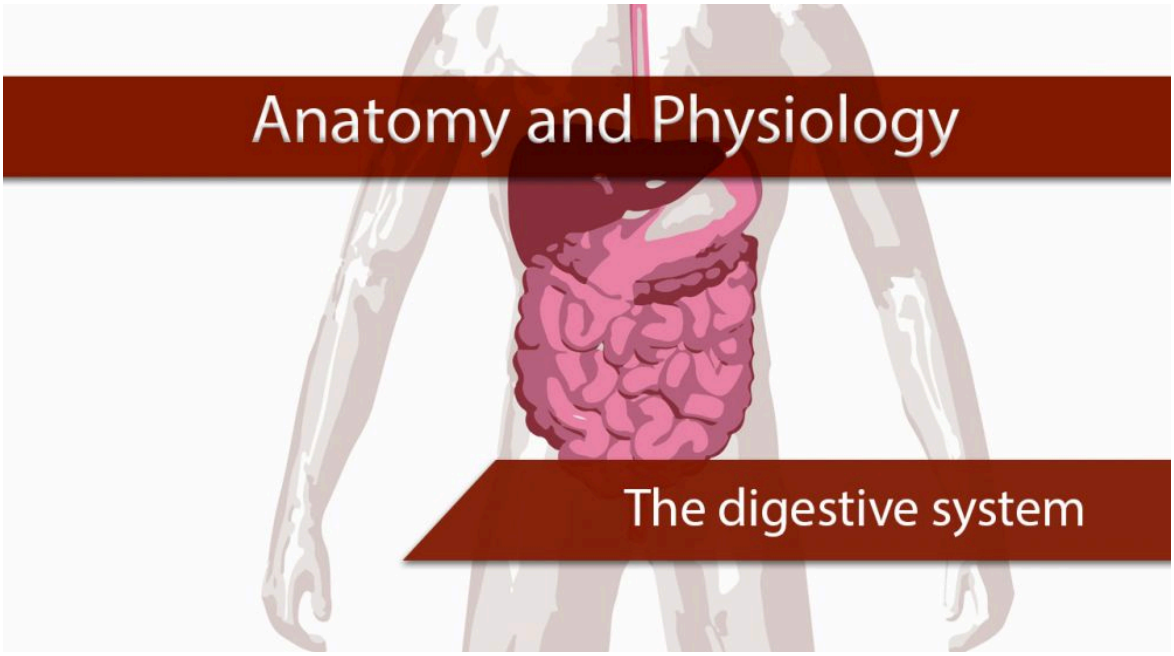
The Digestive System



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Introduction

You might work through this system over several weeks, days or hours, but to enhance your learning and enjoyment make sure you break it up into bite-size chunks. Here are the sections of the digestive system:

Major nutrients and digestion

Organs of the digestive system

The digestive process

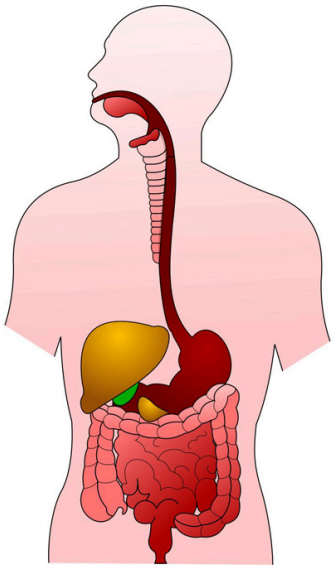
As you study the digestive system you will learn about:

- Foods and key nutrients
- Organs of the digestive system
- Digestion

Make notes as you study each section, and interact fully with the activities – watch the animations and complete the quizzes.

Take a break at the end of each section– resting your eyes from the computer screen, getting some fresh air or taking a coffee break will improve your ability to focus on your study and take in information.

Give yourself time to think about what you have learned, and time to absorb and understand it.



