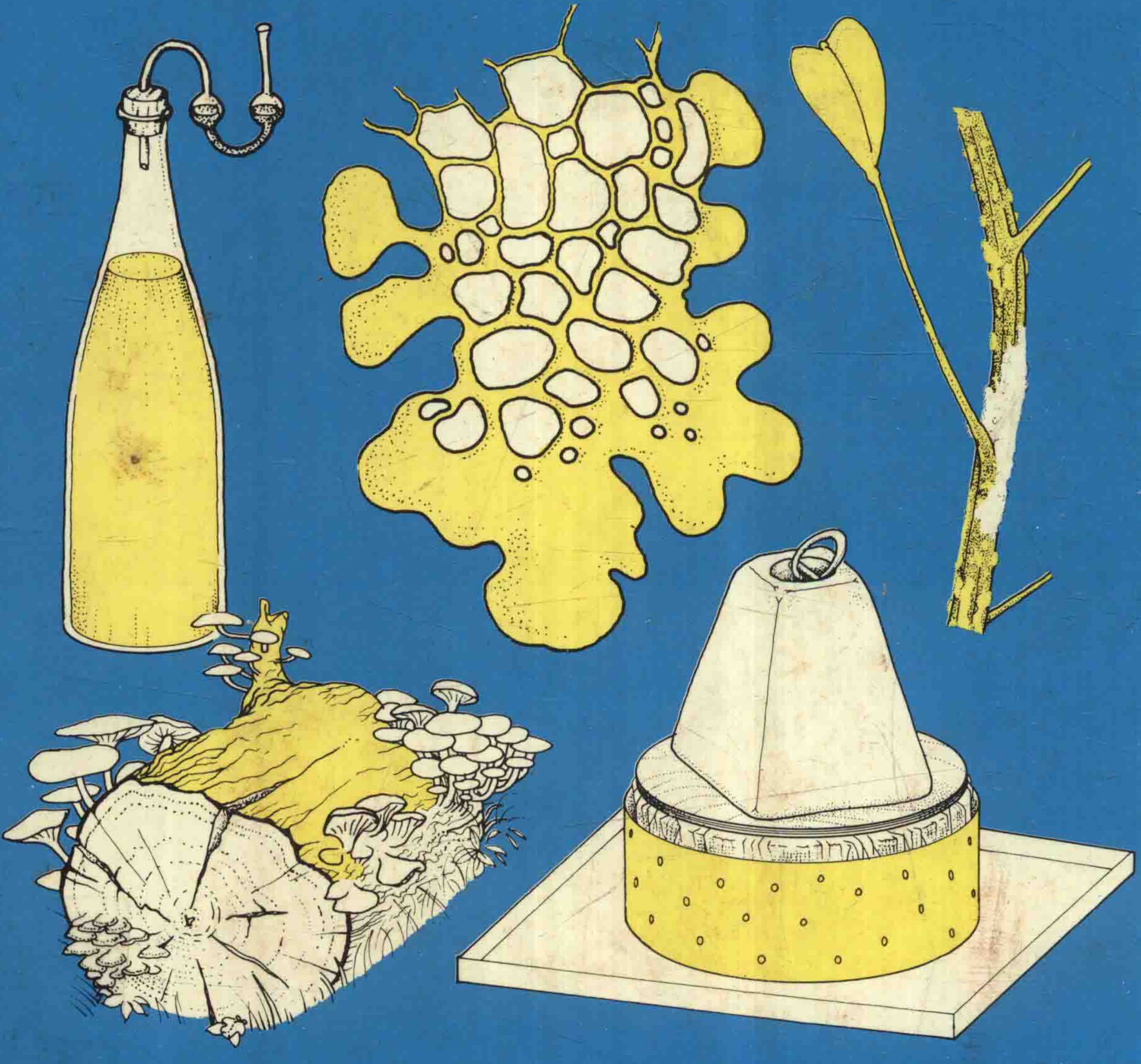
Adventures with Microorganisms



Owen Bishop

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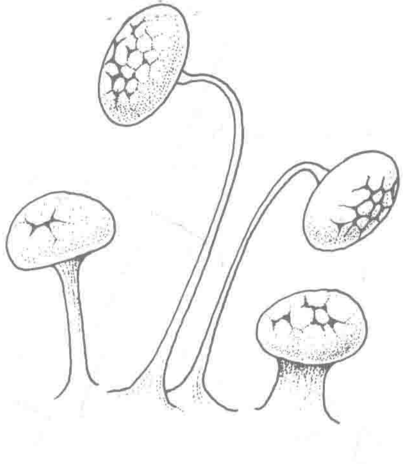

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What this book is about

The organisms that are referred to as 'microorganisms' in the title of this book are the extremely small living creatures that are to be found in abundance everywhere in the world around us. These microorganisms include fungi, bacteria, slime moulds, algae, lichens and viruses. Some are seen only with a microscope; others have visible stages in their life cycles.

Some of these creatures are harmful, causing disease in humans, in other animals and in plants. Most of those which cause disease in humans and other animals are bacteria or viruses. Examples are the bacteria which cause whooping cough and those viruses which cause influenza and the common cold. Other bacteria attack plants, causing diseases such as potato rot. Viruses too may attack plants. Leaf mosaic of tomatoes is a common disease caused by a virus.

Few fungi cause diseases in animals. A fungus which sometimes attacks humans causes athlete's foot. Another example is the fungus which causes ringworm in humans and some animals. Many kinds of fungus attack plants, examples being the downy mildews which we see on the leaves of rose plants, and the fungus which causes silver leaf disease of plum trees.

In Section 1 of the book, you will find out more about each kind of small organism and the part they each play in nature. For safety, you will not be handling those which cause diseases in humans or other animals. In Section 2 you will find out about those small organisms which are specially useful to us. Some of them have been used by humans for many hundreds or thousands of years and continue to play an important part in our way of life today.

Read this before you start

Although most microorganisms are harmless, a few of them can be very harmful and dangerous if they get into the wrong place. This is why the projects in this book deal only with the harmless kinds. Even so, it is sensible to take care that large numbers of harmful organisms cannot get into the wrong place by accident. The instructions in the book are designed to prevent this from happening.

