GROUND WORK

Practical Ways of Learning about Soils

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for Leicestershire Museums,
Art Galleries and Records Service.

Digging In.

What does soil mean to you? Look out of the window. Can you see any flowers or shrubs or trees? They must be growing in something. Can you see a playing field or a park? There is soil under the grass. Can you see any farmland or gardens or allotments? They all depend on soil.

After trying out the ideas suggested in this booklet, you should be well on the way towards appreciating soil for what it really is. It is not just the boring brown stuff that is so hard to dig in the garden nor the wet, slidey mess in front of a goal post. It is not just a support in which plants can stand up but a whole world in its own right. It has a complex of components and processes going on within it and a mass of inhabitants of which few people are aware. This booklet is to help you look inside this secret world.

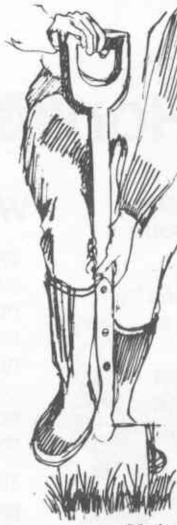
Soil does not stop in the first few inches below the ground; its activities extend down to the rock beneath. It is very important to try to understand how it all works because the delicate balance of water, air, minerals and living and dead organic matter in soil is easily destroyed. Soil is under attack from all sides. Consider these threats, even if they are unintentional; increasing numbers of people demand more food, stretching soil's productivity to its limit; more leisure time and more transport means more people trampling through the countryside; pollutants from irresponsible industries and careless agriculturalists; large areas swallowed up under estates, expanding towns and motorway construction; the possibility of contamination by nuclear radiation. Some of these threats may not be as serious as prophets of doom predict but some changes may be irreversible. To understand soil, you must work with it and in it, really get 'Down to Earth'.

If you want to dig a pit and study soil as a whole then carry straight on down this page. If you are going to look only at a sample of top soil from some 20cm in depth, then turn to page 5.

Digging a pit.

Avoiding any obvious humps and dips, look for some undisturbed ground that is either 'wild' or has had only traditional farming on it. Are you going to consider only a single pit or do you want to look at changes in a particular distance and so dig a series of pits? (See page 4)

What you will need is straightforward
- a trowel for tidying up the soil face. A penknife would do just as well;
- two large polythene dustbin bags or sheets of old newspaper;
- a metre ruler or tape measure.
- **a spade**

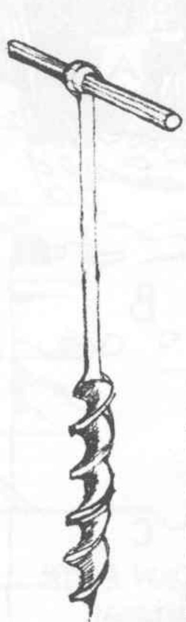


Getting down to earth...

How to dig the pit.

Make sure that there are no shallow underground pipes or electricity cables into which you might dig by accident.

1. First, **get permission** from the owner of the land, farmer, headmaster or park keeper. Explain that you are investigating soil and that you will **leave no trace afterwards**.
2. Since it is very important to be tidy and neat and put everything back when you have finished, spread out your poly bags or newspapers.
3. With the spade blade and the metre ruler, mark out with shallow cuts, a square of 1 metre by 1 metre.
4. Cutting with the spade firmly through the roots, lever off the top soil layer, whole if possible, with the plants still in place. Place this 'lid', intact, on one of the poly bags or newspapers, set aside
5. Dig out the underlying soil as deeply as you can until you can go no further either because you have reached the rock below, **no more than a metre**. Pile this soil onto the other sheet. Set aside.
6. Since you only need one good face of the pit, choose the one on which the light is best, that is, the sunny side. This is particularly important if you want to photograph the soil. Remember, if you do take a photograph, include a ruler for scale reference.
7. Clean up the side of the pit using a trowel or penknife. Make sure that it is free from smears of soil from above.
8. Stand back and take a good look at your handiwork. What you have in front of you is called the **Soil Profile,** a vertical section from the ground surface down to relatively unaltered rock beneath.
9. Complete the tasks outlined on pages 3 to 8.
10. When you have finished, carefully refill the pit with the sub soil and firm it down.
11. Replace the top soil and the plant lid, lowering it gently into position.
12. Look around to make sure that you have not left a mess, that all is as you found it.



If you have not got time to dig a pit, or if the ground has been so disturbed that it is not worth digging, then you may be able to borrow a soil auger from your School's Geography or Biology Department. This is like a giant corkscrew and is designed for obtaining samples of top soil and subsoil. Place the point on the ground and turn the auger clockwise, pushing down firmly as you do so; screw down until the top of the thread is level with the ground surface. Without turning the screw anymore, pull it up. There should be a coating of soil around the thread, unless conditions are very d or the soil is crumbly. Ease this sample off the auger and lay it gently onto a board or piece of plastic. Before you start augering, it is best to measure the depth of the screw thread and then mark off the auger stem with bands of tape into divisions of the same size. When you take your second and third samples from the same hole you will then be able to stop when the next piece of tape is level with the ground. Lay each successive sample beside the one before, in order, on your collecting board.

Broadening your Horizons.

Now that you have put a good deal of effort into digging your pit well, you can begin to make observations about the section or profile you have unearthed.

One of the most striking features could well be marked changes of colour in stripes or in gradual gradations as you look from top to bottom of the profile. Each different coloured layer is an **horizon.** An horizon is an approximately horizontal layer in the soil profile that is different from those above and below it in many ways; these differences may be chemical, biological or textural, not necessarily in colour although this is the most obvious.

The first step is to put in a marker at each point that you think there is a change in the colour, look and feel of the soil. Page 5 will help you here. Skewers, cocktail sticks, plant tags or old ice lolly sticks make suitable markers. Measure the vertical distance between your markers and you have measured the thickness of the horizons. A metre ruler is very helpful, leaning up against the face of the pit, as shown in the diagram below.

What can the horizons be called?

What can these horizons be called? Quite simply, it is often sufficient to call them top soil, subsoil and parent material. However, it can be interesting to look more closely. Different horizons can be called by different initial letters or horizon notations. On either side of the diagram below, there is a column which contains the definitions of the most common notations and each one is labelled in the appropriate place in the picture.

These are two sketches, made at the pits, to show two real profiles. Yours will not necessarily be like either of these, even if it is the same soil type, for there are so many variations. (See even in a local area – see page 6 for soil types. localized. However, both of these profiles are excellent examples on which to pick out different horizons.

On page 3 is a recording table on which you can write down your horizon details.

Soil Horizon Names.

Organic horizons

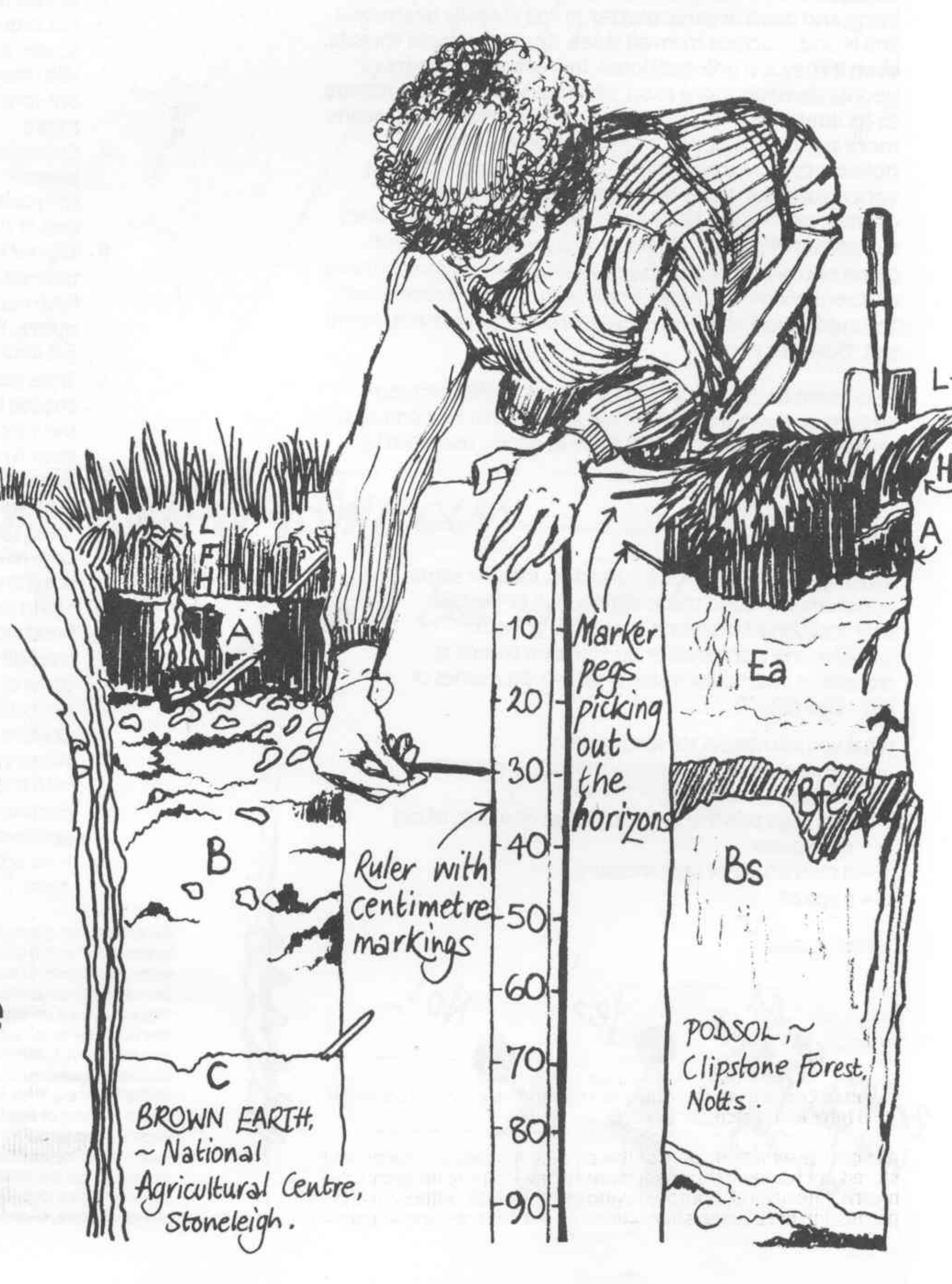
Leaf litter, hardly broken down so all parts recognizable; usually this is the layer added in the autumn.	L
Fermenting layer where the litter is decomposing and being broken down, comminuted, into smaller and smaller pieces, little bits of which are still recognizable as leaves, twigs, seed cases and bud scales.	F
Humus. No bits of plants recognizable. Generally dark brown in colour and spongy in feel. Thoroughly rotted organic material.	H
Peat. Black and soft. Found where it is nearly always wet. Peat is more than 25cm deep.	O

