CHAPTER I

WHAT IS THE SOIL MADE OF?

APPARATUS REQUIRED.* Soil and subsoil from a hole dug in the garden. Clay. Two tripods and bunsen burners or spirit lamps. Two crucibles or tin lids and pipe-clay triangles. Four jars or gas cylinders. Two beakers.

If we talk to a farmer or a gardener about soils he will say that there are several kinds of soil—clay soils, gravel soils, peat soils, chalk soils, and so on—and we may discover this for ourselves if we make some rambles in the country and take careful notice of the ground about us, particularly if we can leave the road and walk on the footpaths across the fields. When we find the ground very hard in dry weather and very sticky in wet weather we may be sure we are on a clay soil, and may expect to find brick yards or tile works somewhere near, where the clay is used. If the soil is loose, drying quickly after rain, and if it can be scattered about by the hand like sand on the seashore, we know we are on a sandy soil and can look for pits where builder's sand is dug. But it may very likely happen that the soil is something in between, and that neither sand pits nor clay pits can be found; if we ask what sort of soil this is we are told it is a loam. A gravel soil will be known at once by its gravel pits, and a chalk soil by the white chalk quarries and old lime kilns, while a peat soil is black, sometimes marshy and nearly always spongy to tread on.

We want to learn something of the soil round about us, and we will begin by digging a hole about 3 feet deep to see what we can discover. At Harpenden this is what the scholars saw: the top 8 inches of soil was dark in colour and easy to dig; the soil below was reddish brown in colour and very hard to dig; one changed into the other so

* The numbers represent the requirement when the experiments are done by the teacher alone or by one group of scholars.

quickly that it was easy to see where the top soil ended and the bottom soil began; no further change could, however, be seen below the 8-inch line. A drawing was made to show these things, and is given in Fig. 1. You may find something quite different: sand, chalk, or solid rock may occur below the soil, but you should enter whatever you see into your note-books and make a drawing, like Fig. 1, to be kept for future use. Before filling in the hole, some of the dark-coloured top soil, and some of the lighter coloured soil lying below (which is called the SUBSOIL), should be taken for further examination; the two samples should be kept separate and not mixed.

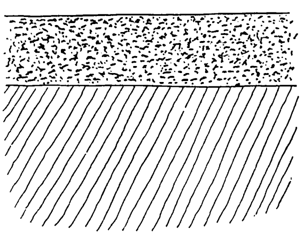


Fig. 1. Soil and subsoil in St George's school garden.

First look carefully at the top soil and rub some of it between your fingers. We found that our sample was wet and therefore contained water; it was very sticky like clay and therefore, presumably, contained clay; there were a few stones and some grit present and also some tiny pieces of dead plants—roots, stems or leaves, but some so decayed that we could not quite tell what they were. A few pieces of a soft white stone were found that marked on the blackboard like chalk.* Lastly, there were a few fragments of coal and cinders but, as these were not a real part of the soil, we supposed they had got in by accident. The subsoil was also wet and even more sticky than the top soil; it contained stones and grit, but seemed almost free from plant remains and from the white chalky fragments.

* Later on we found other soils that did not contain these white fragments.

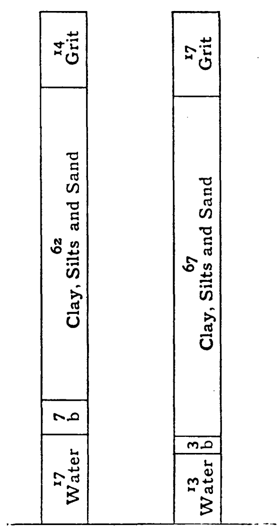
A few experiments will show how much of some of these things are present. The amount of water may be discovered by weighing out 10 grams of soil, leaving it to dry in a warm place near the fire or in the sun, and then weighing it again. In one experiment the results were:

Weight of top soil before drying	10 grams	= 100 decigrams
Weight of top soil after drying	8·3 grams	= 83 decigrams
Water lost	1·7 grams	= 17 decigrams

A column 100 millimetres long was drawn to represent the 100 decigrams of soil, and a mark was drawn 17 millimetres up to show the amount of water (see Fig. 2).

