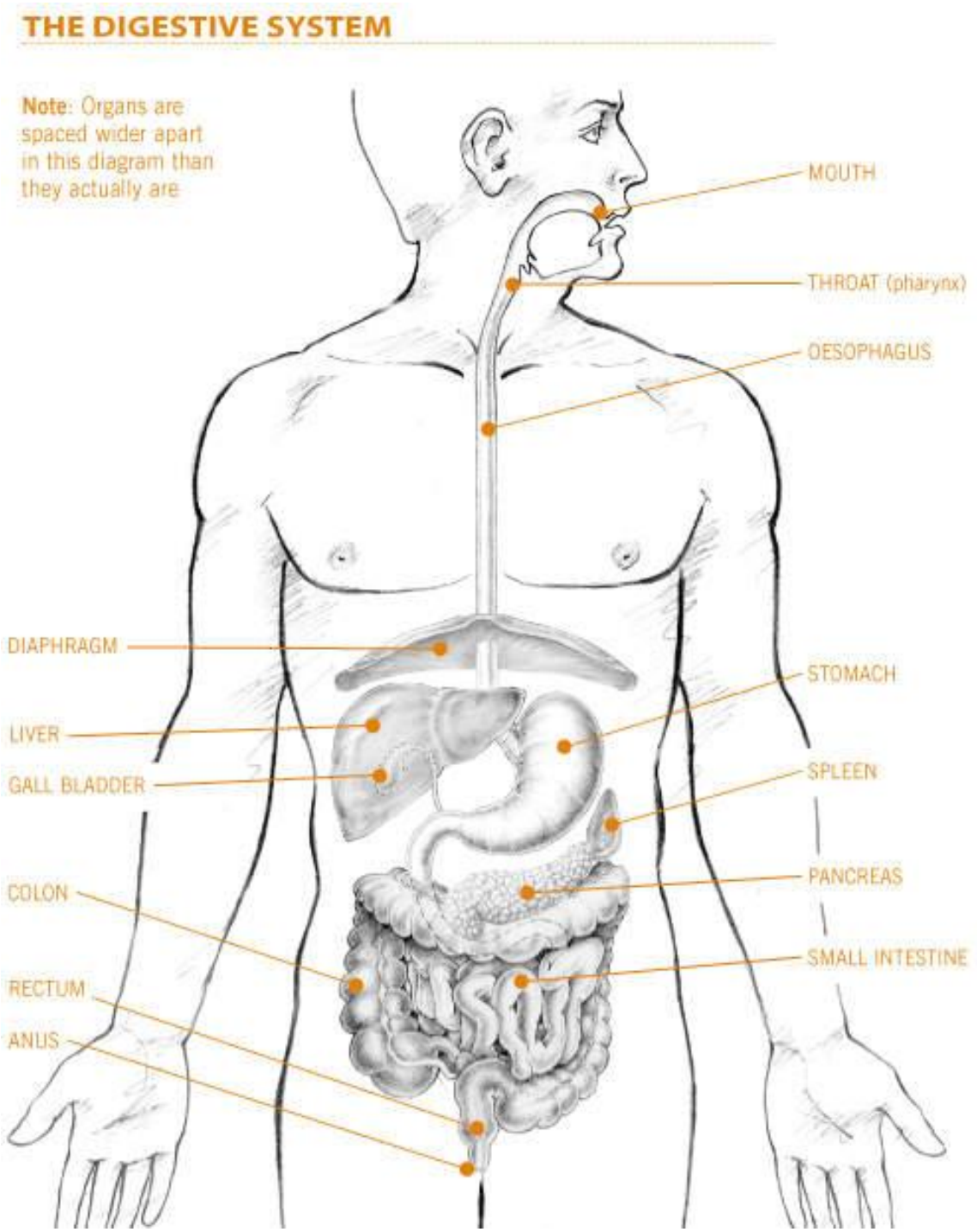
Module 1: How does the gut work?



The Gut as a Conveyer Belt

The gut is a long tube; things move down it, across it and occasionally come back up it.

It is a food processor; the different regions of the gut function in an orderly sequence, like a conveyer belt, enabling you to digest and absorb the food that you eat and to expel the indigestible remains.

How the gut is controlled

The passage of food down the gut from mouth to anus is regulated by nerves and hormones.

Eating and swallowing at the top end and defaecation at the bottom end are conscious processes, but everything in between is automatic and, in most healthy people, unconscious.

The gut is controlled by its own little brain, called the enteric nervous system.

This nerve net infiltrates every region of the gut and responds to the presence and nature of food by altering the contractile activity of the gut, the secretion of digestive juices and the absorption of nutrients.