Mineral and Organic mixed horizons

Mineral horizon with well mixed-in humus.	A
Mineral horizon of altered parent material, not bleached or stained with iron redeposited from above.	B
Soft rock, little altered parent material. Extends downwards until the spade will not go any further.	C

Special terms

Where the A horizon has been ploughed.	Ap
Where the A horizon has been bleached pale or ash by rain water moving through it and washing out the coloured minerals.	Ea
A harder layer in the B horizon called an iron pan where minerals washed down from above have been redeposited. Usually more than 5mm thick and stained bright reddish orange, with darker, almost purple patches.	Bfe
Where the B horizon has greyish mottles and orange flecks. Usually cold and sticky. This is called gley and is the result of being always waterlogged.	Bg
Brightly coloured by iron and aluminium oxides moved down by water from above and redeposited.	Bs



Making a Good Record.

How to make a detailed record of your soil profile.

You will need
- A compass for measuring the aspect if the slope is more than 5 degrees.
- A clinometer for measuring slope angle
- A pH kit – see page 6 for instructions
- An Ordnance Survey map of the area, either 1:50,000 or 1:25,000 or more detailed if possible.
- A ruler, preferably a metre ruler
- Equipment for digging the pit – see page 1
- Writing implements
- A clipboard with copies of this table (below)
- A plastic bag to put over the clipboard and large enough to carry on writing it . . . good soil observers never stop in the rain.

The chart reproduced below is a table for recording your observations. It includes the very important site details as it is necessary to put your soil in the context of the scenery and surrounding landscape in which it has been formed. If your survey involves more than one soil pit or augering site, then you really do need to record the findings on identical charts so that it is easy to compare each part. In that way you can begin to draw conclusions about which factors might make the differences between your soils.

Read pages 4, 5, 6 and 7 before starting to fill in the tables

To measure **aspect** stand with your back to the slope, hold the compass horizontally and firmly against your abdomen, let the North needle steady itself, turn the compass housing so that the N (0°) lines up with the end of the North needle and then read the direction bearing in which you are facing. Any slope with an angle of **less than 5°** does **not** have an aspect as such since it does not face in any particular direction but up into the sky.

Soil Recording Sheet

Site Description	
Site number	Ordnance Survey map ref
Altitude in metres	Relief of the site
Slope angle	Aspect
Vegetation	Land use
Site drainage	Soil temperature °C
Depth in cm	Texture
pH of A horizon	pH of B horizon.
% Moisture	Organic

Profile Description

Horizon

Colour smears

Soils and Slopes.

When you come to fill in the recording sheet on page 3, you will see that some of the details asked for are not about the soil itself but about the **surroundings**, the vegetation, the slopes and the landscape. Soil does not exist just on its own but its development is greatly influenced by **relief**, the hills and valleys, which often closely follow the bedrock beneath. This **bedrock**, that is, the underlying rocks, does not always explain soil type because frequently there is a thick coating of clays or sands or rubble that has been **deposited** over the rock by **glaciers** during the last Ice Age, some 100,000 years ago. The **mineral content** of soil is not drawn from any great depth since the decay processes that make soil only operate within a few feet of the ground. Soil is related to the superficial deposit, not to the deeper rock.

Slope is an important influence on soil for it determines how water will **drain** through or over it and also how rapidly the soil will slide downhill.

The top diagram on this page shows how water behaves down a slope and the second one illustrates the thinning of a soil layer where the slope is steep and gravity makes the soil material **creep** down faster than it can be replaced. The third diagram shows some slope angles and gives some useful words for describing their relative steepness. People often badly misjudge the steepness of a slope, thinking, for example, that it is 40° when in fact it is only 18° or 19° **from the horizontal.** A really steep slope of about 35° can sometimes feel almost vertical! You can try this out. Choose a good steep hill; estimate by eye what angle you think that it is; measure it to see how wrong you are . . . then ask other people for their estimates, and see how much they over-calculate the angle.

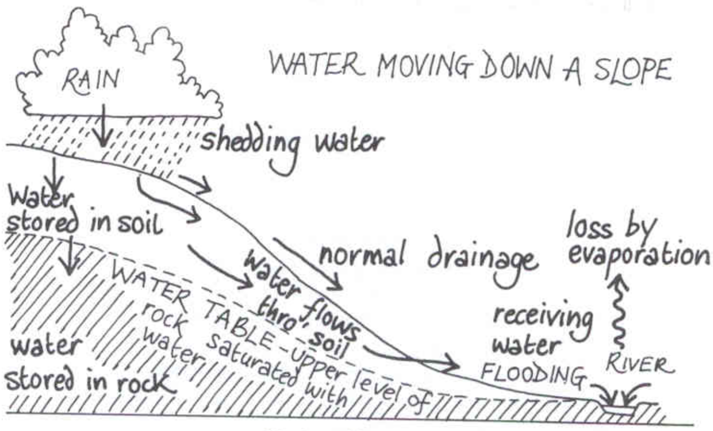
Getting a better angle.

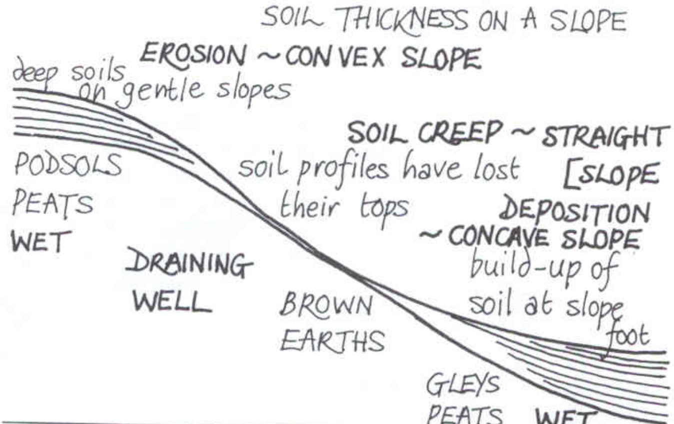
The best way of measuring slope angle is with a **clinometer** or an **abney level.** It is possible that your Geography or Geology Department may have these instruments. They are quite simple to use once you are accustomed to squinting along them and can keep a steady hand. However, it is very easy to make your own clinometer.

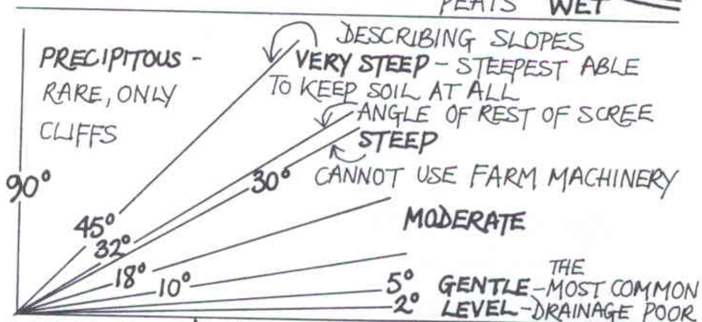
You will need

- a protractor
- a darning needle
- a candle and a box of matches
- a length of strong thread
- a heavy button or small weight.

The last picures on this page show you how to assemble these items and how then to use your clinometer or slope **(incline)** measure outside. Avoid a strong wind!