(files/images/Organs of the digestive system.jpg?1605779522628)UHI /CC0

The digestive system

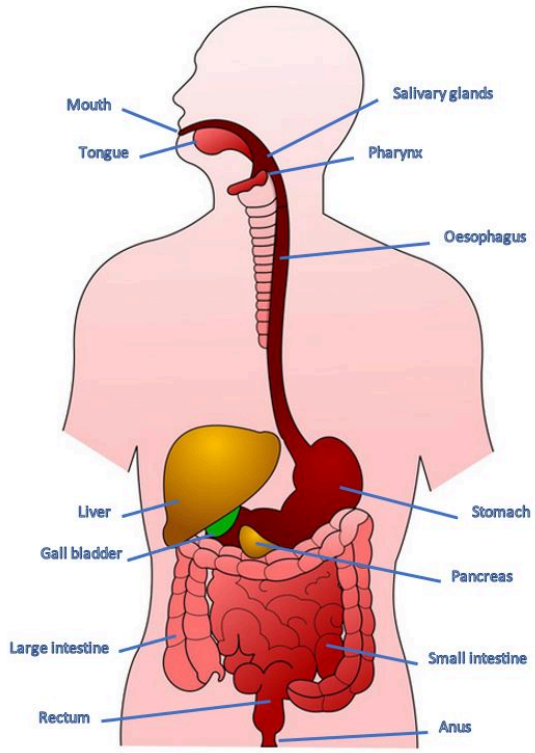
The digestive system includes the digestive tract and its accessory organs, which process food into molecules that can be absorbed and utilized by the cells of the body. Food is broken down until molecules are small enough to be absorbed into the body, and the waste products are eliminated.

The body requires a regular supply of nutrients for energy, for health, and for new tissue growth.

Food undergoes three types of processes in the body:

- Digestion
- Absorption
- Elimination

You will need to be familiar with different types of food nutrient to enhance your understanding of the digestive process, so before we look at the digestive system, let's take a look at the foods that we eat.



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Major classes of nutrients

There are seven nutrients that are classed as essential for good health:

- Carbohydrates
- Proteins
- Fats
- Fibre
- Water
- Vitamins
- Minerals

The first three are known as the macronutrients and are the major organic nutrients that are broken down for energy during the digestive process. These organic nutrients along with fibre and water are required in substantial quantities. Vitamins and minerals are known as the micronutrients, and although they are essential for good health they are required in smaller amounts. These are absorbed in their current state and do not require breaking down with digestive enzymes.

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Carbohydrates

Carbohydrates are found in fruit, vegetables, cereals, bread, rice and pasta, beans and pulses, and refined sugars. They are used primarily for energy in the body, and are classified as follows:

Simple carbohydrates are made up of small molecular structures called monosaccharides and disaccharides (sugars). These are absorbed quickly as they require very little digestion. Complex carbohydrates (starches) are formed from larger molecules called polysaccharides, which are formed from monosaccharides held together by water molecules. These bonds must be broken for the monosaccharides to be released and absorbed.

Simple carbohydrates

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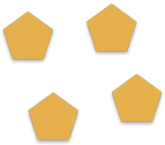

Monosaccharides
(simple sugars)

IDisaccharide
(two sugars covalently attached)

Complex carbohydrates

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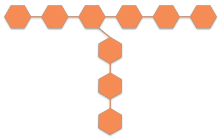


Polysaccharide
(many sugars covalently attached)

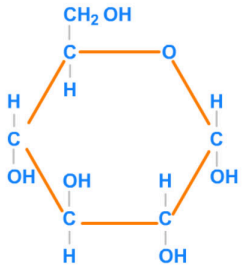
The most common starch is amylose, broken down by an enzyme called amylase. As carbohydrate molecules become smaller, the enzymes that break them down become more specific.

For example, these disaccharide molecules all have their own enzyme which splits the 2-sugar molecule into single monosaccharides.

Maltase breaks down maltose.

Sucrase breaks down sucrose.

Lactase breaks down lactose.



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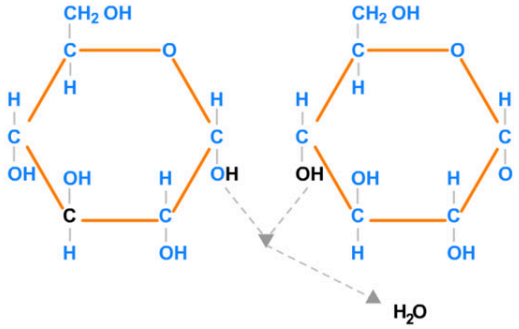
Glucose (monosaccharide)



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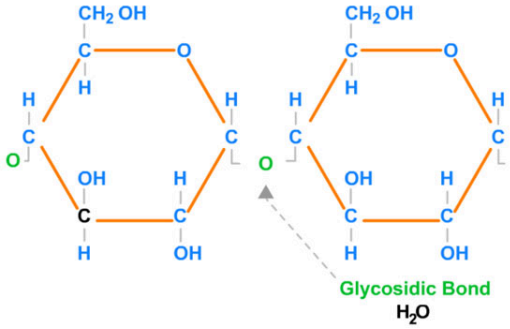
Two glucose molecules are joined together when a water (H2O) molecule is removed.



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When many glucose molecules are joined together like this, a poysaccharide is formed.