This enteric nervous system is supported in its activity by the release of gut hormones, such as gastrin, which stimulates acid secretion from the stomach and secretion and cholecystokinin, which stimulates the secretion of digestive juice from the pancreas and the contraction of the gall bladder.

But digestion and absorption can also be influenced by the way we feel.

" ... The digestions going sacredly and silently right. That is the foundation of all poetry. The most poetical thing in the world is not being sick. "
G K Chesterton (1908)

If we are relaxed and calm, this encourages activity in the **parasympathetic nervous system** which promotes digestion and absorption.

Emotional tension activates the **sympathetic nervous system** (alarm or

fight and flight system) which is antagonistic to peaceful digestion and regular bowel function.

The Anatomy of the Sympathetic and Parasympathetic Nerves supplying the gut.

So perhaps our indigestion and irritable bowels are caused by a lack of harmony in our digestive tract?

But in order to understand what is happening when the gut goes wrong, we first need to appreciate how the gut works when digestion and absorption are proceeding well.

So hold on; we are about to embark on a journey of discovery.

From Mouth to Stomach

Past the lips and over the gums.
Look out stomach. Here she comes!

Food consists of an enormous variety of different chemical substances with different textures, flavours and consistencies. This is why we enjoy eating so much. These chemicals have to be dismantled into simple components that can be transported across the lining of the intestine into the body.

The dismantling process starts in the mouth where food is lubricated by saliva and mashed up by the actions of the teeth and tongue. Saliva moistens and dilutes the food. It also contains enzymes which start to digest starch and protein. Chewing converts solid food into a soft, moist ball, ready to be swallowed.

Swallowing is quite a complicated sequence that requires precise co-ordination of the muscles of the tongue, mouth, pharynx and oesophagus (or gullet). Any disturbance in coordination may result in food dribbling from the mouth, going up the nose or being aspirated into the lungs.

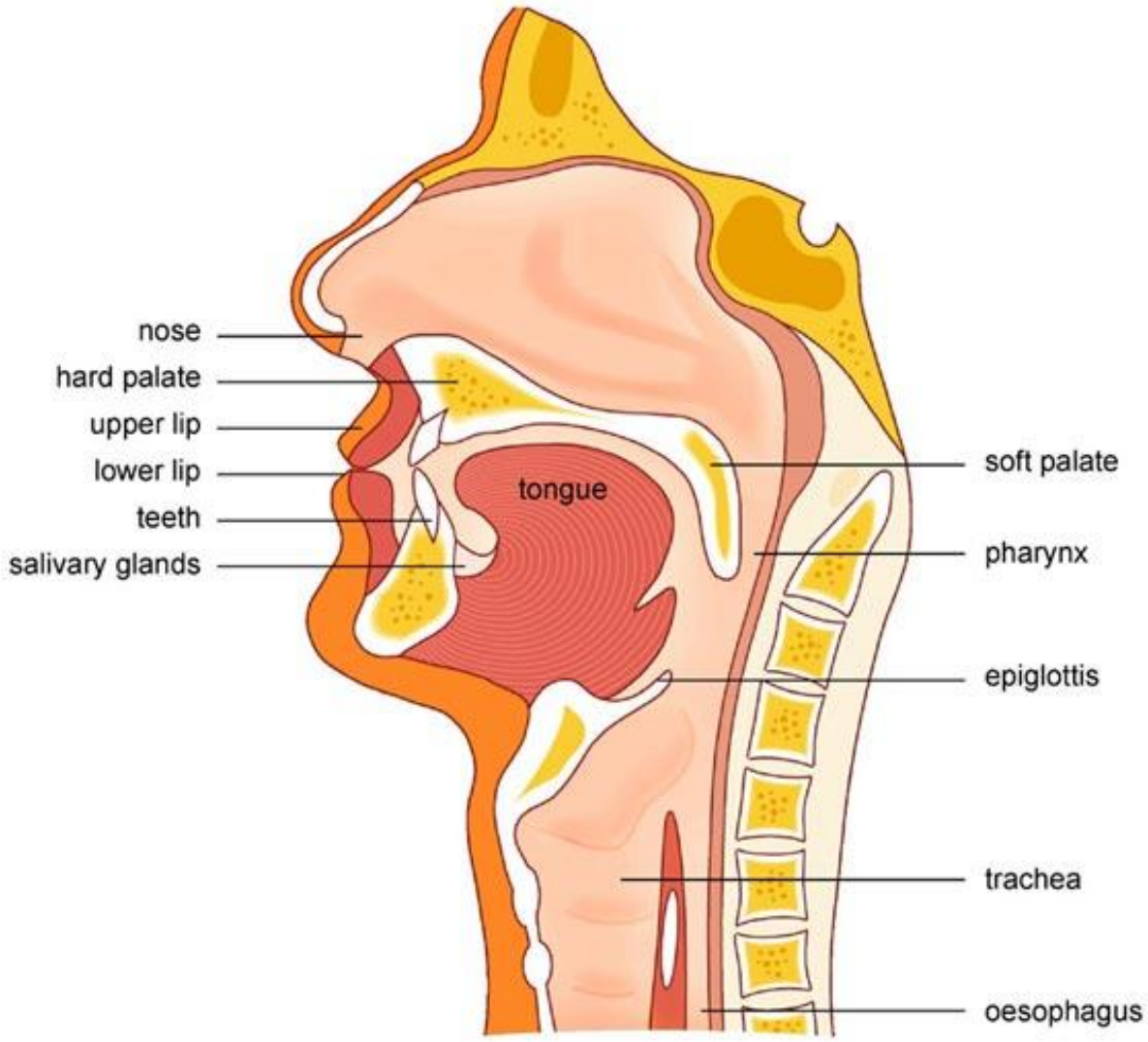
Swallowing is regulated by a swallowing 'centre' in the base of the brain.