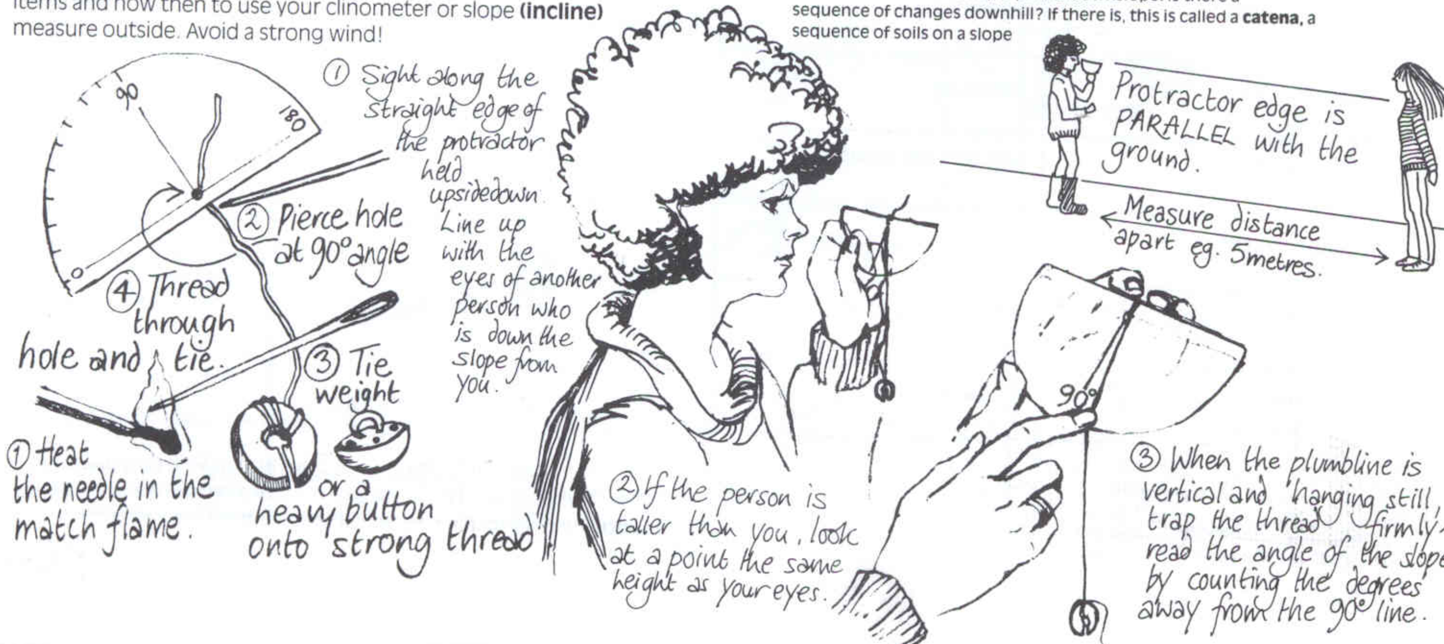






14°, 1 in 4 gradient ~ a car would struggle up in low gear.
18°, 1 in 3 gradient ~ a walk up this makes you really puff!!
45°, 1 in 1 gradient ~ looks vertical but isn't!

So, look around you, describe the scenery in which your soil is found. Make several sample points downslope. Is there a sequence of changes downhill? If there is, this is called a **catena**, a sequence of soils on a slope



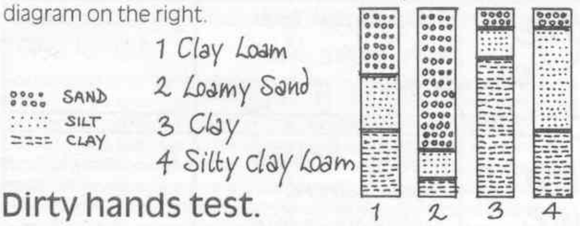
Taking the Rough with the Smooth.

If your hands are not already dirty, it is time to get to grips with your soil. **Texture** is another vital clue to the type of soil being examined. This texture has to be assessed by **feel.** Take a lump of soil in the palm of your hand and wet it until it glistens. If you have not got a bottle of water with you, do not be afraid to spit on it. On the page is a series of steps designed to help you find out what texture your soil has. Follow these steps carefully, seeing if you can make cubes, sausages or rings with the soil.

The texture of the soil is determined by the size of the particles it contains. Generally, particle sizes are put into three groups:

Sand	**2mm – 0.06mm**
Silt	**0.06mm – 0.002mm**
Clay	**Less than 0.002mm in diameter**

Obviously, with particles so small, it is impossible to measure them with a ruler. This is why we must rely on their feel. The common proportions of sand, silt and clay are illustrated in the diagram on the right.



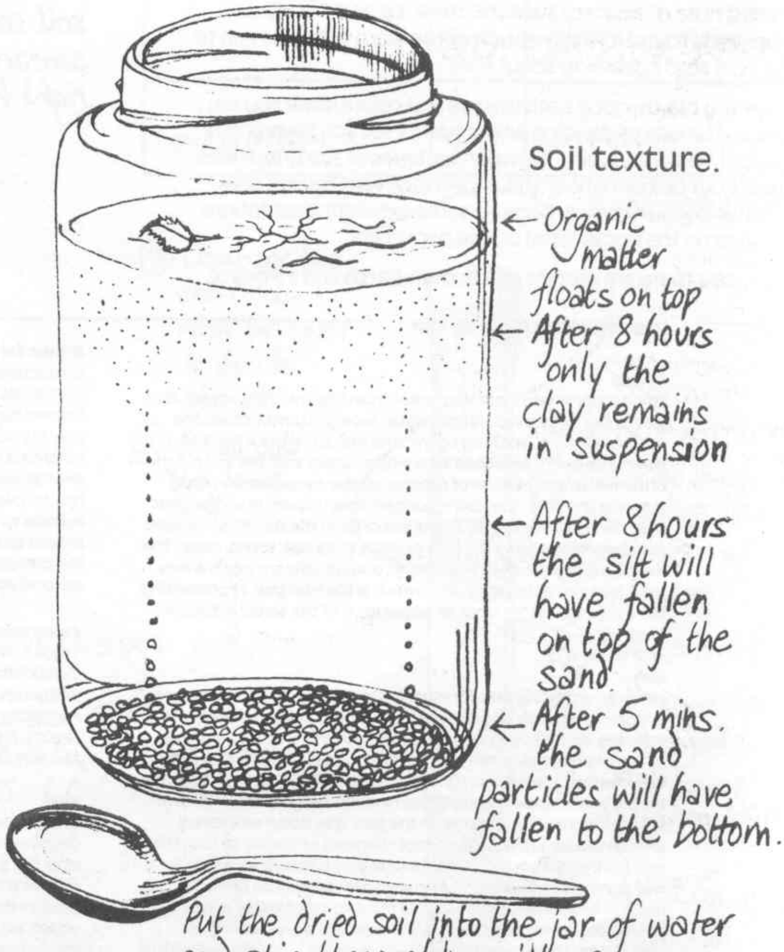
Dirty hands test.

A QUICK TEST FOR SOIL TEXTURE ON SITE

1. Can you roll the soil into a good ball?
   Easily? Go to q. 2
   Only with great care **LOAMY SAND** but check with q. 2 and 3.
2. What happens when you squeeze the ball between your finger and thumb?
   It flattens but does not crack Go to q. 3
   It breaks up **SANDY LOAM** but check with q. 3 and 4.
3. Wet it a little more, then, can you roll it into a sausage about 5mm thick?
   Yes Go to q. 4
   No, it falls to bits **LOAMY SAND.**
4. Wet it a little more. Can you now roll it into a thread about 5mm thick?
   Yes Go to q. 5
   No **SANDY LOAM.**
5. Can you bend the thread into a horseshoe shape without it cracking?
   Yes Go to q. 7
   No Go to q. 6.
6. Wet the soil again and then rub it between your thumb and forefinger. What does it feel like?
   Smooth and pasty **SILT LOAM**
   Rough and gritty **SANDY SILT LOAM.**
7. Can you make a small ring by joining the two ends of the thread without it cracking?
   Yes Go to q. 9
   No Go to q. 8.
8. Re-wetting it and rubbing between your thumb and forefinger, how does it feel?
   Very gritty **SANDY CLAY LOAM**
   Fairly rough **CLAY LOAM**
   Heavy and doughy **SILT CLAY LOAM.**
9. Roll it again but do not wet again and then try and polish a surface with your thumb.
   Yes, it will take a high polish fairly smoothly Go to q. 10
   Yes, it will take a polish but there are particles visible **SANDY CLAY.**
   No Go back to q. 8
10. Wet the soil again and try to get it to stick your fingers together.
   It sticks them together very strongly **CLAY**
   They stick, but not very firmly **SILTY CLAY.**

As you feel the soil, ask yourself, "Is it rough, rasping and gritty?" This is due to a high proportion of sand and you can almost hear the particles grating against each other. "Does it feel smooth, soft and silky?" This is due to a high proportion of silt. "Does it look and feel really fine and sticky, almost glueing the fingers together?" This is due to a high proportion of clay.

To follow on from these texture observations, there is a very simple method for sorting soil out into its constituent size fractions. All you need is a sample of dried soil, a jar, some water and a spoon. The picture at the bottom of the page explains how to use this **sedimentation** technique.



Soils are not just Brown.

