

The Digestive System (The Gastrointestinal System)

The Digestive System is the collective name used to describe alimentary canal, some accessory organs and a variety of digestive processes, which take place in the canal to prepare taken in the diet for absorption.

Figure 1 - Diagram of the Digestive System

Digestion

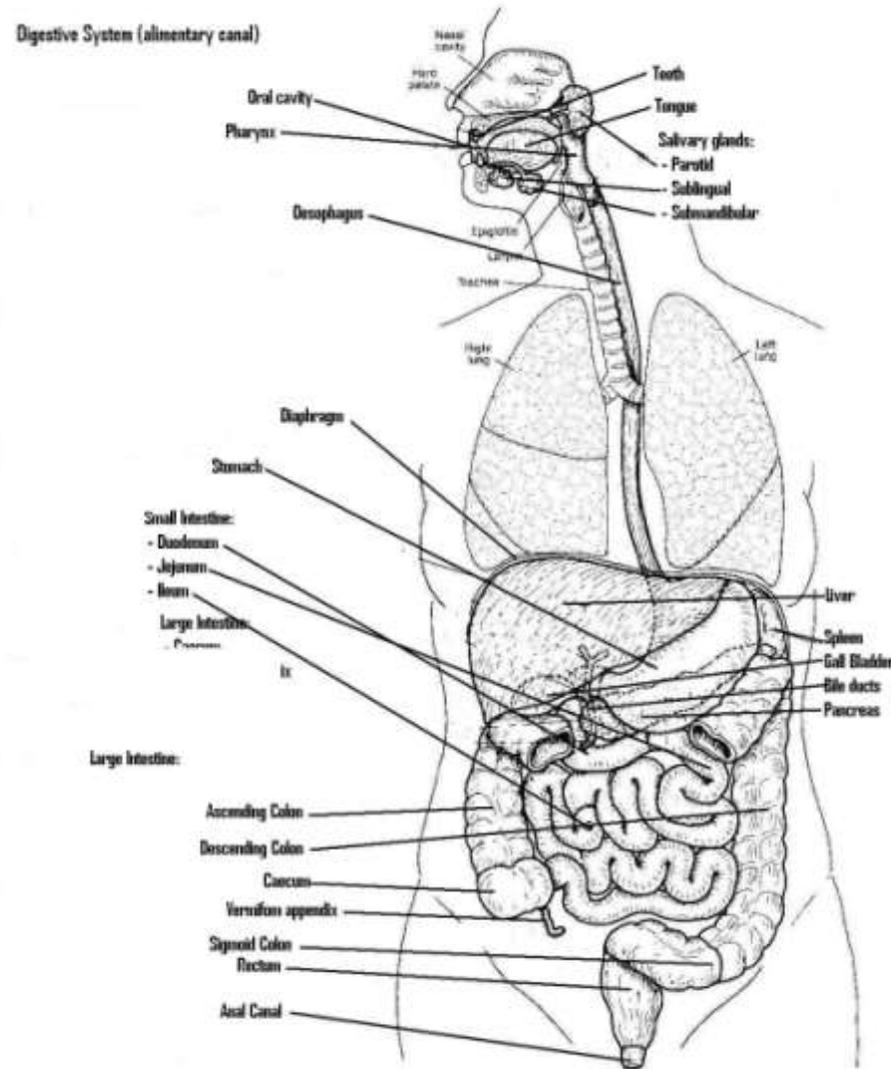
This is the process by which food is broken down so that it may be absorbed and utilised by the body. It is where large molecules are broken down into smaller ones. It should be understood in terms of the breaking down of macromolecules, polymers, into smaller units, monomers. The purpose of this is to create the basic building blocks of anything in the body.

The basic functions of the gastrointestinal tract are:

1. Ingestion-taking food into the body (eating).
2. Movement of food along the GIT by muscle action.
3. Digestion—the breakdown of food by both mechanical and chemical means.
4. Absorption—the uptake of digested food into the blood for distribution to the cells.
5. Defaecation—the elimination of indigestible substances from the body.

Organs of the Digestive System

Alimentary Canal—This is a tube of at least 7 metres length, through which food passes. It consists of the mouth, pharynx, oesophagus, stomach, small intestine, large intestine, rectum and anus; even though it is entirely enclosed within the body, it is classified as an external environment (being a highly controlled one). These provide an enclosed environment for the mechanical and chemical breakdown of food. Mechanical breakdown is by the teeth and the muscular action of the wall of the GIT.



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Accessory Organs of Digestion – The accessory organs are located outside the alimentary tract. Their secretions pass along ducts to enter the tract. They consist of three pairs of salivary glands, the pancreas, the liver and the biliary tract.

The Mouth

The mouth is lined with mucus membrane and mostly surrounded with muscle.

The Teeth are embedded in sockets in the upper and lower jaws and are used to mechanically break down the food. There are the incisors (for cutting), the canines (for tearing), and the molars (for grinding).

There are 3 pairs of **salivary glands** in the mouth, which secrete saliva. The flow of saliva is controlled by the autonomic nervous system in response to food in the mouth or to the sight or smell of food. Saliva is produced by three pairs of salivary glands (**parotid, submandibular and sublingual**), and contains the enzyme salivary amylase, which is mildly alkali and begins the digestion of starches to simple sugars.

