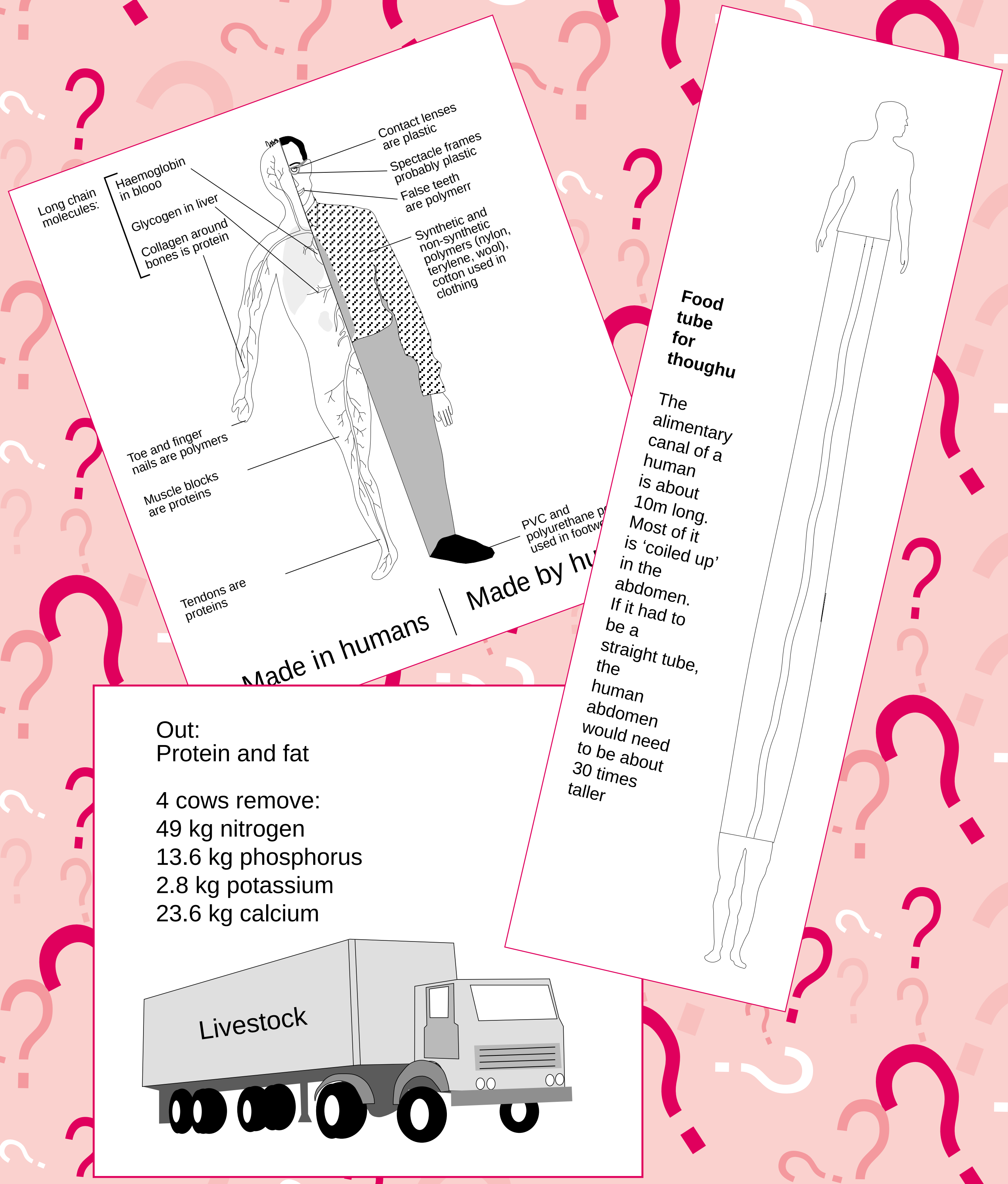
What's your reaction?

Background reading for teachers of primary science from the Royal Society of Chemistry

What's your reaction? Background reading for teachers of primary science



What's your reaction? aims to give primary school teachers a background in science with the emphasis on chemistry. The book is based upon The Royal Society of Chemistry's CRISP (Chemistry Related In-Service Project) work.

