

Digestive System and Enzyme Notes

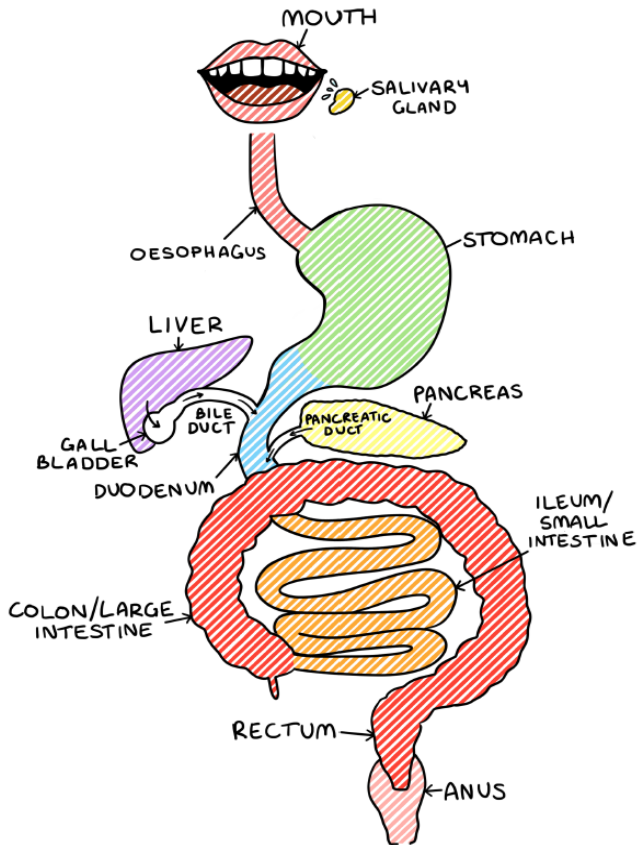
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The digestive system: is a group of organs that are involved in the breakdown of food and absorption of nutrients.

The Human Digestive System



Mechanical digestion: the process in which food is physically broken down into smaller pieces.

This occurs in the mouth and the stomach.

Chemical digestion: the process of breaking down food into smaller molecules using enzymes.

This process occurs in the mouth, the stomach and the ileum/ small intestine.

The figure shows the human digestive system.

It is not to scale 😊

Structure	Function
Mouth	Mechanical digestion occurs here when teeth break down food. Chemical digestion occurs here. Enzymes in the saliva breakdown food.
Oesophagus	Food moves by peristalsis from the mouth to the Stomach.
Stomach	Mechanical digestion occurs here through <u>muscular churning</u> . Chemical digestion occurs here. <u>Enzymes in the stomach breakdown proteins into amino acids.</u>
Duodenum	Is the first part of the ileum. It's about 30 cm long. <u>Chemical digestion occurs here.</u> Enzymes in the duodenum continue the breakdown of carbohydrates and proteins. <u>Lipids are digested here. Each lipid is broken into 3 fatty acids and 1 glycerol molecule.</u>
Gall bladder	It stores bile.
Ileum	Digested nutrients are absorbed here.
Colon	Water is reabsorbed here.
Rectum	Stores undigested waste until it is egested.

Peristalsis: the contraction of circular muscles and relaxation of longitudinal muscles which moves materials through the digestive system.

Function of bile: it emulsifies lipids by breaking large fat droplets into smaller ones (increasing surface area); this allows the enzyme lipase to break down lipids faster. It also neutralises the hydrochloric acid from the stomach.

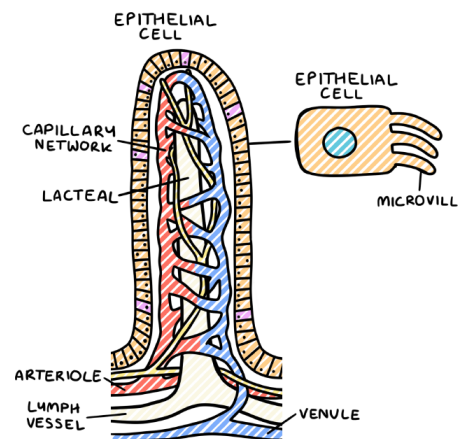
The Villi

What are villi? are millions of tiny, finger-like projections that completely line the inner surface of the small intestine. One is called a villus.

What's their function? Absorption. They absorb the products of digestion such as glucose, amino acids, fatty acids, and glycerol out of the digested food in the small intestine.