Figure 2 - Salivary Glands

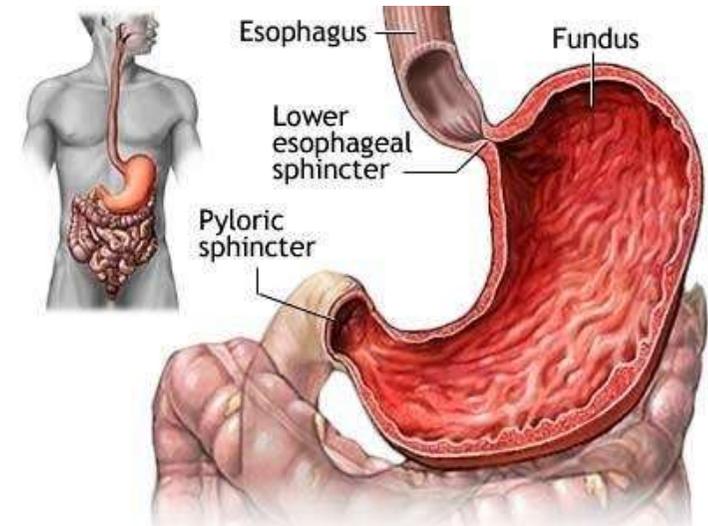
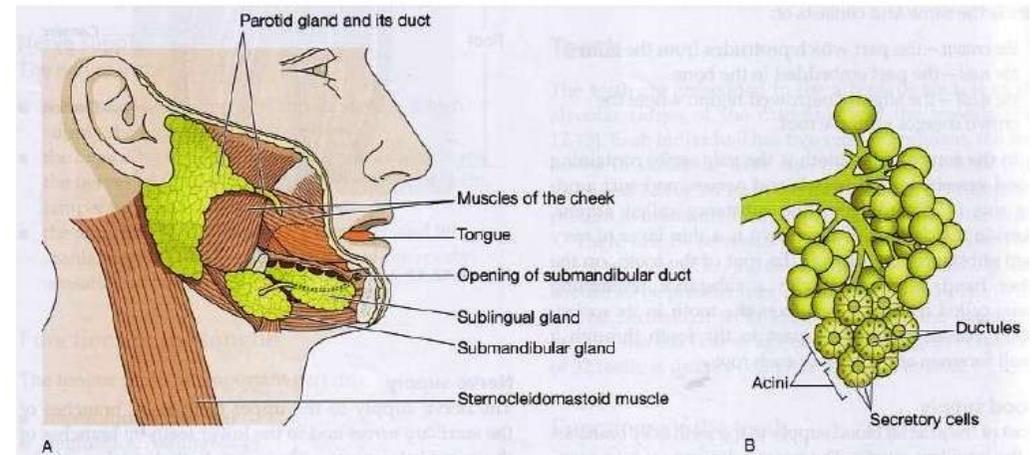
The Pharynx

After mastication the bolus of food is pushed back into the pharynx, which is the space at the back of the mouth and nose) by the tongue. In the swallowing process a small flap called the epiglottis covers the trachea to prevent food going down to the bronchi and lungs.

The Oesophagus

The oesophagus is some 25cms long and lies on the front of the vertebral column and behind the trachea and heart. It is lined with stratified, non-keratinised, squamous epithelium. It acts to protect the oesophagus by being rubbed off as the food moves past,

Salivary Glands



Movement: Peristalsis

- Peristalsis:
 - Contraction and relaxation in waves
- Moves food forward
- Mixes the food
 - Segmentation
- Sphincters control movement

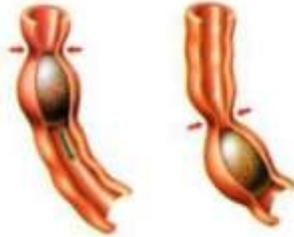


Figure 3 - Peristalsis

but is replaced by more cells. At its top end there is the cricopharyngeal sphincter, to prevent air passing into the stomach with inspiration. Once past the epiglottis food is pushed through the GIT by **peristalsis**.

This is a contraction of the circular muscle in the wall of the gut; it is myogenic in nature and appears as a wave moving along it, thus pushing the bolus of food along. Just above the stomach there is a ring of muscle called the gastroesophageal (cardiac) sphincter, which prevents gastroesophageal reflux (heartburn). A sphincter is a ring of muscle, which acts to close an orifice. There are a few along the length of the GIT to prevent backflow and ensure flow in one direction.

The Stomach

The stomach is a “J” shaped muscular sac (essentially a dilatation of the GIT), continuous with the oesophagus above at the cardiac or gastroesophageal sphincter (lower oesophageal sphincter) and the duodenum below.

Figure 4 - The Stomach

There are four main areas of the stomach:

- **Cardiac**
- **Fundus**
 - The word fundus is used in a number of other bags or sacs in the body (e.g. the bladder, the gall bladder, the uterus) and is always the part furthest away from the exit
- **Body**
- **Pylorus**