Colour is a subtle and varied feature of soil for which you can develop a discerning eye.

By colour, one can distinguish the horizons, have a clue about the minerals that are present in the soil, gain some idea about the conditions under which the soil was formed, and deduce what processes are currently in action or tell from which rock type the soil has been derived. A soil scientist would be very accurate about the way in which he recorded the colour of the soil in his pit using a **Munsell Soil Colour Chart** which enables him to code an infinite variety of colours by hue, purity and darkness. Although fascinating, these charts are very expensive and it is sufficient to describe your soils in **simple** colour words.

On the right of this page there is a series of boxes. The left-hand column is for you to shade carefully in crayon, using the colour written inside it. You could obtain some paint colour cards from a DIY or home decorating shop and cut out those samples that answer to the description of the colours and stick them on.

Beside this column there is a brief outline of what this colour means as far as the soil is concerned. The right-hand boxes are for you to record soil colours that you have found in the field. The very best way in which to record the colour is to wet your finger, dab it in some fresh, moist soil and then firmly smear it on to the paper. (This is an excellent and exciting method for capturing the overall soil colour, but it is almost impossible to reproduce the mottles of grey and orange that occur in a waterlogged soil like a gley.) When you have smeared a box, make a note of what soil type you think it is and the place where you found it. The mention of the word **gley** leads on to the next step in learning about soils.

Once you can describe both texture and colour, then you are well on the way to deciding what **type** of soil you have got in front of you in your pit. The major soil types of the British Isles are set out on the right of this page. However, they are only summarized very simply because some excellent descriptions are given in the books listed on the back cover.

On page 2 there are profiles of a **Brown Earth** and a **Podsol.**

Common soil colours

black	probably peaty, rich in organic matter.	1
dark brown	well mixed humus with minerals.	2
ashen grey	bleached, iron washed out by water downwards.	3
blue - green	where often water logged ~ lack of oxygen.	4
orange-red	stained red with iron where there is plenty of oxygen.	5
yellow ochre	usually derived from parent material's colour.	6

Where I found these soil colours, smeared in the right-hand boxes.

1 ______

2 ______

3 ______

4 ______

5 ______

6 ______

COMMON SOIL TYPES IN BRITAIN

Podsol
This occurs where incoming water from high rainfall exceeds that lost to the air by evaporation. Water moves strongly down the profile. leaching. washing down , the iron from the A horizon, leaving its grains **bleached** ashy white. Above this, the soil is dark brown from a thick layer of organic matter decomposing only slowly in the cold. The iron is washed down mainly in winter in its blue **(ferrous)** condition. As the soil dries in the spring, so oxygen can enter the soil and the iron oxidises to its red, **ferric,** state. This makes the B horizon stained bright orange. Often there is a very hard, thin red or blackish layer which is the **iron pan,** representing the top of the water table, or upper level of the water in the soil, in spring.

Gley
When water movement is restricted in the soil, possibly because it is predominantly clay with only small pore spaces, then the air is kept out. Water has some oxygen in it but this is quickly used up by soil micro-organisms. This **deoxygenates** the soil water and the **stagnant** conditions turn iron compounds blue (ferrous). This means that the soil is tinged blue or grey. Very striking, however, are the vivid orange **mottles** in the gley that occur wherever oxygen can penetrate, down root channels or cracks, to turn the iron back into its orange state. A true gley is formed over thick clay parent materials. However, any soil type may be gleyed in one horizon or another, wherever the movement of water is impeded, so that there are gleyed podsols and gleyed brown earths. So, look out for those mottles!

Brown Earth
Characteristic of deciduous forests but by no means restricted to such areas. Litter layer decomposes rapidly and so the A horizon is stained dark brown. Main characteristic is that, since rainfall is not only moderate in areas where brown earths are formed, the A horizon is not bleached. However, many of the clay minerals have been **translocated,** washed down, and redeposited in the B horizon, which makes it **rich in clay** and so distinctive in texture. In areas where rainfall is low, then the clays will not have been moved down and so the horizon will only have those those things like calcium that are very soluble. Removal of calcium makes the soil acid and a typical pH is about 5. This is an **Acid Brown Earth.**

Calcareous soils
These form over rocks that contain a high proportion of calcium carbonate, like chalk or limestone, or where the calcium is washed out from limestone hills onto the land around. The test for calcium carbonate described on page 7 can have spectacular results. If the A horizon is rich in nutrients and crumbly when dry and soft in feel, then this is a rendzina, typical of chalk grassland.

Peat
In extremely wet and cold climates, common on mountains, decomposition of organic matter is almost impossible and so over the parent material there is a very deep layer, often several metres thick and always more than 40cm of black, soft, frequently sodden **fibrous** peat. This is like a sponge in the way that it holds water. Just take a handful, notice how cold it is, and squeeze out the red stained water!

Experimenting with Soil Chemistry.

How well will plants grow in soil? The answer to this question is quite a complex one but page 13 gives an outline of an experiment cultivating plants in different media. However, you still need to analyse the soil that you have exposed in your pit or unearthed with your auger. (If you are using an auger, then for the tests you will need a sample from at least 20cm down, **NOT** from the litter or humus layers.) The first thing to measure is the **Acidity** or **pH** of the soil in the A and B horizons. pH is a measure of the **concentration** of hydrogen ions in the soil water.

pH explained.

The chemistry of pH is quite involved but it is very clearly explained in two of the books mentioned on the back page, those by Briggs and by Courtney and Trudgill, so if you really want to know what it all means, read the appropriate chapters. In simple terms, water, for which the chemical formula is H_2O, sometimes tends to dissociate into two parts, H^+ ions and OH^- ions. pH measures the **proportion** of one to the other. The more H^+ ions there are, then the more **ACIDIC** is the soil; the more OH^- ions there are then the more **ALKALINE** it is.

On the right there is a chart which needs colouring in. The boxes are numbered from 3 to 9 and they are labelled with the colours that represent them in soil acid tests.

Look carefully at all the labels beside these boxes. Now think back to a few sentences ago. It was stated that the more hydrogen ions there are present then the more acidic is the soil, that is, there is a high percentage of hydrogen ions. But how do the pH numbers go? Is an acidic soil given a higher or a lower number? This is not a contradiction. Acidic values of pH appear lower because they are given the negative logarithms of the actual numbers of hydrogen ions which have unmanageable strings of decimal points. Hopefully, these technical details will not put you off the most colourful part of soil work; it is necessary to try to explain what otherwise seems like nonsense.

At what value is soil neutral, having an equal proportion of H^+ and OH^- ions? What pH is the optimum for plant growth?

Now to carry out the experiment. You will need the following:

1. A testube with a bung at each end.
2. A small spoon or spatula.
3. Barium sulphate, a white powder easily obtained from a Chemistry or Biology Department. (It is used because it combines with the fine clay particles and makes them heavier so that they will settle out of the liquid quickly. This is called **flocculation**
4. Soil Indicator liquid.
5. Distilled water.
6. Colour chart against which to check the finished results.

For suppliers of the chemicals, see back page. For the method, all the steps are illustrated in the diagram on the right.

A fizzical test.

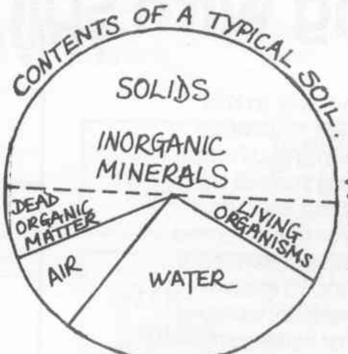
A second test looks at the calcium carbonate, $CaCO_3$ content of the soil. All you need is a small sample of soil and a plastic bottle of dilute hydrochloric acid Drop a little acid on the soil and then look and LISTEN. You might hear a faint spitting and see nothing happen, or you might hear a loud fizzing and see violent frothing. The little table on the right is the guide to calcium carbonate content using these signs. It is important to know the amount of calcium carbonate in the soil. Adding more lime to soil that is deficient increases the pH which improves it for plant growth. Also, lime tends to hold clay particles together making larger pore spaces and easier drainage.

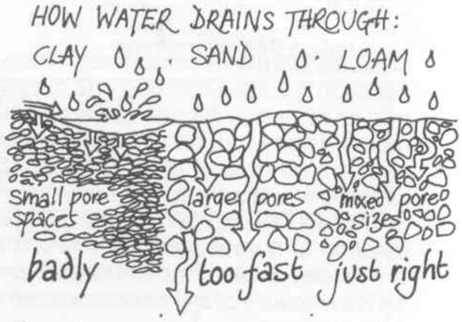
acid	pH 3	red
	4	pinky-red
	4·5	orange-red
	5·0	light orange
	5·5	golden yellow
best for plants	6·0	lemon yellow
	6·5	lime green
neutral	7·0	grass green
	7·5	emerald green
	8·0	blue-green
alkaline	9·0	blue

A colourful test.