Each chapter in the book covers a different science topic, dealt with at three levels of difficulty. For each level, there is a list of key ideas, explanatory text and diagrams, and a number of challenges.

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How to use 'What's your reaction?'

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The aim of this book is to improve and expand teachers' knowledge of the underlying chemistry concepts in the primary science curriculum. In England and Wales apart from the Attainment Target concerning materials there is a great deal of chemistry in the other Attainment Targets, some of which may not be apparent to the non-specialist. The book is appropriate for use not only in England and Wales but throughout the UK. Many teachers express a lack of confidence in their own knowledge and fear that they may give children 'the wrong idea'. This book will help teachers to examine their own ideas and resolve any misconceptions they may have.

Each of the 11 chapters can stand alone. Within each chapter there are three levels of difficulty labelled A, B and C. Level A assumes no science knowledge at all and is concerned with the most basic principles. Level B may be most suited to those teachers who have some background in science and involves more complex ideas. It is hoped that level C contains ideas to challenge all teachers. Listed at the beginning of the section (*ie* level A,B or C) is a list of 'Key ideas' that the section deals with. Following this is the 'text' which explains the underlying chemical concepts involved in the Key ideas. Periodically within the text are 'Challenges' which pose a question to be investigated. These may involve research in a library, a visit (*eg* to a garden centre) to find information, or an activity. An important feature of the book is the reference throughout to the relevance of chemical ideas to every day life.

Since each chapter can be used independently the priority for tackling the chapters could be determined by the term's topic. Growth may be best served by using chapters 1 and 2. A topic on food could be backed up by parts of chapter 9 which deals with acids and alkalis, chapter 3 which deals with food as a fuel, chapter 4 which involves preservatives and chapter 2 which deals with classification of foods, digestion, and how we get energy from food.

Another prompt to use this book may come from those awkward questions children ask which sound so benign and yet have very complex answers or indeed no answer at all. The book may enable you to give a simplified explanation but it may be inappropriate to try to explain because the concepts involved are too advanced. Teachers should however gain confidence themselves either in the knowledge they have gained or the knowledge that there is not a simple explanation.

There are various ways in which the book can be used for in-service training (INSET). It is possible for an individual to use the book on their own. Depending on their own knowledge they could start at level A and work their way through to level C or they may find level A contains ideas with which they are already familiar and begin with level B text. A teacher with a good grounding in science may want to use only level C text to broaden their knowledge.

It is often more enjoyable and beneficial if teachers can discuss ideas with each other, particularly if they lack confidence, and much could be gained by staff working together. Ideally the science coordinator needs to be familiar with the contents so that they have an idea of what levels A, B and C involve. Since the chapters are differentiated staff could divide into groups depending on which level they feel would be most appropriate for them. The science coordinator could help them in deciding by producing a simple questionnaire with true/false statements concerning some of the Key ideas which would help to indicate which level is an appropriate starting point for individual teachers. Teachers could then work through the text in groups of similar level tackling the challenges as they come to them. The coordinator needs to be aware of materials needed for the activities and make sure they are to hand. Some research (*eg* the visit to the garden centre) needs to be undertaken either after reading the text or perhaps prior to reading the text in order that the challenges can be tackled. Again this needs to be decided by the coordinator or INSET provider. Since explaining ideas to others helps to consolidate what has been learnt, a possible strategy may be for the level B group to present and teach their text to the level A group.

Another approach may be to begin with a challenge – *eg* 30 chapter 5C. If ice had a greater density than cold water, would any life on planet earth be possible even in hot countries? After discussion the science coordinator could use the supporting diagrams in the text to explain what would happen if ice was more dense than cold water and what the implications for life on our planet would be, and how a pond actually does freeze over. Teachers could then go on to read the text on water.

Similarly, challenge 27 chapter 5B. Is your local drinking water obtained from surface water such as a reservoir, or is it obtained from a borehole? Why do you think water obtained from a borehole is considered purer and cleaner than that obtained from a reservoir? A discussion could lead on to filtration as a means of purifying water (which may be familiar to many teachers) and a practical investigation on filtering water through gravel of different sizes to see which is most effective.