Figure 5 - The Four Areas of the Stomach

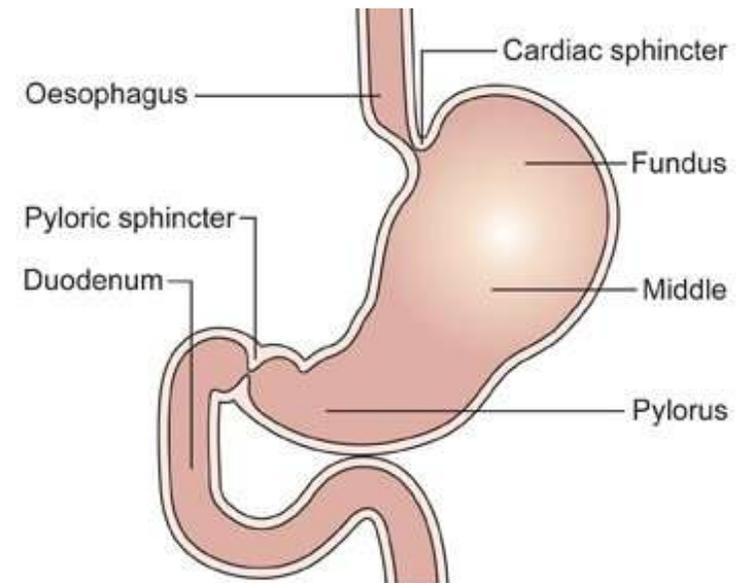


Diagram showing the parts of the stomach
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The cardiac area is the entrance to the stomach, the fundus is the top, and the pylorus is at the distal end; the main area for digestion is the pylorus, with the fundus and the body functioning more of a ‘hopper’, a waiting/storage area, for food prior to digestion. The muscular wall consists of three layers of muscle (longitudinal, circular and oblique) to churn the food and assist with the mixing of chyme and enzymes; the muscles are relaxed when the stomach is empty and fold in upon themselves forming rugae. At the distal end of the stomach is the pyloric sphincter,

which defines the end of the stomach and the beginning of the duodenum. It stays contracted until the food is sufficiently digested to be 'passed on to' the next section.

The stomach wall contains gastric glands which secrete a clear colourless fluid of high acidity (low pH) that contributes to chemical digestion and changes the food to a more fluid consistency. The gastric juices contain:

Water – 97-99%

- **Mineral salts.** Secreted by gastric glands.
- **Mucus** – secreted by goblet cells in the glands and on the stomach surface. Mucus prevents mechanical injury to the stomach wall by lubricating its contents and prevents chemical injury by acting as a barrier between the stomach wall and the gastric juices (remember, the stomach wall is essentially muscle – protein – and can be digested by the enzymes secreted into it).
- **Hydrochloric Acid**
 - acidifies the food and stops the action of ptyalin.
 - kills many bacteria, which may be harmful.
 - provides the acid environment needed for the effective digestion by pepsin.
 - Pepsinogen - activated into pepsin by hydrochloric acid and this then begins the digestion of proteins breaking them up into smaller molecules.
 - Intrinsic factor – necessary for the absorption of vitamin B12.
 - Rennin – an enzyme which is important for the digestion of milk in children. It helps produce a milk curd, which allows milk to be retained in the stomach for longer while it is digested by pepsin.
 - Gastric Lipase – this is produced in small amounts and begins the digestion of fats.

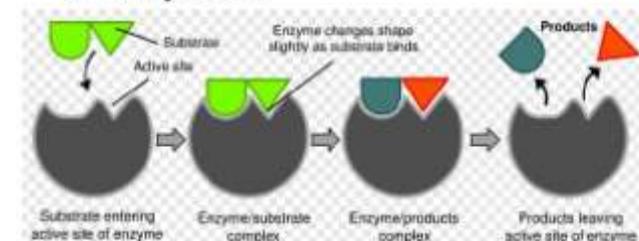
The stomach empties its contents into the small intestine 2-6 hours after eating. The activity in the stomach is twofold

- Mechanical
 - The action of the muscles in the wall of the stomach also contribute to further grinding of food
 - Enzymic breakdown
 - an enzyme is a substance which acts as a catalyst, facilitating the course of a reaction (here, the breakdown of large molecules into smaller ones) without being altered itself in the reaction (this means that it can be used over and over again)

Figure 6 - Enzymic Action

Enzymes

- An enzyme is a chemical that catalyses a reaction, without taking part in the reaction
- Salivary amylase
 - enzyme in mouth
 - breaks down starches to simple carbohydrates



The Small Intestine

The small intestine consists of three main sections:

- The duodenum
- The jejunum
- The ileum

Figure 7 - The Duodenum, with the Pancreas lying in its Loop

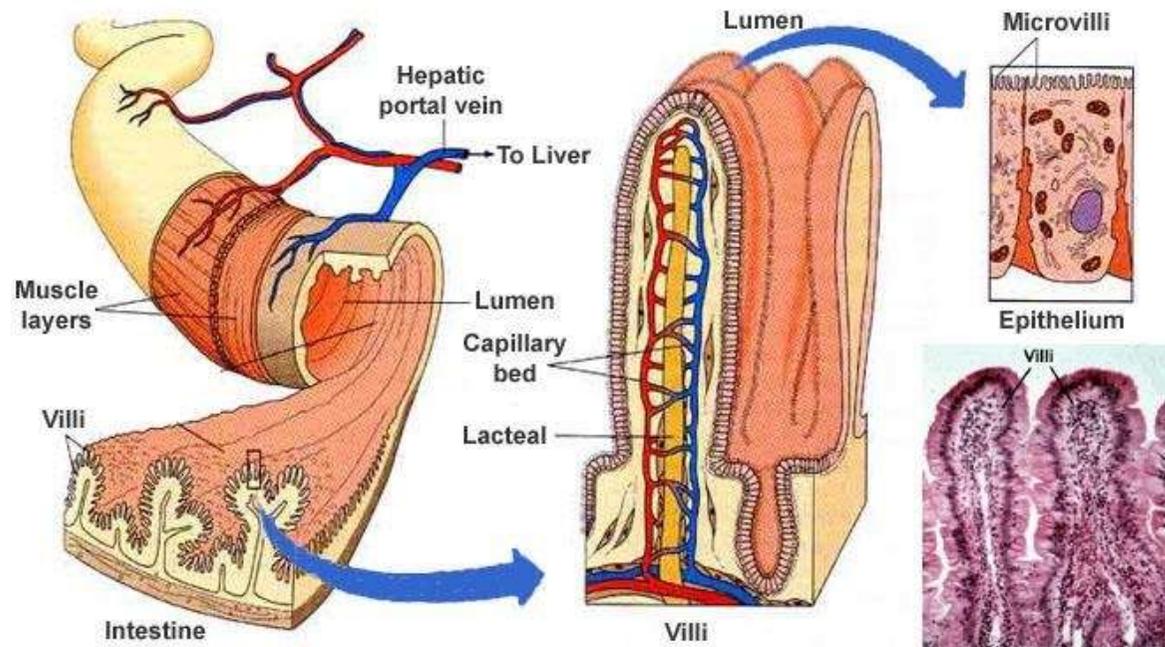
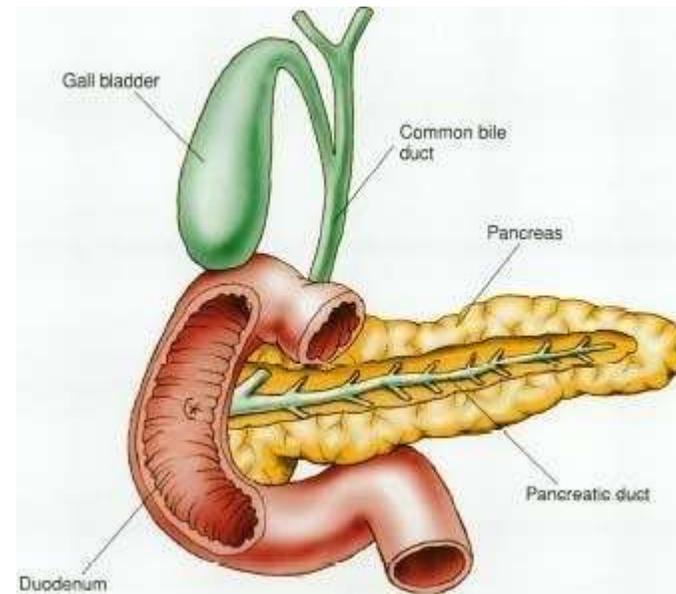
The Duodenum

