted in an inactive form. This is to protect against self-digestion when the enzymes are actually inside their glands.

The control of digestive secretions

Saliva is released continuously in small volumes but more is released for feeding. The release from the salivary glands is under **parasympathetic** nervous control and is stimulated by the thought, smell, sight and taste of food, by the presence of food in the buccal cavity and by chewing. The taste receptors are in taste buds in the epithelium over the tongue and cheeks, and the olfactory receptors are in the nasal mucosa.

Gastric juice secretion is also initiated by parasympathetic stimulation through the vagus nerve which is stimulated by the smell, sight, taste of food and by the presence of food in the buccal cavity. Once food is in the stomach, the release of gastric juice is enhanced by the action of the hormone gastrin from the G-cells of the gastric glands. The flow of gastrin can also be stimulated by the presence of caffeine or alcohol in the stomach and by a reduced blood glucose concentration. Eventually the gastrin stimulates the pyloric sphincter to relax momentarily, thus releasing a small volume of acidic chyme (the stomach contents after gastric digestion) into the duodenum. The presence of acid chyme in the duodenum causes nerve impulses to pass to the medulla of the brain. These then pass out through the parasympathetic vagus nerve to stimulate:

1. the flow of bile from the liver and gall bladder
2. release of pancreatic juice from the pancreas
3. cells in the duodenal glands to release (a) **cholecystikinin** which stimulates the release of more bile and pancreatic juice and (b) **secretin** which stimulates the release of more intestinal and pancreatic juice.

The secretion of gastrin is switched off, the pyloric sphincter opens for longer periods and the stomach contracts to empty its chyme into the duodenum. When the stomach is empty the pyloric sphincter closes. After digestion and absorption in the small intestine, cells in its wall secrete more gastrin which causes the ileocolic valve to relax and the small intestine muscles to become more active. Thus the chyle (contents of the small intestine after digestion) is forced into the ascending colon. The release of the intestinal hormones is then switched off.

Absorption of digested products

This occurs mainly via the villi in the small intestine, although the colon also absorbs water, electrolytes and vitamins.

In the small intestine, water is absorbed into the blood osmotically, salts and vitamins are absorbed into the blood by diffusion or active transport, and monosaccharides, amino acids and short chain fatty acids are absorbed into the blood mainly by active transport. Long chain fatty acids and monoglycerides are absorbed as micelles, resynthesised to trigycerides which form chylomicrons. These are transferred into the lacteals. Glucose, galactose and sodium ions are all actively transported into the epithelium of the villus by the same carrier molecule which has receptor sites for all three substances. All three receptors must be filled before the transport can occur. Thus glucose cannot be absorbed efficiently in the absence of sodium or galactose. Fructose is absorbed by facilitated diffusion (this uses a carrier but does not require the expenditure of energy). These monosaccharides then move from the epithelium into the blood by facilitated diffusion.

Amino acids are also absorbed into the epithelium by active transport. They then enter the blood stream by diffusion. Short chain fatty acids (less than 10 carbons long) enter the epithelium and then the blood by simple diffusion.

Bile salts form spherical micelles about 25nm in diameter. Each micelle contains about 50 bile salt molecules and is soluble in water. Long chain fatty acids and monoglycerides will dissolve into the centre of the micelles which then ferry the lipids to the epithelial surface of the villi. The fatty acids and monoglycerides then diffuse into the epithelial cells, leaving the micelles behind to carry out further ferrying. In the epithelial cells, the fatty acids and monoglycerides recombine to form triglycerides. These associate with cholesterol and phospholipids and are then coated with proteins to form chylomicrons. These pass into the lacteals of the villi to be transported via the lymph.

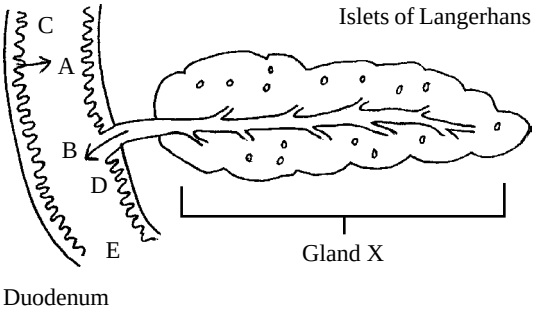
Practice questions

1. Complete the following passage by inserting the most suitable word or words into the spaces:

   After a few hours of digestion in the stomach, the _____ relaxes, momentarily allowing a small quantity of acid _____ to be released into the _____. This stimulates the gut wall to release two hormones, cholecystikinin and _____, which stimulates the flow of _____.

   (6 marks)

2. The diagram below shows part of the human digestive system:



   (a) Name gland X as shown on the diagram (1 mark)

   (b) Name secretions A and B (2 marks)

   (c) These secretions contain enzymes concerned with the digestion of carbohydrates. Name **two** such enzymes present in A and **one** such enzyme present in B. (3 marks)

Answers

Marking points are shown by semicolons

1. pyloric sphyncter;
   chyme;
   duodenum;
   secretin;
   intestinal juice/pancreatic juice;

2. (a) pancreas;

   (b) A = intestinal juice (succus entericus);
   B = pancreatic juice;

   (c) A = Maltase;
   Lactase;
   Sucrase;

   B = Amylase

Acknowledgements;

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