There are a few specially important rules which you should always keep to when you are using this book:

1 When you are working on the topics of Section 1:
Work in a clean room, but preferably not a kitchen. A laboratory, a utility room, or a clean garden shed is a better choice.
Wash your hands every time you finish working, even if you are only breaking off for a few minutes to do something else.
Do not eat or drink anything while you are working.
Never let the organisms which you grow touch your fingers.

2 When you are making food or drinks in Section 2:
Work in a kitchen or other room suitable for the preparation of food.

Make sure that everything you use, including the surface you work on, is absolutely clean.
Wash your hands every time before you start work.
Wash your hands again from time to time, *and again* when you return to work after a break.

Contents

Section I

Microorganisms–what they are and what they do

1 Make a model microorganism

One of the problems of studying microorganisms is that many of them are too small to be seen clearly, even with a microscope. The bacteria and the viruses are the smallest of all living things. The viruses are so small that we need the most powerful kind of microscope, an electron microscope, in order to be able to see anything of them at all. It is partly because they are so small and partly because many of them cause diseases that we do not have many projects on bacteria and viruses in this book. The main exceptions are the bacteria which we use in the making of cheese, butter and yoghurt. In this project we try to get some idea of what bacteria and viruses look like by making some large-scale models.

WHAT YOU NEED

Ten or more spheres about 35–40 mm in diameter: you can use old table-tennis balls, or spheres of expanded polystyrene. If you cannot get ready-made polystyrene or wooden spheres, you could make them from a block of expanded polystyrene or balsa wood.

A fine drill if you are using wooden spheres; a candle or gas flame if you are using table tennis balls.

A needle over 40 mm long (you can make one out of stiff wire bent double and twisted); and button thread or other strong thread.

White or cream paint, if the spheres you are using are not white or cream already.

Stiff wire (e.g. 30 amp): ten pieces each about 15 cm long; six pieces 8 cm long.

A sheet each of: stiff white card, about A4 size, for the bacillus; white writing paper for the virus head; white A4 or foolscap paper for the virus sheath.

Quick-drying adhesive (e.g. clear Bostik).

A large cork or pencil rubber 30 mm across (or pieces of expanded polystyrene or wood).

A used ballpoint pen (BIC or similar) or a pencil or wooden stick of about the same size.

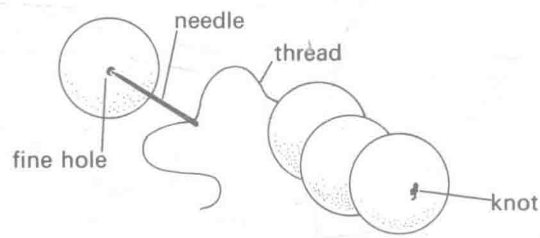
Six nails about 40 mm long.

GETTING STARTED

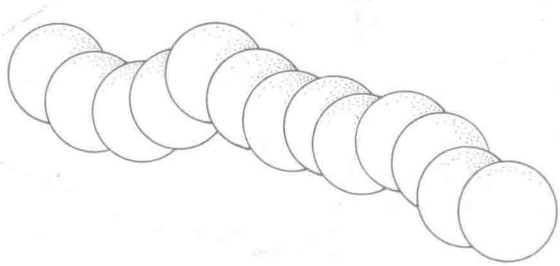
The first model is the simplest to make. It is a model of a kind of bacterium called a *streptococcus*. The bacteria which we call *cocci* have the shape of a sphere. In the streptococci, the bacteria are grouped together in chains, rather like a string of beads. Some kinds of streptococcus are harmful, such as the ones which cause sore throats. Another kind lives in milk, causing it to go sour if it is kept too long. A third kind is very useful to us; it can live in milk and produces a pleasant and slightly sour taste. We use this bacterium, *Streptococcus cremoris*, for making butter and cheeses, as explained in projects 11 and 12.

If you are using wooden spheres, drill a fine hole through the centre of each. If you are using spheres of polystyrene or plasticine, or are using table tennis balls, you simply thread them all on to a length of button thread, using the needle.

Threading the spheres together

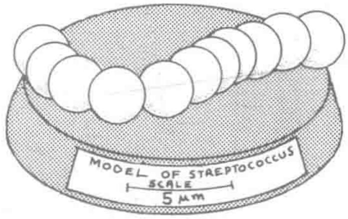


The completed model streptococcus



Keep just two of the spheres aside, for making the next model. Tie a knot at each end of the thread to prevent the spheres from slipping off. If the spheres are not already white or cream, paint them. The model streptococcus is now complete.

One way of displaying your model, mounted on an inverted food carton, painted in a contrasting colour.



This is supposed to be a scale model, so it is important to work out what its scale is. The diameter of a single individual in a streptococcus chain is about 1 μm. Now, 1 μm (one micrometre) is a millionth of a metre, or a thousandth of a millimetre. If the spheres in your model are 40 mm in diameter, the model is 40 000 times natural size. If your spheres are 35 mm in diameter, the scale of the model is 35 000 times life size.

To get an idea of what this scale means, think of an average 12-year-old boy or girl, who is 1.08 m tall. We choose this age because girls and boys have nearly the same average height then. Magnified 40 000 times, the height is over 40 000 m, or 40 km. This is roughly the distance from Coventry to Leicester, from Glasgow to Stirling, from London to Guildford or from Caernarvon to Llandudno.