CALCIUM CARBONATE CONTENT	REACTION
less than 0·1%	None
0·1–0·5%	Spitting heard slightly
0·5–1·0%	Spitting clearly heard
1–2%	" " and slight frothing seen
2–5%	Both clear and loud
5–10%	Vigorous noisy frothing

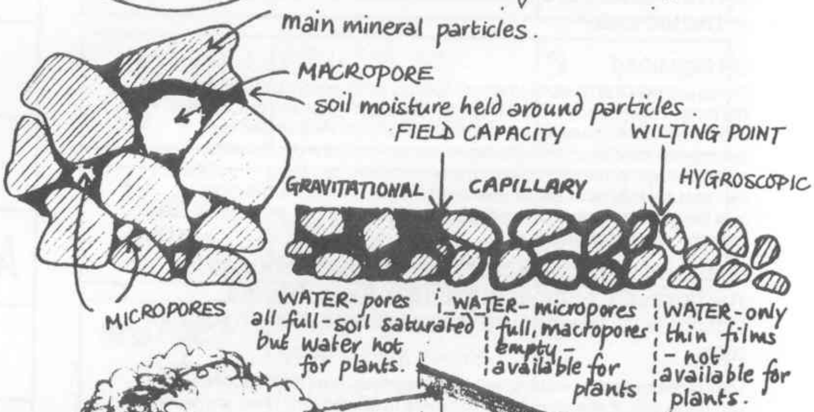
Water in the Soil.





On pages 5, 6 and 7, you have learned that soil is made up of minerals which influence its colour, acidity and texture. But what else is in soil? From the graph at the side it is clear that minerals account for 50% of the content of soil. What is the second most important component? It may seem surprising that it is water. And the third most important? Why, air! We can look at air and water together. The final ingredient, organic matter, will be considered on page 9.

Air and water can be taken together because they occupy the same spaces, the **pores** between the particles of soil. In the sketch of some soils in close-up at the side of this page, different sizes of pores are illustrated. Texture plays a vital part in the **draining** of the soil; in a sand, the pore spaces are large so that water runs through too fast. In a clay, the pores are so small that they are rapidly saturated with water and so **water-logged.** For ideal drainage, which is neither too fast nor too slow, a mixture of particle sizes is needed, approximately equal parts of sand, silt and clay. This mixed soil is called a **loam**.



There is always water in the soil, even in a serious drought. (Officially, a drought is 15 consecutive days without rainfall.) Plants will droop and die when the **wilting point** is reached. This is when the soil water is trapped as thin films around each grain, stuck on like a tightly held skin. This is **hygroscopic water** and is first of the three types of water in the soil. It is unavailable to plants' roots. The second kind of water is **capillary water** and is found in the **micropores.** This is mobile and can only move slowly so that plants have a chance to extract it. This water can also move upwards or sideways, not drawn by gravity.

The pull of the films of water round particles is strong enough to attract water from wetter to drier areas. This is **capillary action.** You can see it for yourself Next time you have a drink like tea or coffee, take a lump of sugar and hold it just above the surface of the liquid. As if by magic, the tea will move up into the sugar staining the white grains brown.

The third type of water is, like the first, unavailable to plants. Although the **macropores** fill up fast when it rains, and rain water **infiltrates** the soil, they also empty fast due to gravity. Thus this is called **gravitational water.** When the micropores are full and the macropores have emptied, then soil is said to be at **field capacity.** It ought not to be ploughed or dug when it is this wet since this can destroy the structure of soil. This is true of silty soils although clay soils may be ploughed wet in autumn and left over winter for the frost to break them up into a fine **tilth**.

Two experiments concerning water in the soil are outlined on this page. The first requires the **drying** of soil in an oven; the steps to calculate the **percentage moisture** are set out clearly. The second test is done outdoors, literally pouring water on to the soil to see how fast it will go in or infiltrate. The **infiltration rate** is a result of two things, how wet the soil was beforehand and its texture. As has already been pointed out, a coarse sand drains faster than a fine clay. Not only can the infiltration rate help you to compare soils, by calculating how much water will soak in in a given time, it is also very useful in assessing how eroded an area is. The more the soil is walked on the more compacted and 'water resistant' it is – the natural structure has been destroyed and the grains squashed together. Water runs over the surface and will not sink in at all. This concept is useful to bear in mind when looking at 'trampling' on page 12.

Drying the soil

Infiltration test.

1. Record the amount of water going into the soil every 30 secs. for 10 - 20 minutes.
2. Keep topping up the water in the pipe if level falls below 5cm.
3. Plotting time against amount of water that has gone into the soil in that time, you can draw line graphs to show changing rates.

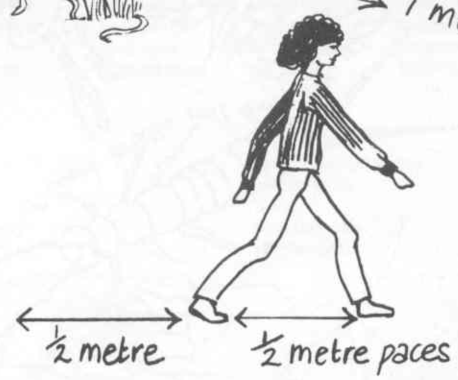
What lives in the Soil?

The web of creatures that inhabit the dark, damp world of the soil is intricate and minute. The pictures on the next page show just a tiny selection of the whole range. Those on the left are larger, easily seen and recognizable with the naked eye. These are the **mesofauna.**

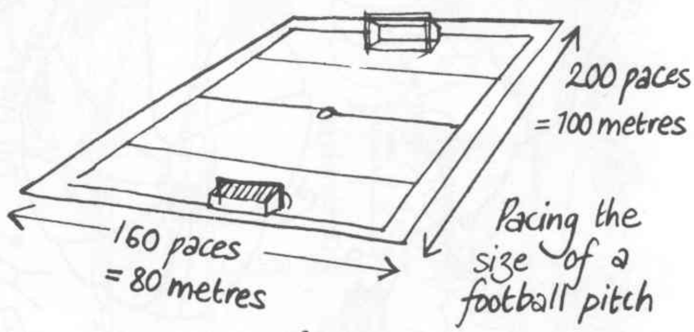
The organisms on the right are less familiar. They are drawn enlarged so that you can see them all. If you follow the second experiment, you can catch some for yourself, put them under a magnifying glass and draw them. (When you start to draw, do not worry too much about being accurate – try to capture what you see, the shape, texture or pattern.) These microscopic beings are called the **microfauna.** To give you some idea of size, a mole's nose is drawn to the same scale.

Counting worms.

Counting worms. This is an easy experiment to do on a nice warm day; avoid it when there is frost on the ground because you will kill the worms. On the lawn, playing field or meadow, mark out a square, 1 metre by 1 metre. Using a bucket of **warm not boiling** water, sprinkle the contents over the square. The wetting of the soil should force the worms up to the surface and you can catch them, collect them in a pot and then release them once you have finished your count.



Now you know how many worms there are in one square metre of your grass. How large is the lawn or field altogether? You may have to measure it, either with a tape or with great big paces, stretching your legs to a metre apart if you are tall, half a metre if you are not. Keep your paces the same size and you can then multiply the totals of the two sides (see drawing) and you will have the area. How many square metres is that? So . . . how many worms are there in the whole field? You will be surprised at the huge answer. Are worms important in the soil? What do you think they do to the soil?

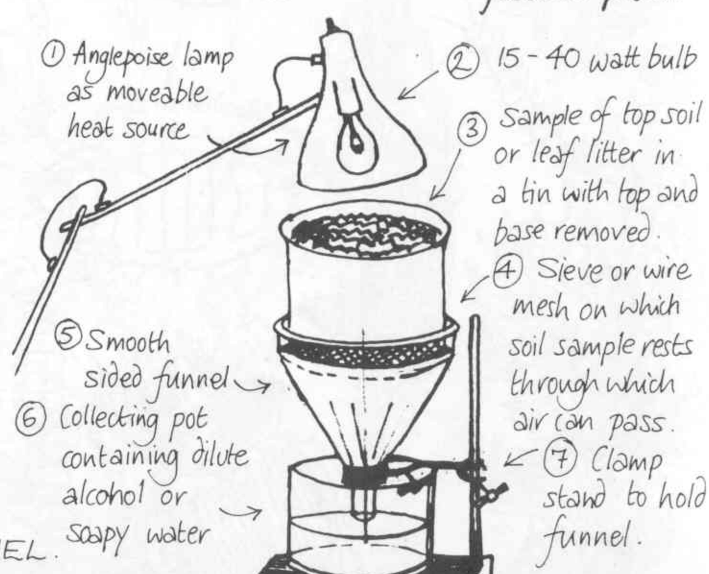


Pacing the size of a football pitch

Looking for micro-organisms in the soil

To do this, you need to collect all the items labelled in the diagram beside this paragraph and assemble them like the picture. **Warning** . . . do not get a bulb with a high wattage or you will roast the animals before they have a chance to escape from the soil. A bulb of between 15 and 40 watts is best.

