

**FIRST STUDIES
OF PLANT LIFE**

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OF PLANT LIFE**

by

George Francis Atkinson

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INTRODUCTION

FOR a long time botanical science, in the popular mind, consisted chiefly of pulling flowers to pieces and finding their Latin names by the use of the analytical key. All the careful descriptions of the habits of plants in the classic books were viewed solely as conducive to accuracy in placing the proper label upon herbarium specimens. Long after the study of botany in the universities had become biological rather than purely systematic, the old regime held sway in our secondary schools; and perhaps, some of us to-day know of high schools still working in the twilight of that first ray that pierced primeval darkness. However, this has practically passed away, and to-day life and its problems, its successes and its failures, absorb the attention of the botanist and zoölogist. The knowledge of the name of the plant or animal is simply a convenience for discrimination and reference. The systematic relations of a plant or animal are used in showing present anatomical affinities and past development. The absorbing themes of investigation and study are the life processes and the means by which the organisms living in the world to-day have climbed upward and placed themselves in the great realm of the "fit."

INTRODUCTION

When the idea of nature study first dawned in the educational world, it was inevitably confused with the sciences on which it was based. Hence in earlier times we tried to teach the nature study of plants by making the children pull the flowers to pieces and learn the names of their different parts. This was as bad nature study as it was bad science, for we were violating the laws of the child's nature. The child cares very little about the forms of things; he is far more interested in what things do.

To-day nature study and science, while they may deal with the same objects, view them from opposite standpoints. Nature study is not synthetic; it takes for its central thought the child, and for its field work the child's natural environment. The child, through nature study, learns to know the life history of the violet growing in his own dooryard, and the fascinating story of the robin nesting in the cornice of his own porch. The differences of this violet and this robin from other violets and other robins in the world he considers not at all.

That the plant as well as the animal in nature study should be regarded a thing of life has long been recognized, and most of our nature study of plants begins with the planting and sprouting of the seed. Unfortunately, it mostly stops here; the life processes of the plant have seemed too complex to be brought within the comprehension of the child. There is much of chemistry in operations of plant growth, and we find very few things in chemistry that are simple enough to be properly a part of nature study.

INTRODUCTION

First Studies of Plant Life has been written with the sole view of bringing the life processes of the plant within the reach of the child and, with the aid of the competent teacher, it will certainly be comprehensible to the pupil of even the lower grades. In this book the plant stands before the child as a living being with needs like his own. To live, the plant must be born, must be nourished, must breathe, must reproduce, and, after experiencing these things, must die. Each plant that is grown in the window box of a schoolroom should reveal to the child the secrets and the story of a whole life. He realizes that the young plant must be fed; it must grow; it is no longer a matter of commonplace; it is replete with interest, because it is the struggle of an individual to live. How does it get its food? How does it grow? It is of little moment whether its leaves are lanceolate or palmate; it is a question of what the leaves do for the plant; it is a matter of life or death.

When the child has once become acquainted with the conditions and necessities of plant life, how different will the world seem to him!—Every glance at forest or field will tell him a new story. Every square foot of sod will be revealed to him as a battlefield in which he himself may count the victories in the struggle for existence, and he will walk henceforward in a world of miracle and of beauty,—the miracle of adjustment to circumstances, and the beauty of obedience to law.

ANNA BOTSFORD COMSTOCK.

BUREAU OF NATURE STUDY,
CORNELL UNIVERSITY.

AUTHOR'S PREFACE

IN presenting these "First Studies of Plant Life" the object has been to interest the child and pupil in the life and work of plants. The child, or young pupil, is primarily interested in life or something real and active, full of action, of play, or play-work. Things which are in action, which represent states of action, or which can be used by the child in imitating or "staging" various activities or realities, are those which appeal most directly to him and which are most forceful in impressing on his mind the fundamental things on which his sympathies or interests can be built up.

There is, perhaps, a too general feeling that young pupils should be taught things; that the time for reasoning out why a thing is so, or why it behaves as it does under certain conditions, belongs to a later period of life. We are apt to forget that during the first years of his existence the child is dependent largely on his own resources, his own activity of body and mind, in acquiring knowledge. He is preëminently an investigator, occupied with marvelous observations and explorations of his environment.