What happens when you swallow

When you start to swallow, the tongue contracts and pushes up against the palate, propelling the food ball back into the throat. There it stimulates a wave of contraction that spreads down and around the pharynx and migrates downwards pushing the food ball ahead of it.

Food is prevented from going back up the nose by the soft palate pressing back against the bony structures at the back of the nose.

Aspiration of food into the lungs (**choking**) is prevented by the closure of the vocal chords, the contraction of the mylohyoid muscle which lifts the larynx upwards and forwards, setting the trachea at an acute angle to the pharynx and producing the visible movement of Adam's apple, the closure of the



epiglottis over the entrance to the trachea and the cessation of breathing.

As the wave of contraction pushes the food through the pharynx, the ring of muscle or **sphincter** at the top end of the oesophagus relaxes, allowing entry into the oesophagus.

When you are not eating, this sphincter, otherwise known as the **cricopharyngeus**, protects the lungs from aspiration of gastric acid, especially when you are lying down or asleep. It also prevents air from being sucked into the gut when you breathe in.

Swallowing does not usually occur by gravity. It is quite possible to swallow while lying horizontally or even upside down. Swallowing occurs though the coordinated activity of the oesophageal muscle.

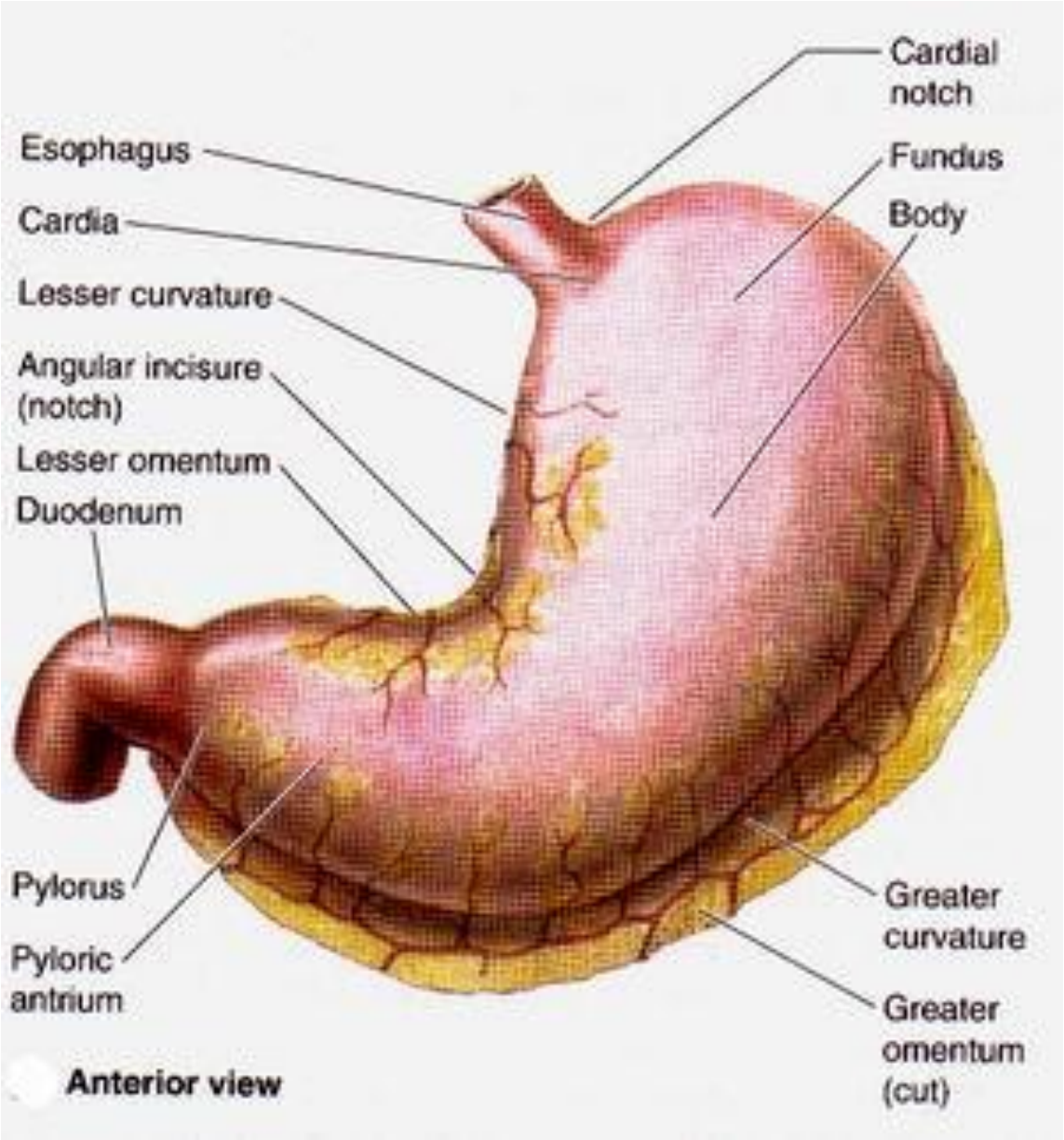
The oesophagus is lined, like the rest of the gut, by an inner layer of muscle with fibres that are orientated in a concentric manner (circular muscle) and an outer layer of muscle where the fibres are orientated in a longitudinal manner (longitudinal muscle). Swallowing occurs by the process of peristalsis, in which the advancing band of circular muscle squeezes the food down the oesophagus while contraction of the longitudinal muscle pulls the oesophagus up over the advancing food ball in much the same way as a 'T' shirt is pulled up over the head. As the wave of contraction reaches the end of the oesophagus, the lower oesophageal sphincter relaxes, allowing the food to proceed into the stomach.

