Nutrition

A mixture of different types of food in the correct amounts is needed to maintain health. The main food types are:


Carbohydrates, found in potatoes, pasta, bread, bananas, sugar and rice. Carbohydrate is required by our bodies as a source of **energy** for other life processes. Sometimes referred to as **starch**, which is actually just one (very common) *type* of carbohydrate.


Fats, found in cheese, butter, margarine and oils. Fats are needed to make cell membranes and to insulate our bodies. They also contain important fat-soluble **vitamins**.


Protein, found in meat, fish, eggs and cheese. Proteins are required for **growth** and **repair**.


Fibre, found in wholemeal bread, fruit, vegetables and pulses. The fibre or roughage in our diet is not digested - but is important because it allows the muscles in our intestines to move the material along by **peristalsis**.

Digestive system: 1

The food we eat consists of large lumps of material. We must bite off small pieces and chew them up into even smaller ones before swallowing them. Once it gets to the stomach the food is further broken down by being pumelled by the stomach's muscular walls. This is **physical digestion**.

But the substances which our body needs cannot be absorbed into our blood until they have been broken down further - converted into small soluble

chemicals. This is done with the aid of **enzymes** and other chemicals in our gut, and is called **chemical digestion**.

Food is moved through the digestive system by the contractions of two sets of muscles in the walls of the gut - one set running along the gut and the other set circling it. Their wave-like contractions create a squeeze moving down the gut. This movement is called **peristalsis**.

What food is converted to:

- **Carbohydrate** is turned into **glucose**, which our bodies need to make energy.
- **Protein** is turned into **amino acids**, required for cell growth and repair.
- **Fats** and oils are turned into **fatty acids** and **glycerol**, needed to make cell membranes and to insulate our bodies. Fats also contain fat-soluble vitamins.
- **Vitamins** and mineral salts do not have to be digested because they are already small enough to get into our blood.

Digestive system: 2

In the exam you could be asked to label a diagram of the human digestive system, so make sure you know the names of all the parts!

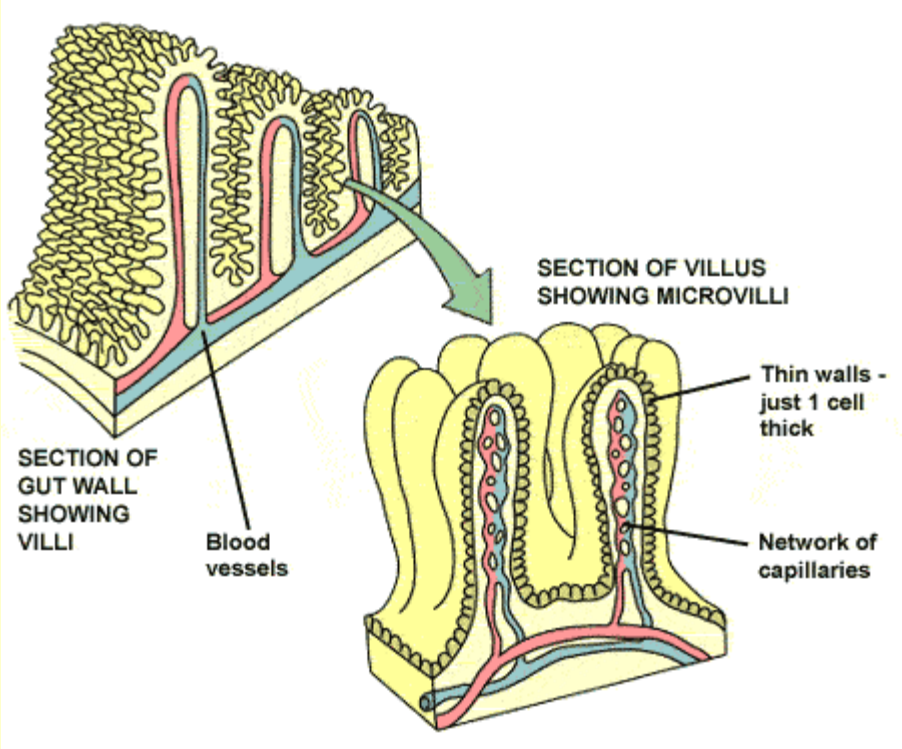


Mouth and stomach
Chemical digestion starts in the mouth, as enzymes in the saliva start to break down starch. Food is then moved to the stomach, where chemical digestion continues with the help of the **hydrochloric acid** and protease enzymes in the gastric juices.

Small intestine
The food is next moved into the small intestine, where enzymes produced in the intestine wall and **pancreas** continue the process of chemical digestion. Bile, produced in the **liver**, helps to breakdown fats.

The intestine is lined with tiny protuberances called **villi**, each in turn covered with even smaller microvilli. The villi have very thin walls and a plentiful blood supply to enable the products of digestion to be absorbed from the gut into the blood. There are many millions of them - providing a

massive surface area to maximise the rate of **absorption**.



Large intestine
Whatever indigestible food is left now moves to the large intestine, where any excess water is absorbed before it is excreted from the anus.

Digestive enzymes

The enzymes in our digestive system break down complex substances into simpler ones which can be absorbed. Enzymes work best at their **optimum pH** - so if the stomach, for example, does not have enough acid, its enzyme, pepsin, will not work properly.

Amylase

The enzyme amylase is in the saliva, and starts to work as soon as we put food into our mouths. Amylase digests the long, complex **starch** molecules, cutting them up into the shorter, simpler molecules of the sugar maltose. The word equation is:
starch $\xrightarrow{\text{amylase}}$ maltose.

Maltose however needs further digestion before it can be absorbed - as do the sugars sucrose and lactose. Another group of **carbohydrase** enzymes break these sugars down, turning them into the simple sugar glucose. The word

equations are:

maltose $\xrightarrow{\text{maltase}}$ glucose

sucrose $\xrightarrow{\text{sucrase}}$ glucose

lactose $\xrightarrow{\text{lactase}}$ glucose

Protease

Protease enzymes (also called pepsin) are secreted in the stomach and pancreas, and digest proteins. Proteins are long chains of amino acids, and protease enzymes cut them up into **peptide** - smaller chains of amino acids molecules - and eventually into individual **amino acids**, which are absorbed in the small intestine. The word equation for the protease reaction is:

proteins $\xrightarrow{\text{protease}}$ amino acids

Lipase

Lipase is secreted in the pancreas and the walls of the small intestine. It is the enzyme which digests **lipids** - ie, fats and oils. Lipids are complex molecules made up of **fatty acids** and **glycerol**. Lipase cuts lipids up into fatty acid molecules and glycerol molecules. The word equation for this reaction is:

Lipids $\xrightarrow{\text{lipase}}$ fatty acids + glycerol

You need to remember the main digestive enzymes and the food types they break down. Test yourself by dragging the correct enzyme onto each food type, and see them cut up the complex molecules into simpler ones...

More about enzymes

Enzymes are **proteins**. They are very important substances because they control the chemical reactions that happen in our bodies. They are known as **biological catalysts** - substances which speed up reactions but which do not get used up themselves. Enzyme names usually end in the letters **-ase**, as in amylase, protease and lipase.