Why then should we not encourage a continuance of this kind of knowledge-seeking on the part of the

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child? The young pupil cannot, of course, be left entirely to himself in working out the relation and meaning of things. But opportunities often present themselves when the child should be encouraged to make the observations and from these learn why the result is so. No more excellent opportunities are afforded than in nature study. The topics most suitable are those which deal with the life, or work, or the conditions and states of formation.

To the child or young pupil a story, or the materials from which a story can be constructed, is not only the most engaging theme, but offers the best opportunity for constructive thought and proper interpretation.

In the studies on the work of plants some of the topics will have to be presented entirely by the teacher, and will serve as reference matter for the pupil, as will all of the book on occasions. The chapter dealing with the chemical changes in the work of starch-making is recognized by the author as dealing with too technical a subject for young pupils, and is included chiefly to round out the part on the work of plants. Still it involves no difficult reasoning, and if young children can appreciate, as many of them do, the "Fairyland of Chemistry," the pupils may be able to get at least a general notion of what is involved in the changes outlined in this chapter.

The chapters on Life Stories of Plants the author has attempted to present in the form of biographies. They suggest that biographies are to be read from the plants themselves by the pupils. In fact, this feature

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of reading the stories which plants have to tell forms the leading theme which runs through the book. The plants talk by a "sign language," which the pupil is encouraged to read and interpret. This method lends itself in a happy manner as an appeal to the child's power of interpretation of the things which it sees.

Many older persons will, perhaps, be interested in some of these stories, especially in the Struggles of a White Pine.

The story on the companionship of plants also affords a topic of real interest to the pupil, suggesting social conditions and relations of plants which can be read and interpreted by the young.

GEORGE F. ATKINSON.

CORNELL UNIVERSITY
MARCH, 1901.

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PART I

**THE GROWTH AND
PARTS OF PLANTS**

CHAPTER I

HOW SEEDLINGS COME UP FROM THE GROUND

The life in a dry seed. For this study we shall use seeds of beans, peas, corn, pumpkin, sunflower, and buckwheat. You may use some other seeds if they are more convenient, but these are easy to get at feed stores or seed stores. If you did not know that they were seeds of plants, you would not believe that these dry and hard objects had any life in them. They show no signs of life while they are kept for weeks or months in the packet or bag in a dry room.



FIGURE 1. *Bean seedlings breaking through the soil.*

But plant the seeds in damp soil in the garden or field during the warm season, or plant them in a box or pot of damp soil kept in a warm room. For several days there is no sign that any change is taking place in the seeds. But in a few days or a week, if it is not too cold, some of the surface earth above the buried

seeds is disturbed, lifted, or cracked. Rising through this opening in the surface soil there is a young green plant. We see that it has life now, because it grows and has the power to push its way through the soil. The dry seed was alive, but could not grow. The plant life was dormant in the dry seed. What made the plant life active when the seed was buried in the soil?

How the corn seedling gets out of the ground. One should watch for the earliest appearance of the seedlings coming through the soil. The corn seedling seems to come up with little difficulty. It comes up straight, as a slender, pointed object which pierces through the soil



FIGURE 2. *Corn seedlings coming up.*

easily, unless the earth is very hard, or a clod or stone lies above the seedling. It looks like a tender stem, but in a few days more it unrolls, or unwinds, and long, slender leaves appear, so that what we took for a stem was not a stem at all, but delicate leaves wrapped round each other so tightly as to push their way through the soil unharmed. What would have happened to the leaves if they had unfolded in the ground?

How the bean behaves in coming out of the ground. When we look for the bean seedling as it is coming up we see that the stem is bent into a loop. This loop forces its way



FIGURE 3. *The "loop" of the bean seedling.*

HOW SEEDLINGS COME UP

through the soil, dragging on one end the bean that was buried. Sometimes the outer coat of the seed clings to the bean as it comes from the ground, but usually this slips off and is left in the ground. Soon after the