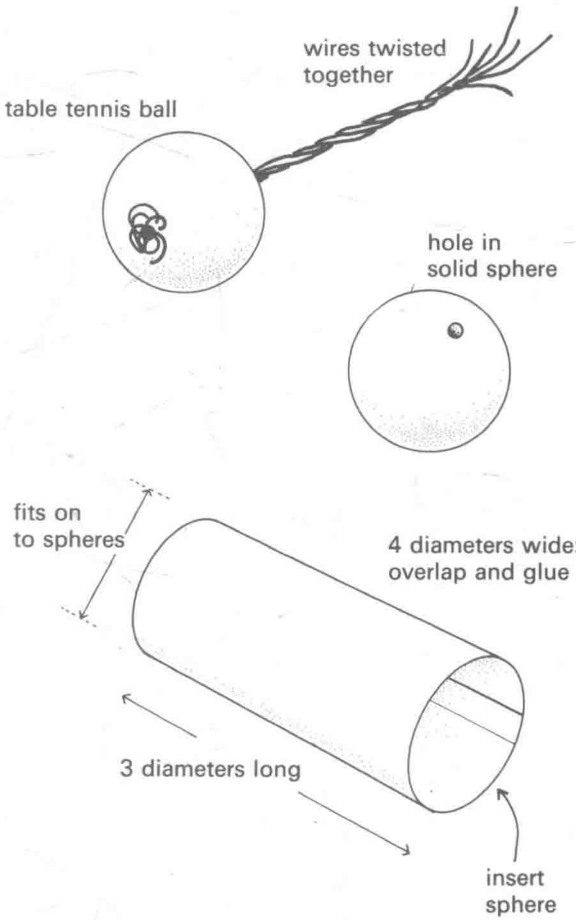
The next model is made to the same scale.

WHAT TO DO NEXT

The second model is of a different kind of bacterium, one with a rod-like shape, called a *bacillus*. There are very many kinds of bacilli. Some are long and thin, some shorter and fatter, some with whip-like hairs (*flagella*) as in the model, some without. The hairs are used by the bacillus for moving around in water or in the fluids of the body. Most bacilli are harmless, but some cause diseases. Typhoid and anthrax are examples of diseases caused by bacilli.

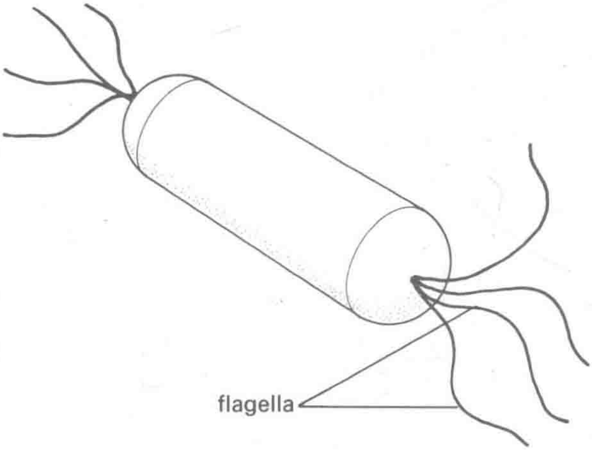
Attach the flagella, represented by wires, to each sphere first. If you are using table tennis balls, twist four or more 15 cm wires sufficiently to keep the ends together. Carefully heat the twist at one end over a flame and push the bunch of wires through the ball. After cooling, twist the wires round as in the diagram and glue at one hole, allowing them to protrude about 8 cm at the other. For solid spheres, bore a hole about 10 mm deep in each, fold two or more wires double and push the looped ends into the hole, wedging them with a matchstick if necessary.

Preparing the spheres and the cylinder of paper



Cut out a rectangle of card and glue it to form a cylinder which fits tightly on to the spheres at each end; the rectangle should be about 3 diameters long by 4 diameters wide, as shown in the drawing. Now glue the spheres into the ends of the cylinder. If the spheres are not white, paint them white now.

The completed model bacillus



Bend the wires to suitable shapes as in the drawing to suggest how they lash through the water to make the bacillus move along. The model bacillus is now complete.

The design for the head of the model virus; all dimensions are in millimetres

Trace this outline, cut along the heavy line, fold at the dotted lines and glue the flaps, as shown in the diagram opposite.