How do we stop food coming up the oesophagus?

Food may be stored in the stomach for several hours and during that time you may lie down, sit up, bend over, cough, gasp, breath deeply, strain to defaecate, laugh, play football, make love; in fact do a hundred and one different things that may cause the pressure in the abdomen and the stomach to rise above that in the chest and the oesophagus.

- Contraction of the sphincter at the lower end of the esophagus prevents corrosive gastric contents from entering the oesophagus and causing inflammation, ulceration and scarring, or even being aspirated into the lungs with life threatening complications of pneumonia.
- This lower oesophageal sphincter is assisted by the hiatal fibres of the diaphragm, which pinch the lower oesophagus at around the level of the sphincter when you breathe in, cough or strain.
- Also the presence of a short length of oesophagus within the abdomen acts as a flap valve when the abdominal pressure rises.
- Any acid that gets into the oesophagus is usually neutralised by alkaline saliva and cleared back into the stomach by peristalsis.

From stomach to small intestine



The stomach lies tucked up under the diaphragm on the left side of the abdomen protected by the lower rib cage. It consists of three major parts: the bulbous **fundus** which relaxes to receive a meal and secretes acid, the muscular **antrum**, which mixes and grinds food up and propels it into the small duodenum and the **pyloric sphincter**, which helps to regulate the delivery of food into the duodenum and to prevent reflux back into the stomach. These three components act together to regulate the rate at which food empties from the stomach.

The passage of food from the mouth to the stomach stimulates reflexes that

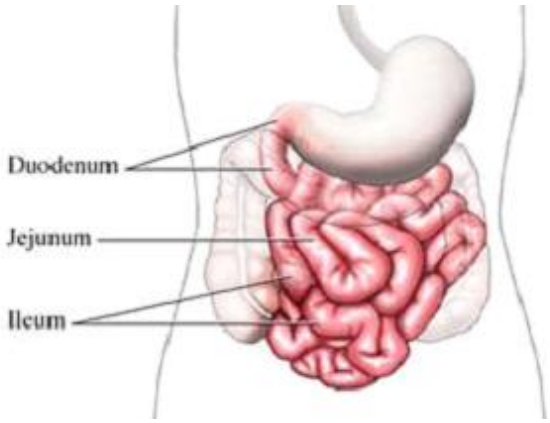
cause the muscle of fundus to relax. The solid components of the meal collect in the fundus of the stomach as a food ball, held back by a band of contraction, while the liquid is distributed throughout the stomach.

Food stimulates the secretion of acid of hydrochloric acid and pepsin. This corrosive mixture softens and breaks down the material on the outside of the food ball. The soft outer layer is then creamed off by the advancing antral contractions and propelled towards the pylorus. The pylorus relaxes ahead of the advancing antral wave and semi liquid food is propelled in squirts into the duodenum, where it is picked up by clusters of intestinal contractions and mixed with bile and pancreatic juice.