This begins at the pyloric sphincter and ends at the ilio-coecal valve, where it joins the colon. It is a little over 5 meters long. It is 25cms long and curves around the head of the pancreas. The pancreatic duct and bile duct enter the duodenum at the sphincter of Oddi. Its main function is to neutralise the acids coming out of the stomach this being achieved by the Brunner's glands, which produce lots of bicarbonate.

The rest of the small intestine has a brush border on its inner layer of mucous membrane. The surface area for increased circular folds and by villi. Villi (or singular – villus) are microscopic finger like projections from the mucosal surface, lined with columnar epithelium.

Figure 8 - Small Intestine with Brush Border Consisting of Villi

They contain a network of blood and lymph capillaries into which nutrients are absorbed from the intestine. Between the villi are intestinal glands, which secrete intestinal juice, which further contribute to digestion. In the mucous membrane there are lymph nodes called Payer's Patches which are essentially lymphoid tissue and help combat ingested infection. Acid chyme passes into the small intestine where it is mixed first with pancreatic juice and bile and then with intestinal juice.



Digestion in the Small Intestine

Pancreatic Juice – This enters the duodenum at the ampulla of the bile duct. It is now strongly alkaline from the bicarbonate pumped out by the Brunner's glands and consists of;

- Water.
- Mineral salts.
- Enzymes – Trypsinogen, pancreatic amylase and lipase.

Trypsinogen – this is activated by **enterokinase** (contained in the intestinal juice), which converts it into trypsin. This enzyme digests protein to peptides and amino acids. **Pancreatic Amylase** – This digests all remaining starches to simple sugars.

Pancreatic lipase – This converts fats to fatty acids and glycerol.

Bile – Bile is produced by the liver and released by the gall bladder. It contains;

- Water.
- Mineral salts.
- Mucus.
- Bile salts.
- Bile pigment – bilirubin.
- Cholesterol.

The bile salts (acting like washing up liquid) emulsify the fats in the small intestine, i.e., reduce the size of the globules. Bilirubin is a waste product of the breakdown of erythrocytes in the liver. It is altered by bacteria in the intestine and excreted in urine and faeces. The presence of bile in the small intestine is also necessary for the absorption of Vitamin K (a fat soluble vitamin)

Intestinal Juice – This is secreted by the glands of the small intestine and consists of water, mucus and the enzyme enterokinase (activates trypsinogen).

90% of all absorption takes place in the small intestine via the villi. The other 10% takes place in the large intestine. All digested sugars and amino acids are absorbed into the blood and are transported to the liver via the hepatic portal vein. All digested fats are absorbed into the lymphatic system and enter the blood stream at the right subclavian vein.