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1A. Growing Plants

Key ideas

- Plants require chemicals to live.
- When plants die the chemicals from which they were made will eventually be recycled.
- Recycling maintains the chemical balance. If plant material is removed from where it grows an imbalance is created.
- Natural cycles have evolved to recycle certain chemical elements – *eg* carbon, nitrogen and phosphorus.

Soil

Text

Nearly all plants make their own food through the process called photosynthesis (see chapter 2A). Carbon dioxide for the reaction comes from the air and water comes from the soil. In addition, many other chemical substances are required for natural growth and these are usually available in the soil. Soil is a solid and is composed of a mixture of particles of coarse and fine sand, silt and clay which is interspersed with liquids and gases. To a gardener a 'good loam' is soil where the sand or clay components are not present in excess and which contains some humus. Humus is decaying plant and animal remains which helps to retain moisture, creates air spaces in the soil and slowly breaks down to release chemical compounds including those of nitrogen, phosphorus and potassium. These chemical compounds are normally found in the soil as chemicals dissolved in water – *ie* as solutions. In waterlogged soil most of the air spaces are filled with water; in compacted soil there are fewer air spaces.

Essential chemicals

As soon as a seed starts to germinate and grow into a seedling it uses the chemicals required for growth from the supply within the seed. Once this supply is exhausted the plant takes up the major chemicals required (*ie* those based on nitrogen, phosphorus and potassium) from the soil. Leaf production requires a great deal of nitrogen, root formation demands phosphorus while during the period of flowering and fruiting potassium is in demand. In addition, plants require the chemical elements magnesium, iron, manganese, sulphur, calcium, chlorine, boron, zinc and copper to incorporate into new compounds as a requirement for healthy growth.

So far the names of the elements have only been used when referring to the plant's food requirements but while this is not strictly wrong it does not indicate what happens in reality. Potassium metal for example will react with air and moisture and has to be kept under oil. So potassium as the metal element is not the material to put on your indoor plants! Yellow phosphorus has to be kept under water to prevent it catching fire when exposed to the air so, again, it is not exactly a friendly fertilizer! Nitrogen, the third main plant food is a gas and it is unreactive. So how are these important elements made available to plants by the soil? The only way is for them to be joined with other chemical elements to form chemical compounds.

For a compound to be used by the plant it must be soluble in water, non-toxic to the plant and be acceptable to the metabolism of the plant. Nitric acid for example is a compound containing nitrogen but it is not very acceptable to plants except in dilute solution such as that produced when rain dissolves 'nitrogen oxide' gases formed during a thunder and lightning storm (see chapter 1B). Fortunately both soil and fertilizers contain compounds which plants can absorb *eg* nitrogen is usually combined with oxygen to form nitrates; phosphorus is usually combined with oxygen to form phosphates; and potassium is usually combined with oxygen to form potash.

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'Potash fertilizer' is an agricultural term and refers to a mixture of potassium oxides and other compounds containing potassium. 'Nitrate' and 'phosphate' cannot exist on their own; they have to be attached to another element (such as a metal) or contained in a compound. In fertilizers this is quite useful because it makes it possible for other important chemical elements to be given to the plant. Calcium for example can be given as calcium nitrate and chlorine can be given as potassium chloride (see figure 1A.1). Some crops require particular chemical elements and most of these are supplied as compounds - *eg* sodium chloride (table salt) which is a requirement of sugar beet.

A seed can be considered to be an embryo with its own supply of food, so each seed has its own basic supply of nutrients which are essential for the early life of its seedling. After these reserves have been used up nutrients have to be available in the soil for continued growth.

Ancient woodland or forest probably provides the only remaining examples of natural recycling on land. Leaves, whole plants, branches and sometimes trees fall to the ground. With the help of insects, fungi, bacteria, and their enzymes the materials decay to release their chemicals into the soil for use by the next generation of plants.

'This load of cattle went to market,
This load of grain went to the mill.
.....................................and as result, a whole lot of mineral salts
were removed from the farm.'