A moderate sized meal takes about four hours to empty from the stomach, which is about the time a person might feel like something else to eat. Larger meals and those that contain a lot of fat take longer to empty. The rate at which the stomach empties is regulated by special duodenal cells that respond to the presence of acid, fat, sugars and proteins by regulating the delivery of food into the duodenum and stimulating the secretion of alkaline digestive juices from the pancreas and gall bladder. In this way digestion is precisely tuned to the delivery of the food slurry from the stomach.

Stomach emptying is often disturbed in people with IBS, and this may cause upper gut symptoms.

Digestion and Absorption in the Small Intestine



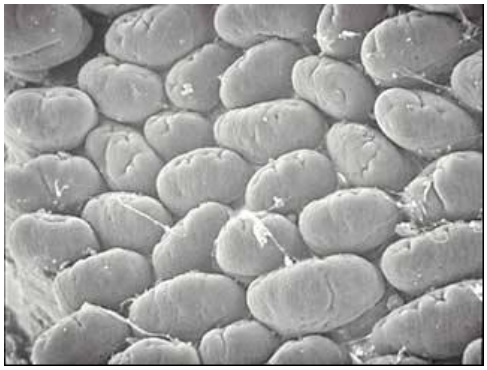
The small intestine is about 14 feet long and is functionally subdivided into the **duodenum** where food is mixed with digestive juices, the **jejunum**, where most absorption takes place and the **ileum**, which has special mechanisms for absorption vitamin B12 and bile acids and stores the undigested remnants of food before they enter the colon.

After the semidigested food has emptied from the stomach, propulsive contractions that form and reform, gently 'milk' it downstream, mixing it with digestive juices and spreading the mixture again and again over the surface of the small intestine. This allows optimal contact between food and both the digestive juices and the absorptive surface.

Enzymes secreted from the pancreas break starch down into simple sugars and complex proteins into amino acids and small peptides. These then lock onto specific receptor sites on the surface of the intestinal cells and are carried across the cell into the blood stream.

Fats melt at body temperature, coalescing as droplets that require special mechanisms for dispersal and digestion. Dispersal commences in the stomach by combination with protein and continues in the duodenum due to the action of bile acids. **Bile acids** are the body's detergents; they break up the fat into microscopic droplets, small enough to be quickly digested by pancreatic lipase to fatty acids. Bile acids also act a molecular ferry, transporting the fatty acids to the intestinal cells, where they are reconstituted to triglyceride while the bile acids diffuse back to combine with more fat. In the last few feet of small intestine, in the region known as the ileum, the bile acids are themselves absorbed and return via blood stream to the liver, where they are secreted in the bile and stored in the gallbladder to be used again. The recycling of bile acids may occur three or four times during the digestion of a moderate sized meal. About 10 percent of the

body’s bile acids fail to be absorbed in the ileum. Although this loss is replenished by the manufacture of more bile acid in the liver, the entry of bile acid irritates the colon and can cause diarrhoea. For that reason, bile acids are sometimes called ‘**natures laxatives’.**



The absorptive surface of the small intestine is increased by finger-like villi and microvilli, creating a thick shag pile carpet, equivalent to the size of a tennis court.

This prodigious absorptive capacity permits three moderately sized meals to be processed every day.

In Coeliac Disease, an allergy to wheat protein causes the villi to become stunted so that the absorptive surface looks flat and absorption is limited.

It can take anything from about an hour to six hours for a meal to pass from the duodenum to the colon, but the rate of passage depends on the size and the composition of a meal. Concentrated fruit juices, beer and hot spicy meals stimulate peristalsis and can pass through the small intestine within an hour, whereas meals that are viscous and contain large amounts of fat take much longer. Fat combines with specialised cells in the ileum to reduce small intestinal contractile activity and slow small bowel transit. This mechanism, which has been termed **'the ileal brake'** optimises absorption by allowing more time in the small intestine.

Undigested food tends to gather in the ileum until you eat your next meal, when it is propelled into the colon. This is known as **the gastro-ileal reflex**.

The average British person eats about 2kg of food and drinks about 2 litres of beverages every day. To this is added about 7 litres of digestive juices; 1.5 litres of saliva, a litre of gastric acid, 3 litres of bile and pancreatic secretions

and a litre of secretions from the small intestine. Most of this fluid is absorbed, leaving up to a litre of thick slurry of undigested food remnants to enter the colon.

The Dark Continent

"No other organ of the body is so misunderstood, so slandered and so maltreated."