There are two main types of enzyme. Digestive enzymes are **extracellular enzymes** - they control reactions that take place outside cells. Those enzymes which control reactions inside cells are called (not surprisingly!) **intracellular enzymes**.

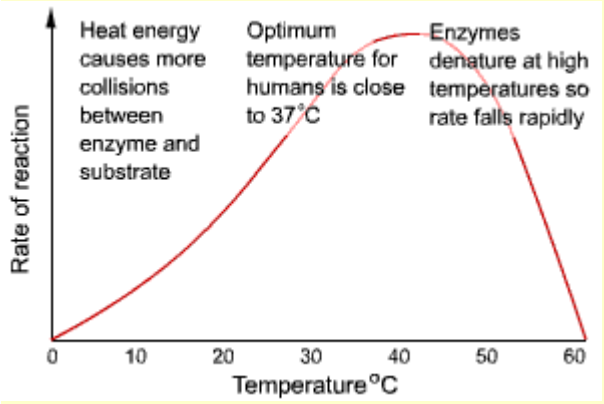
Enzymes intervene in chemical reactions by locking onto one of the **reactants** and speeding up the reaction. The chemical which the enzyme locks onto is called the **substrate**, and the enzyme has a kind of chemical sensor, called an **active site**, which helps it to recognise the substrate. Just

like a key only fits into a specific lock, each enzyme has its own specific substrate. Once the reaction is complete and the required product has been produced, the enzyme releases itself and moves on to the next reaction.

Effect of temperature on enzymes

Temperature is important in all reactions. As the temperature increases, so does the rate of reaction. This is because heat energy causes more collisions between the particles in the enzyme and particles in the substrate. However, very high temperatures damage or **denature** enzymes.

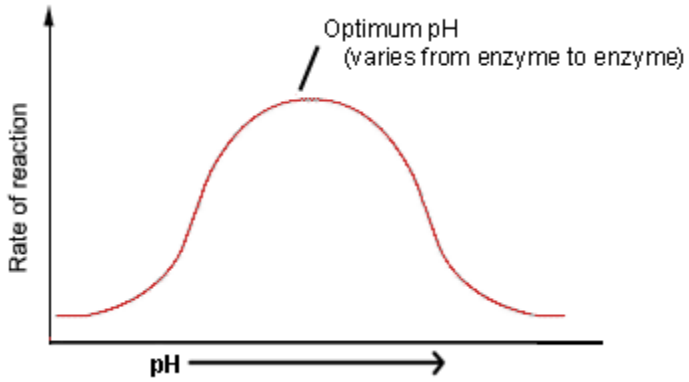
If you plot the rate of an enzyme reaction against temperature, the rate gradually increases with temperature until it reaches around 37°C or body temperature. Then as the temperature continues to rise the rate of reaction falls rapidly as the heat energy begins to denature the enzyme.



The effect of pH on enzymes

Different enzymes work best at different pH values. The **optimum** pH for an enzyme depends on its site of action. For example, enzymes in the stomach have an optimum pH of about 2 because the stomach is acid, but intestinal enzymes have an optimum pH of about 7.5.

A graph plotting reaction rate against pH for any enzyme looks like this:

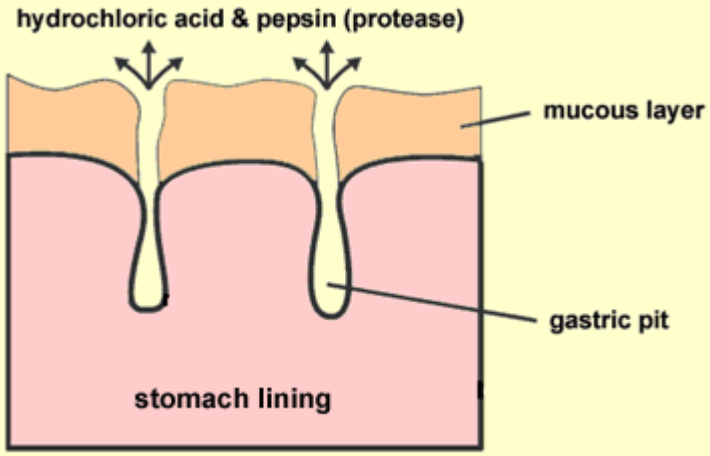


Other substances that help digestion

Hydrochloric acid

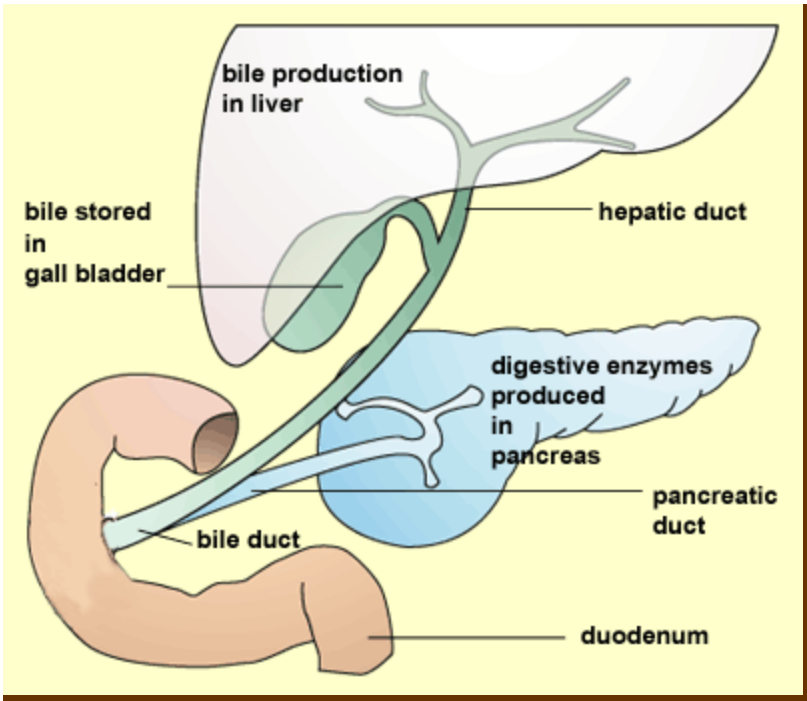
The enzyme pepsin requires the presence of **hydrochloric acid** to create the right pH conditions for the enzyme to work effectively. Pepsin works best at pH2 (acidic) - which is also acidic enough to kill the bacteria taken in with food.

The hydrochloric acid is secreted, along with the pepsin, from tiny pits in the stomach lining. The stomach lining protects itself against digestion and corrosion by secreting sticky neutralising mucus.



Bile

Fats and oils are broken down by the enzyme lipase; but before lipase can really get to work the lipids first need to be emulsified. This is done by **bile**, a substance secreted in the liver and stored in the gall bladder, which is added to food via the bile duct when food is passing through the duodenum. Bile is not an enzyme.



Bile works like detergent - it disperses fats into droplets (an emulsion) and so enlarges the surface area so that the enzyme lipase can get to work breaking down the fat much more efficiently. Bile salts also neutralise the stomach acid and help to create optimum pH conditions for digestive enzymes in the small intestine.