Proteins

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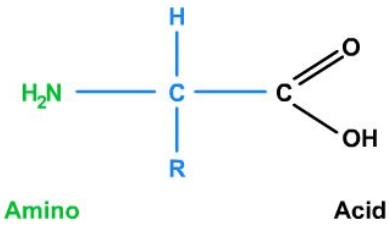
Proteins are formed from amino acids and have many essential functions in the body:

- formation of new cells
- growth and repair
- production of enzymes, hormones and antibodies
- transportation of other nutrients (e.g.haemoglobin)

We need a constant supply of amino acids in the diet to synthesise these proteins.

Proteins are found in abundance in meat, fish, eggs, dairy foods, soya and beans and pulses.

Proteins are broken down by protease enzymes.



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Fats

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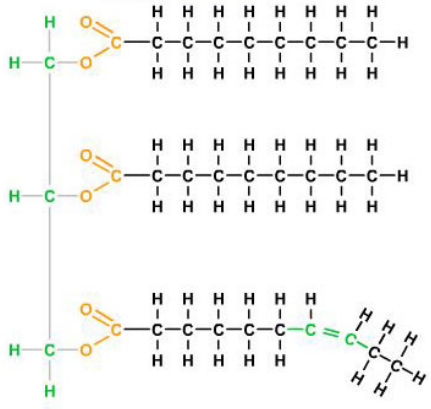
Fats are found in oils and spreads, nuts and seeds, meat, eggs, dairy foods and fish, as well as in some vegetable foods such as coconut and avocado. We need to include fat in our diet as it has several important functions:

- it provides 9 calories of energy per gram
- it provides insulation and protection
- it is a component of cholesterol and cell walls
- it insulates nerve fibres
- fatty foods provide vitamins A, D, E and K
- fats form compounds called prostaglandins which help to regulate blood pressure and immune function.

Fats are formed from triglycerides – a glycerol molecule attached to three fatty acid chains.



(files/images/fat-molecules.jpg?1611678812717)Fats are formed from triglycerides – a glycerol molecule attached to three fatty acid chains.

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Fibre

Fibre is found in carbohydrate foods such as cereals, fruit and vegetables, nuts and seeds, whole grains, beans and pulses. It is also known as non-starch polysaccharide (NSP), a type of carbohydrate that passes through the human body largely undigested. The functions of fibre are...

- aiding peristalsis (moving food along the digestive tract)
- helping to prevent constipation
- absorbing excess cholesterol and removing it from the body
- increasing satiety (feeling full), aiding in reducing calorie intake

There are two types of fibre, soluble and insoluble. Soluble fibre is soft and absorbs great quantities of water, which enable it to carry excess fats, toxins and cholesterol out of the gastrointestinal tract. Insoluble fibre provides a palpable mass which aids peristalsis of food along the intestinal tract.

As humans, we do not possess the enzymes required to break down fibre such as cellulose (found in leaves, fruits and vegetables), so most fibre passes undigested through the gastrointestinal tract.

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Quiz

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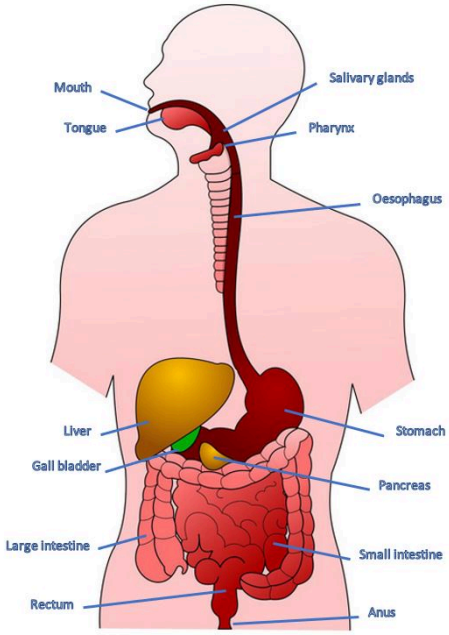
Stages of the digestive system

The digestive system consists of the gastrointestinal tract (GI tract) and a number of organs which contribute to the digestive process. The gastrointestinal (GI) tract is also known as the digestive tract and is essentially a long tube beginning with the mouth and

ending with the anus. Food is only considered to be ‘inside’ the body once it has been absorbed through the walls of the digestive tract. Anything that is not absorbed simply passes through the body.

There are also a number of organs which contribute to the digestive process; these are sometimes referred to

as accessory glands or secondary digestive organs, as they are not part of the GI tract itself. These organs are the salivary glands, liver, gall bladder and pancreas.