Arthur Hurst (1935)

The colon is uncharted territory - the dark continent of gastroenterology - a vast fermenting vat, packed with teeming colonies of bacteria. There are more than 400 types of bacteria in the human colon. Most of these are beneficial; they perform a number of useful functions.

- They complete the digestive process by fermentation of unabsorbed starch and protein to fatty acids, which supplement the body's intake of energy and maintain the health of the colonic lining.
- The absorption of fatty acids facilitates the extraction of salt and water leaving a small plug of bacteria and woody plant cell walls to be evacuated as faeces.
- They manufacture some vitamins, for example, Vitamin K and Vitamin B12.
- They help to maintain the integrity of the colonic wall, preventing it from becoming leaky and enhancing absorption.
- They produce antibiotics that inhibit the growth of more dangerous species.
- They convert unabsorbed fats and bile acids to laxative compounds that encourage evacuation of the bowels. **Castor oil, for example is a hydroxy-fatty acid.**

The colon may be functionally divided into the proximal portion, where most fermentation takes place, the distal colon, where salt and water is extracted and colonic contents are concentrated and solidified, and the rectum which is specialised for defaecation.

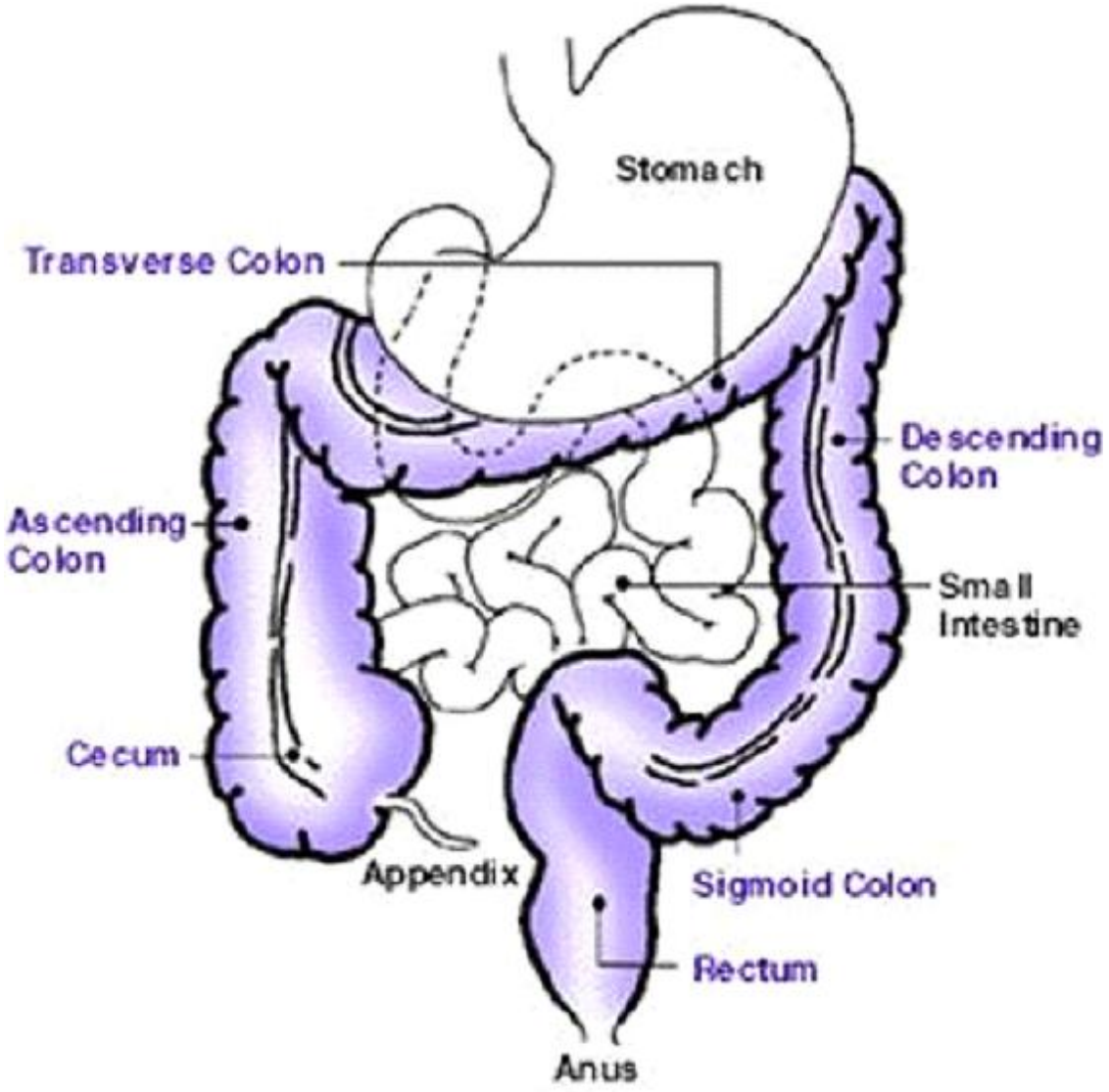


Diagram of the Colon and Rectum

A hundred years ago, following **Louis Pasteur's** discovery of the bacterial origin of infections, the colon was considered nothing more than a stinking infected organ, a Stygian pool of corruption that threatened the integrity of the body by generating toxic substances that might cause lethargy and bodily illness. This view was championed by the London Surgeon, **Arbuthnot Lane**, who advocated colectomy for anything from depression and short-sightedness, to premature senility and knock knees. We might smirk at Mr Lane's ideas, but is it so very different from the current enthusiasm for colonic irrigation?

The lethal potential of the colon was even employed for dramatic effect by the novelist, Agatha Christie. In her novel,

The Blue Train, the murderer give his victim a drink containing an extract of plumstones in London before he left by train and ferry to Paris. Plumstones contain chemicals called cyanogens, which can be converted by colonic bacteria to highly toxic hydrogen cyanide. It can take up to 10 hours for the digested remains of a meal to reach the colon, so that by the time the victim became ill with obvious signs of intoxication he was in Northern France, speeding towards Paris.

We fear what we fail to understand. But in reality, toxic substances that enter the blood stream from the colon are usually rendered harmless by the liver. For example, toxic ammonia produced in the colon is converted to urea by the liver and excreted in the urine.