Weight of bottom soil before drying	10 grams	= 100 decigrams
Weight of bottom soil after drying	8·7 grams	= 87 decigrams
Water lost	1·3 grams	= 13 decigrams

Another column should be drawn for the subsoil. On drying the soil it becomes lighter in colour and loses its stickiness, but it has not permanently changed, because as soon as water is added it comes back to what it was before.



Surface soil Subsoil

b stands for the part that burns away

Fig. 2. Columns showing what 100 parts of surface soil and subsoil were made of.

The dried lumps of soil are now to be broken up finely with a piece of wood, but nothing must be lost. It is easy to see shrivelled pieces of plant, but not easy to pick them out; the simplest plan is to burn them away. The soil must be carefully tipped on to a tin lid, or into a crucible, heated over a flame and stirred with a long clean nail or bradawl. First of all it chars, then there is a little sparkling, but not much, finally the soil turns red and does not change any further no matter how much it is heated. The shade of red will at once be recognized as brick red or terra cotta; indeed 'terra cotta' means 'baked earth'. When the soil is cold it should be examined again; it has become very hard and the plant remains have either disappeared or have changed to ash and crumble away directly they are touched. On weighing, a further loss is discovered, which was in our experiment:

Weight of dry top soil before burning	83 decigrams
Weight of dry top soil after burning	76 decigrams
The part that burnt away weighed	7 decigrams
Weight of dry subsoil before burning	87 decigrams
Weight of dry subsoil after burning	84 decigrams
The part that burnt away weighed	3 decigrams

These results are entered on the column in Fig. 2.

The surface soil is seen to contain more material that will burn away than the subsoil does. When the burnt soil is moistened it does not become dark and sticky like it did before, it has completely changed and cannot be made into soil again. It is more like brick dust than soil.

For further experiments we shall want a fresh portion of the original soil.

On a wet afternoon something was noticed that enabled us to get a little further with our studies. The rain water ran down a sloping piece of ground in a tiny channel it had made; the streamlet was very muddy, and at first it was thought that all the soil was washed away. But we soon saw that the channel was lined with grit, some of which was moving slowly down and some not at all. GRIT can therefore be separated from the rest of the soil by water.

This separation can be shown very well by the following experiment. Rub 10 grams of finely powdered soil with a little water (rain water is better than tap water), keep it still for 10 seconds,* then carefully pour the muddy liquid into a large glass jar. Add more

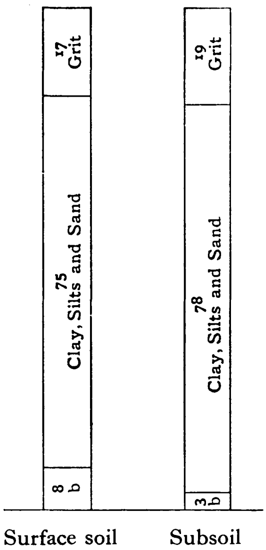
* Instead of using a watch you can adopt a device often used by photographers: say at ordinary conversational speed '1 little second, 2 little seconds...' up to '10 little seconds' and with a little practice this takes approximately 10 seconds.