The Pancreas

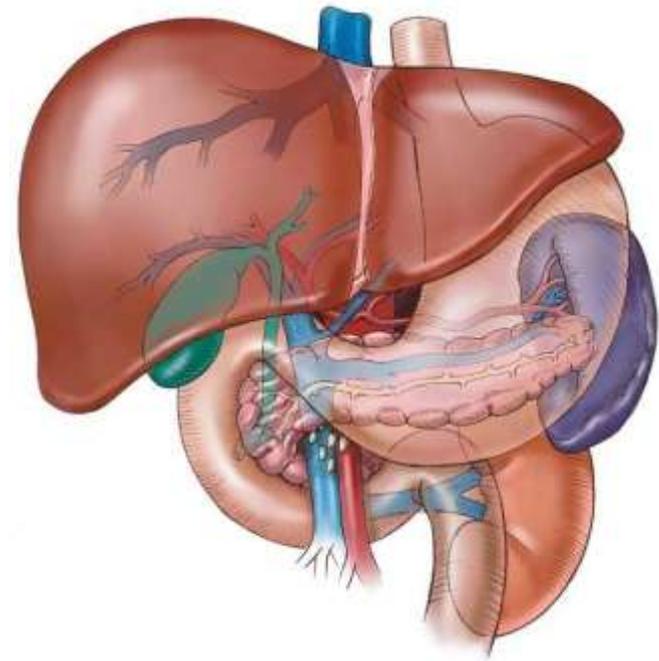
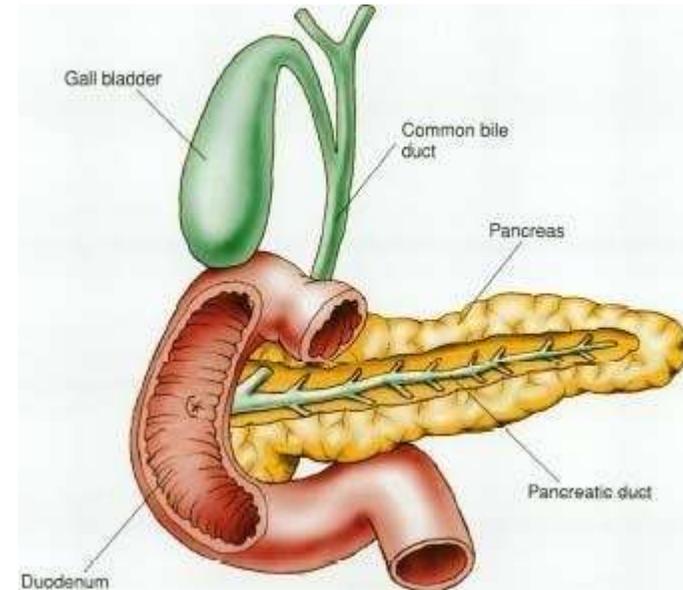
The pancreas is a pale grey gland weighing about 60 grams and about 12-15 cm long. It consists of a broad head, a body and a narrow tail. It lies behind the stomach, the head lying in the curve of the duodenum, with the body and tail up and to the left towards the spleen. The function of the pancreas is to produce pancreatic juice. Throughout the substance of the gland are collections of a different type of cell. These cells form the **Islets of Langerhans** and will be covered more in the endocrine section. They secrete the hormones insulin and glucagon, which pass directly into the blood and are concerned with blood sugar regulation.

Figure 9 - The Liver shown in Relation to the Stomach, Gall Bladder and Duodenum

The Liver

The liver is the largest organ in the body and is located just under the ribs and diaphragm on the right of the abdomen. It is supplied by 5 vessels: the hepatic artery and portal vessels from the stomach, spleen, pancreas, and small intestines. Its functions are;

- **Carbohydrate metabolism** –the liver is a storage site for glycogen, and if the blood is low in glucose it will break this down and release it into the blood. Conversely it can take glucose out of the blood and store it as glycogen. It can also convert other sugars absorbed (fructose, galactose) to glucose, and can convert certain amino acids into glucose (in starvation), and lactic acid into glucose following anaerobic exercise.
- **Lipid metabolism** –hepatocytes store some triglycerides; break down some fatty acids (for ATP synthesis); synthesise lipoproteins (to transport fatty acids, triglycerides and cholesterol to and from the body's cells); synthesise cholesterol; and use cholesterol to make bile salts
- **Protein metabolism** –hepatocytes synthesise most plasma proteins (globulins, albumin, prothrombin and fibrinogen); they also remove the amino group (-NH₂) from amino acids so that they can be used for ATP production or converted to glucose and fats; they also convert the toxic waste (from the -NH₂) into urea, which is excreted in urine.



- **Processing of drugs and hormones** - the liver detoxifies substances such as alcohol. Or secretes drugs (penicillin, sulphonamides and erythromycin) into bile. It also inactivates thyroid hormones and steroid hormones like oestrogen and Aldosterone.
- **Excretion of bilirubin** –bilirubin is derived from the haem (of haemoglobin) of old blood cells, absorbed into the liver and secreted into bile. Most of bilirubin is metabolised by the small intestine by bacteria (making the faeces brown and urine yellow)
- **Storage of vitamins and minerals** - the liver stores vitamins (A, B12, D, E and K) and minerals (iron and copper), which are released when needed.
- **Activation of vitamin D** –The skin, liver and kidneys participate in the synthesis in the active form of vitamin D

The Gall Bladder

This is a pear shaped sac found under the right costal angle on the edge of the liver. Its function is to store and concentrate bile, which is made by the liver. The bile duct connects the gall bladder with the duodenum at the sphincter of Oddi. Bile is pumped into the duodenum when fatty food is eaten. It acts to homogenise fats (break them down into very small particles; this creates a very large surface for enzymes to digest the fats).