Food tests

We eat many complex foods which contain mixtures of carbohydrates, fats and proteins. Food tests enable you to find out what food types a food contains.

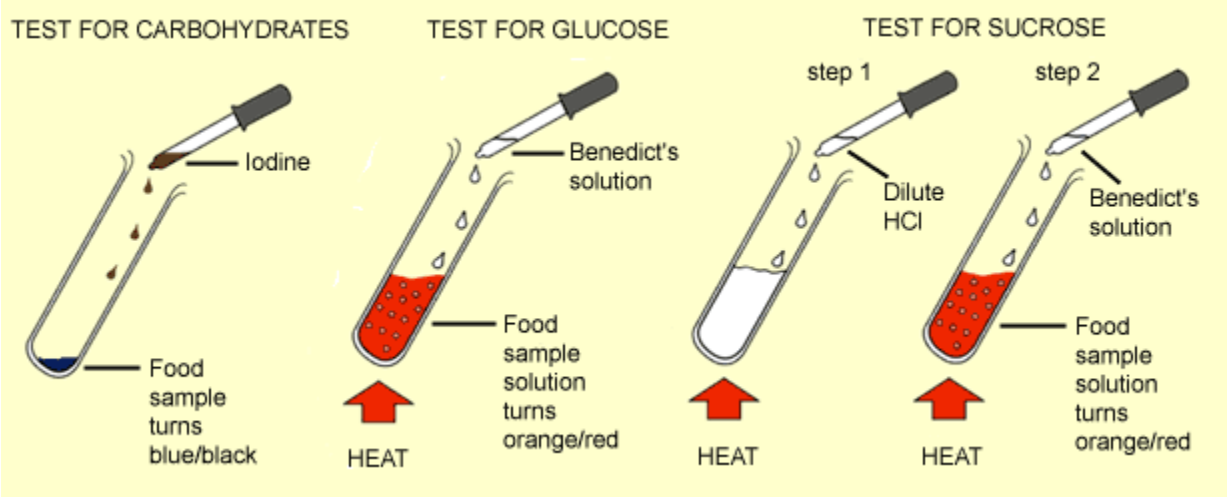
For fats the test is simply to squash a sample of food onto a piece of paper and leave it to dry. A positive test for fat is a translucent stain around the food sample when you hold the paper up to the light.

For the other food types, first prepare a sample of food for testing:

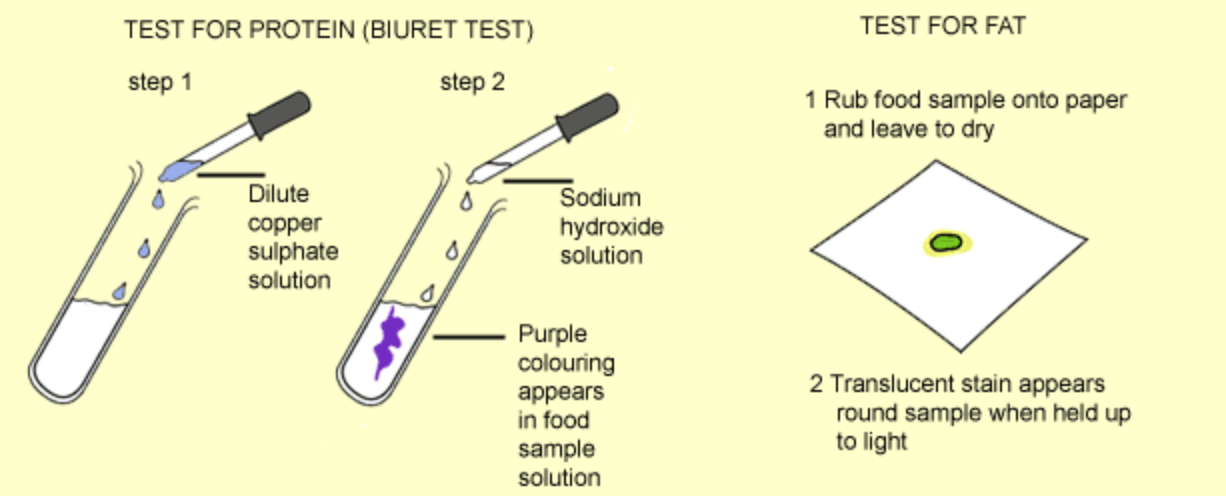
1. Crush some food in a pestle and mortar
2. Add a spatula-full to a boiling tube
3. Add 5cm^3 of distilled water and stir
4. Bring to boil and simmer for 1 minute
5. Cool and add the test **reagent**

You need to know the different tests for starch, sugars and protein.

Test for	Reagent	Positive test
Carbohydrates - starch	Dilute iodine	Turns blue-black
Carbohydrates - glucose	Benedict's solution	Orange/red **precipitate**
Carbohydrates - sucrose	A few drops of dilute HCl acid + a few drops of Benedict's solution	Orange/red precipitate



Test for	Reagent	Positive test
Protein	Biuret test - add a few drops of dilute copper sulphate solution, followed by a few drops of sodium hydroxide	Purple or violet precipitate
Fat	Rub a food sample onto a piece of paper. Leave to dry.	Translucent stain round the sample when held up to the light



Now try a **Test Bite**

7 - Coenzymes

There are other groups that contribute to the reactivity of enzymes beside amino acid residues.

These groups are called **cofactors** - chemicals required by apoenzymes (inactive) to become holoenzymes (active).

There are two types of cofactors:

1) **essential ions** - metal ions -inorganic
2) **coenzymes** - organic molecules that act as group-transfer reagents (accept or donate groups)- can also be H^+ and/or e^-

Both provide reactive groups not found on a.a. side chains.

Coenzymes can be either **cosubstrates** (loosely bound to enzyme; is altered, then regenerated) or **prosthetic groups** (tightly bound to enzyme).

Coenzymes can be classified by their source:

1) metabolite coenzymes
   - synthesized by common metabolites
   - include nucleoside triphosphates
   - most abundant is ATP, but also include uridine diphosphate glucose (UDP-glucose) and S-adenosylmethionine
   - ATP can donate all of its three phosphoryl groups in group-transfer reactions
   - S-adenosylmethionine can donate its methyl group in biosynthetic reactions.
   - UDP-glucose is a source of glucose for synthesis of glycogen in animals and starch in plants.

2) vitamin-derived coenzymes

- Vitamins are required for coenzyme synthesis and must be supplied in the diet
- Lack of particular vitamins causes disease
- There are two catagories of vitamins:
    1) water-soluble - B vitamins and vit. C
        required daily in diet
        excess excreted in urine
    2) lipid-soluble - vitamins A, D, E, K
        Intake must be limited
        Stored in fat

B vitamins and their coenzymes

Niacin (nicotinic acid) --> nicotinamide -->
Get niacin in enriched cereals, meat, legumes.
NAD^+ and $NADP^+$ are the coenzymes (cosubstrates).