water to the rest of the soil, shake, pause for 10 seconds, and again pour the liquid into the jar; go on doing this till the jar is full. Then get some more jars and still keep on till the liquid is no longer muddy but nearly clear. The part of the soil that remains behind and will not float over into the jars is at once seen to be made up of small stones, grit, and sand. Set the jars aside and look at them after a day or so. The liquid remains muddy for some time, but then it clears and a thick black sediment gathers at the bottom. If now you very carefully pour the liquid off you can collect the sediments: they are soft and sticky, and can be moulded into patterns like clay. In order to see if they really contain clay we must do the experiment again, but use pure clay from a brick yard, or modelling clay, instead of soil. The muddy liquid is obtained as before, it takes a long time to settle, but in the end it gives a sediment so much like that from the soil, except in colour, that we shall be safe in saying that the sediments in the jars contain the CLAY from the soil. And thus we have been able to separate the sticky part of the soil—the clay—from the gritty or sandy part which is not at all sticky. We may even be able to find out something more. If we leave the soil sediment and the clay sediment on separate tin lids to dry, and then examine them carefully we may find that the soil sediment is really a little more gritty than the clay. Although it contains the clay, it also contains something else.

When the experiment is made very carefully in a proper way this material can be separated from the clay and divided into fine sand, and a still finer material called SILT. But these divisions are not sharp: the coarse sand shades off into the fine sand, the fine sand shades off into the silt, and the silt into the clay. Between the clay and the sand there are great differences, though it would be impossible to say exactly where clay ends and silt begins.

If there is enough grit it should be weighed: we obtained 14 decigrams of grit from 10 grams of our top soil and 17 decigrams from

10 grams of bottom soil. We cannot separate the clay from the silt, but when this is done in careful experiments it is usually found that the subsoil contains more clay than the top soil. We should of course expect this because we have found that the subsoil is more sticky than the top soil. These results are put into the columns as



b stands for the part that burns away

Fig. 3. Columns showing what 100 parts of dried surface soil and subsoil were made of.

before so that we can now see at once how much of our soil is water, how much can burn away, how much is grit, and how much is clay and other things.

What would have happened if the sample had been dug out during wetter or drier weather? The quantity of water would have been different, but in other respects the soil would have remained the same. It is therefore best to avoid the changes in the amount of water by working always with 10 grams of *dried* soil. The results we obtained were:

	Top soil	Subsoil
Weight of dry soil before burning	100	100 decigrams
Weight of dry soil after burning	92	97 decigrams
The part that burned away weighed	8	3 decigrams
Weight of grit from 10 grams of dried soil	17	19 decigrams

The columns are given in Fig. 3.

SUMMARY. The experiments made so far have taught us these facts:

1. Soil contains water, grit or sand, silt, clay, and a part that burns away; some soils also contain white chalky specks.

2. The top layer of soil to a depth of about 8 inches is different from the soil lying below, which is called the subsoil. It is less sticky, easier to dig, and darker in colour. It contains more of the material that burns away, but less clay than the subsoil.

3. When soil is dried it is not sticky but hard or crumbly; as soon as it is moistened it changes back to what it was before. But when soil is burnt it completely alters and can no longer be changed back again.

CHAPTER II

MORE ABOUT THE CLAY

APPARATUS REQUIRED. Clay about 6 lb.; a little dried, powdered clay; sand, about 6 lb. Two glass jars or cylinders. One beaker. One egg-cup. Two funnels and stands. Two perforated glass or tin disks. Two glass tubes. Two tubulated bottles fitted with corks. Some seeds. Two small jars about 2 inches × 1 inch. Bricks. The apparatus in Fig. 9. Pestle and mortar.

We have seen in the previous chapter that clay will float in water and only slowly settles down. Is this because clay is lighter than water? Probably not, because a lump of clay seems very heavy. Further, if we put a small ball of clay into water it at once sinks to the bottom. Only when we rub the clay between our fingers or work it with a stick—in other words, when we break the ball into very tiny pieces—can we get it to float again. We therefore conclude that the clay floated in our jars (p. 4) for so long, not because it was lighter than water, but because the pieces were so small.

Clay is exceedingly useful because it can be moulded. Dig up some clay, if there is any in your garden, or procure some from a brick works. You can mould it into any shape you like, and the purer the clay the better it acts. Enormous quantities of clay are used for making bricks. Make some model bricks about an inch long and half an inch in width and depth, also make a small basin of about the same size, then set them aside for a week in a warm, dry place. They still keep their shape; even if a crack has appeared the pieces stick together and do not crumble to a powder.