If any part of a plant is taken from the spot where it has been growing a 'packet' of chemicals is in effect removed. The harvesting of one tonne of wheat grain effectively removes about 18.1 kg of nitrogen, 3.6 kg of phosphorus and 4.0 kg of potassium from the soil. The despatch to market of a tonne of fat cattle (on average, two cows) is equivalent to removing 24.5 kg of nitrogen, 6.8 kg of phosphorus, 1.4 kg of potassium and 11.8 kg of calcium from the land (see figure 4B.2).

Fertilizers

In intensive agriculture (and even in a heavily cropped gardens) a deficit in chemical food can be created. An alternative scenario is that as a result of management methods (*eg* the burning of vegetation), high concentrations of mineral salts accumulate in one area. After human intervention has taken place and the crops have been harvested one of two things can be done to replace the nutrients. The grower can either 'move on' and exploit another area, leaving nature to take its course as ancient man did, or the grower can put some chemicals back into the soil by applying fertilizer.

The idea of applying fertilizers is not new. The first British settlers in North America found that the Indians improved their crop yield by burying a small fish with every maize seed they planted. Medieval farmers recognised the benefits of planting clover and other legumes in rotation to increase the level of nitrogen in the soil. Legumes (*eg* peas and clover), increase 'nitrogen' in the soil through the action of bacteria which are held in nodules on the roots of these plants (see figure 1B.2). The bacteria are able to convert nitrogen gas in air into a form which plants can use. This process is part of the nitrogen cycle and a simplified version of this is shown in figure 1A.2 (more details are given in chapter 1B). It is one of the recycling systems found on earth, others include the carbon (see chapter 3) and phosphorus cycles.

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Chemical element	Main forms in which chemical is supplied to plant	Biochemical function	Main area of use in plant	Effect of shortage	Conditions for nutrient uptake
Nitrogen (N)	(i) Nitrates (ii) Ammonium compounds	Forming protein	Leaf production	Pale, yellowish sometimes purplish leaves	Slightly alkaline conditions are best for maximum nutrient uptake
Phosphorus (P)	(i) Phosphate (ii) Oxides soluble in water	Energy transfer Nucleic acids and enzyme systems	Root formation and growth. Fruit ripening, seed maturation and germination	Slow stunted growth, lower leaves can be dark blue-green in colour. Low yield of leaves and fruit	
Potassium (K)	Combined with other chemicals *eg* potassium sulphate	Not certain; possibly in enzymes. Control of water loss and photosynthesis	Essential for flower and fruit production	Slow growth, poor fruit and flowers. Older leaves turn yellow with brown mottling and withered edges	
Sulphur (S)	Sulphate	Protein production	Throughout plant but NOT associated with particular function	Younger leaves become yellower especially between veins	
Magnesium (Mg)	Magnesium sulphate	Production of green pigment (chlorophyll)	Leaves and all green areas	Older leaves become chlorotic (yellowish) between veins. Leaves fall off	
Calcium (Ca)	As carbonate or hydroxide or oxide	Cell structure, plant rigidity and as a 'chemical carrier'	Throughout plant but especially in areas of active growth	Stunted growth, especially of younger leaves and growing points	