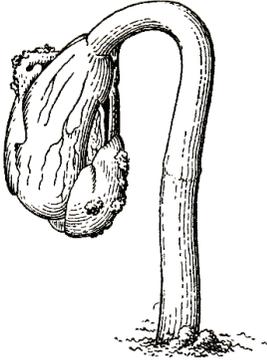
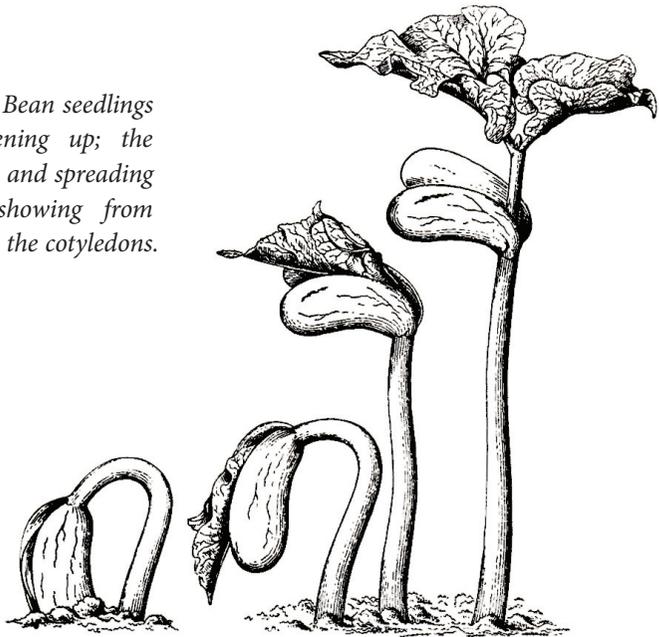


FIGURE 4. *Germinating bean shedding the seed coats.*

loop appears above ground it straightens out and lifts the bean several inches high. As the bean is being raised above ground the outer coat slips off. Now we see that the bean is split into two thick parts (*cot-y-le'dons*), which spread farther and farther apart, showing between them young green leaves, which soon expand into well-formed bean leaves.

FIGURE 5. *Bean seedlings straightening up; the plumule and spreading leaves showing from between the cotyledons.*



The pea seedling comes up in a different way. The stem of the pea also comes up in a loop. As it straightens



FIGURE 6. *Pea seedlings coming up.*

up we look in vain for the pea on the end. There are small green leaves, but no thick part of the pea which was buried in the ground. This part of the pea, then, must have been left in the ground. When we have seen how the other seedlings come up, we can plant more seeds in such a way as to see just how each

seed germinates, and learn the reason for the different behavior of the seedlings in coming from the ground.

The pumpkin seedling also comes up in a loop, and on one end of the loop, as it is being lifted through the soil, we see two flat, rather thick parts. Together they are about the size of the pumpkin seed. By looking carefully we may sometimes find the old shell, or seed coat, still



FIGURE 7. *Pumpkin seedlings coming from the ground, showing loop and opening cotyledons.*

HOW SEEDLINGS COME UP

clinging to the tips of these parts of the seed; the shell is split part way down only, and so pinches tightly over the tips. Usually, however, it is left empty in the ground.

It will be interesting later to see how this little pumpkin plant gets out of its shell. It usually escapes while still buried in the soil. As the loop straightens out, these two thick portions spread wide apart in the light and become green. There are little lines on them resembling the “veins” on some leaves. Are these two parts of the pumpkin seed real leaves? Look down between them where they join the stem. Very young leaves are growing out from between them.

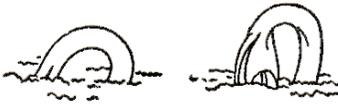


FIGURE 8. Loop on stem of sunflower as it comes from the ground.

The sunflower seedling. The sunflower seedling comes up with a loop, dragging the seed on one end. The shell, or seed coat, is sometimes left in the ground, because it splits farther through when the root wedges its way out. But often the seed coat clings to the tips of the cotyledons until the plant straightens. Then the cotyledons usually spread far apart. The seed coat of the pumpkin

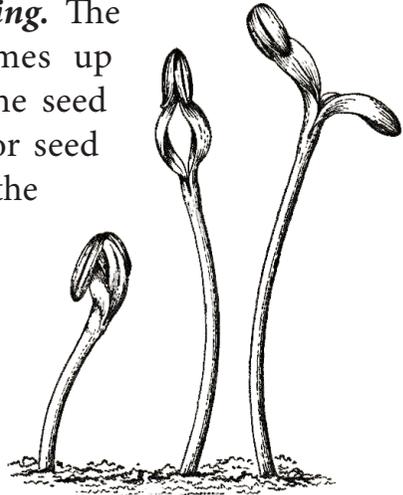


FIGURE 9. Seedlings of sunflower casting seed coats as cotyledons open.

sometimes clings to the tips of the cotyledons until the sunlight pries them apart.