If you now measure with a ruler any of the bricks that have not cracked, you will find that they have shrunk a little and are no longer quite an inch long. This fact is well known to brickmakers; the moulds in which they make the bricks are larger than the brick is wanted to be. But what would happen if instead of a piece of clay 1 inch long you had a whole field of clay? Would that shrink also, and, if so, what would the field look like? We can answer this question in two ways; we may make a model of a field and let it dry, and we can pay a visit to a clay meadow after some hot, dry weather in summer. The model can be made by kneading clay up under water and then rolling it out on some cardboard or wood as if it were a piece of pastry. Cut it into a square and draw lines on the cardboard right at the edges of the clay. Then put it into a dry warm

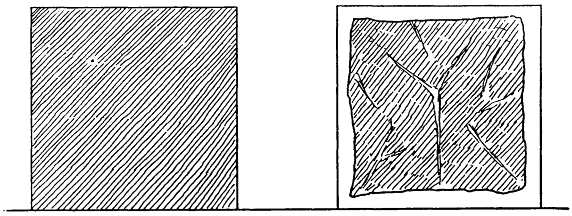


Fig. 4. Clay was plastered over a square piece of board and completely covered it. After drying for a week the clay had shrunk and cracked.

place and leave for some days. Fig. 4 is a picture of such a model after a week's drying. The clay has shrunk away from the marks, but it has also shrunk all over and has cracked. If you get an opportunity of walking over a clay field during a dry summer, you will find similar but much larger cracks, some of which may be 2 or 3 inches wide, or even more. Sometimes the cracking is so bad that the roots of plants or of trees are torn by it, and even buildings, in some instances, have suffered through their foundations shrinking away. We can now understand why some of our model bricks cracked. The cracks were caused by the shrinkage just as happens with our model field. As soon as the clay becomes wet it swells again. A very pretty experiment can be made to show this. Fill a glass tube or an egg-cup with dry powdered clay, scrape the surface level with a ruler, and then stand it in a glass jar full of rain water so that the whole is completely covered. After a short time the clay begins to swell and forces its way out of the egg-cup as shown in Fig. 5, falling over the side and making quite a little shower. In exactly the same way the ground swells after heavy rain and rises a little, then it falls again and cracks when it becomes dry. Darwin records some careful measurements in a book called *Earthworms and Vegetable Mould*—'a large flat stone laid on the surface of a field sank 3·33 millimetres* whilst the weather was dry between 9 May and 13 June, and rose 1·91 millimetres between 7 and 19 September of the same year, much rain having fallen during the latter part of this time. During frosts and thaws the movements were twice as great.'

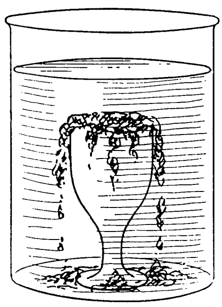


Fig. 5. Clay swelling up when placed in water and overflowing from the egg-cup into which it was put.

You must have found out by now how very slippery clay becomes as soon as it is wet enough. It is not easy to walk over a clay field in wet weather, and if the clay forms part of the slope of a hill it may be so slippery that it becomes dangerous. Sometimes after very heavy rains soil resting on clay on the side of a hill has begun to slide downwards and moves some distance before it stops. Fortunately these LAND SLIPS, as they are called, are not common in England, but they do occur. Fig. 6 shows one in Devonshire, and another is described by Gilbert White in *The Natural History of Selborne*.

Another thing that you will have noticed is that anything made of clay holds water. A simple way of testing this is to put a round piece of tin perforated with holes into a funnel, press some clay on to it and on to the sides of the funnel (Fig. 7), and then pour on rain water. The water does not run through. Pools of water may lie like

* A little more than one-eighth of an inch.