Gas

Colonic fermentation of starch and protein release carbon dioxide, inflammable methane and hydrogen gases, as well as small quantities of smelly toxic gases, such as **hydrogen sulphide**.

The inflammable nature of colonic gases was demonstrated to me many years ago by a school friend of mine called Marvin. Earlier in the pub he had loudly asserted that 'farts burn'. We each offered to buy him a pint of beer if he could prove it. So later, we gathered around the entrance to our tent, cigarette lighters at the ready, when his bottom appeared through the tent flaps like the rising moon. On his command, we ignited our lighters. The effect was amazing. A brilliant blue flame lit up the darkness, surprising some sleepy sheep that were still grazing nearby. Then, after a pause, as our eyes readjusted to the darkness, there was a piercing scream and Marvin was last seen leaping across the field in the direction of the river. Blow-back! This single event not only stimulated a lifelong interest in gastroenterology, but also underlined its dangers!

Colonic Motility

It normally takes between 4 and 10 hours for the remnants of a solid meal to reach the colon, but between 1 and 3 days to pass through the colon and be evacuated as faeces. Longer times are needed in the colon because fermentation requires conditions of stagnation and colonic absorption is slow.

For most of the time, colonic contractions gently mix the slurry of unabsorbed food material with colonic secretions and bacteria. In the **transverse and descending colon**, ring-like contractions form and fade

and reform a few centimetres away, digging into the solidifying colonic contents and turning them over in much the same way as the gardener might turn over the soil with his spade. This action increases the exposure of the colonic contents with the lining of the colon where absorption takes place.

The **sigmoid colon** is narrower than the rest of the colon, and seems to function like a valve or sphincter restricting the entry of colonic contents into the rectum, from where they are expelled.


From time to time, but especially after arising from sleep or after breakfast, powerful contractions develop in the transverse or descending colon and sweep downstream, propelling faeces into the rectum. These **'mass movements'** often create the need to open our bowels.

Meals, especially those that are large and contain a lot of fat stimulate colonic motility and may induce an urge to defaecate. A drink of coffee can have the same effect. This response is known as **the gastrocolonic reflex** and is mediated by parasympathetic nerves and the release of the hormone, **cholecystokinin** from the duodenum.

The gastrocolonic reflex can be particularly active in people with IBS.