Figure 1A.1 Major plant nutrients

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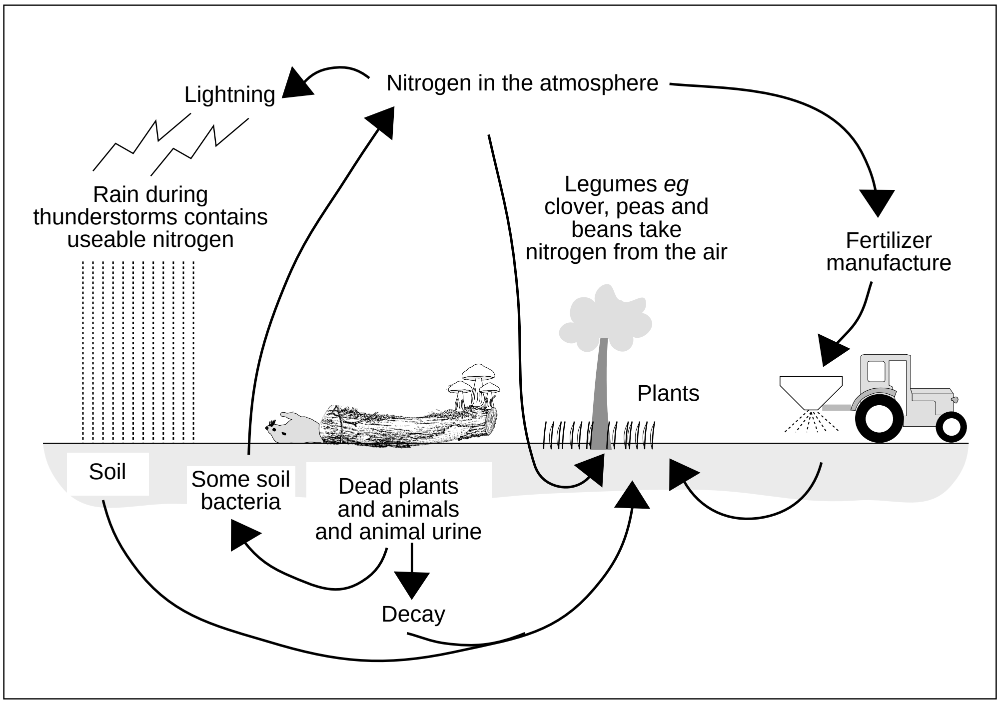

Figure 1A.2 Simplified nitrogen cycle

Challenge 1

Visit a garden centre. Look at a packet of fertilizer for maturing tomato plants and note down the NPK ratio shown on the packet. Find a fertilizer for grass and one for flowers. Again note the NPK ratio. What conclusions can you draw from these three ratios?

'Organically grown - no chemicals used'

Although we think we know what this phrase means, if taken literally it is misleading. What the producers should tell us is the form in which the chemicals are available. There are three types of fertilizer: 'organic', 'natural' and 'chemical'. ALL three release essential chemicals into the soil for plants to use (see figure 1A.3).

Natural and chemical fertilizers do not provide humus. Although organic fertilizers generally contain some humus, the amounts are often low and additional humus is often required. Most general fertilizers are marked with the plant food ratio of the major components in the order N (nitrogen), P (phosphorus as phosphate) and K (potassium as potash). This is known as the NPK ratio or number.