Figure 10 - The Gall Bladder, Lying on the Underside of the Liver

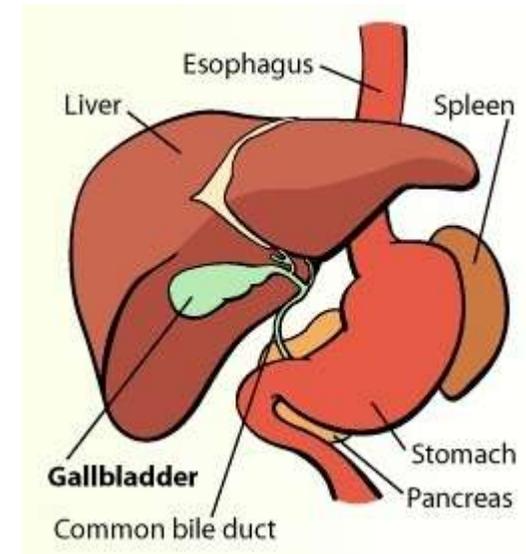


Figure 11- The Large Intestine - Colon

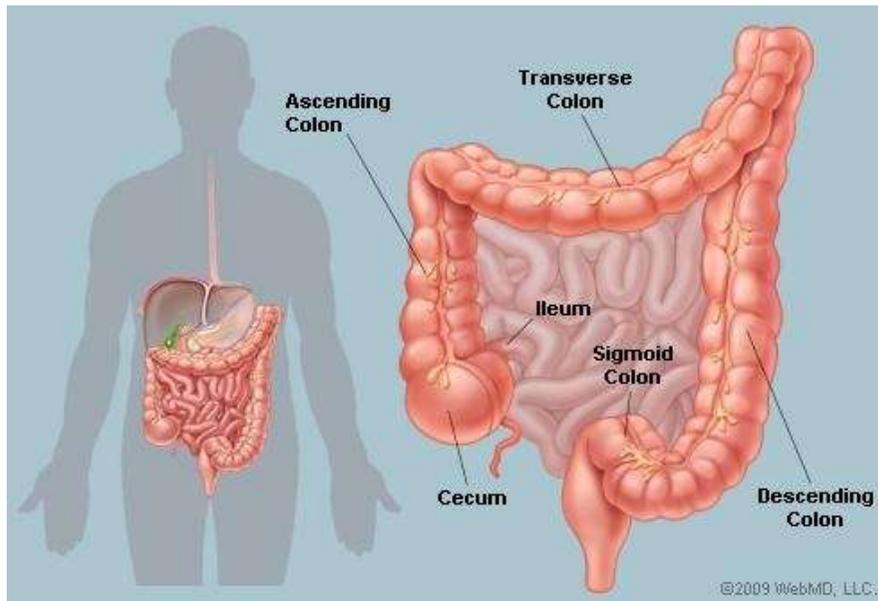
The large intestine begins at the caecum in the right iliac fossa and terminates at the rectum and anus. Its lumen is larger than that of the small intestine, around which it forms an arch.

The large intestine is divided into; the caecum (with the appendix attached)

- The ascending colon
- The transverse colon
- The descending colon
- The sigmoid or pelvic colon
- The rectum

It ends at the anus.

The Large Intestine



The wall of the large intestine is supported along its length by circumferential taut bands, called haustra. The primary function of the large intestine is absorption of water. Of every 1000mls that enter the body, 90% is absorbed.

There is an active bacterial colony here (E. Coli, aka gut commensals) which with we have a symbiotic relationship; they perform various functions including the synthesis of Vitamins B and K.

Disorders of the Digestive System

Heartburn

This is caused by a reflux of the stomach acids back up into the oesophagus. As was said, the stomach produces mucus to protect itself from these acids, but the oesophagus has no such protection, so it is burned. This results in oesophagitis, or heart burn, experienced as retrosternal pain. If this condition persists it can predispose to cancer.

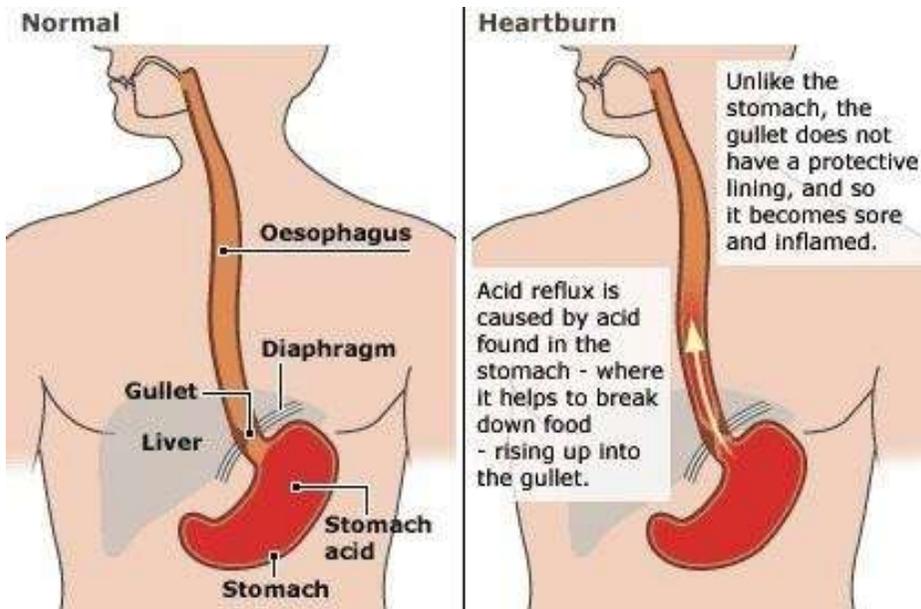


Figure 12 - Heartburn - Gastro-oesophageal reflux

Dyspepsia

Subjectively known as stomach ache; it is commonly caused by eating too fast, or by eating foods 'that don't agree with you'. There can be associated factors like hyperacidity (too much acid), or an overactive muscle, causing spasms and cramps.

Peptic ulcers

This is when there is a breakdown of the protective mucosa lining the stomach. It is frequently associated with stress (Hans Selye [The Stress

of Life] noted that there were always a trilogy of symptoms with stress: hypertrophy of the adrenal cortex, involution of the thymus and peptic ulcers), but can be associated with a bacterium – *Helicobacter pylori*; this results in a bare area and cavity (an ulceration), usually on the lesser curvature of the stomach. They are diagnosed by symptoms and barium meal (a contrast medium for X-rays). They are usually representative of long term stress, a chronic condition, and are slow in healing.