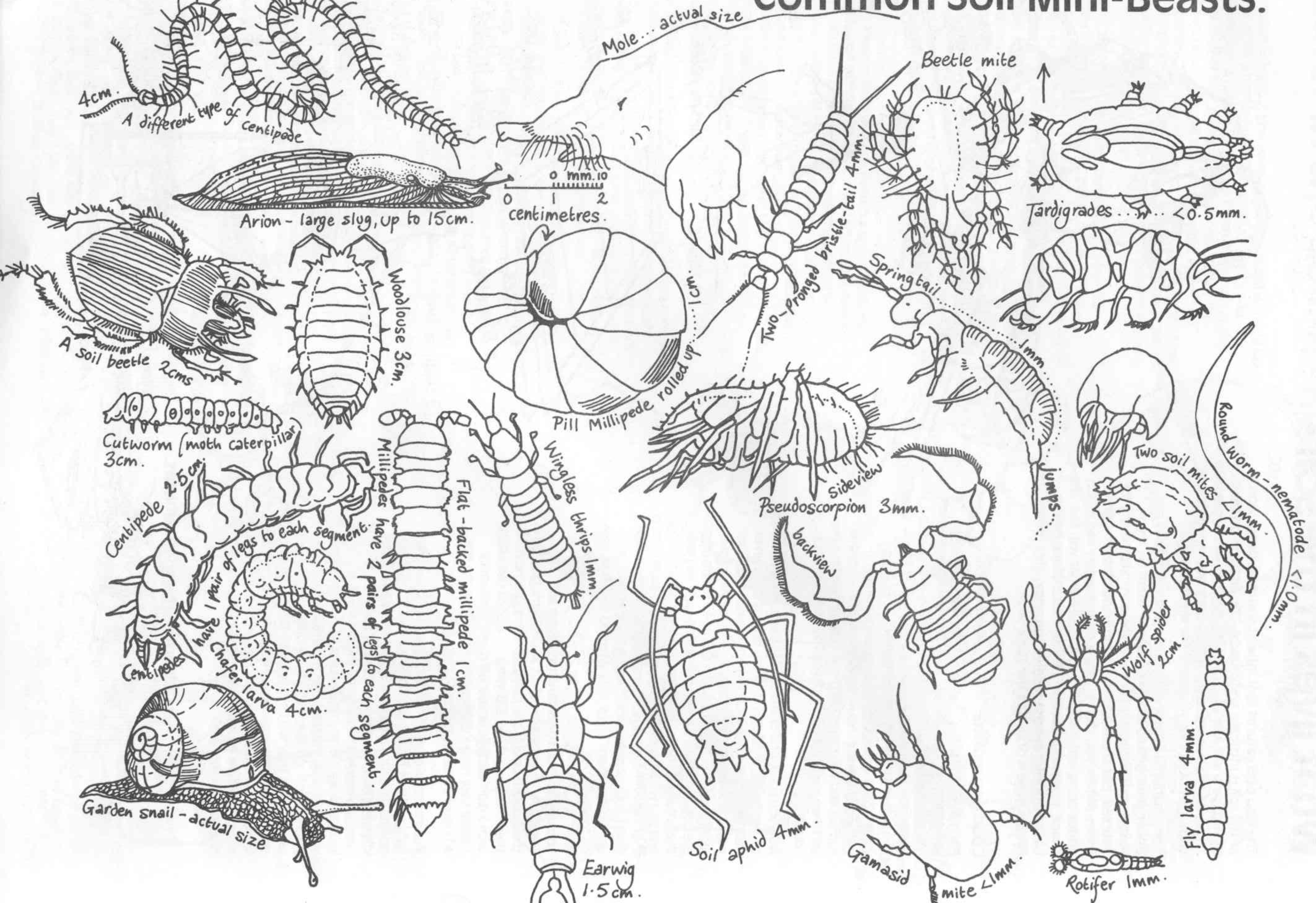
Put a handful of soil into the old tin, switch on the light and wait for the results. Since it usually takes several days for all the mini-beasts to emerge, start off with the light source a little way away and gradually move it nearer until the soil surface temperature is in the region of 30°C. This experiment works because the creatures move away from the heat of the lamp. Once they have fallen into the pot underneath, they will be preserved in the dilute alcohol or water with a little washing-up liquid in it. You will then be able to put them under a microscope and have a good look at them. What are your minibeasts like? Do they resemble any of the ones drawn here?



Looking for micro-organisms.

A SIMPLE TULLGREN FUNNEL.

Common Soil Mini-Beasts.



Types of Plant and Types of Soil.

If you refer back to page 7 then you can see that the acidity of a soil is an important characteristic to measure. Not only is it important in analysing what type of soil there is but also it helps to explain why certain species of plant are present and some are absent from an area. There are plants, such as buttercup and dandelion, that will grow in almost any soil, regardless of its acidity. The **optimum pH** for plant growth is **6,** but there are plants that will only thrive where it is pH 7 or 8 and yet others that will only tolerate pHs as low as 3, very acid soils indeed. Plants that do well where there is much calcium carbonate in the soil are called **Calcicoles,** 'Calcium lovers'. The list below of plants that only grow on chalk and limestone contains some of the best English examples of calcicoles. There are other flowers that simply will not survive on **calcic** (alkaline), soils and these are called by the opposite name, **Calcifuges** or 'Calcium haters'. Those plants that will tolerate only one sort of soil are known as **Indicators** because their presence indicates what soil supports them. So, even if you do not have time to test the soil, simply looking at the plants that are growing will give you a good clue to soil type.

Some indicator plants are illustrated on this page; look them up in a flower book and then crayon in the drawings with their correct colours.

The table below lists some of the most common indicators to common soil types. They are chosen because they are easy to recognize. With the help of a good flower book such as –

Understanding Wild Flowers
by Ros Evans (Usborne)
A Field Guide to Wild Flowers
by D. Aichele (Octopus)
The Spotter's Guide to Wild Flowers
(Usborne)
The Wild Flowers of Britain and Northern Europe
by R. Fitter, A. Fitter and M. Blamey (Collins)

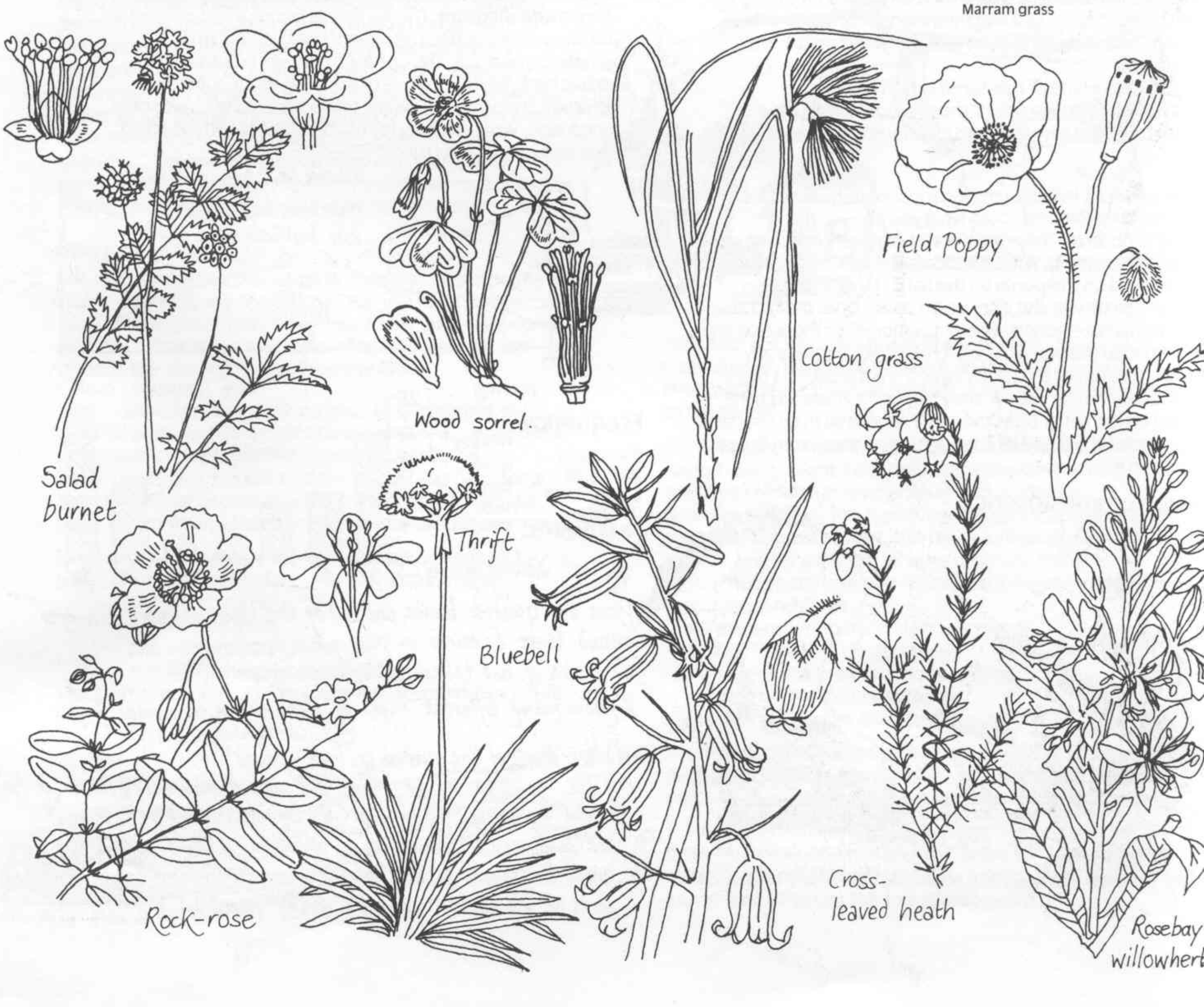
– you will be able to identify many more.