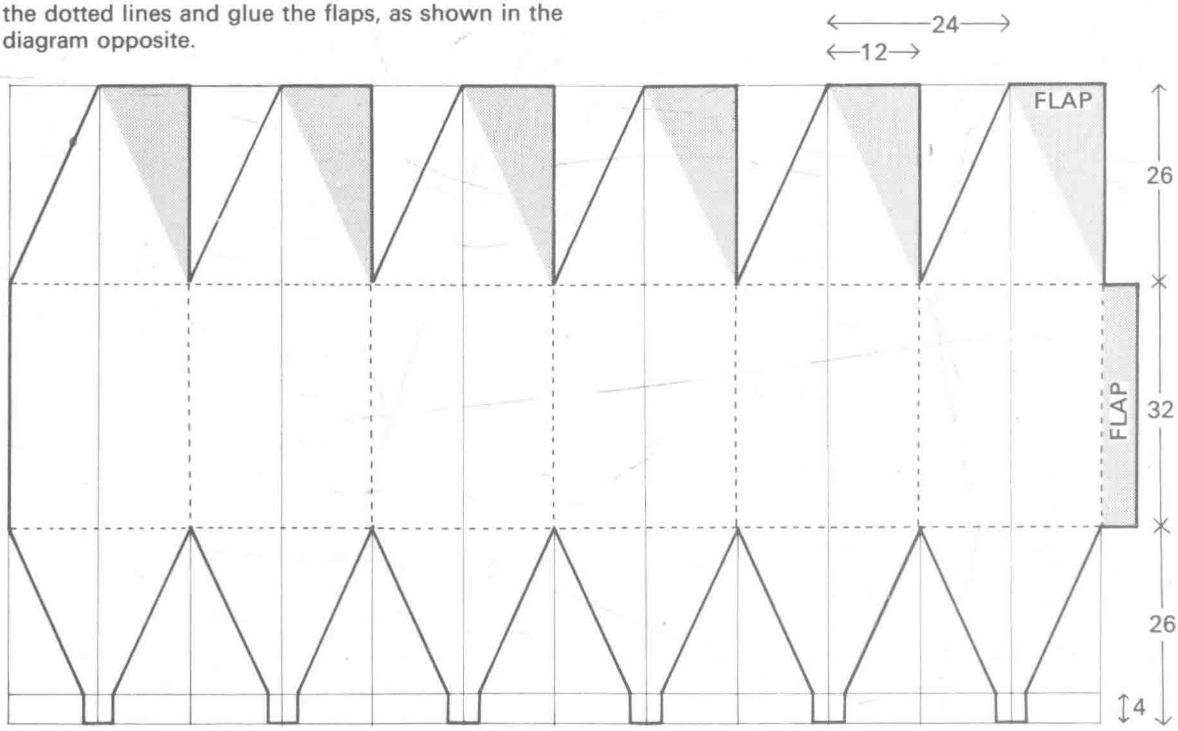
A MODEL VIRUS

The virus modelled here is one known as T2. It is a member of a special group of viruses known as the *bacteriophages*. These are viruses which attack bacteria. One of the difficulties in studying viruses is that they can be grown only inside a living organism. If you try to grow them in broth, for example, as used for growing moulds in project 6, they do not multiply. It is not easy to find people who will volunteer to be infected with influenza virus just so that we can study its life history. But we can easily grow large quantities of bacteria and then infect them with bacteriophages, so that we can study these viruses in detail.

T2 has a very complicated structure, more intricate than many of the other known viruses, but one that makes a rather impressive model.

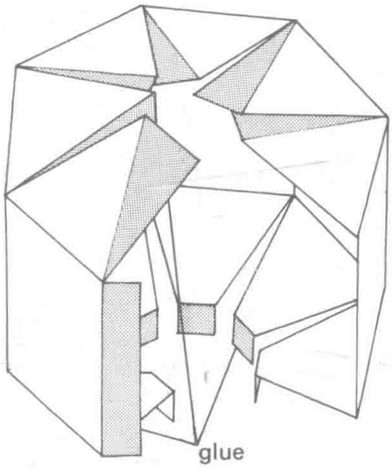
Mark out the design for the head carefully on a sheet of white writing paper. You can trace it from the diagram below. Cut it out and assemble it as shown in the drawings.

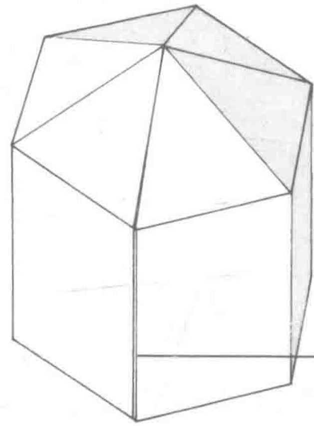
The tail may be made from a used ballpoint pen. Make the tail sheath by rolling round the pen a long strip of white paper, marked with thick black lines to represent grooves (see the drawing on page 6).



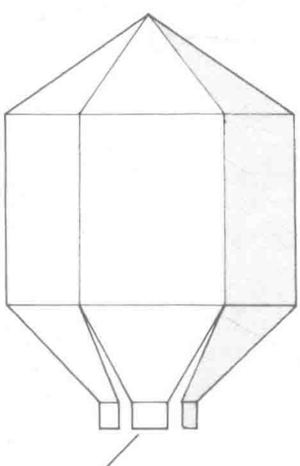
MAKING THE MODEL VIRUS

The head cut out and folded

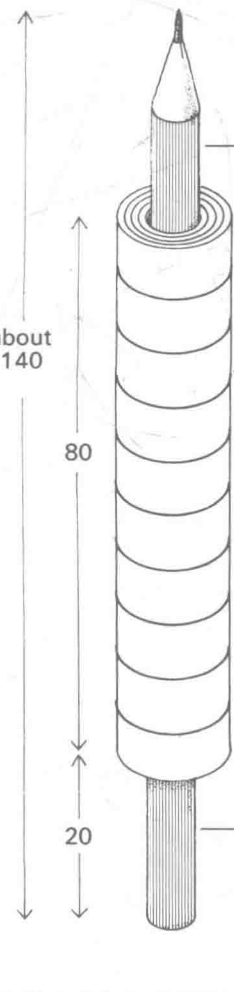




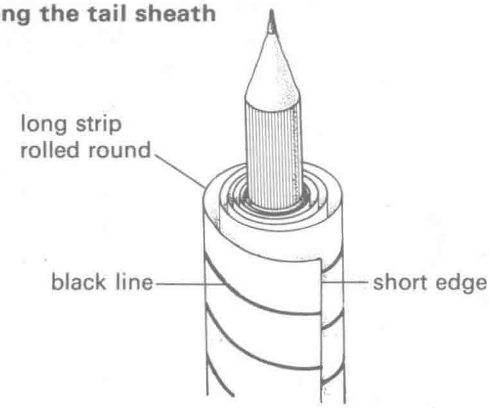
Side view of the completed head



Tail and tail sheath



Making the tail sheath

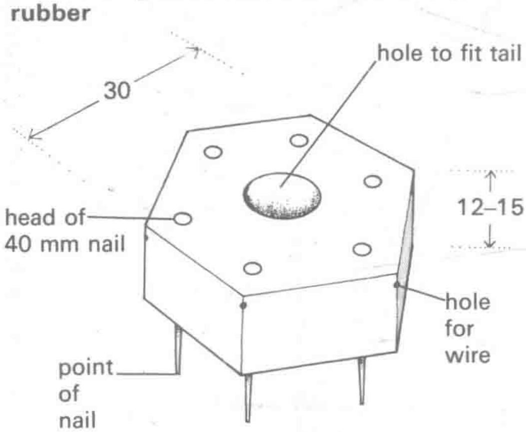


Make a long strip: cut A4 or foolscap sheet into 4 strips across width, join strips end to end—length about 800 mm. Mark thick black lines 50 mm long at one short edge. Stick the other short edge to the tail and roll the paper tightly round, sticking down the lined end.

A cork or thick rubber cut into a hexagonal shape is glued to the end of the tail, forming the end plate. Push six long nails through it at the corners. Bend the six 8-cm lengths of stiff wire as shown, then push them through the upper corners of the hexagonal end plate. Paint the model white if it is not white already.

