Digestive system

Components

The digestive system is made up of:

- the alimentary canal (also called the gut), which runs from the mouth to the anus, through the buccal cavity, oesophagus, stomach, small intestine (duodenum and ileum) and large intestine (appendix, caecum, colon and rectum);
- associated organs that secrete digestive juices, including salivary glands, the liver, gall bladder and pancreas.

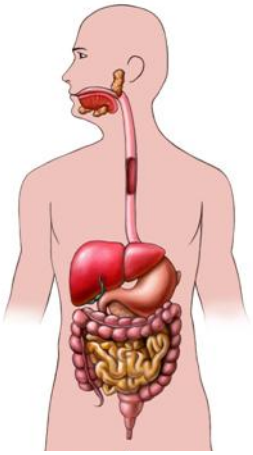

Figure The human digestive system.

Functions

The body requires a constant supply of nutrients from digested food. They are essential for body functions and the maintenance of health. The digestive system breaks down food so that it is small enough to be absorbed and used by the body. It transfers nutrients from the external environment to body fluids and eliminates undigested food residues as faeces.

Key mechanisms

Nutrient molecules are absorbed through the membranes lining the gut into the body. They are transported in the blood and lymph systems to where they are needed. Small soluble molecules can be taken up directly. Larger molecules such as polysaccharides, fats (lipids), proteins and nucleic acids must first be digested by hydrolytic digestive enzymes in the gut.

Main processes of digestion

Foodstuff	Enzyme / source	Intermediate products	Enzyme / source	End products that can be absorbed
Carbohydrates				
Polysaccharides (starch and glycogen)	Amylase / salivary glands, pancreas	Maltose	Maltase / small intestine	Glucose
Disaccharides				
Sucrose	Sucrase / small intestine			Glucose and fructose
Lactose	Lactase / small intestine			Glucose and galactose
Fats (lipids)	Lipase / pancreas No enzymes / bile			Fatty acids and glycerol Emulsified lipids
Proteins and polypeptides	Pepsin / stomach Trypsin, chymotrypsin, carboxypeptidase / pancreas	Peptides	Peptidases / intestine	Amino acids
Nucleic acids	Nuclease/ pancreas	Nucleotides	Nucleotidase / small intestine	Purine and pyrimidine bases, ribose and deoxyribose, phosphate

Role in homeostasis

Balanced diet

A balanced diet contains all the necessary foods in the correct proportions to maintain health. The digestive system contributes to homeostasis by transferring nutrients from the external environment to the internal environment. Generally, it does not vary uptake based on body needs, but absorption of dietary iron and calcium is regulated according to the body's needs. Nutrient intake must contain the molecules needed to:

- provide all the energy required by cell processes according to the needs of the individual – these molecules must constantly be replaced;
- maintain a positive nitrogen balance to avoid losses to body proteins;
- supply nutrients such as essential amino acids, fatty acids and vitamins which cannot be synthesised by cells;
- maintain the composition of body fluids despite losses from the body (such as in sweat, urine or bile), or incorporation into body structures such as bones and other tissues.

The constituents of a balanced diet

Type of nutrient	Form in which absorbed	Comments
Carbohydrates	Monosaccharides, disaccharides	Glucose is usually the main source of energy for cells. Stored in the body as glycogen or converted to lipids.
Lipids	Lipid droplets, fatty acids and glycerol	Certain fatty acids, such as linoleic acid, are essential in the diet.
Protein	Amino acids, dipeptides	Certain amino acids, such as leucine, are essential in the diet.
Vitamins		Do not require digestion. Essential in small quantities.
Inorganic ions	Hydrated ions	Do not require digestion. Some essential in very small quantities.
Water	Water	Concentration of body fluids must be maintained (osmoregulation).
Fibre (indigestible cellulose and woody material found in plants) is also important to maintain the healthy functioning of the gut.		

Precise nutrient requirements vary according to the individual's size, age, genetic make-up, gender, reproductive status, health and occupation / daily activity.