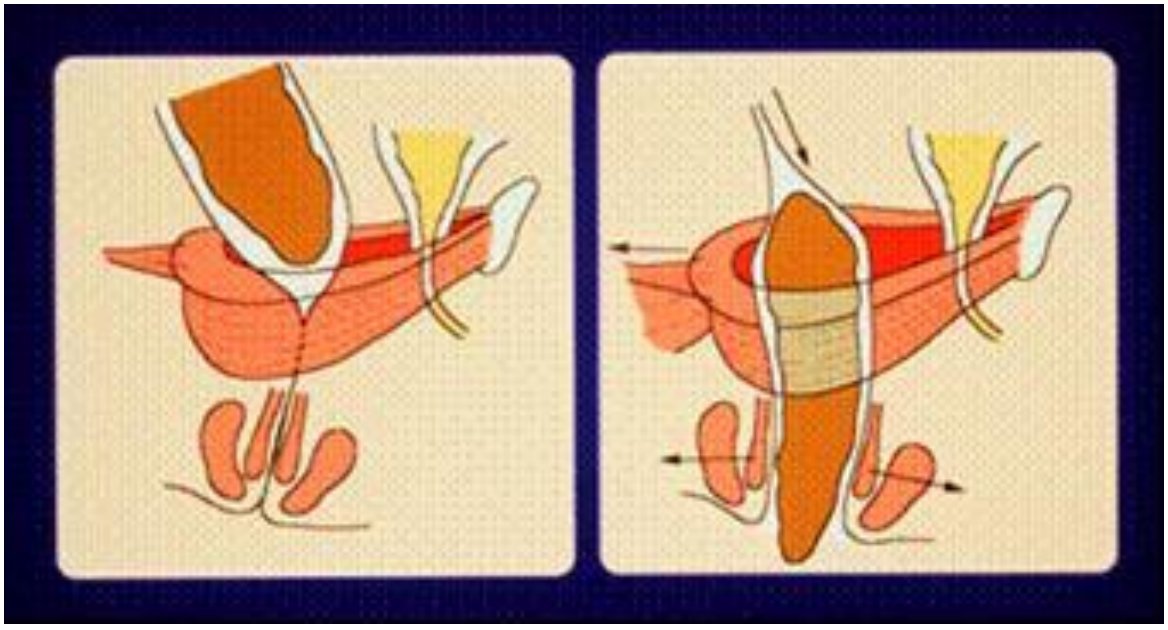
Defaecation

"A good set of bowels is worth more to a man than any quantity of brains"
Josh Billings

We are social and territorial animals. We do not just deposit our faeces anywhere when the urge takes us, like horses and cattle. We share the capability of other territorial species, such as dogs, cats and primates, to hold onto our faeces until we find an appropriate time and place to release them.

Defaecation is initiated from a centre in the base of the brain and coordinated by a collection of nerve cells at the bottom of the spinal cord.

The arrival of faeces in the rectum signals the urge to defaecate and at the same time encourages the rectum to contract and the anal sphincter to relax. The movement of faeces into the anus intensifies the urge and would inevitably result in evacuation were it not for the fact that we can consciously prevent defaecation taking place.



Control of Defaecation

Control of defaecation is conferred by the exquisite sensitivity of the distal

rectum and the anal canal and the contraction of the **external anal sphincter** and a sling of muscle called the **puborectalis** which pulls the junction between the rectum and anus forwards making an acute angle that obstructs the passage of solid faeces.

The arrival of faeces or gas elicits protective contraction of these muscles. This spinal reflex gave our ancestors time to seek a quiet bush away from the home base and out of sight of predators in order to deposit their faeces, and allows modern man and woman to undertake journeys on underground railways early in the morning after breakfast without fear of embarrassment.

A similar spinal reflex triggers a contraction of striated muscles of the pelvic floor when we increase the pressure in the abdomen during coughing, laughing, sitting up or giving a speech.

Urgency and Faecal Incontinence are common symptoms in IBS.

When the time and place are right for defaecation, these spinal reflexes are suppressed by nervous impulses travelling down from the brain. This opens up the anorectal angle and reduces the resistance of the sphincter and so with the subject sitting or squatting, faeces stored in the rectum can be expelled by a peristaltic contraction of the lower colon and rectum and aided by the increase in abdominal pressure caused by contraction of the abdominal muscles and diaphragm.

Many people with IBS experience a difficulty in evacuating their stools.

Variation in Bowel Habit

Bowel habit shows considerable variation between individuals and within the same individual at different times. A healthy person may defaecate just once a week or go five or six times a day depending on his or her emotions and diet. The average stool weight in people living in western countries is about 100g, but some people regularly pass as little as 50g per day and others on a high fibre diet can pass up to 400g of solid stool every day and yet would not be considered to have diarrhoea.

Stools have been classified into seven types, on what is called the Bristol Stool Form Scale (see below), according to their appearance as seen in the toilet water. Type 1 has spent the longest in the colon and type 7 the least time.

Stools at the lumpy end of the scale are hard to pass and often require a lot of straining. Stools at the loose or liquid end of the spectrum can be too easy to pass – the need to pass them is urgent and accidents can happen. The ideal stools are types 3 and 4, especially type 4, as they are most likely to glide out without any fuss whatsoever. Also, they are least likely to leave you with an annoying feeling that something is left behind.

THE BRISTOL STOOL FORM SCALE		
Type 1		Separate hard lumps, like nuts
Type 2		Sausage-like but lumpy
Type 3		Like a sausage but with cracks in the surface
Type 4		Like a sausage or snake, smooth and soft
Type 5		Soft blobs with clear-cut edges
Type 6		Fluffy pieces with ragged edges, a mushy stool
Type 7		Watery, no solid pieces