NAD^+ consists of 2 5'ribonucleotides (AMP and nicotinamide monomucleotide) joined by a phosphoanhydride linkage.
For $NADP^+$, have a phosphoryl group on 2'-oxygen.
Both coenzymes act as cosubstrates for dehydrogenases --> catalyze the oxidation of substrates by transfer of $2e^-$ and $1H^+$ ---> NADH and NADPH.

Vitamin B_2 (riboflavin)

Coenzymes are flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD).
Riboflavin found in milk, whole grains, liver.
The coenzymes serve as prosthetic groups involved in $1e^-$ or $2e^-$ transfers.

$FAD + 2e^- + 2H^+ \longrightarrow FADH_2$
$FMN + 2e^- + 2H^+ \longrightarrow FMNH_2$

Enzymes that require FAD or FMN are called **flavoenzymes** or **flavoproteins**.
Can actually donate 1 or 2 e^- at a time --> form partially oxidized compound when only $1e^-$ is donated --> relatively stable.

Vitamin B_1 (thiamine)

Structure: pyrimidine ring and positively charged thiazolium ring.
Found in husks of rice and other cereals, liver, meat, particularly pork.
Deficiency in thiamine causes beriberi - extensive nervous system and circulatory system damage, muscle wasting, edema.

Coenzyme form is thiamine pyrophosphate (TPP) - synthesized by transfer of pyrophosphoryl group from ATP via thiamine pyrophosphate synthetase.

Used primarily in decarboxylases as a coenzyme.

Vitamin B6 family

pyridoxine, pyridoxal, pyridoxamine are the vitamins.

Act as prosthetic groups.

Formed by the following reaction:

pyridoxine + ATP --> pyridoxine 5'phosphate --> pyrodoxal 5' phosphate (PLP).

Lack of B_6 results in defects in protein metabolism.

PLP found in enzymes that catalyze reactions involving amino acids, e.g. isomerizations, decarboxylations, R-group removal or replacements.

Most frequent reaction is a transamination, where the a-amino group of a.a. is transferred to carbonyl group of a-keto acid --> new a.a. made or is excreted.

PLP binds covalently with Lys residue in active site --> keeps PLP from running away.

Biotin

Synthesized by intestinal bacteria.

Prosthetic coenzyme is called biocytin - covalently linked to Lys residue in active site.

Involved in carboxyl group transfer reactions and ATP-dependent carboxylations.

E.g. pyruvate carboxylase

pyruvate + HCO_3^- ---> oxaloacetate

Binds to HCO_3^- and acts as a CO_2 carrier (Figure 7-20).

Folic Acid or Folate

Found in green leafy vegetables, liver, yeast.

Coenzyme form is tetrahydrofolate.

Used by enzymes that transfer 1-C units as methyl groups (CH_3^-).

Another folate coenzyme is tetrahydrobiopterin - used in hydroxylases.

Pantothenic Acid

Used in coenzyme A formation.

Reactive center is -SH group

Key in all acyl-group transfers

Coenzyme form is phosphopantethine - added to serine residue of protein --> acyl carrier protein (ACP) --> important in fatty acid synthesis.

Vitamin B_{12} or cobalamin

Found in organ meat (kidney and liver).

It is a prosthetic coenzyme.

Ring structure similar to heme, with cobalt atom in center.

Involved in molecular rearrangements.

Deficiency in B12 results in pernicious anemia (decreased production of blood cells from bone marrow).

Vitamin C or ascorbic acid

Found in fresh fruit and vegetables.

Participates in hydroxylation reactions, e.g. collagen synthesis.

Deficiency causes scurvy.

LIPID VITAMINS

Vitamin A or retinol

Is a 20 carbon lipid molecule.

Found in carrots, yellow vegetables, liver, egg yolk, milk products.
-carotene ---> vitamin A

Exists in three forms:

1) retinol and 2) retinoic acid - binds to intracellular protein receptors --> regulates gene expression

2) retinal - prosthetic group of rhodopsin

Vitamin D

Exists as several lipids;

1) D3 - made in skin exposed to sunlight.

2) D2 - additive in fortified milk

Deficiency causes rickets in children or osteomalacia in adults --> insufficient Ca phosphate deposition in bone.

Vitamin E or α-tocopherol

Is an antioxidant that scavenges free radicals.

Vitamin K or phylloquinone

Found in plants.

Required for synthesis of proteins involved in blood coagulation.

Ubiquinone or coenzyme Q

Ring with hydrophobic tail --> inserted into membranes.

Transports e^- between enzyme complexes in inner mitochondrial membrane.

Related molecule is plastiquinone - found in thylacoid membrane of chloroplasts.