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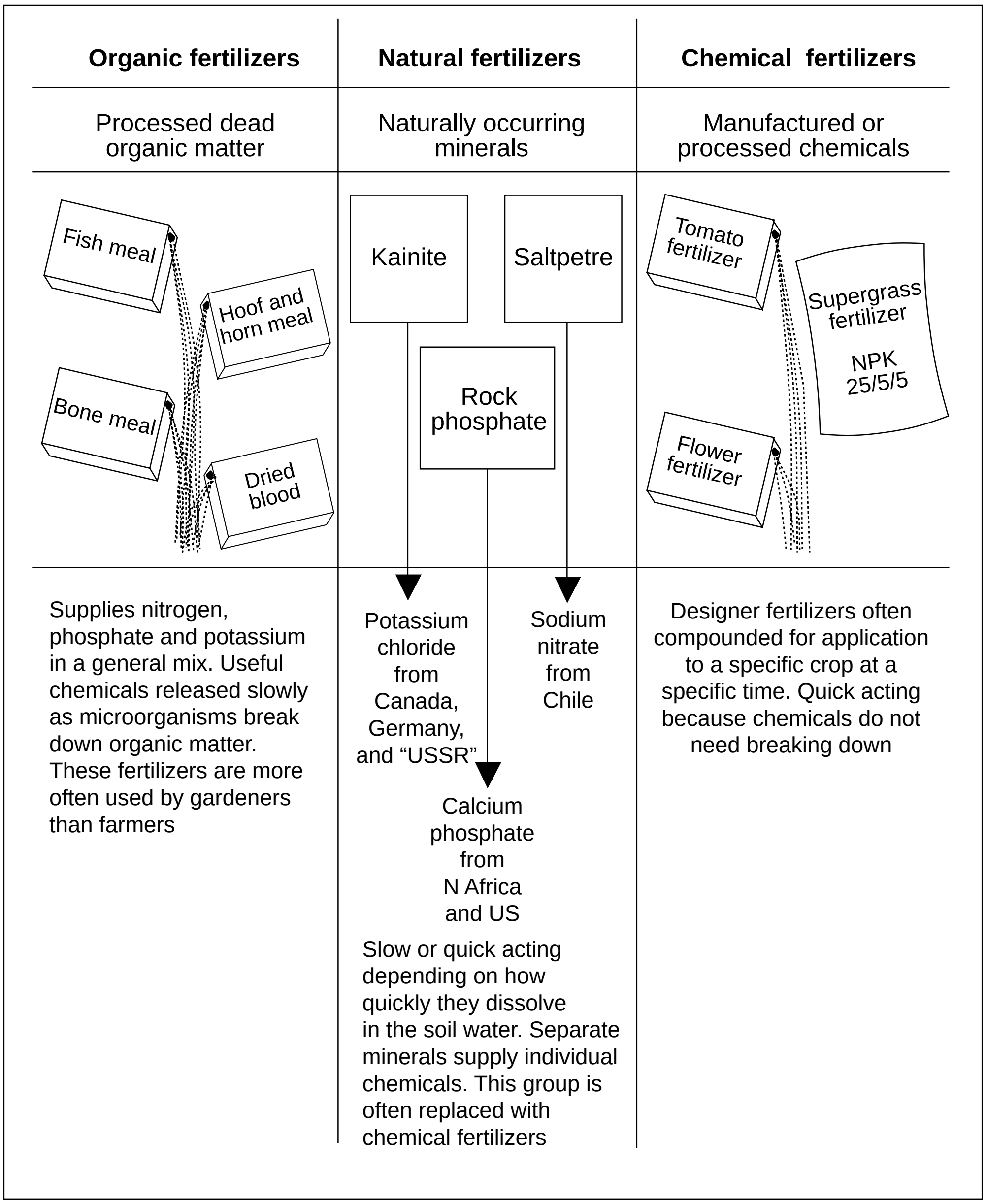

Figure 1.A3 Fertilizers

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10B. Making new materials

- In everyday living we use many chemical reactions.
- Chemicals are sometimes used to bring about physical changes.
- Nature uses microorganisms to carry out many of its chemical reactions.
- Chemical reactions always involve either the input or release of energy.
- One important type of chemical reaction is the changing of metal compounds found in ores to the pure metal.

Washing me, washing you?

It is sometimes difficult for people to appreciate that chemical reactions play such a fundamental part in our everyday lives. Somehow, the idea of a chemical reaction brings to mind awful smells, newspaper headlines of pollution, tall chimneys billowing out smoke and things we don’t understand. In fact many of the former are incorrect. The vast majority of chemical reactions are undertaken by us as we go about our everyday lives without us even noticing them. And, in fact, as a society, we are accomplished chemists, although we don’t think in that manner.

In this section three examples illustrate different types of reaction. The action of soap shows how a chemical can bring about a change in physical conditions. Making yoghurt shows how microorganisms can bring about chemical reactions and the production of iron illustrates the more traditional view of a chemical reaction.

When we wash ourselves or our clothes we are using a physical change not a chemical reaction. In soap, their are two parts. One part makes the soap particle dissolve in the water, the other part is responsible for dissolving the dirt (see figure 10B.1).

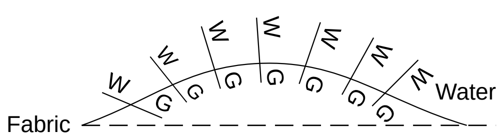
However, when it comes to removing stains we might resort to a bleach. Common bleaches contain either a chemical called chlorine or sulphur dioxide as their active ingredient. They work by reacting chemically with the offending stain, to change it and remove it from the article. This is a chemical reaction not a physical change (see chapter 9A).

How soap works

(i) In a soap and water wash, each soap molecule has a water loving end, (W) and a grease loving end (G)

W ----------- G

(ii) When soap molecules contact a grease spot, the grease loving end of the molecule attaches itself to the spot with the water loving end sticking out.