The buckwheat seedling. This also comes up with a loop, and we begin to see that this way of coming up is very common among seedlings. The seed coat of the

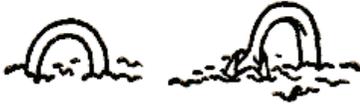


FIGURE 10. *Loop of buckwheat seedlings coming through the surface of the soil.*

buckwheat is often lifted above ground on one end of the loop. It is split nearly across. Through the split in the seed we can see that there are leaves packed inside very differently from the way in which the cotyledons of the pumpkin and sunflower lie. The buckwheat cotyledons are twisted or rolled round each other. As the seedling straightens up they untwist, and in doing this help to throw off the coat.

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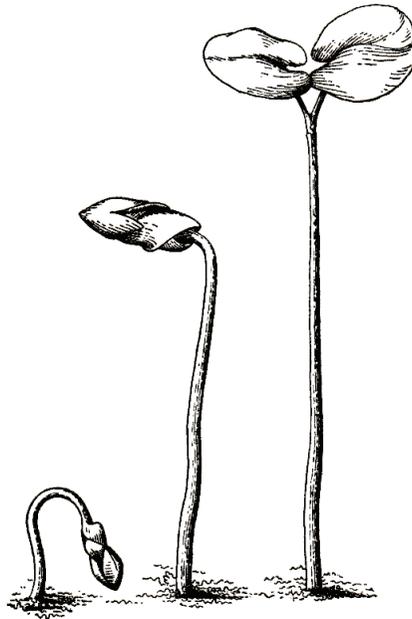


FIGURE 11. *Cotyledons of buckwheat seedlings untwisting and casting seed coats.*

CHAPTER II

HOW THE SEEDS BEHAVE WHEN GERMINATING

To prepare the seeds for observation. We could

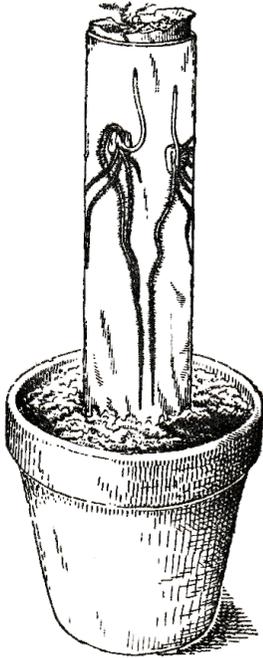


FIGURE 12. *Corn seedlings growing in lamp chimney.*

not see how the seeds planted in the ground behaved while they were germinating, for they were hidden from sight. To watch the behavior of the different kinds, the seeds are put where there is warmth and moisture under glass, or they are covered with damp paper or moss, which may be lifted at any time to see what is going on. They may be grown in tumblers, or in shallow vessels covered with glass, with wet moss or paper inside. The best way to plant them for easy observation is to put them in a lamp chimney filled with wet peat moss or sawdust, as shown in Figure 12. Or a box may be made with glass

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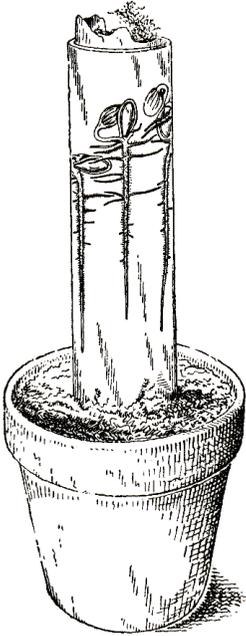


FIGURE 13. *Pumpkin seedlings growing in lamp chimney.*

doors on the side. This may be filled with wet moss or sawdust, the seeds put in place, and the door then closed. If desired, some soft manila paper may be placed on the moss or sawdust, and the seed placed between this and the glass. If the lamp chimney is used, roll the paper into a tube smaller than the chimney and slip it in. Now put the peat moss inside, not very tight. The seeds may be started between the glass and paper, and with a blunt wire may be pushed into any position desired.