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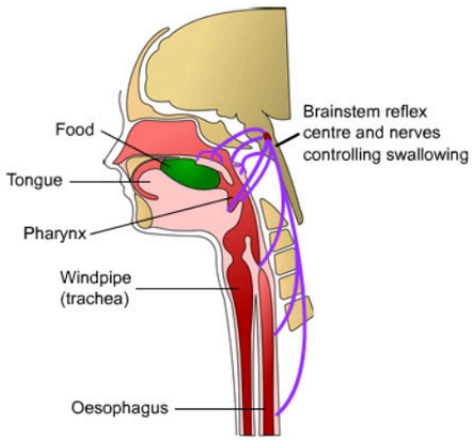
The mouth

Salivary amylase is secreted from the salivary glands in the mouth, and this enzyme begins to break down starches, a type of complex carbohydrate. There are three sets of salivary glands: the parotid at the back of the jaw and the sublingual and submandibular which lie under the tongue. The pH in the mouth is slightly alkaline, which enhances the function of salivary amylase.

Although all nutrients undergo mechanical breakdown in the mouth, only starches undergo chemical digestion.



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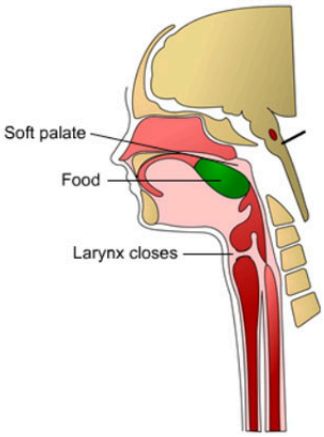

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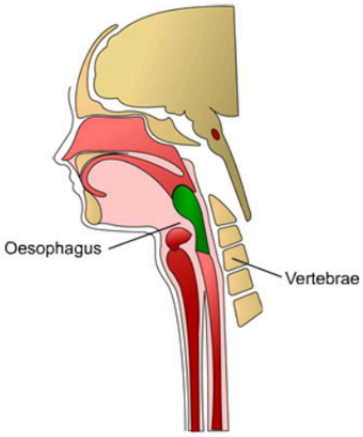

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Text version (files/docs/the-mouth.docx)

Video

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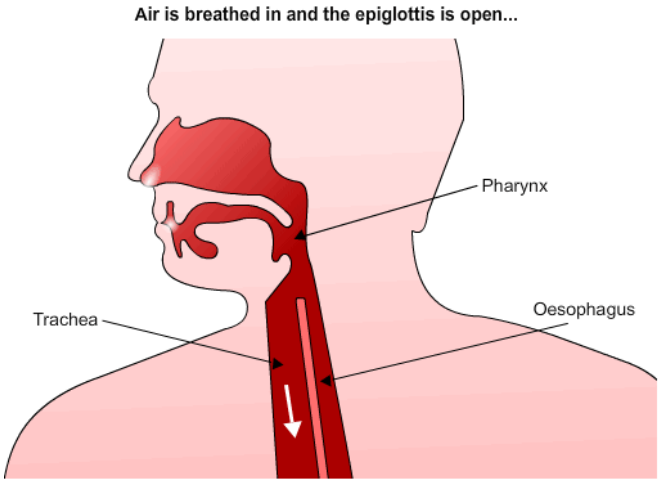
Swallowing (YouTube 1:24)

The oesophagus

The oesophagus is a tube that runs alongside the trachea (windpipe). During deglutition, the epiglottis automatically closes over the trachea to prevent food and water from entering the lungs.

Once food has been swallowed, it travels down the oesophagus to the stomach, aided by peristalsis in the oesophagus. This involves contraction of the smooth muscle in the gastrointestinal tract, effectively squeezing the food bolus further along.

The upper and lower ends of the oesophagus are closed by sphincter muscles. The upper sphincter muscle prevents air from passing into the oesophagus, while the lower sphincter muscle prevents regurgitation of the gastric juices into the oesophagus.



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Text

- Pharynx
- Epiglottis
- Trachea
- Oesophagus

Air is breathed in and the epiglottis is open...

Food is consumed and epiglottis closes over the trachea.

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Travelling down the oesophagus / Animation: UHI

The stomach

The stomach is a J-shaped broadening of the digestive tract between the oesophagus and the small intestine. It is an elastic sac - its size at any one time is determined by its contents.

The mucosa of the stomach wall has prominent folds known as rugae. These rugae increase the surface area. The mucosa is also studded with glandular gastric pits, which contain specialised cells that secrete the constituents of gastric juice.

The pH in the stomach is highly acidic which enhances enzyme function.