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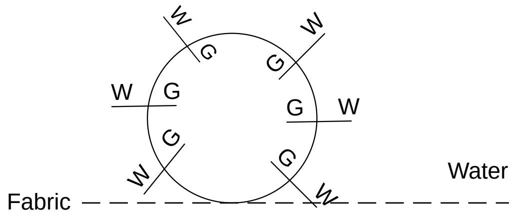
How soap works… continued

(iii) This happens all over the spot and so the grease is surrounded by a film of soap molecules with their water loving ends sticking out.



(iv) With agitation by hand or from a washing machine, the grease droplet, surrounded by a soap film, is released. Since oil is lighter than water the droplet floats off the fabric. The soap solution must also keep the particles suspended so that they do not drop back again on to the fabric.

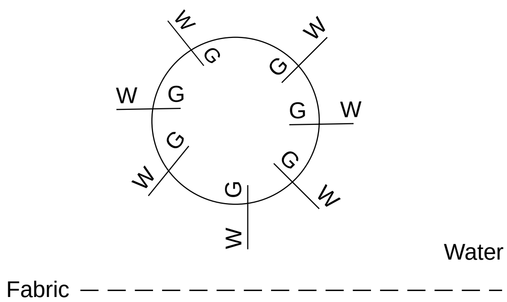


Figure 10B.1 Washing with soap

Food for thought?

A very commonplace use of a chemical reaction which is utilised in nature is the making of yoghurt.

Challenge 61

Make some yoghurt. You will need: 500 ml UHT or one pint of ordinary fresh milk. Fresh, live ie not pasteurised, plain yoghurt. Dried milk powder like 'Marvel', a non-stick saucepan, tablespoon, thermometer, Thermos type flask. (Instead of the Thermos flask use a 'yoghurt maker' if you have one. A warm airing cupboard might do.)
You must work with clean equipment in a clean area.

Procedure:
(i) If you are using ordinary fresh milk, bring one pint to the boil and allow it to cool. Remove any skin which forms.
(ii) Heat 500 ml of UHT milk, or the one pint of milk already boiled and cool, to 43 ^{0}C. (Do not heat beyond this temperature, if the temperature does rise allow to cool before starting stage iii.)
(iii) [a] For firm yoghurt, mix in 50 g of dried skimmed milk powder eg 'Marvel'.
[b] Mix in one level tablespoon of plain yoghurt.
(iv) Pour the mixture into a pre-warmed heat retaining flask. Seal and leave for 7 hours.
(v) Pour the yoghurt into a basin. Stand the basin in cold water and stir the yoghurt gently.

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(vi) Cover the basin and place in refrigerator for 4 hours to cool and thicken further.

Your yoghurt will keep in a refrigerator for 4-5 days. Adding a small amount of marmalade creates a pleasant flavour but only add this just before you eat the yoghurt otherwise the marmalade tends to separate.

What makes milk 'yog'?

Basically it is the effect of chemicals produced by bacteria on the milk. In ordinary yoghurt there are two types of harmless bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus.* With warm conditions and plenty of food the bacteria multiply and release chemicals including acetaldehyde (ethanal). This gives yoghurt its characteristic flavour. Chemicals including lactic acid released by *lactobacilli* result in the breakdown of milk protein and the release of peptides. This encourages the *streptocci* to produce formic acid and carbon dioxide and this helps create acid conditions (pH 4.4-4.6) which in turn causes milk protein to be coagulated. At the end of the incubation the two organisms are present in about equal proportions. Continued incubation encourages *Lactobacillus bulgaricus* to produce more lactic acid which imparts a more acidic taste to the yoghurt.

The coagulation of the protein and the acidic conditions created help preserve the yoghurt for a longer period of time than ordinary milk. If acidic conditions are prevented by adding sodium hydrogencarbonate (sodium bicarbonate) at stage (iii), the milk will not 'yog'.

For the 'yoghurt reaction' to work the microorganisms must be alive and healthy. They must be warm enough to be active *ie* warm enough for chemical reactions to take place within them. They must also have plenty of food from which to obtain energy, together with the chemicals needed for growth and reproduction.