A question that we may see could ask **how are the villi of the small intestine adapted for the absorption of nutrients?** Please find below the ideal answer to this type of question. 😊

1. **Thin structure** – diffusion occurs faster when a layer is one cell thick compared to a layer that is three cells thick. The thinner it is the faster the substance can move through.
2. **Large surface area** – this increases the amount of absorption that can occur per second.
3. **Microvilli** – these hugely increase the surface area of the small intestine.
4. **Network of capillaries** – capillaries ensure that there is a large concentration gradient, this increases the diffusion rate.
5. **The lacteal** – this is involved with the absorption of fatty acids and glycerol.



A structure of a villus

Enzymes

Enzymes are really one of the most underappreciated components of the body. It is no exaggeration to say that without enzymes most life would not exist, including us. But, what are they?

An enzyme: is a biological catalyst that is made of protein.

Optimum temperature: this means that there is a temperature that enzymes will work at their fastest rate. In humans this is 37 degrees Celsius.

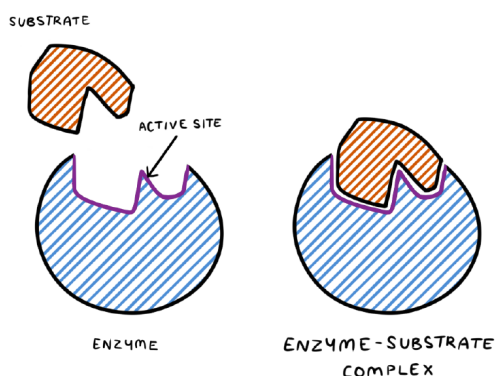
Optimum pH: each type of enzyme in the body has a different optimum pH. Each enzyme will work at its fastest rate if it is at both its optimum temperature and pH.

Mode of action: the mode of action is the name given to how something (in this case enzymes) works. The mode of action of enzymes for the GCSE exam is called the **“lock and key model”**.

It's a nice, simple model. It works on the idea that each enzyme is like a lock and that only one type of key will fit it.

Enzyme Structure

Enzymes are protein molecules. At GCSE the part of an enzyme that we are most interested in is called the active site.



The active site: is the part of an enzyme where the substrate binds and where the chemical reaction takes place.

The substrate: the general name given to a molecule that binds with an enzymes active site. Each type of enzyme has its own substrate a bit like how each lock has a different key.

Denaturing

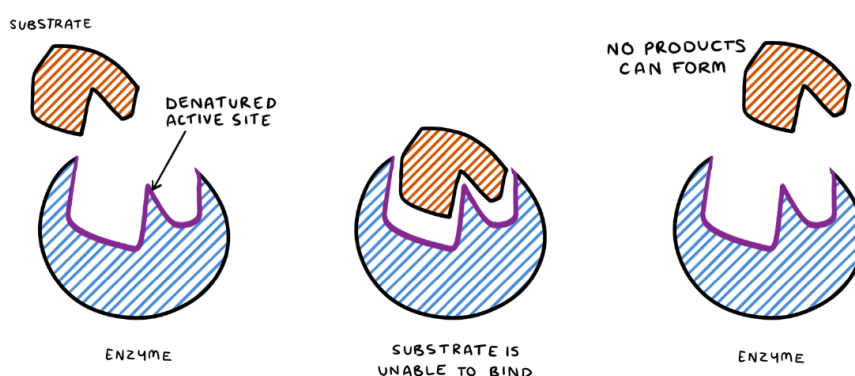
Enzymes can be denatured. This means that the active sites of the enzymes can change shape and substrate won't be able to fit into the enzymes active site. Denaturing is a process that takes time, (though it can also happen very quickly) so as the enzyme becomes more and more denatured, the rate of reaction will decrease until it stops completely.

Enzyme denaturation: is when the active site of the enzyme changes shape. This means that the substrate will not be able to bind to the active site. This means no products are produced.

What are the conditions that cause an enzyme to be denatured?

1. **High temperature** – when the temperature of the enzyme is too high it will have too much kinetic energy. This causes its bonds to vibrate too much and break.
2. **High or low pH** – extremes of pH can denature enzymes, this will vary from enzyme to enzyme.
For example, the enzymes that are active in the mouth have an optimum pH of about 8 but when we swallow these with our food they are denatured by the low pH of the stomach acid.

The figure below shows a enzyme that is denatured. Its active site has changed shape so the substrate is not able to bind to it. Therefore, there is no reaction.