Types of soil and common indicator plants:

Acid Upland	**Chalk Limestone**	**Woodland Brown Earth**	**Newly Disturbed**
Cotton grass	Marjoram	Moschatel	Field Poppy
Cross-leaved	Squinancywort	Bluebell	Rosebay willowhe
Gorse	Bee orchid	Wood sorrel	Ragwort
Common sundew	Salad burnet	Foxglove	Dandelion
Bilberry	Rock-rose	Stitchwort	Shepherd's purse
Wavy hair-grass	Quaking grass	Periwinkle	Spear thistle

Sandy Salty Seaside
Yellow Horned Poppy
Sea campion
Thrift
Rest-harrow
Marram grass

Some easily recognizable indicator plants.



And did those Feet?

In the 1980's when transport is so much easier, many parts of the countryside are accessible to visitors than they ever were before. This, plus the fact that there is much more leisure time in which to go sightseeing, has meant that the surface of our hills is increasingly vulnerable. Although **soil erosion** is actually caused by rain water splashing down and throwing particles aside, as shown in this diagram, it is the action of human feet, and those of animals like sheep and cattle, called **trampling** that sets the scene for soil erosion. Footpaths and gateways are perfect places to look for the impact of this constant pressure.

Some species of plants cannot tolerate being walked on and will not grow where trampling is severe. Others do not mind so much and, though flattened, will struggle on. It is a very revealing project to look for gradations in the density of trampling from a footpath where it is so severe that nothing grows to relatively untouched areas away from the path. This undertaking is much easier in summer when at least some of the plants are in flower.

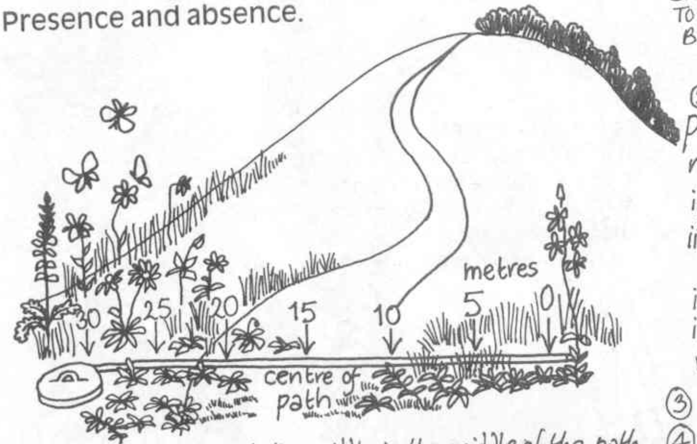
Not only are plants physically damaged by trampling but also soil is compacted and left bare, easy prey for eroding raindrops that can no longer sink into the ground.

You will need:

- a notebook and pen for recording;
- a half metre square **quadrat** (see picture on the right for instructions) or a two metre length of string or tape with four skewers or pegs or even twigs to mark the corners;
- a 30 metre tape or measured length of string;
- a flower book, like one of those suggested on page 11 that you find easy to use to identify flowers and leaves.

Before you start to follow the instructions outlined below you should be thinking about what you are aiming to observe. These are the sort of questions which you should have in mind. What effect has the walking of people on the path had on the plants on the path? Have any plants managed to survive and if so, which ones? Does the fact that some plants have gone have any advantage for those that are left? What do the ones that are left look like? Is there any change in height of the plants away from the path? Is there more variety on the path or away from it? Is there any bare ground on the path? Does the soil change at all from the path to the end of the tape? Which plants grow away from the path but not on it?

Presence and absence.



① Lay the tape out with the middle in the middle of the path.

② Place the quadrat beside one end of the tape and every 5 metres record these features in your notebook ~

i.) Height of the tallest plant in the square

ii.) How many different types of plant, list their names if you can identify them.

iii.) How much of the quadrat is bare ground.

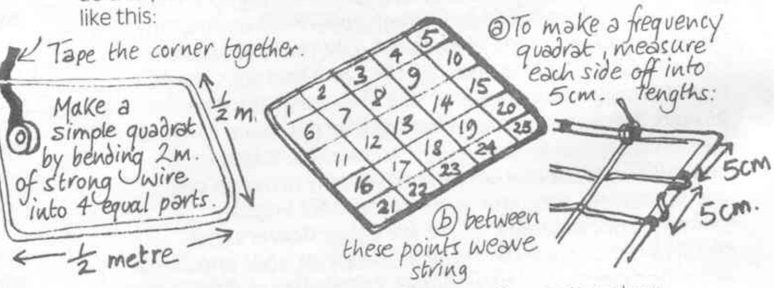
iv.) The condition of the soil ~ is it soft, hard, wet, dry, thick or thin

v.) You could try infiltration experiments, described on page 8.

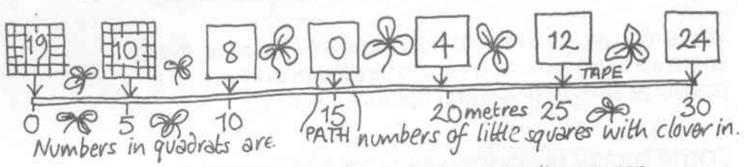
③ You could repeat the exercises further uphill or along the path.

④ Draw bar graphs to illustrate your answers, one below the other so that you can see changes away from the path.

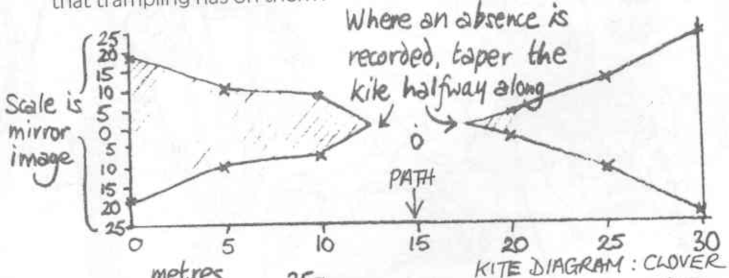
The method given at the bottom of the page tells you how to record simple **presence and absence** of any species. If you find that this does not tell you as much detail as you would like to know, then try assessing the **frequency** of each species. To do this you will need to divide your quadrat into 25 squares like this:



Now, select, say, five species and for every five metres along the tape, place the frame on the ground and count the number of small squares in which each species in turn occurs. For example, if clover was one of your plants, then it might have a distribution like this along the tape.

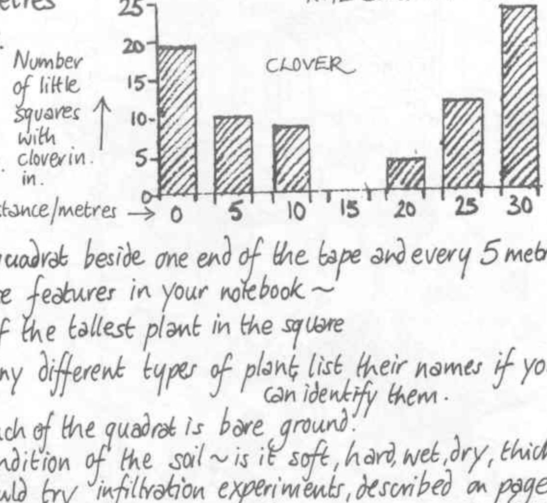


Once you have counted and recorded your results, you can draw a **kite diagram.** This is a very effective visual method of showing what has been observed, the kite diagram is simple to construct. The one for the clover figures above is drawn here. When you have drawn all of them, shade each different species in a different colour and you will have some good kites. What can they tell us about plants and the effect that trampling has on them?



Frequency.

YOU COULD USE THE SAME DATA TO DRAW BAR GRAPHS.



How will your 'Garden' Grow?

By now, we have looked at soil in as much detail and from as many different viewpoints as is possible in a short space, but we have not yet considered what use the soil is to those whose income depends on it. Go and discuss the problems and advantages of soil with a local farmer. Ask him about his drainage, about fertilizers (listen for the proportions of **N, P, K** that he needs for which crops. K stands for potassium, P for phosphorus and N for nitrogen Does he have any serious **deficiencies** of **micro-nutrients** such as magnesium, manganese, molybdenum or copper? Ask him about the **rotation** of crops and the grazing timetable that are necessary to prevent the soil getting too exhausted.

What does he do with his **stubble?** Does he burn it or plough it back in to the soil to increase fertility? What does he do with the left-overs of other crops? Does the soil harbour any pests? When does he **plough?** What type of soil has he got and does it change across the farm? Using a detailed Ordnance Survey map, make a **survey** of the farm, marking what is in each field, what the soils are like and where the slopes are gentle or steep.

Do these changes reflect in the choice of land-use for different areas of the farm? This is only the barest outline of the whole **economic** question of soil, but you could also run your own experiments as if you were a soil scientist.

Some **horticulturalists** have developed such an advanced technological approach to soil that they no longer see it as something from which plants can grow but merely as a **support** in which the plants can stand upright. Indeed, sometimes they dispense with soil altogether and simply use gravel. But, is that **all** they do, put the plants in the soil and leave them? It is not as simple as that. Plants do need **nutrients**, but how are they supplied with them? This experiment is one where you can try out different growing **media** and different **régimes** for propagating plants.