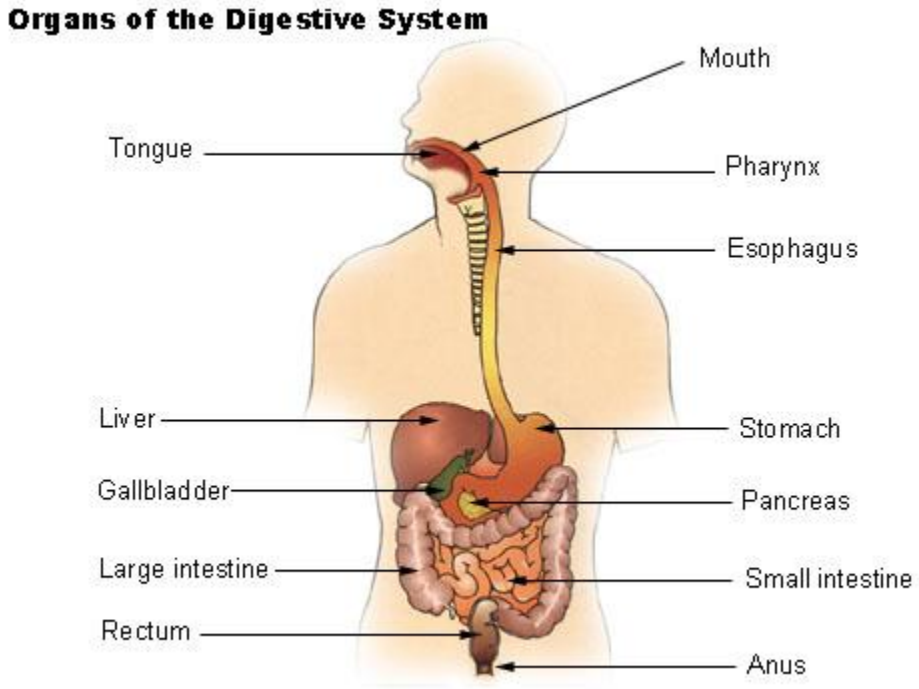
Cytochromes

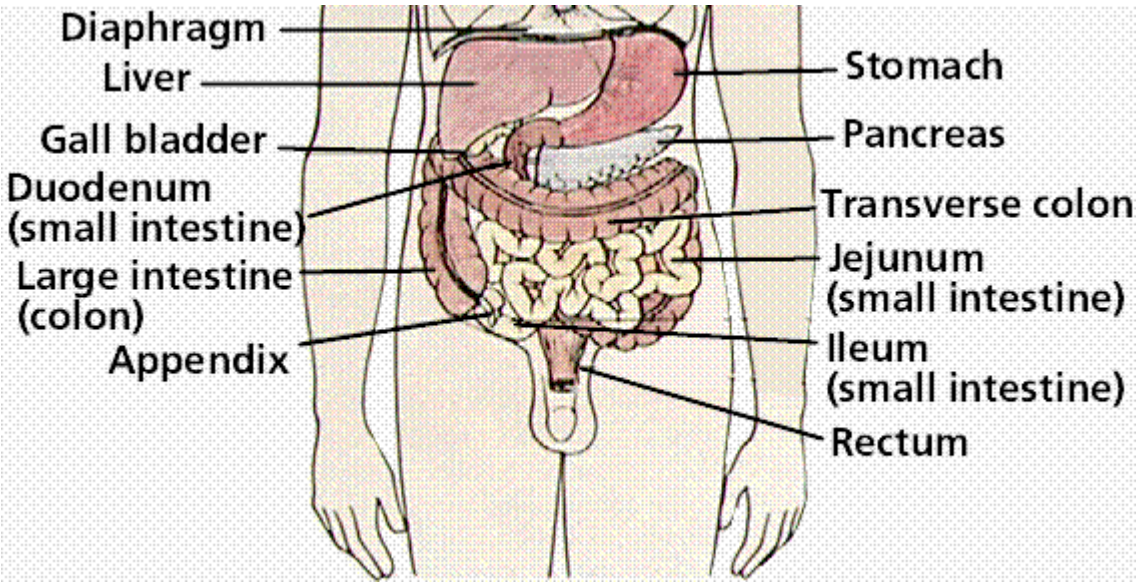
Hemo-containing protein coenzyme Fe^{3+} <--> Fe^{2+}.

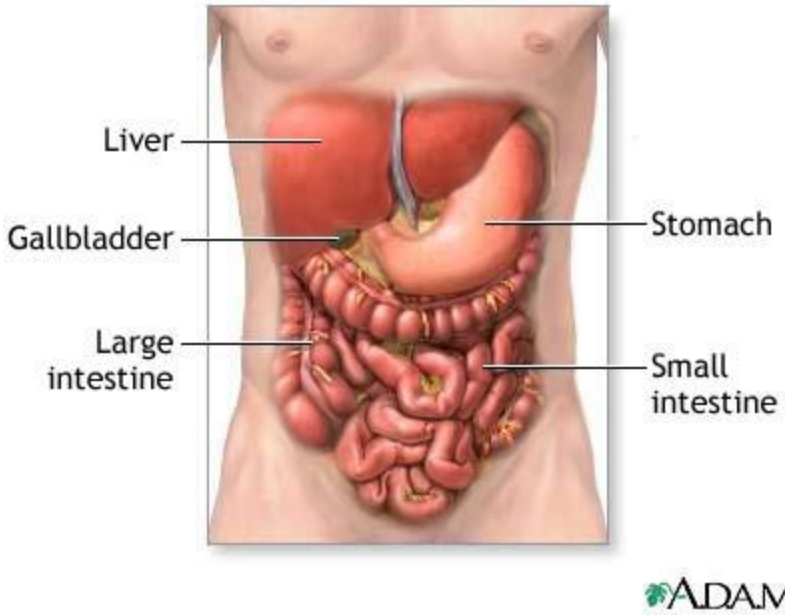
Classified as a, b, c based on absorption spectra.

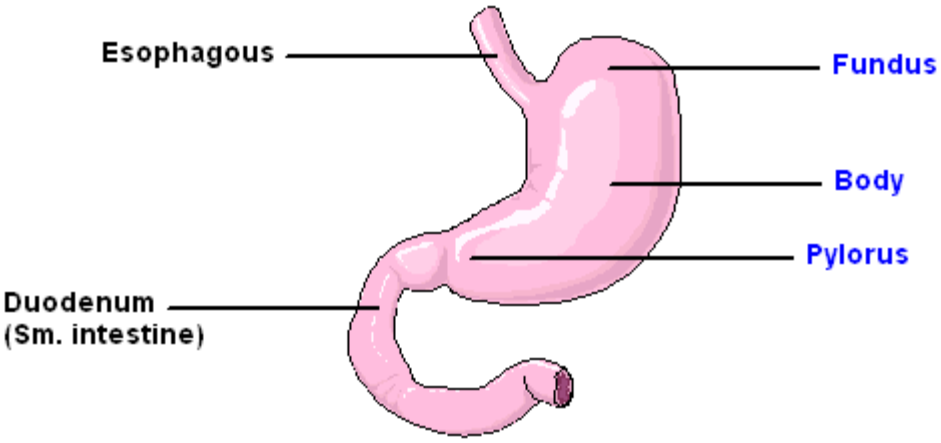
Transfers e^-.