Since viruses are so much smaller than bacteria, this model is on a much larger scale than the other two. The T2 virus is about 400 nm long.

Assembling the end plate from a large cork or rubber

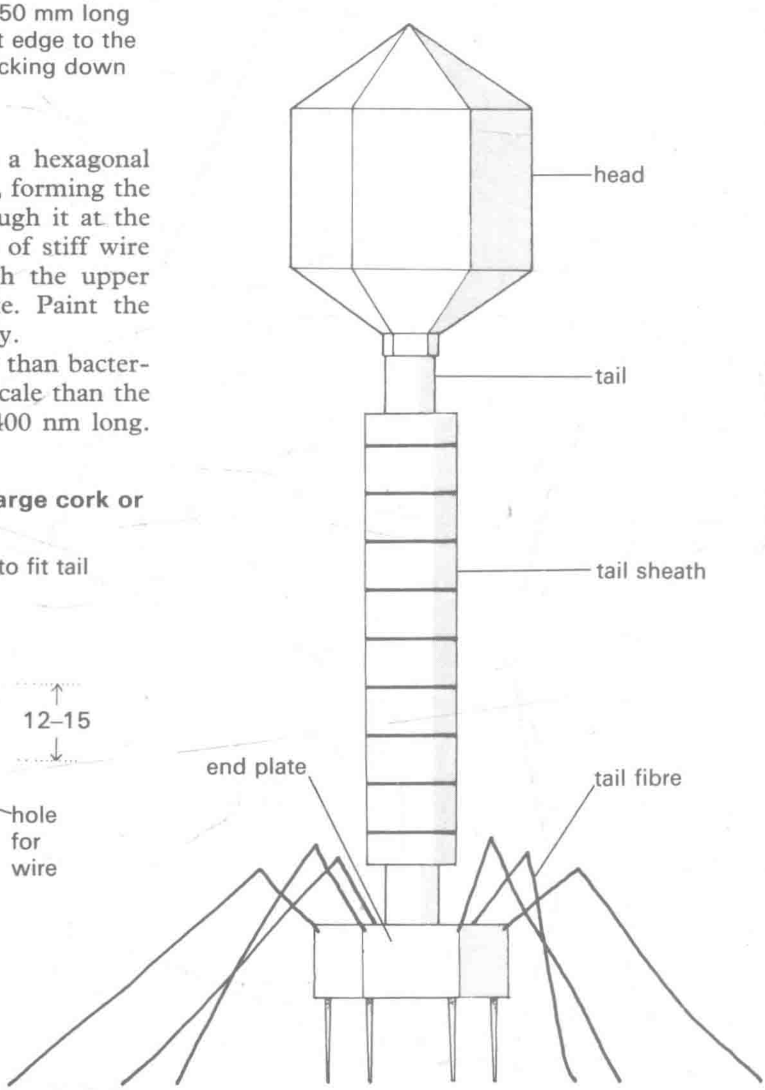


1 nm (one nanometre) is a thousand-millionth of a metre, or a millionth of a millimetre. If your model is 150 mm long, the scale is:

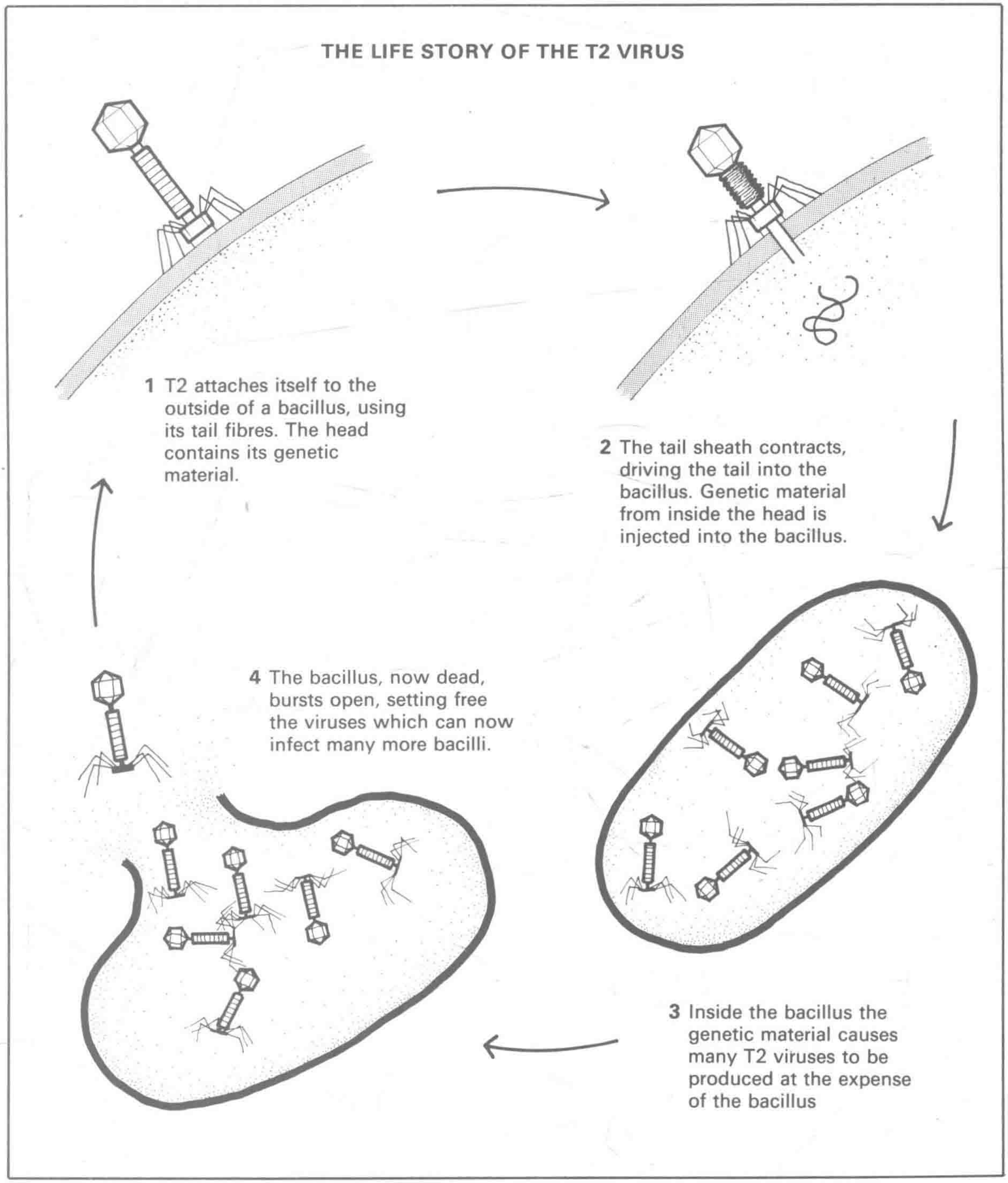
$$\frac{150}{400} = 0.375 \text{ million times} = 375\,000 \text{ times.}$$