Energy needed?

It is nearly always necessary to supply energy to a chemical reaction to get it going. You may not even realise that you are doing it. In the case of a chemical reaction which occurs at room temperature the energy is coming from the room itself. More commonly you need to supply vast amounts of energy. This is particularly true when the chemical element iron is obtained from its ore.

Challenge 62

Take three nails and put them into three jars with screw top lids. Half fill one jar with water, fill a second jar to the same level with water and this time add a teaspoon of salt. In the third place the nail on its own. Put on the lids. Which one rusts the quickest? Does the result surprise you? It's the reason why you should always wash your car if you've been near the seaside.

In air, iron will slowly react with the water and the oxygen to form a new compound, hydrated iron oxide. It will come of no surprise to you to learn that the chemical element iron does not occur in nature in its pure form. Iron is found combined with other chemical elements in chemical compounds which we call ores. These ores are not much use to us, but iron is because we can use it to make steel, a substance used in everyday life.

Iron, used to make steel, is extracted in a blast furnace. In fact iron was one of the first metals to be extracted by humans, hence the title 'iron age'.

Operation iron – how a blast furnace works

The blast furnace is used to convert iron ore into iron. Iron ore (haematite) contains 'iron oxide' and this material together with coke (carbon) and limestone (calcium carbonate) is loaded into the top of the furnace by conveyor belt or skip on a

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continuous basis.

Inside the furnace a chemical reaction takes place. Hot air (containing oxygen) is blasted into the already hot furnace. The oxygen in the air reacts with the coke to produce carbon monoxide.

coke + oxygen in air ⟶ carbon monoxide
(reaction A)

This reaction gives out a lot of heat and the gas carbon monoxide reduces the iron oxide in the ore to metallic iron. Carbon monoxide does this by joining with the oxygen in the iron oxide to form carbon dioxide leaving molten iron (reaction B).

carbon monoxide + 'iron oxide' ⟶ carbon dioxide + iron
(reaction B)

The molten iron is drained or tapped off from time to time and run into moulds. When the mould is full and slightly overflowing it resembles a mother pig with a row of teats and became known as pig iron.

Limestone is used in the furnace to remove impurities by combining with them to form slag. When heated, calcium carbonate turns to calcium oxide and this combines with the sand (an impurity in the ore) to form 'slag'.

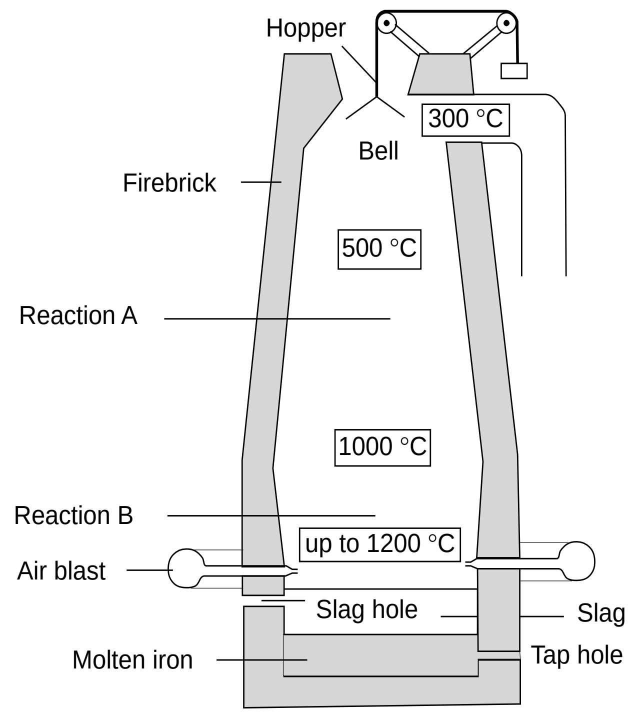

Figure 10B.2 The blast furnace

Challenge 63

One interesting property of iron, or substances that contain a lot of iron (steel) is that they are attracted by a magnet. Make a list of the things in your home that are magnetic. Of those things which are magnetic and are kept outside (ie bicycle), why are they painted? What has happened to the parts where the paint has been scratched?