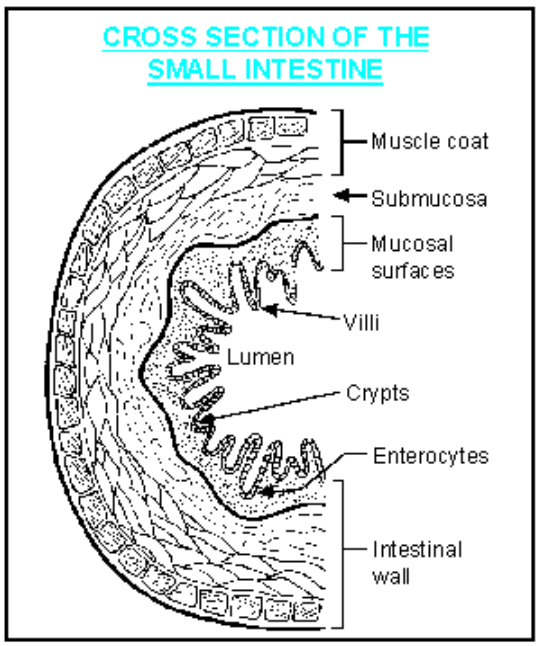
DIGESTIVE SYSTEM



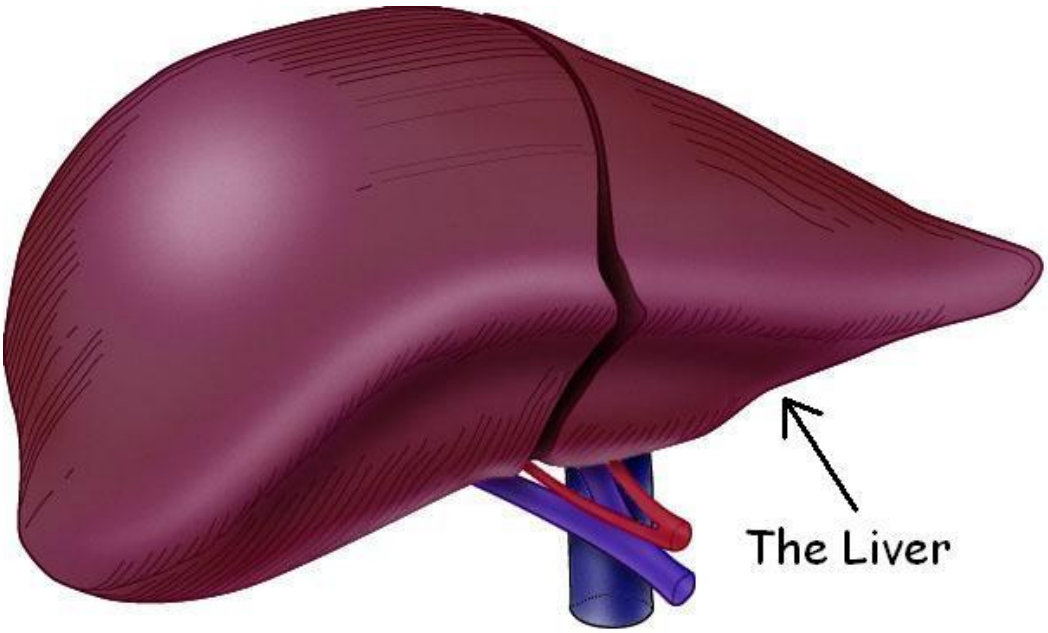



Liver
Gallbladder
Large intestine
Stomach
Small intestine
A.D.A.M.


Esophagous
Fundus
Body
Pylorus
Duodenum
(Sm. intestine)



(Fig.1-3)



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, bit by bit, until the molecules are

small enough to be absorbed and the waste products are eliminated. The digestive tract, also called the alimentary canal or gastrointestinal (GI) tract, consists of a long continuous tube that extends from the mouth to the anus. It includes the mouth, pharynx, esophagus, stomach, small intestine, and large intestine. The tongue and teeth are accessory structures located in the mouth. The salivary glands, liver, gallbladder, and pancreas are major accessory organs that have a role in digestion. These organs secrete fluids into the digestive tract.



Food undergoes three types of processes in the body:

- Digestion
- Absorption
- Elimination

Digestion and absorption occur in the digestive tract. After the nutrients are absorbed, they are available to all cells in the body and are utilized by the body cells in metabolism. The digestive system prepares nutrients for utilization by body cells through six activities, or functions.

Ingestion

The first activity of the digestive system is to take in food through the mouth. This process, called ingestion, has to take place before anything else can happen.

Mechanical Digestion

The large pieces of food that are ingested have to be broken into smaller particles that can be acted upon by various enzymes. This is mechanical digestion, which begins in the mouth with chewing or mastication and continues with churning and mixing actions in the stomach.



Chemical Digestion

The complex molecules of carbohydrates, proteins, and fats are transformed by chemical digestion into smaller molecules that can be absorbed and utilized by the cells. Chemical digestion, through a process called hydrolysis, uses water and digestive enzymes to break down the complex molecules. Digestive enzymes speed up the hydrolysis process, which is otherwise very slow.

Movements

After ingestion and mastication, the food particles move from the mouth into the pharynx, then into the esophagus. This movement is deglutition, or swallowing. Mixing movements occur in the stomach as a result of smooth muscle contraction. These repetitive contractions usually occur in small segments of the digestive tract and mix the food particles with enzymes and other fluids. The movements that propel the food particles through the digestive tract are called peristalsis. These are rhythmic waves of

contractions that move the food particles through the various regions in which mechanical and chemical digestion takes place.

Absorption

The simple molecules that result from chemical digestion pass through cell membranes of the lining in the small intestine into the blood or lymph capillaries. This process is called absorption.

Elimination

The food molecules that cannot be digested or absorbed need to be eliminated from the body. The removal of indigestible wastes through the anus, in the form of feces, is defecation or elimination.



Introduction:

Our digestive system is made up of the body parts that change raw food into nutrients that the body can use and waste. It also moves the nutrients and waste through our body. It is made up of the mouth including the teeth, jaws, tongue and salivary glands, esophagus, stomach, liver, gall bladder, bile duct, pancreas, pancreatic duct, small intestine including the duodenum, jujenum and ileum, large intestine, rectum and anus.

The Mouth: When a person eats any food such as an apple, digestion starts when the jaws use the teeth to bite into the apple. This begins to break down the food by dividing it into bite sized pieces. Then the teeth and jaws chew the apple to break the bite sized pieces into smaller pieces. This is to make the pieces small enough to fit through the esophagus and to make less work for the stomach. While the food is still in the mouth, the salivary glands produce saliva containing an enzyme which starts off the digestive process.

The Esophagus:

The food is then swallowed which takes the food from the mouth to the esophagus. The esophagus is the tube that connects the mouth to the stomach. Food moves through the esophagus by peristalsis, which is a wave of muscle contractions that pushes the food down the tube.

At the end of the esophagus is the lower esophageal sphincter(LES), which closes to prevent food from re-entering the esophagus.

Sometimes, when something gets in the stomach that the stomach doesn't like, the stomach muscles contract and force anything that is in your stomach up through the lower esophageal sphincter. The LES is trying to stay closed but the contractions create more pressure than your LES can hold. When this happens, the stomach contents go back up through the esophagus and come out through the mouth. We call this "throwing up".

The Stomach:

After food has left the esophagus it enters the stomach. The stomach provides four basic functions that assist in the early stages of digestion and prepare the food for further processing in the small intestine:

The stomach is a temporary storage container which can hold a large meal for a long time.

This is where chemical and enzymatic digestion starts. There are natural chemicals in your stomach

that we call digestive juices. They are acids that dissolve food down into smaller pieces so it can be absorbed into the blood stream.

The muscles around the stomach squeeze the stomach and food in the stomach like mixing pancake batter in a plastic bag. Just like you need to put water in the bag to get a smooth mix, the stomach makes juices to mix with the food to liquefy it which is a requirement for the food to go to the small intestine.

As food is liquefied in the stomach, it is slowly released into the small intestine for further processing.

The Liver:

The liver has hundreds of functions. One of its main functions is to process fat and other nutrient-rich liquefied food that drains from the small intestine so it can be used. Another important function of the liver is that it produces sugars from proteins and fatty substances; and it secretes albumin which helps to keep fluid within the blood vessels.

The liver also converts poisons in the blood into materials which can be safely excreted from the body. The liver uses calcium to reduce the amount of acid in the body waste. This allows us to go to the bathroom without pain or body damage.

It also secretes bile which is a substance containing fatty materials. These help in the digestion, as well as the absorption of fatty products.

The Gall Bladder:

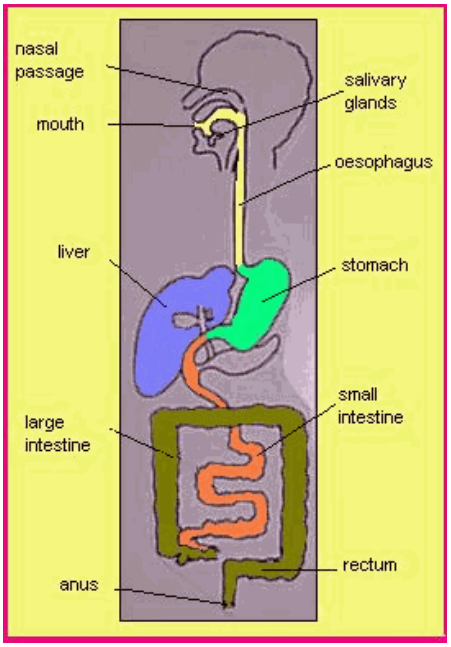
The gall bladder is a pouch-shaped organ which lies near the liver. It accepts bile from the liver, and stores it. When food is digested, the gallbladder releases bile into the small intestine where it is able to help dissolve fats.