The height of an average 12-year-old boy or girl modelled to the same scale would be 1.08 × 375 000 = 405 000 m = 405 km. This is equal to the distance from Coventry to Glasgow, or from Caernarvon to Brighton. Think of this distance, then look at your model and you will begin to realize just how small are the viruses.

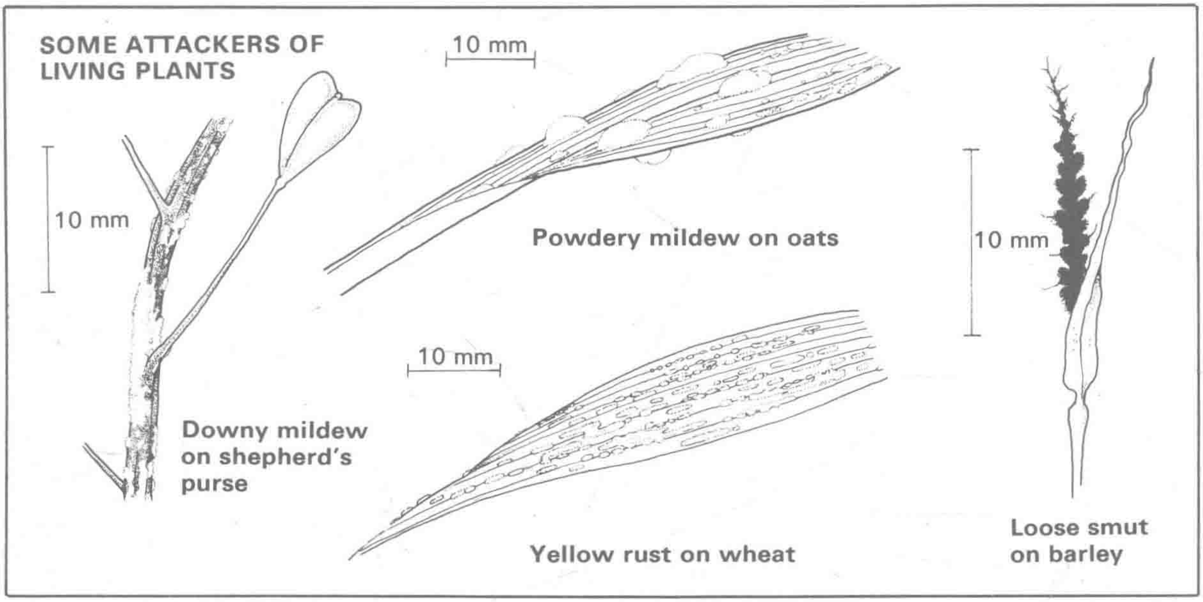
You can see the remarkable way the virus structure operates in the diagram of its life cycle.



The completed model


THE LIFE STORY OF THE T2 VIRUS
1 T2 attaches itself to the outside of a bacillus, using its tail fibres. The head contains its genetic material.
2 The tail sheath contracts, driving the tail into the bacillus. Genetic material from inside the head is injected into the bacillus.
3 Inside the bacillus the genetic material causes many T2 viruses to be produced at the expense of the bacillus
4 The bacillus, now dead, bursts open, setting free the viruses which can now infect many more bacilli.

2 The attackers



Many small organisms attack living plants and animals by living in their bodies and feeding on them. They usually cause the plant or animal to become diseased. We shall not try to have adventures with those which cause diseases in animals—this could be unpleasant and dangerous.

The microorganisms which attack plants can be divided into three groups, the *viruses*, the *bacteria* and the *fungi*. Viruses cause diseases such as tomato mosaic, in which the leaves of tomato plants become yellowish in patches, so that the leaf looks like a mosaic. The plant grows poorly, produces few fruits and may die. Although the effects of the disease are easy to see, viruses themselves are the smallest of all living things and cannot be seen, except with an electron microscope. Bacteria cause diseases such as canker on plum and cherry trees and diseases in which the living stems and buds of potato and rhubarb rot away. The effects of the attack can be serious and are often incurable. Bacteria are so small that they appear only as tiny specks under a high-powered microscope, so they are not particularly interesting to look at.

Fungi are larger than viruses and bacteria. They can be seen with a low-powered microscope or hand lens and some can even be seen with the unaided eye. This makes them very good subjects for an adventure. Although very few indeed attack animals, there are many different kinds of fungus which attack plants. This means that they are easy to find and much safer to work with.

Fungi are the cause of several important and devastating diseases of crop plants. Perhaps the most serious is Potato Blight, caused by the fungus *Phytophthora infestans*. This fungus was responsible for the devastating Potato Famine in Ireland in the nineteenth century, and it is still a problem today.

A plant which is being attacked by a fungus is called the *host* plant. The fungus lives inside the living host and feeds destructively on the tissues of the host. For this reason the fungus is called a *parasite*.

Not only do fungi attack crop plants but they are parasites on many garden plants and wild plants too. You will not have to look far to find some to study.