Unlike the rest of the digestive tract, the stomach wall has three layers of smooth muscle tissue: oblique, circular and longitudinal. Muscular contractions in the stomach wall knead the contents of the stomach and mix food thoroughly with the gastric juice secreted in the stomach for up to 3.5 – 4 hours. About 2.5 litres of gastric juice are produced daily.

All nutrients undergo mechanical digestion in the stomach, but only proteins undergo chemical digestion.

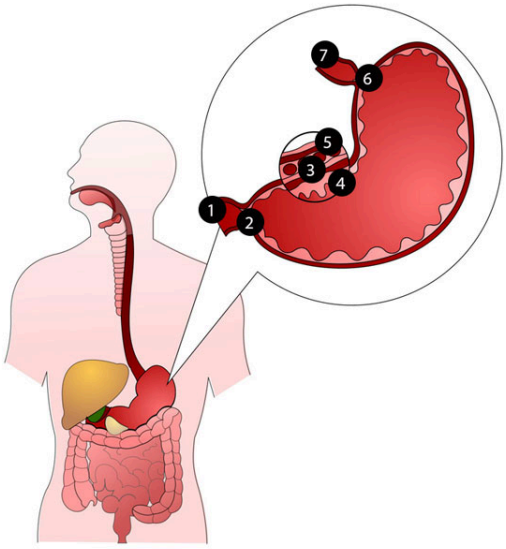

Image key

1. Duodenum
2. Pyloric sphincter
3. Muscle: circular
4. Muscle: oblique
5. Muscle: longitudinal
6. Lower oesophagus sphincter
7. Oesophagus

(files/images/stomach.jpg?1611735977017)

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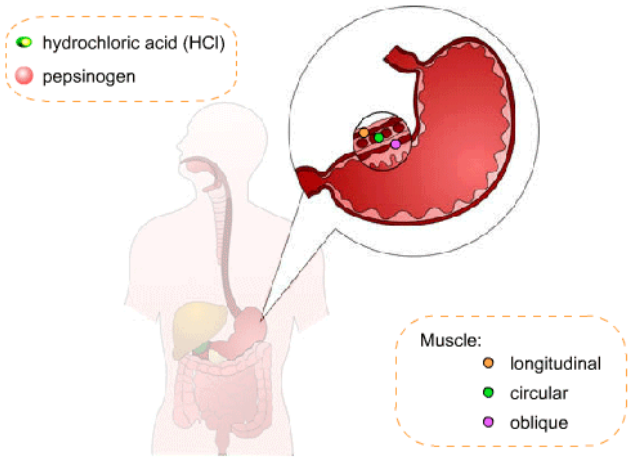
Digestive secretions of the stomach

Enteroendocrine cells near the base of the stomach secrete gastrin when food enters the stomach. This hormone travels via the circulatory system to the gastric cells in the stomach wall, where it increases motility throughout the GI tract and triggers the release of gastric juices from parietal and chief cells.



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Text

Hydrochloric acid (HCl)
Pepsinogen

Pepsin, protien

Muscle:
longitudinal
circular
oblique

Parietal cells

Parietal cells secrete intrinsic factor which assists with the absorption of vitamin B12. Parietal cells also secrete hydrochloric acid (HCl) which creates an acidic environment (low pH) within the stomach. This is the environment required for the breakdown of proteins. Hydrochloric acid acts as a bactericide to kill any ingested bacteria and converts pepsinogen into pepsin.

Chief cells

Chief cells secrete pepsinogen, which converts to pepsin in acid conditions. Pepsin digests proteins by breaking the peptide bonds between amino acids, releasing smaller protein fragments. Secreting pepsin in this inactive form (pepsinogen) prevents the digestion of the proteinaceous stomach wall. Goblet cells secrete mucus to form an alkaline barrier between the gastric juices and stomach lining.

The thorough mixing in the stomach results in the production of a liquid called chyme, which is squirted in small amounts out of the stomach into the small intestine through the pyloric sphincter at the base of the stomach.

Gastric cell quiz

Complete the table below and click on the submit button to check your answers.

Type of gastric cell	Secretion	Function
Parietal cells	Intrinsic factor	select ...
Parietal cells	Hydrochloric acid	select ...
Chief cells	Pepsinogen	select ...
Mucous cells	Mucus	select ...
Enteroendocrine cells	Gastrin	select ...