The Pancreas:

The pancreas makes and delivers digestive juices through a tube called the pancreatic duct to the upper part of the small intestine.

The Small Intestine:

The small intestine is approximately 20 feet long and is divided into 3 segments - the duodenum, jejunum, and ileum.



The **duodenum** begins just beyond the stomach and curves around the head of the pancreas and the entrance of the common bile duct, in a C-shaped formation. At the spot where the stomach and duodenum meet, is a muscle called the pyloric sphincter

which prevents the regurgitation of material back into the stomach. The duodenum is responsible for further processing the material from the stomach (called chyme), by secreting enzymes which aid in digestion. Bile and pancreatic juice also enter the duodenum around its midpoint, and by moving the chyme in a shaking kind of motion, the duodenum mixes the chyme with these enzymes within its lumen, further aiding digestion.

The **jejunum** is the next portion of the small intestine, and it has a lining which is specialized in the absorption of carbohydrates and proteins. The proteins have been broken down in the stomach by enzymes called pepsin and acid into amino acids. The carbohydrates are broken down in the duodenum by enzymes from the pancreas and liver into sugars. Fats are broken down in the duodenum by "lipase" from the pancreas into fatty acids. Amino acid, sugar, fatty acid particles, vitamins, minerals, electrolytes and water are small enough to soak into the villi of the jejunum and drop into the blood stream. The blood takes all these nutrients to all the other parts of the body to provide fuel to do their jobs.

The **ileum** is the last portion of the small intestine, and it is responsible for absorption of fats, and bile salts which are a component of bile. The pores in the ileum are slightly bigger than those in the jejunum and allow vitamin B12, vitamins dissolved in fatty liquids, electrolytes, bile salts and

water to soak through the walls and into the blood stream.

Where the ileum joins the large intestine is a valve, called the ileocecal valve, which prevents the back flow of materials into the small intestine. By the time material reaches this point, it has a rather pasty consistency.

The Large Intestine:

The parts of the food that can't be digested get pushed into the large intestine, also called the colon. It is about 5 feet long. Its function is to move the waste from the small intestine on to the rectum. The material first passes through the **ascending colon** and then through the **transverse colon**. Throughout this process, it absorbs more water. By the time the waste reaches the segment called the **sigmoid**, it is quite firm. The sigmoid colon is designed to slow down this movement of the waste until it is ready to be eliminated.

The lowermost segment of the large intestine is called the **rectum.** It stores the firm waste until you are ready to get rid of it by "going to the bathroom". It has a specialized muscle, called the anal sphincter, which prevents the body waste from escaping until the appropriate time.

Digestion
Basic Processes

Digestion Hydrolyzes Macromolecules into their Building Blocks

- Digestion is the reverse of biosynthesis:
- Requires ATP energy
- Involves addition of water: hydrolysis
    - Proteins + H2O -> Amino Acids (20 types)
    - Polysaccharides + H2O -> Simple Sugars
    - Triglycerides + H2O -> Glycerol + Fatty Acids
    - Nucleic Acids + H2O -> N-bases + Pentose Sugars + Phosphate
- Food macromolecules are broken down into their building blocks
- Hydrolysis is necessary because:
    - Our bodies cannot directly use food proteins, polysaccharides and other macromolecules- we must make our own types
    - It is difficult to transport macromolecules across cell membranes

Digestion is Spontaneous and Does not Require ATP Energy

- Digestion does not require ATP energy (in contrast to biosynthesis)
- Macromolecules spontaneously take up water and break down into their building blocks

The Digestive System Has Several Ways of Speeding up Hydrolysis

- Although macromolecules spontaneously break down, the process is often very slow
- All organisms speed up digestion in several ways
    - Mechanical breakdown- chewing, churning
    - Solubilization: emulsification of fats
        - Bile salts made by liver and stored in gall bladder act as detergents
    - Enzymes: catalyze hydrolysis reactions of all the major macromolecules:
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Source	Enzymes	Substrates
Saliva	Amylase	Starch
	Lingual lipase	Triglycerides
Stomach	Pepsin	Proteins
	Gastric lipase	Triglycerides
Pancreas	Proteases	Proteins

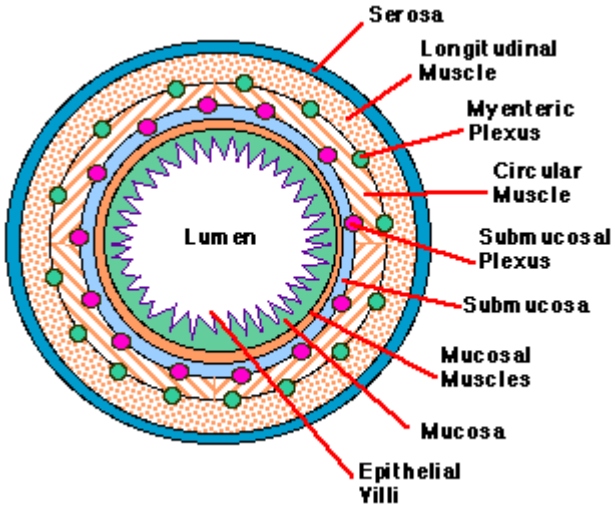
	Amylases	Starch
	Pancreatic lipase	Triglycerides
	Nucleases	DNA & RNA
Intestinal lining (microvilli)	Disaccharidases	Small sugars, such as sucrose, lactose & maltose
	Peptidases	Small protein fragments

- Hydrochloric acid production in stomach: also accelerates hydrolysis
  - pH changes in digestive tract:

Mouth	Stomach	Duodenum	Lower Intestine	
pH 7	pH 1-2	pH 7	pH 5	pH 7
Saliva buffered around pH 7; can become acidic due to bacterial action.	HCl secretion by parietal cells	Partially digested food neutralized by bicarbonate ions in bile fluid	pH varies, can become acidic due to bacterial action	

- Body temperature of 37 deg C accelerates hydrolysis (faster than at room temperature)

The Intestinal Lining Has a Complex Structure



- Multiple layers:
  - Serosa: layer: layer closest to blood; continuous with mesentery
  - 3 Muscle layers (smooth muscle, except in esophagus, which has some striated)
    - Longitudinal muscles
    - Circular muscles
    - Mucosal muscles

- 2 Nerve networks:
    - Myenteric (Auerbach) plexus
    - Submucosal (Meissner) plexus
- Submucosa
- Mucosa- lamina propria, lined with epithelium
    - Organized into projections called villi

- Entire digestive system has this structure, with minor exceptions
    - Esophagus and distal rectum have no serosa