WHAT YOU NEED

Pair of fine-pointed scissors for collecting diseased parts of plants.
Small bottles, plastic cartons or similar small containers for holding the material you collect.
Packet of self-adhesive labels, small size (e.g. 1 cm × 3 cm).
A hand lens.
Mounted needle (two needles, if possible) for handling the fungus.
Some microscope slides and cover slips, or small glass or clear plastic sheets.
Squeeze-pipette (eye-dropper) for putting water on the slides.
A microscope. Though not essential, it is a great help for looking at the smaller fungi. It need not be a powerful one. A magnification of ×40 is quite enough, although ×100 will help you to see more.
Razor blade.
Small flower pot or saucer. Glass or plastic tumbler.
Packet of cress seeds.

GETTING STARTED

The fungus enters a plant and grows inside its host, and for some time no signs are visible from the outside. Later the fungus produces spores by means of which it can spread to other hosts. Most fungi rely on the air to carry their spores, so the spores are produced on the outside of the host. The drawings show various ways in which fungi arrange for their spores to catch the wind. It is at this stage that it becomes obvious that the host is being attacked. The visible stage is reached when the fungus has had time to mature, usually from May onwards, so that May is the best month to begin this project.

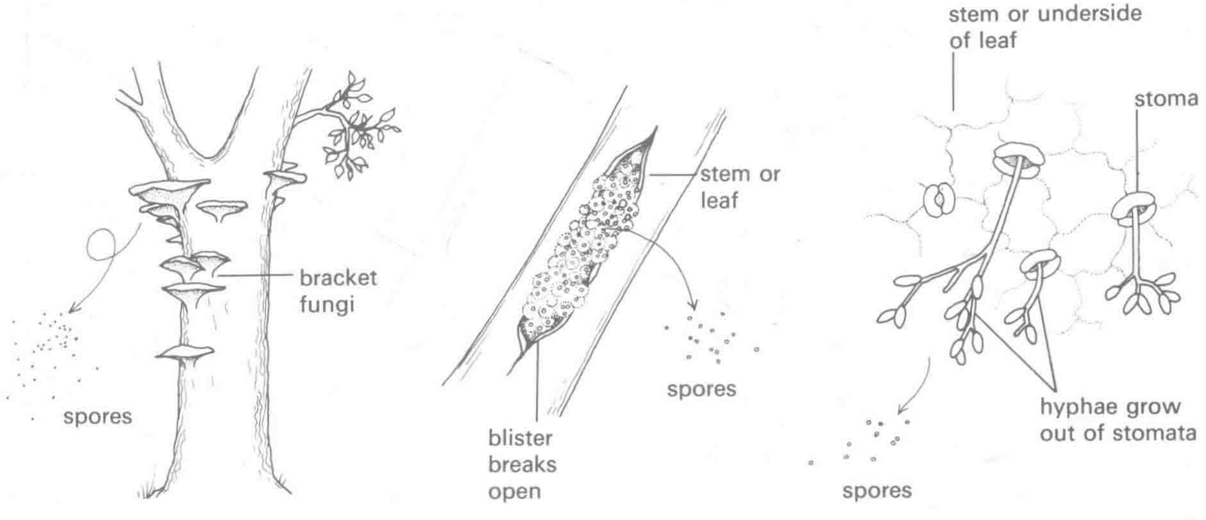
The table on page 11, and the drawings, will help you to recognize the signs of attack by fungi. There are several major groups of fungal parasite, and you will soon learn the main features of each group.

When possible, it is a good idea to begin in the garden. Most gardening books have chapters on plant diseases, some with colour photographs of diseased plants. If you can borrow such a book, you will have no difficulty in finding and identifying material.

If you live in a town, it is usually easy to find weed plants such as shepherd's purse growing in cracks in the pavement. Snapdragons are now and then found growing on old brick walls. Michaelmas daisies are another kind to look for. These are frequently attacked by fungi (see table, p. 11). There are many others to be found if you look in out-of-the-way places.

Having found a plant which is obviously diseased, cut off the diseased part and put it in one of the small containers. Label the container with the name of the plant and the place in which it was found. In the case of fungi such as the bracket fungi, which have very large sporing bodies, you can simply cut out a piece of this for study.

How spores are released into the air to be carried away by currents



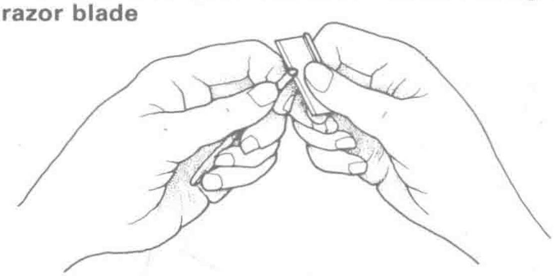
WHAT TO DO NEXT

Look at the diseased part under a lens. Is the surface of the plant broken or blistered, so that the spores are easily visible from the outside? Can you see thin cotton-wool-like threads (hyphae) of the fungus on the outside of the plant?

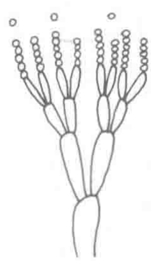
If the fungus is not completely inside the plant, use the needle to remove some of it for study. Place a drop of water on a microscope slide (or on a small sheet of glass or transparent plastic) and place the piece of fungus in the drop. You can hold this up to a light and look at it with a lens. If you have a microscope, cover the drop with a cover slip before examining it under the microscope.

Look for spores. What colour are they? What shape are they? How many are there? Are they produced singly, in chains, on branching tufts of hyphae? Or are they arranged in some other way? Make a few sketches to show what you see.

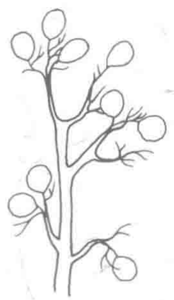
How to hold a stem and cut a section using a razor blade



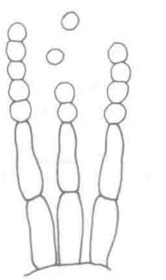
material to cut. Cut the stem across where there is a patch of disease. Wet the cut end and the razor blade, then slice across, cutting sections about half a millimetre thick. There is little point in trying to cut them any thinner. Transfer a section to a drop of water on a microscope slide and examine as described above. You will not find it easy to pick out the hyphae which are woven in and around the cells of the stem but it should be easy to see regions where spores are forming.