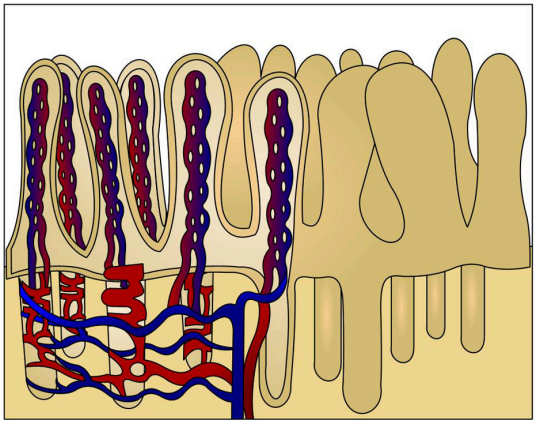
Submit answers

The small intestine

Most digestion and absorption occurs in the small intestine which is approximately 5 - 6 metres long. It begins at the pyloric end of the stomach and ends at the ileocaecal valve opening into the large intestine. It is comprised of three parts:

- the duodenum (0.25m)
- the jejunum (2m)
- the ileum (3.5m).

Along the length of the small intestine, the inside wall has minute folds of tissue called villi which vastly increase the surface area and enable maximum absorption.



(files/images/Villi of small intestine.jpg?1605882504787)Villi of the small intestine UHI / CC0

Mechanical digestion in the small intestine

Digestive processes in the small intestine are mechanical and chemical, and all nutrients are broken down in this section of the gastrointestinal tract.

Mechanical digestion

Movement of the chyme (partly digested food) back and forth within the small intestine, without any real forward movement, is called segmentation, controlled by the autonomic nervous system along with peristalsis, which moves chyme along the small intestine at approximately 1cm a minute. The chyme is mixed with the gastric juices and brought into contact with the submucosa (cells of the small intestine) for absorption.

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Contraction of small intestine / Animation: UHI

Chemical digestion in the small intestine

About 3 litres of intestinal juices are secreted daily by the small intestine in response to the presence of acidic chyme entering from the stomach. The pH in the small intestine is slightly alkaline, which enhances enzyme function.

Composition of intestinal juices

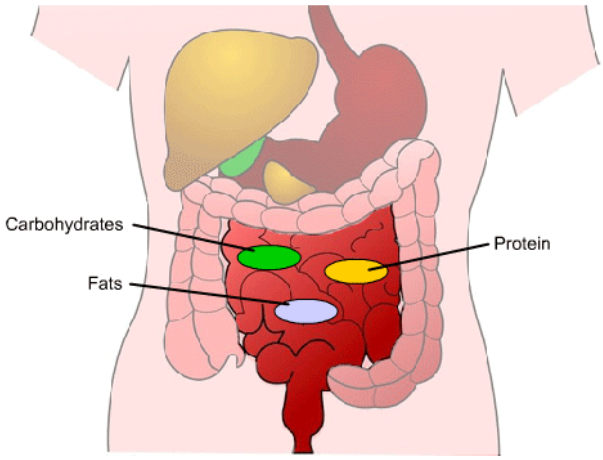
- water
- mucus
- mineral
- salts
- enzymes

Hormones secretin and cholecystokinin (CCK) are secreted into the blood by enteroendocrine tissues. The main contributor to chemical digestion in the small intestine is from pancreatic juice secreted by the pancreas and bile secreted by the gall bladder.

Digestible carbohydrates (starches) are transformed into monosaccharides by the action of amylase.

Proteins (polypeptides) are converted to amino acids by the pancreatic protease enzymes trypsin and chymotrypsin. Their precursor enzymes trypsinogen and chymotrypsinogen produced in the pancreas remain inactive until they come into contact with the enzyme enterokinase produced in the microvilli of the small intestine to prevent damage to the pancreas.

Fats are converted to fatty acids and monoglycerides by lipase, assisted by bile.



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Text

Carbohydrates > Monosaccharides

Protien > Amino acids

Fats > Monoglycerides and fatty acids

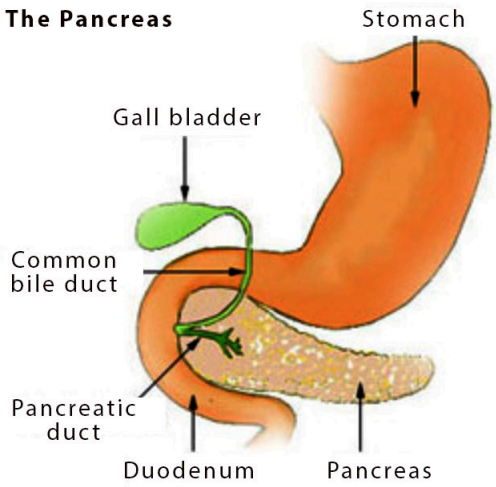
The pancreas

The pancreas is an oblong gland about 12 centimetres long by 2.5 centimetres thick lying in the fold between the stomach and the duodenum. Although it is not part of the gastrointestinal tract itself, it plays a key part in the process of digestion, producing 1.2 – 1.5 litres of pancreatic juice daily which travels to the duodenum via a pair of ducts.