Note: Low temperatures do not denature enzymes. Low temperatures reduce the rate of reaction as particles have less kinetic energy and collide less frequently.

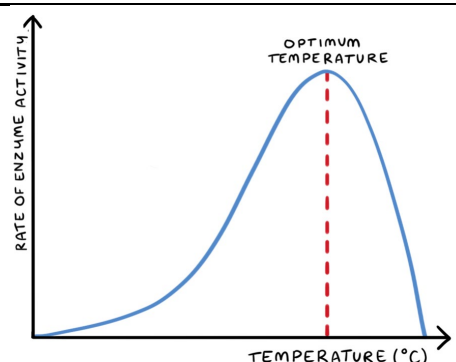
Factors Affecting Enzyme Action

Temperature

Recall that enzymes work best at their optimum temperature 😊

Low Temperature: at low temperatures particles have less kinetic energy. So they are moving around less and having less collisions between enzyme and substrate, so reaction rate is slow.

High Temperature: enzyme activity increases as particles move faster. Above the optimum temperature, the enzyme denatures (active site changes shape), and the reaction rate drops sharply.



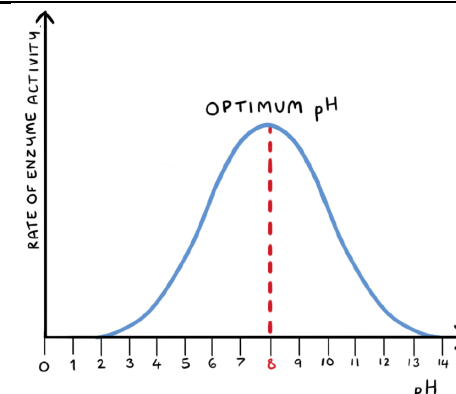
pH

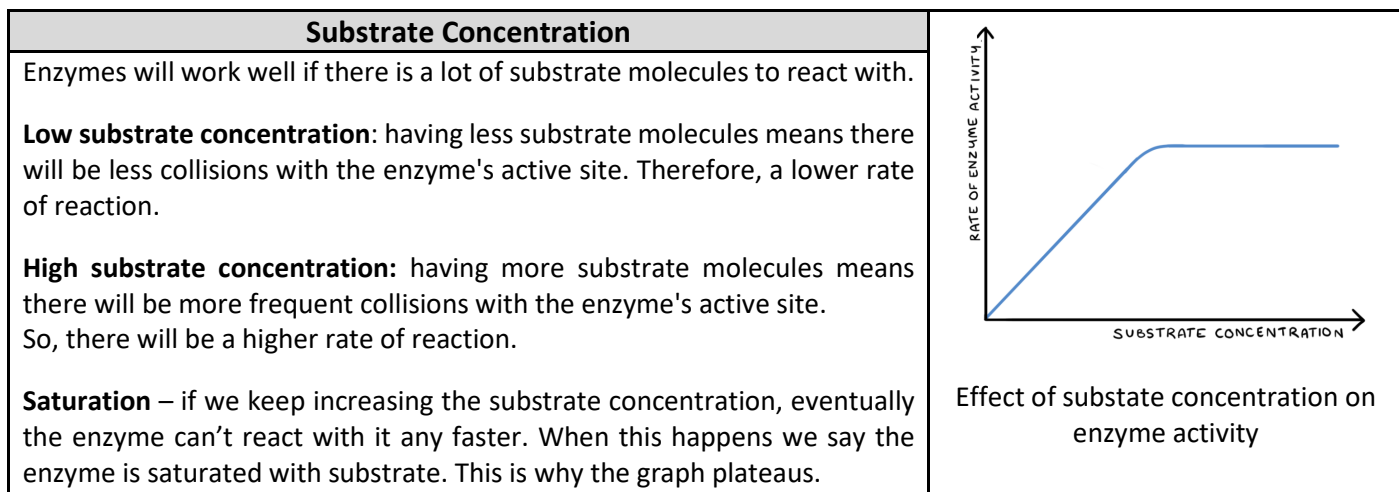
Recall that enzymes work best at their optimum pH.

Low pH: some enzymes will be denatured at a low pH. Though others like pepsin will work really well at a low pH.

High pH: some enzymes will be denatured at a high pH.

The graph shows the effect of pH on the activity of the enzyme Amylase.





Digestive Enzymes

Digestive enzymes: are enzymes that are involved in the breakdown of food into smaller molecules which are easier and quicker to absorb.