Figure 13 - Peptic (Stomach) Ulcer

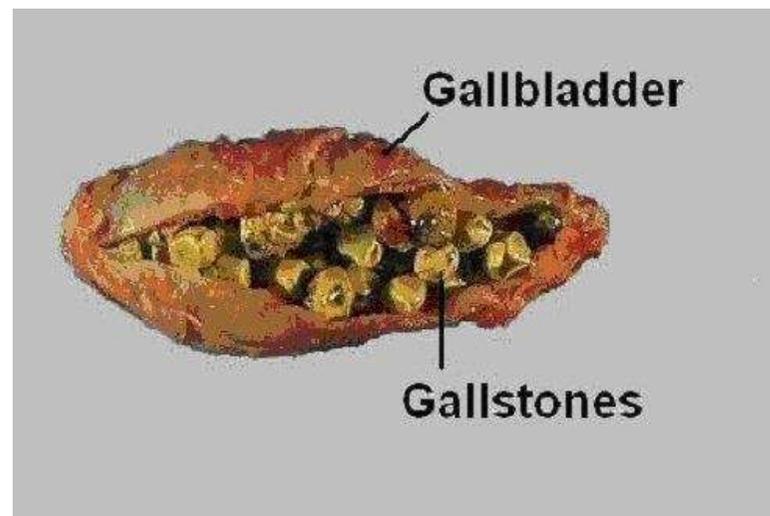


Gallstones

These are stones of crystallised cholesterol that form in the Gall bladder. They can cause symptoms locally, but mainly cause symptoms when they pass into the bile duct, which can cause blockage; this can cause a back-pressure into the liver

causing jaundice and pancreatitis. They can cause pain locally (around the 8th costal cartilage at the front), or referred pain in the right shoulder. If severe they can be removed surgically.

Figure 14 - Gall Bladder Cut Open to Show Gallstones



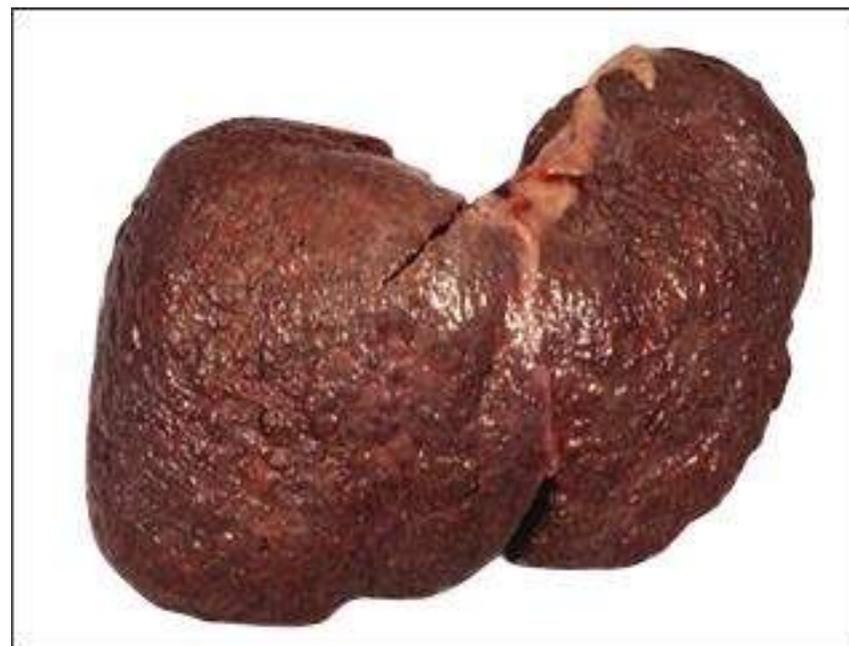
Hepatitis

- Hepatitis A (infectious hepatitis) – caused by Hep A virus from faecal contamination of food, toys, clothes, surfaces etc. by the faeco-oral route (ingested). It is a mild disease of children and young adults causing loss of appetite, malaise, nausea, diarrhoea and fever; jaundice then appears. It does not do any lasting damage
- Hepatitis is an inflammation of the liver. Various types have been recognised:
Hepatitis B (serum hepatitis) – caused by hep B virus and spread by bodily fluids (blood products, unsterile syringes, sexual activity, saliva and tears). It can be present for years or decades and can cause cirrhosis and cancer. People with it can become carriers (have it and can transmit it, but don't have any symptoms).
- Hepatitis C (non-A, non-B) – caused by Hep C virus; it is similar to B and is spread by contaminated blood products
- There are hepatitis D and E as well – these are also of virus origin.

Figure 15 - Cirrhosis of Liver

Cirrhosis

This refers to a liver that is distorted or scarred due to chronic inflammation. A lot of the functional cells are replaced by fibrous or fatty tissue. Symptoms of it include jaundice, oedema of the legs, uncontrolled bleeding, and increased sensitivity to drugs. It may be caused by hepatitis, certain chemical, parasites and alcoholism.



Diverticulosis

This is an condition affecting the colon. In the area between the haustra can form an area of weakness, causing a section of the colon wall to prolapse outwards, this prolapse being known as a diverticulum. If this becomes inflamed, it is known as **Diverticulitis**. It is usually a condition that affects older people, or who are less active. It suggests an increased tonus of the gut wall increasing pressure on the contents.

Figure 16 - Diverticulosis - Diverticulitis

Irritable bowel syndrome/disease

A disease of the GIT in which a person reacts to stress showing symptoms like abdominal cramping and pain, constipation and diarrhoea. The difference between the syndrome and the disease is that with the disease there are pathological changes on endoscopic examination.

Colitis

Inflammation of the mucosa of the colon in which water resorption is reduced; it produces watery, bloody faeces, and dehydration and salt depletion in severe cases.