Pancreatic secretions are stimulated by the hormones secretin and cholecystokinin (CCK) produced in the duodenum as food enters the small intestine. In addition to containing inactive protein enzyme precursors trypsinogen and chymotrypsinogen, pancreatic juice consists of these enzymes:

- pancreatic amylase for starch digestion
- pancreatic lipase for fat digestion
- pancreatic protease for protein digestion

The pancreas also secretes sodium bicarbonate into the duodenum to help neutralise the acidic stomach contents.



(files/images/pancreas.jpg?1611746735250)Wikimedia (https://commons.wikimedia.org/wiki/File:Pancreas_nih.jpg) / Public domain

Text

- Stomach
- Gall bladder
- Common bile duct
- Pancreatic duct
- Duodenum
- Pancreas

Gall bladder and bile

The larger pancreatic duct joins with the bile duct from the liver which carries bile.

Bile, which is secreted by the liver, is stored in the gall bladder. Release of bile is stimulated by the hormone cholecystokinin (CCK) from the duodenum. As peristalsis moves food along the duodenum, bile from the gall bladder emulsifies (spreads out) fats assisting their breakdown and absorption through pancreatic lipase, the enzyme secreted from the pancreas which breaks down fats.

Bile is composed of :

- water
- mineral and bile salts
- mucus
- bilirubin
- cholesterol

Bilirubin is a waste product from the breakdown of erythrocytes (red blood cells) in the liver.

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The liver

The liver is the largest organ in the body and weighs roughly 1.4 kg. It is protected by the lower ribs and is situated mainly in the upper right side of the abdomen.

The liver carries out numerous functions including:

- processing digested food from the intestines
- regulating blood glucose levels
- regulating fats/lipids
- regulating amino acids
- detoxifying alcohol, drugs and poisons absorbed by the blood
- producing bile for fat emulsification
- generating heat
- forming and breaking down red blood cells
- producing enzymes and proteins for chemical reactions in the body
- fighting infections, particularly bacterial infection
- storing vitamins and minerals, such as vitamin B12 and iron

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Absorption

Absorption of carbohydrates and protein

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Absorption involves the passage of digested nutrients from the gastrointestinal tract into the blood and lymphatic systems. Most nutrients are absorbed via the small intestine although some are absorbed through the stomach or large intestine.

Monosaccharides, amino acids and a few short-chain fatty acids pass into the epithelial cells of the small intestine, through capillary walls into the bloodstream. Capillaries join up to form the hepatic portal vein which carries the products of digestion to the liver.

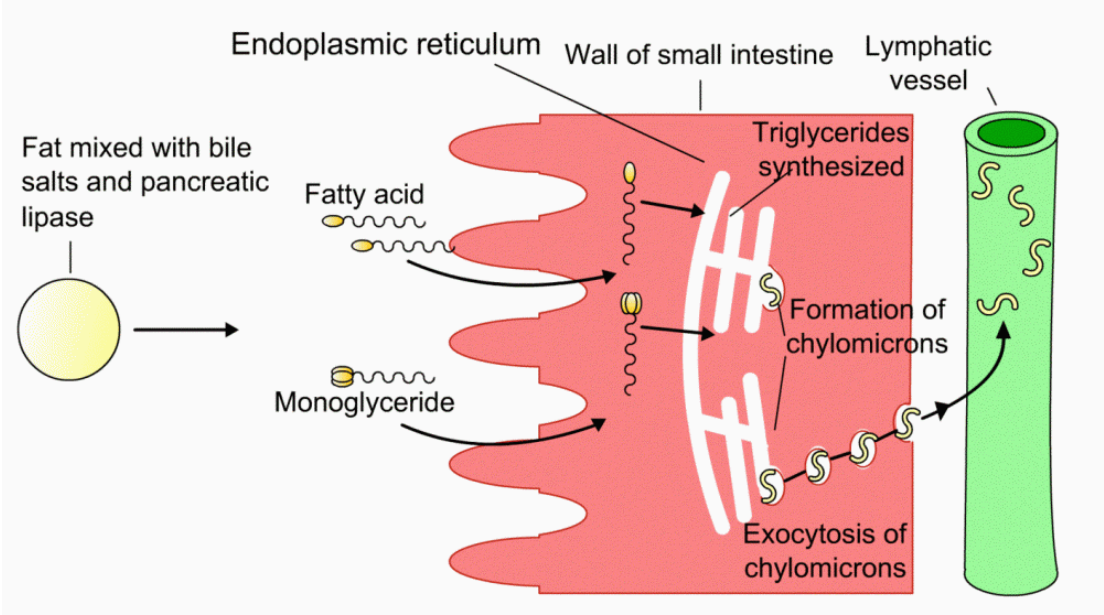
Carbohydrate digestion and absorption process