There are three categories of digestive enzymes – think of them as families 😊

1. **Carbohydrase enzymes** – this is a group of enzymes which break down carbohydrates.
2. **Protease enzymes** – are a group of enzymes which break down proteins.
3. **Lipase enzymes** – are a different group of enzymes which breakdown lipids (fats).

Each of these enzymes is produced in a different part of the body and while they all have the same optimum temperature they all have different optimum pHs. For ease, let's look at each category of enzymes in a table.

Carbohydrase Enzymes

Carbohydrase enzymes breakdown carbohydrates into simple sugars such as glucose so it can be absorbed in the Ileum. The most common carbohydrate we encounter is starch. There are two carbohydrase enzymes that we meet at GCSE...

Enzyme	Produced in the...	Substrate	Product
Amylase	Salivary glands	Starch	Maltose
Maltase	Lining of the ileum	Maltose	Glucose

Protease Enzymes

Protease enzymes break down proteins into amino acids so they can be absorbed in the Ileum. We could be asked to give an example of one. Here's two...

Enzyme	Produced in the...	Substrate	Product
Pepsin	Stomach	Protein	Amino acids
Trypsin	Pancreas	Protein	Amino acids

Lipase Enzymes

Lipase enzymes break down lipids into three fatty acids and one glycerol molecule. This takes place in the Ileum, the products are absorbed here as well. Even though this is a whole group of enzymes for the GCSE we just treat it as one single enzyme. This is the only example where we can be asked the **number of each product**.

Enzyme	Produced in the...	Substrate	Products
Lipase	Pancreas	Lipids	3 × fatty acids & 1 × Glycerol

Enzymes – Rate of Reaction

We could see a question that asks us to calculate the rate of reaction for an enzyme controlled reaction. This just means a reaction where the enzyme is the substance that is causing the reaction to happen as long as there is a substrate and good conditions.

How do we calculate the rate of reaction? There are two pretty common ways that we can use to calculate the rate of a reaction and those are using an equation or using the gradient of a graph.

The equations below show two variations of the same equation. Which one we would use will depend on the question.

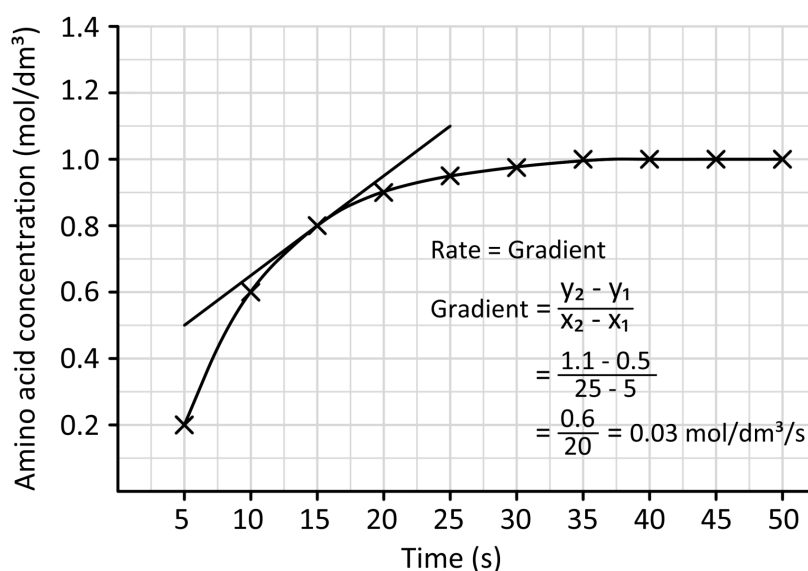
$$\text{Rate of reaction} = \frac{\text{change in mass of reactant or product}}{\text{time}}$$

$$\text{Rate of reaction} = \frac{\text{change in concentration of reactant or product}}{\text{time}}$$

It will depend on the question whether we are looking at the change in mass of the reactant or product. Or we could use the concentration of the reactant or product instead but it's the same equation. Just make sure you read the question and are answering it correctly. 😊

A question on rates could have a graph. This graph could be pre-drawn or more likely it will be a graph that we need to complete. Let's look at the example below.

Example 1: use the graph below to find the rate of reaction at 15 seconds.



How do we get the rate of reaction from a graph? We draw a tangent at the point in a graph that the question has asked for. In this case we draw a tangent at point in a graph above 15 seconds. We then just find the gradient of the line. The gradient of the line is equal to the rate of the reaction at that point.

gradient of tangent = rate of reaction

The Food Tests

Food tests are used to identify the presence of specific substances in a sample of food. These substances are starch, reducing sugars, proteins, and lipids. Each type of test involves a specific reagent that reacts with a specific nutrient to give a colour change.