A Horticultural experiment.

Here is the method.

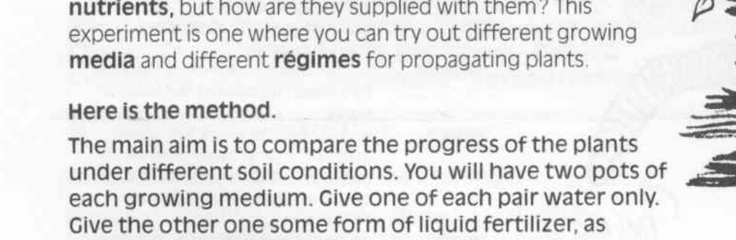
The main aim is to compare the progress of the plants under different soil conditions. You will have two pots of each growing medium. Give one of each pair water only. Give the other one some form of liquid fertilizer, as directed by the instructions on the label.

Select a packet of seeds that are **easy to germinate** and quick to grow, such as runner beans, sweet peas, nasturtiums or cosmea. Get **identical** flowerpots; terracotta or earthenware are the most suitable. You will also need some **liquid fertilizer** or plant food like Phostrogen or Baby Bio, and some cards on which to make records, one for each pot.

In all of your eight pots, put a few pieces of broken crock, gravel or small stones for drainage. Fill them as follows:

two with sand only;
two with peat only;
two with ordinary garden soil;
two with John Innes **Seeding** Compost.

Wet them thoroughly and leave them to absorb the moisture.



Plant each pot with the same number of seeds, five or six depending on the size of the seeds and the pot. Space them **evenly** and make sure that they are at the depth mentioned on the packet.

Put all the pots where they can get the **same** amount of warmth and sunlight. (You could always have more pots with the same contents in conditions of cold or shade.)
Now wait for things to happen, making sure that you keep the surface **constantly moist.** Use the record cards, clearly labelled, one for each pot, to write down the following:

how much water and how frequently it is given to keep the pots moist **not wet**.
the dates on which the first shoots appear;
the first full leaves, the first flower;
the heights after certain lengths of time;
the lengths that the leaves reach;
and any other details that interest you.

The main aim is to compare the progress of the plants under different conditions. You have two pots of each growing medium. Give one of each pair water only. Give the other one some form of liquid fertilizer and record how often.

Does this make any difference? What can you conclude about what plants need to grow in and with? Which conditions produce the healthiest plants?

Glossary Game.

Just imagine that, in digging a pit, you discovered along the lines of the horizons, strings of letters made in the traces of worm tunnels. *Lumbricus* (that's his Latin name), the Earthworm, has been busy burrowing out this puzzle to help you become familiar with some of the complicated soil vocabulary that has been used in this booklet.

In this square are concealed 25 important soil words. These are listed on the right with a simple definition beside each one. Can you find these words? The letters wriggle about like the casts of worms, forwards, backwards, horizontally and vertically, up and down, and diagonally; they can even change direction in the middle of a word. Some letters can be used more than once, but in different words and **never** twice in the same word. To show you how to look for the words, Lumbricus has squirmed his way through the letters of **'capillary'**.

When you have found a word, draw a line through it on the letter grid and tick it off on the list

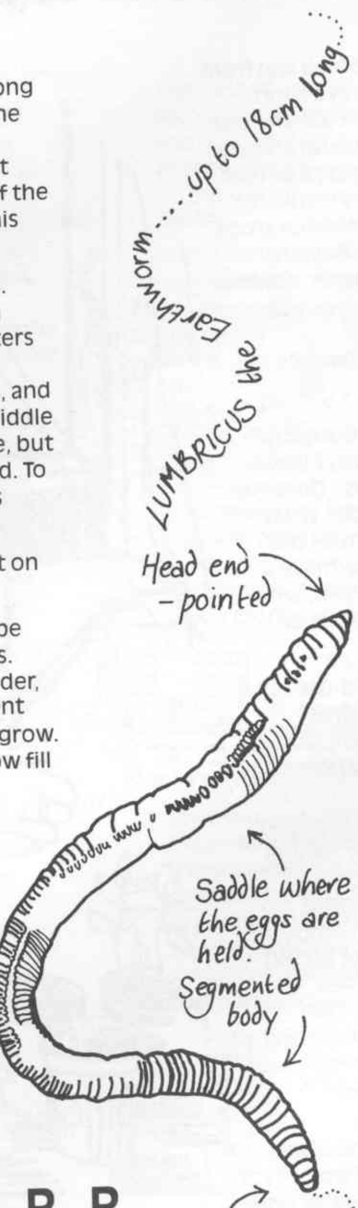
When you have found ALL the words, there should be TWELVE letters left, not included in any other words. Taking three at a time, for they are in the correct order, these letters are the beginnings of four vital nutrient elements in the soil, without which no plant could grow. Here are the endings of these elements' names; now fill in their first letters…

1.............PER

2.............SPHATE

3.............ROGEN

4.............ASSIUM



C	L	O	S	D	O	P	O	P	P
H	O	I	O	W	L	O	O	A	N
T	N	E	M	R	A	M	N	C	A
E	D	L	F	E	N	T	E	T	B
L	A	I	O		P	A	R	I	L
I	C	Z	R	H	U	N	Y	A	E
T	H	O	P	I	M	O	R	L	L
T	I	N	G	L	U	T	I	C	I
E	T	P	Y	E	S	A	N	D	P
R	O	T	T	C	P	C	I	C	A


FERMENTED the layer under the litter that has started to be broken down into humus. It will be the vital source of organic matter in the soil.

pH numerical expression of the acidity of soil, the concentration of hydrogen ions. pH 7 is neutral, more than 7 alkaline, less than 7 is acidic.

SAND particles of mineral or rock in the soil between 2 and 0.06mm in diameter.

CLAY the finest particles in soil, less than 0.002mm in size.

HORIZON a layer of soil roughly parallel to the ground surface which can be distinguished by different colour, texture, or acidity or organic content.

PROFILE a vertical section through the horizons from the ground surface down to the parent material.

ACIDIC a soil with pH of less than 7.

GLEY a soil in which iron compounds have been reduced by oxygen-short conditions, usually due to water-logging. Blue colours are the result.

LITTER plant material like loose leaves, broken twigs, seed cases, bark, lying on the ground surface. It has not begun to decompose.

IRON PAN a harder layer in the profile where clay minerals and iron salts have been redeposited after being washed down from above. Can restrict roots.

LEACHING the removal of chemical compounds, like iron salts, by dissolving in water. The soil from which these substances are washed away are left pale.

BACTERIA soil is a favourite habitat for these microscopic, often single-celled, organisms. They break down the organic material. Millions of them to a gram.

LOAM a texture in which sand and clay size particles are equal in volume.

PODSOL a type of soil found in cold and wet climates where evaporation is less than precipitation. It has sharply defined coloured layers, an upper one bleached and a lower one stained reddish.

EROSION broken down rock material and soil, by something moving like wind or water.

HUMUS layer at the top of the soil profile made of organic material so much decomposed that no actual pieces are identifiable. Usually dark in colour.

WATER an essential ingredient of soil. About 30% of soil by volume.

AIR contained in pore spaces in the soil. Essential for plant growth and keeping the soil warm. About 20% of the soil ingredients.

LIME $CaCO_3$ or calcium carbonate. Can be used to correct soil when it is too acidic for plant growth, that is less than 6. Obtained from limestone and chalk.

CAPILLARY water held in thin films around soil particles and in fine pore spaces. It can move in any direction once the soil has drained the major pores.

INDICATOR a plant that grows only in a particular type of soil and nowhere else and so its presence indicates the nature of the soil.

ASPECT the direction of the compass in which a slope faces. The slope must have an angle of more than 5.

CATENA a sequence of soil changes down a slope.

TABLE used in soil as the upper level of permanent saturation by water in the ground, water table.

PARENT the material from which the mineral part of the soil is derived; either the bedrock or some drift deposit such as may be left behind by a glacier.

Practical Ways of Learning about Soil.

This booklet contains:–

Suppliers of Equipment.

Simple soil testing kits for nitrates (N) phosphates (P) potash (K) pH and lime are available from garden centres

BDH Chemicals Ltd., Midlands Branch,
Fourways,
Carlyon Industrial Estate,
Atherstone, Warwickshire CV9 1JQ.

Griffin and George,
Head Office,
Ealing Road,
Alperton,
Wembley, Middlesex, HA0 1HJ.

Philip Harris Ltd.,
Lynn Lane,
Shenstone, Staffordshire, WS14 0EE.

Drying the soil.

1. Collect small heat-proof dishes, jampot lids would do well.
2. Label them clearly and weigh each one EMPTY (=A)
3. Put a little (15 gm.) fresh soil in each one.
4. Reweigh them (=B) with soil
5. Dry samples in oven at 105°C for several hours.
6. When cool, reweigh lid plus soil (=C)
7. Calculate soil moisture as a %

$$\%\text{MOISTURE} = \frac{(B-C)}{(B-A)} \times 100$$

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