Crohn's disease

An inflammation of the distal ileum and proximal colon.

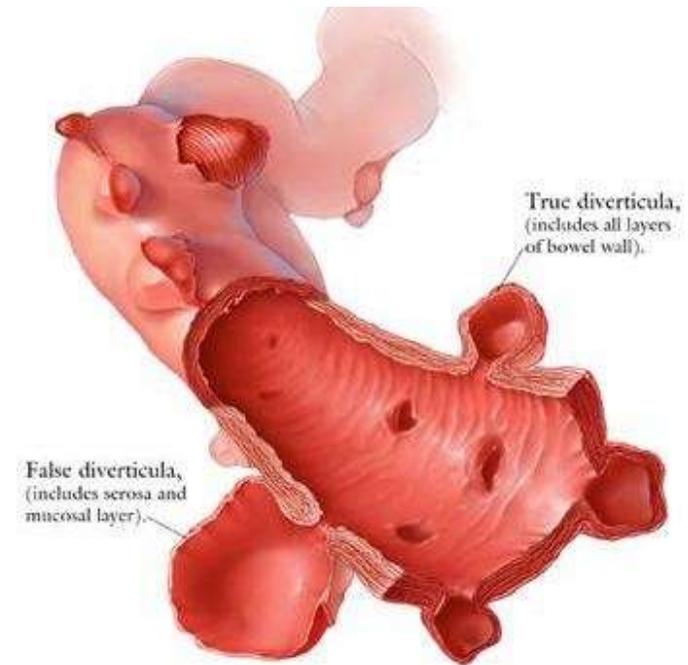
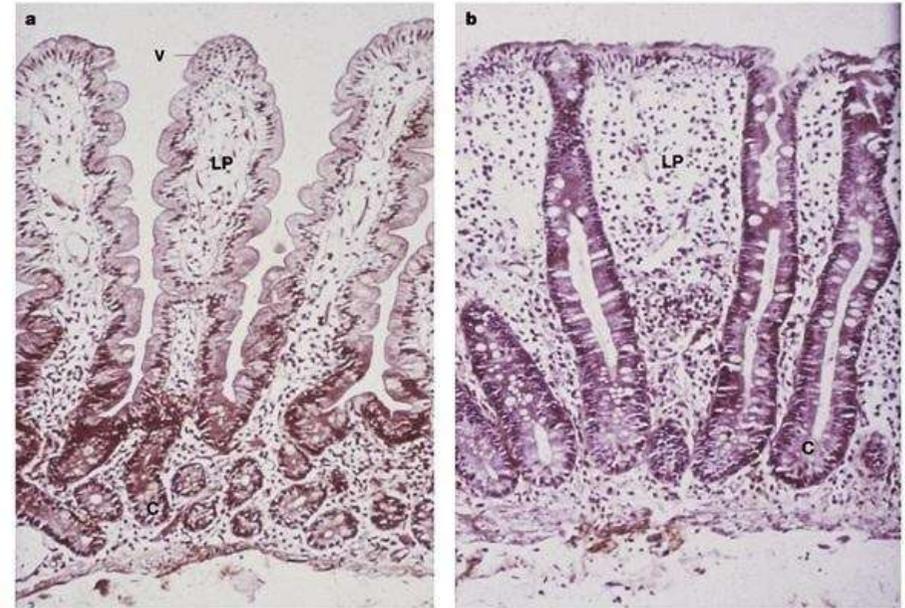


Figure 17 - Crohn's Disease

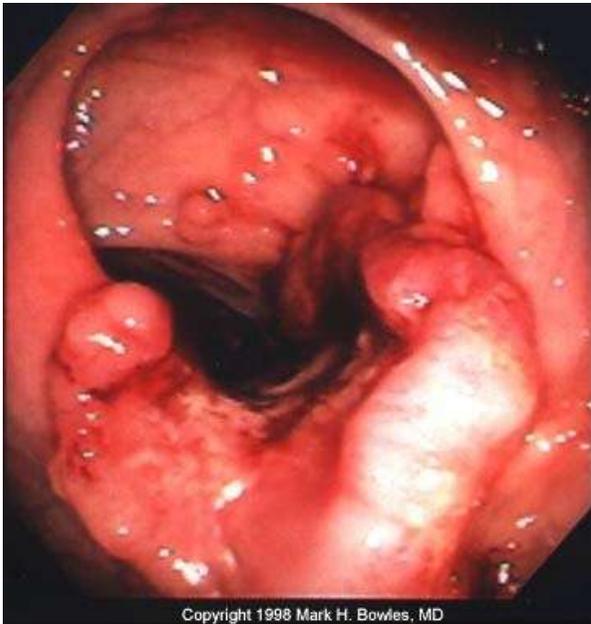
Coeliac disease

Coeliac disease is an inflammatory condition in the gut resulting from an allergy to gluten, the binding substance in wheat products (e.g. pasta and bread). The pictures here (below) show a section of normal gut with healthy villi. The other shows evidence of inflammation, with swelling and blunting of the villi.

Figure 18 - Coeliac Disease, Showing Blunting of Villi from Inflammation



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Cancer

Cancer can affect also any part of the GIT, of which benign ones are more common. Of the malignant types the most common is colorectal cancer, occurring low in the gut. It ranks second to lung cancer in males, and third to lung and breast cancer in females. These are many affecting factors, environmental and genetic for example; but protection has been suggested by use of dietary fibre, retinoids, calcium, selenium and other antioxidants. Signs and symptoms include: changes in bowels habits (diarrhoea, constipation), cramping, abdominal pain and bleeding (obvious or occult). Any of these should be investigated.

Figure 19 - Cancer of the Large Intestine