A reagent: is a chemical that is added to a sample that is being tested to cause a reaction or colour change that shows that a specific substance is present.

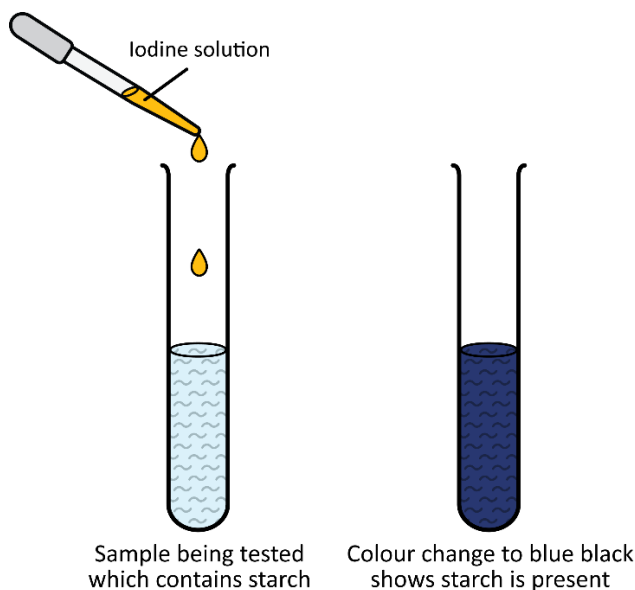
The Starch Test

Reagent: Iodine solution.

Method: Place a small sample of the food in a test tube or on a white tile. Then add a few drops of iodine solution (which is amber in colour) to the sample. Look for a colour change. The figure below shows the starch test.

Positive result: a blue black colour is seen.

Negative result: there is no colour change.



The Benedict's Test

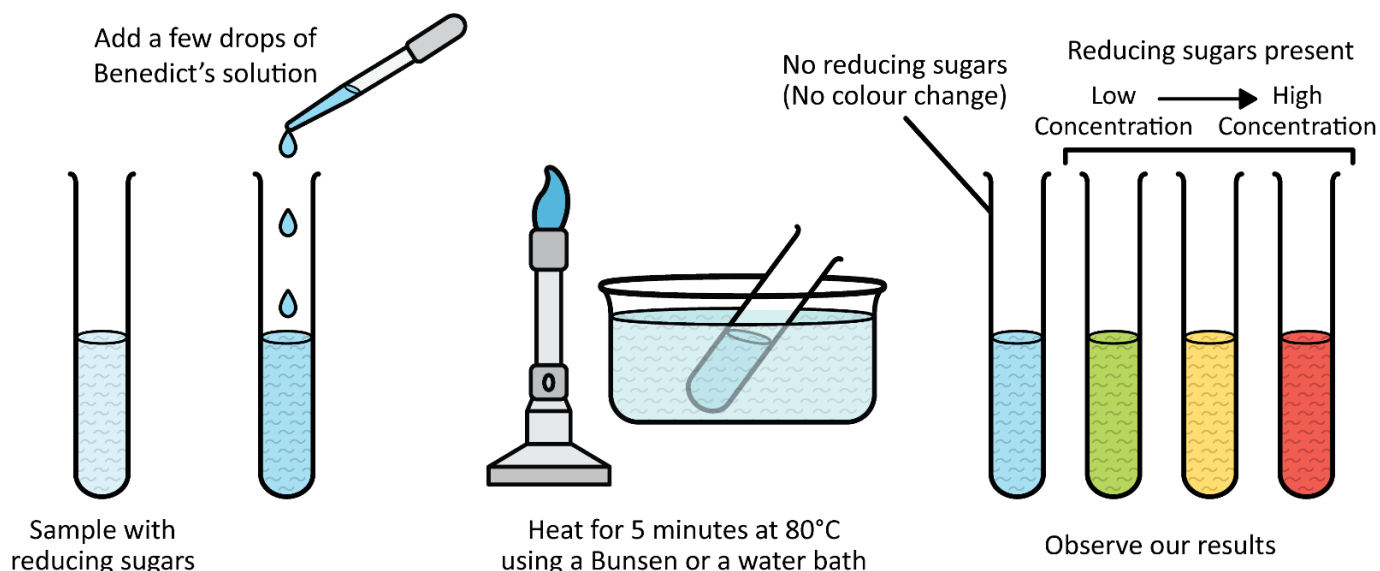
Note: The Benedict's test is also known as the test for reducing sugars.