Embedded content: https://www.youtube.com/embed/9HNz_QW838Q (https://www.youtube.com/embed/9HNz_QW838Q)

Carbohydrate digestion and absorption process (YouTube 3:45)

Absorption of fats

Long-chain fatty acids and monoglycerides are surrounded by bile salts to form small droplets called micelles. These pass into lacteal vessels in the epithelial lining, first re-forming into triglycerides, then attaching to protein molecules to form chylomicrons in the lymph fluid. The digested fats in the lymph fluid eventually drain into the cardiovascular system at the left subclavian vein, travelling on to the liver via the hepatic artery.



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Lipids digestion and absorption

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Lipids digestion and absorption (YouTube 5:54)

Quiz

Put the correct nutrient breakdowns together, in the correct order.

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What happens to the food we eat?

Some nutrients such as glucose may be utilised for energy before reaching the liver, but nutrients which enter the liver have a number of functions in the body.

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Fats forming a cell wall
UHI / CC0

Carbohydrates

Carbohydrates form glycogen, a storage form of glucose, for energy.

Proteins

Proteins have numerous functions in the body. They form enzymes, antibodies and hormones as well as transport molecules and structural components such as collagen and keratin in skin, or actin in muscle.

Fats

Fats may form membranes or cell walls, or be used to create cholesterol or lipoprotein molecules. Fats are also used for energy, so any excess fat may be stored as adipose tissue.

Indigestible matter

Any substances that are not absorbed into the blood or lymph system continue through the gastrointestinal tract to the large intestine (bowel). The

large intestine re-absorbs water, creating a more solid bolus to push along the digestive tract. This bolus is eventually passed through the colon and rectum as faeces. The pH in the bowel is slightly acidic, the perfect environment for healthy probiotic bacteria to thrive and maintain a healthy colon.

Indigestible matter includes:

- fibre
- undigested food particles
- bile from the liver and gall bladder containing a number of toxins and substances to be eliminated from the body

The whole process of digestion takes several hours, but digestion time is affected by the type and amount of food eaten. Proteins and fats usually take longer to digest, and a high amount of fibre in the diet may slow absorption time but will quicken intestinal transit in the large intestine.

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The large intestine

The large intestine is about 1.5 metres long. It receives undigested food as a fluid from the small intestine through a sphincter, the ileocaecal valve, which prevents backflow of contents back into the small intestine.

Waste food is moved by peristalsis through the first part of the large intestine, the ascending colon. The transverse colon crosses above the small intestine and below the liver and stomach. The descending colon takes the waste down to the pelvic (sigmoid) colon, then on to the rectum and the anus, from which the waste and gases are excreted.

Waste remains in the large intestine for 3 to10 hours, during which time water is reabsorbed into the body, forming a solid or semi-solid substance known as faeces. Drugs, salts and some vitamins synthesised by bacteria in the colon may be absorbed into the blood capillaries of the large intestine rather than be eliminated from the body.

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Digestive system quiz

On the diagram, label the different areas of the large intestine as well as other organs of the digestive system.

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PH value quiz

Each pH value along the gastrointestinal tract creates the ideal environment for the digestive processes that take part in each. Complete this activity to see if you can remember the correct pH at each stage of digestion.

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Test your knowledge

Now it is time to test your knowledge of the digestive system, there are 10 questions to complete.

You might want to take some time to read your notes, draw diagrams or watch animations again before you test yourself.

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Summary

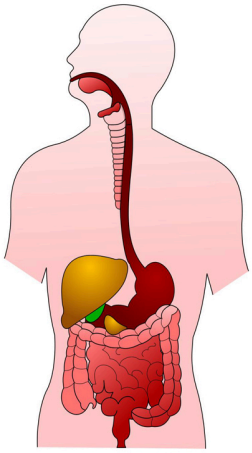
You have completed your study of the digestive system.

You should now have a good knowledge and understanding of the anatomy and physiology of the digestive system.

You should be able to...

- Identify and name the major parts of the digestive system
- Explain the functions of each part of the gastrointestinal tract
- Explain the functions of other organs involved in digestion
- Describe the digestive process from ingestion to elimination

If you think that your knowledge or understanding of any section of the digestive system could be improved further, go back to the relevant sections and work through them again, taking time to make notes and complete the activities.



(files/images/Organs of the digestive system.jpg?1606132674800)Image: UHI