Muscle Contractions Mix the Food and Move it Along the Gut

- Complex muscle contractions aid digestion:
    - Segmental contractions: move food back and forth, mixing it
    - Peristalsis: moves food in one direction, from stomach toward anus
    - These muscle activities are reflex actions, responding to the stretching of the gut wall when it fills with food
    - Reflexes are generated by local nerves in the myenteric plexus, but are also modulated by the autonomic nervous system

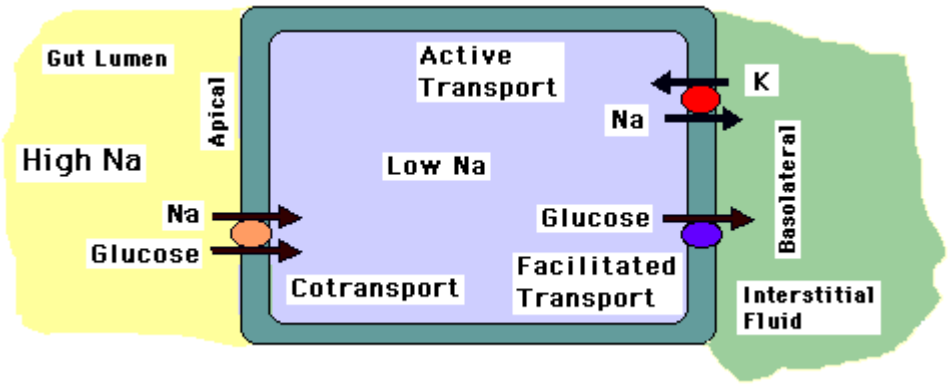
Special Membrane Transport Systems are Used to Accelerate Absorption of the Building Blocks

- Transport of materials from the gut into the blood is accelerated by greatly increased surface area
- Methods used to increase surface area:
    - The mucosal layer has large folds
    - The surface of the mucosal layer has projections called villi
        - About 30 per mm2, about 1 mm long
    - The membranes of the epithelial cells have microscopic projections, called microvilli
        - Produce a surface layer called the brush border
    - Together these suface modifications increase the surface area by 600 X
-

Modification	Surface area cm2	Area Ratio
None: plane tube	3300	1.0
Folding of surface	10000	3.0
Addition of villi	100,000	30
Addition of microvilli	2000000	600

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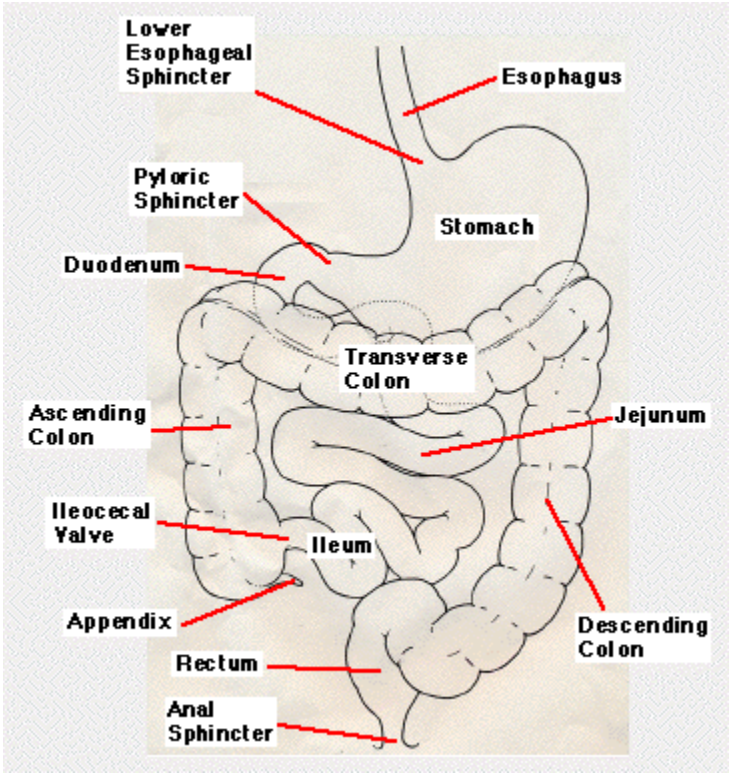
- Almost all nutrients are absorbed from the gut by special active and facilitated transport mechanisms, often involving more than 1 transport molecule:
    - Secondary active transport is commonly used
        - Na pump sets up a Na gradient (high Na in intestine, low Na in cells)
        - Na and nutrients are cotransported into cells lining the intestine
        - Glucose, amino acids are transported in this manner



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    - Explanation of figure:
        - Na pump on basolateral membrane (side towards blood) lowers Na inside cell
        - Na & glucose are cotransported across the apical membrane (side towards gut)
        - The glucose inside the cell is transported across the basolateral membrane, into the interstitial fluid, by a facilitated transport system
- A few substances cross the intestinal membranes by simple diffusion: water, some K

Basic Gut Anatomy

- The gastrointestinal (GI) tract is a set of tubes and compartments extending from the mouth to the anus

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  Topologically the gut is external to the body- it is possible to pass through it without crossing any cell membranes
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The Gut: Tubing		
Compartment	Components & size	Functions
Mouth	32 Teeth 3 Pairs salivary glands Tongue	Food chewed to break it up Salivary gland enzymes begin digestion of starch. Some substances dissolve in salivary fluid.
Pharynx		Connects mouth to esophagus
Esophagus	Sphincters at both ends (upper & lower)	Transports food from pharynx to stomach by peristaltic reflexes
Stomach	Has glands that secrete HCl and enzymes. Sphincters at both ends. 25 cm long Volume can increase from 50 mL to 1500 mL	Muscular wall churns the digesting food (chyme), mixing it with HCl & enzymes and breaking it up. HCl and pepsin begin digestion of proteins.

Small Intestine	Duodenum Jejunum Ileum Sphincters at both ends 6 meters long	Digestion of all types of macromolecules, using pancreatic enzymes. Absorption of most of the building block molecules. Note: length of intestines changes a great deal when the longitudinal muscles contract and relax.
Large Intestine	Colon Rectum Sphincters at both ends. 1.5 meters long	Contains large numbers of bacteria. Absorption of water and salts. Expels undigested food (feces).

The Gut Has a Simplified "Brain"

- The gut has a complex nerve network, in the myenteric and submucosal plexuses
    - Has about 100 million neurons (the enteric nervous system)
        - Myenteric plexus: controls contraction of circular & longitudinal muscles
        - Submucosal plexus: controls secretion by intestinal glands
    - Additional nerve input comes from outside (autonomic nervous system)
        - Parasympathetic system promotes secretion of enzymes and intestinal motility
        - Sympathetic system inhibits intestinal activity
- Gut "brain" generates contractile rhythms for peristalsis and segmented movements:
    - Pacemaker cells generate slow rhythmic depolarizations (about 5-10/minute) of circular and longitudinal muscles lining the gut
    - Depolarizations spread along the gut tube
    - Additional depolarization occurs when the parasympathetic nervous system is activated
    - If the depolarization reaches the threshold level action potentials occur and the muscles contract