Reagent: Benedict's solution.

Method: Add a few cm³ of the food sample solution to a test tube. We add some Benedict's solution to the sample. We must heat the mixture in a water bath at 80°C for about a few minutes. This is the only food test that is heated.

Positive result: a colour change is seen. This can be green, yellow orange or brick red. Though the most common answer is a brick red colour.

Negative result: there is no colour change or the solution remains blue.



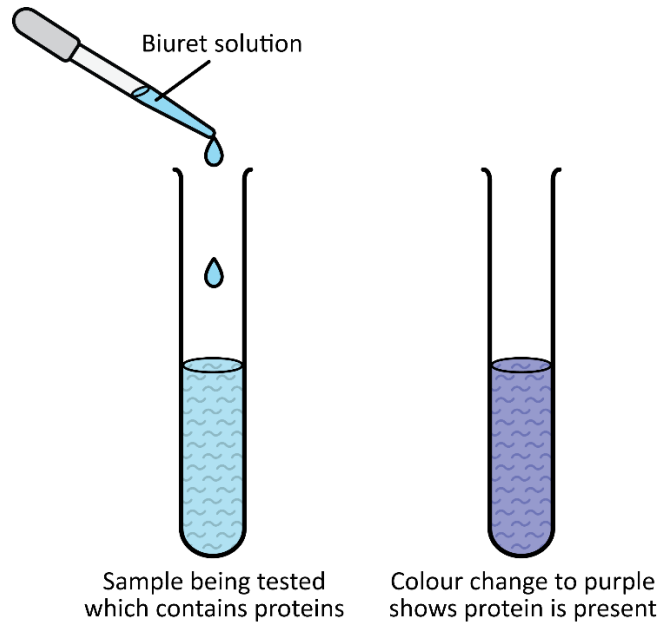
Protein Test

Reagent: Biuret solution. This is also known as copper sulphate solution.

Method: Add a few cm³ of the food sample solution to a test tube. We then add a few cm³ of Biuret solution.

Positive result: a purple or lilac colour change is seen.

Negative result: there is no colour change.



The Lipid Test

Reagent: Ethanol.

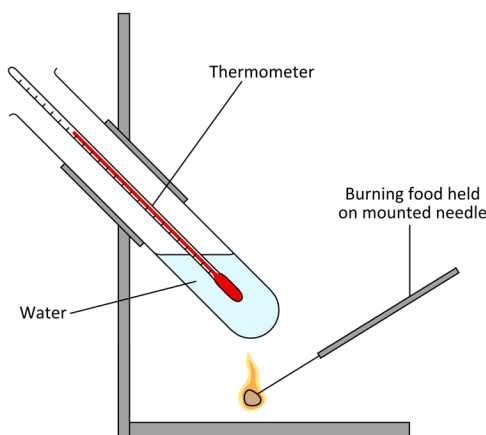
Method: Add a few cm³ of the food sample solution to a test tube. We then add a few cm³ of ethanol and shake the mixture. **Positive result:** a white emulsion is seen. **Negative result:** there is no colour change.

Calorimetry

Calorimetry: the energy given off when the material burns is measured using a device called a calorimeter.

Calorimeters are used in the food industry to measure the energy in food. This energy value is given in joules or calories in the nutritional information on the food package.

A calorimeter can be made by arranging a beaker of water above a burning sample of food. The change in temperature of the water is a measure of the energy within the food sample. The figure below shows a very simple calorimeter.



How do we use a calorimeter in the lab?

1. Measure a known volume of water (100 cm³) and pour it into the calorimeter or beaker.
2. Record the initial temperature of the water using a thermometer.
3. Weigh the spirit burner containing the fuel.
4. Place the burner under the calorimeter and light it.
5. Allow the fuel to burn and heat the water until there is a significant temperature rise (for example, 20 to 30°C).
6. Extinguish the flame and record the final temperature of the water.
7. Weigh the spirit burner again to determine the mass of fuel burned.

Are there any sources of error with this set up? Yes 😊 indeed there is.

1. **Heat can be lost:** Some heat is lost to the surroundings instead of heating the water. This can be reduced by using a lid or adding insulation.
2. **Incomplete combustion can occur:** The fuel may not burn completely, this will reduce the energy released.
3. **Equipment absorbing heat:** Some heat can be absorbed by the calorimeter or beaker during the experiment.