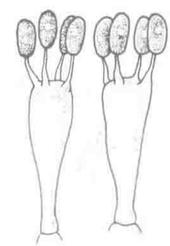
Spores on a brush-like structure



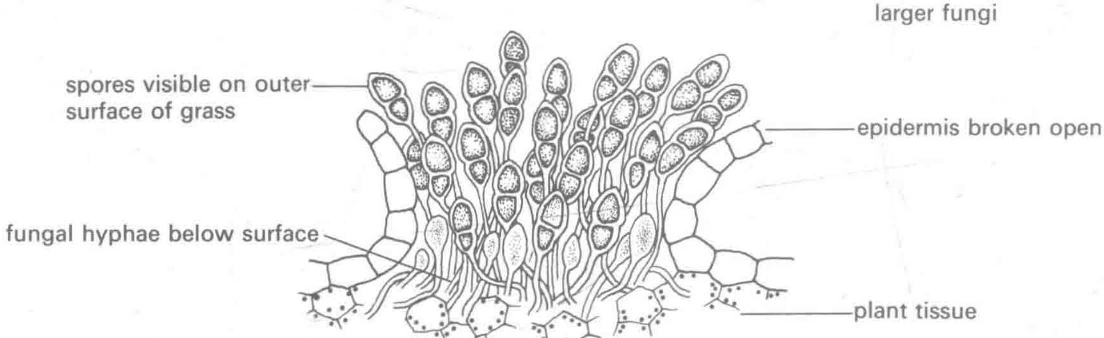
Spores on branched hyphae



Spores in chains



Spores in groups of four, as in bracket fungi and most other of the larger fungi



Section through a 'blister' on the blade of a grass, caused by a rust fungus

If the fungus is not visible on the surface of the plant you will need to cut sections of the plant to see the fungus properly. Stems are the easiest

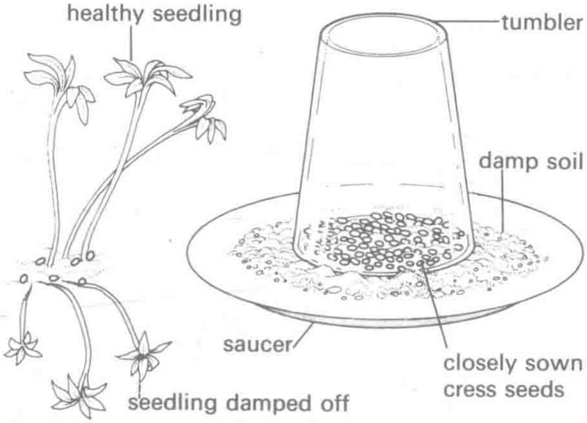
The larger spore-forming bodies can be cut in thin sections as described above, and examined for spores.

SOME THINGS TO TRY

Seedlings grown close together under very damp conditions, such as in boxes of compost, often suffer from the disease called 'damping off'. The stem of the seedling becomes soft and thin just where it leaves the soil. The top of the seedling falls over and eventually the seedling dies.

Try growing some cress seedlings under conditions which help the damping-off fungus (*Pythium*) to attack the plant. Sow the seeds very thickly on soil in a pot or a saucer. Cover with a glass tumbler to keep conditions really moist. Water often. After the seeds have begun to grow you should find some of them falling over. Cut out pieces of the stem at soil level and mount them as described above. Look for spores. If these are not easily seen, pull (or tease) the diseased stem apart using two needles. It is soft

Cress seedlings



and the cells will separate easily. Put a cover slip on the teased stem. Slight pressure on the cover

SOME FUNGI WHICH ATTACK LIVING PLANTS

Name of fungus or group	Examples of plants attacked	Part attacked	Appearance of disease
Rusts	Snapdragon, hollyhock, chrysanthemum, rose, groundsel, plum, currant, grasses and cereals	Leaves	Yellow, brown, or orange patches, looking like rusty spots
Smuts	Grasses and cereals	Leaves and flowers	Blackish patches, like sooty smuts
Pythium (damping off)	Young seedlings of many kinds of plant	Stem at soil level	Stem goes soft
Downy mildews	Wallflower, snapdragon, clover, shepherd's purse, cauliflower, lettuce, onion	Leaves and stems	Whitish patches like cotton wool
Powdery mildews	Apple, pea, marrow, currant, rose, many garden flower plants, grasses and cereals, oak	Leaves and stems	Powdery patches (spores); later, tiny black dots (sexual spores)
Botrytis (grey mould)	Many kinds of plant, both in gardens and in the wild	Leaves, stems, flowers and fruits	Grey cotton-wool-like patches
Blight	Potato	Leaves, stems and tubers	Brown patches, becoming black and wet
Bracket fungi	Tree trunk	Trunk	See drawing, p. 9

slip will help to spread out the material, making the spores and the hyphae easier to see.

How do spores get to the seedlings to cause the disease? Do they come from the soil? Try the same experiment, but use soil which has first been baked in an oven for 30 minutes, then cooled and moistened with tap water. Do the seedlings become damped off now?

Can damping off be prevented by treatment? To test this, try growing the seedlings on fresh garden soil, as before, but sow them thinly and do not cover them with the tumbler. This gives drier conditions. Does *Pythium* attack the plant under these conditions and if so, is the attack as severe as in the covered seedlings?

Also try growing seeds under damp crowded conditions (as you did at first), but treat the seeds or the soil with a fungicide. Several kinds can be bought in a garden shop; it is important that you follow the directions which are provided with the packet. Is the fungicide effective in preventing the disease?

How do the spores get carried from an infected plant to one which is not infected? Does the water help carry them? Grow two sets of seedlings, one in dry conditions, the other in damp conditions. When the seedlings in damp conditions begin to damp off, drain some of the water from their pot into the other pot. Does this action transfer the disease to the other pot?