Iron absorption

Iron is essential for haemoglobin production, but only a fraction of a typical intake is absorbed, about 0.5-1.0 mg in men and 1.0-1.5 mg per day in women of the 15-20 mg/day ingested in food. Women need more to compensate for menstrual losses. It is actively transported from the gut into intestinal epithelial cells. Fe^{2+} ions are absorbed more easily than Fe^{3+} ions. Vitamin C increases iron absorption, mainly by reducing Fe^{3+} to Fe^{2+}.

Iron is stored as ferritin or moved into blood plasma using a transmembrane carrier called ferroportin. In the blood iron is transported by a protein carrier, transferrin. Iron not transferred within three days is lost in the faeces, as intestinal epithelial cells are continually sloughed off and replaced. Hepcidin inhibits iron transport by binding to ferroportin.

Calcium absorption

An average of 1 g of calcium is taken in daily, of which about two thirds is absorbed. Some calcium is absorbed passively, but vitamin D greatly stimulates the active transport of Ca^{2+}. Vitamin D needs first to be activated in the liver and kidneys under the influence of parathyroid hormone. Secretion of parathyroid hormone increases in response to a fall in blood concentration of Ca^{2+}, stimulating its uptake.

Examples of what can go wrong

Malnutrition

Malnutrition may occur due to deficiencies or excesses of certain nutrients. Excessive intakes of saturated fats and salt have been linked to heart disease. In the UK, the Food Standards Agency has devised the 'eatwell plate'[1] to enable individuals to get the balance right when choosing a healthy, balanced diet. It is designed to provide all the nutrients required in the correct proportions, while avoiding excessive intake of saturated fats and salt.

Most individuals get the nutrients they need from a balanced diet. However, certain groups are at greater risk than others of getting insufficient supplies. They may take dietary supplements.

At risk group	Recommended supplement / notes
Pregnant and breastfeeding	Folic acid (vitamin B_9) 400 micrograms (µg) per day, plus folate rich foods (to give total of 600 µg).
Women planning pregnancy	Folic acid 400 µg per day, plus folate rich foods (to give total of 600 µg) and vitamin D 10 µg daily.
People who are old, of Asian origin, always cover up all of their skin when outside, rarely go outdoors or eat no meat or oily fish	Vitamin D 10 µg daily. The action of sunlight on skin is a major source of vitamin D. Some adults do not receive sufficient sunlight.
Under 5 year-olds who are not good eaters	Vitamins A, D & C.

Diarrhoea and oral rehydration therapy (ORL)

Diarrhoea is characterised by highly fluid faeces, usually with increased frequency of defaecation. Rapid emptying of the intestines aids the elimination of harmful material from the body. However, excessive loss of intestinal contents causes dehydration, loss of nutrients and loss of HCO_3^- which causes metabolic acidosis.

The most common cause of diarrhoea is excessive motility and too rapid transition of the gut contents for absorption, due to irritation caused by bacterial or viral infection. This type of diarrhoea is the main cause of the death of infants in developing countries. Originally, intravenous replacement of water and electrolytes was used to save some victims. However, this was expensive and required trained personnel with specialised equipment and so could not be used in many parts of the world.

Oral rehydration therapy (ORT) is a low cost, effective treatment that is saving millions of lives. In 1966 it was found that the Na^+-glucose co-transport carrier system is not affected by the micro-organisms that cause diarrhoea. When both Na^+ and glucose are present in the gut, the co-

[1] http://www.food.gov.uk/multimedia/pdfs/publication/eatwellplate0210.pdf

transport carrier takes up both into epithelial cells and then into the blood. Water follows by osmosis, effectively replacing that which has been lost due to diarrhoea.

Packets of dry ingredients for ORT are now manufactured in over 60 countries for local use. The lives of over 1 million children are saved annually by this treatment.

Finding out

Malnutrition includes problems of excess. Orlistat is a pancreatic lipase inhibitor used to assist weight loss.

- Suggest possible reasons why obesity is on the increase in the UK.
- Suggest how Orlistat could help in weight loss programmes.