The seeds first absorb water and swell. Before the seeds are planted for this study they should be soaked from twelve to twenty-four hours in water.

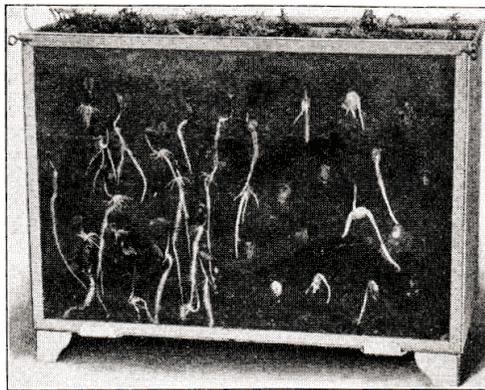


FIGURE 14. *Box with glass door on side for growing seedlings.*

HOW THE SEEDS BEHAVE

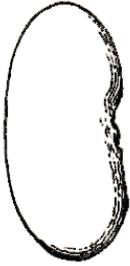


FIGURE 15. *Bean seed before soaking in water.*

Then they may be placed in the germinator for observation. Look at the seeds in the water several times during the day, and see what changes take place in them. All of them become larger. After they have been in the water for a day, cut one, and also try to cut one of the dry seeds. The seeds that have been soaked in water are softer and larger than the dry seed. Why is this so? It must be that they have

taken in water, or have absorbed water, as we say. This has increased their size, made them wet inside, and soft.

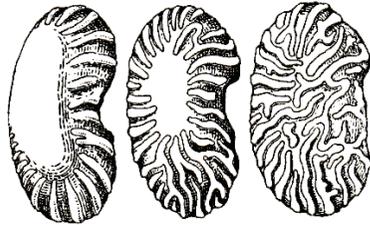


FIGURE 16. *Bean seeds with coats wrinkling as they soak in water.*

How the pea and bean seeds swell. The pea and bean swell in a curious way, as can be seen by looking

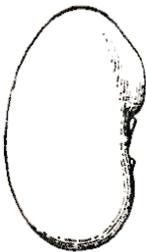


FIGURE 17. *Bean seed after soaking in water, larger, and now smooth.*

at them at short intervals after they have been placed in the water. The water is taken in at first more rapidly by the coat of the seed than by the other parts. The coat becomes much wrinkled then, as if it were too big for the seed. First the wrinkles begin to appear round one edge. Then they become more numerous, and extend farther over the surface, until the entire coat is

strongly wrinkled, as shown in Figure 16. This loosens the coat from the bulk of the seed, and perhaps is one reason why this coat slips off so easily while the loop of the stem is pulling the inside of the seed out of the ground. Finally the inside parts swell as they take up water. They fill out the coat again so that it is smooth, as shown in Figure 17.

The first sign of the seedling. In a very few days, now that the seeds are thoroughly soaked with water,

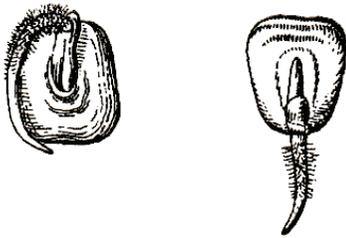


FIGURE 18. Corn seeds germinating under glass, the lefthand seed upside down.

the signs of life begin to appear. The root grows out of the seed as a small, white, slender, pointed object. It comes from the same spot in every seed of one kind. In the sunflower, pumpkin, buckwheat, and corn it comes from the smaller end of the seed. In

the bean it comes out from the hollowed, or concave, side. As soon as the root comes out it grows directly downward, no matter which way the seed happens to lie.

When the seeds are placed in the lamp chimney, or in a box with a glass side, they can be easily held in any position desired. It will be interesting to watch seeds that have been

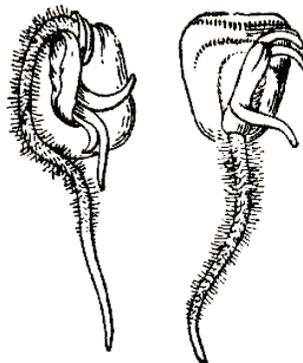


FIGURE 19. Later stage of Figure 18.

HOW THE SEEDS BEHAVE

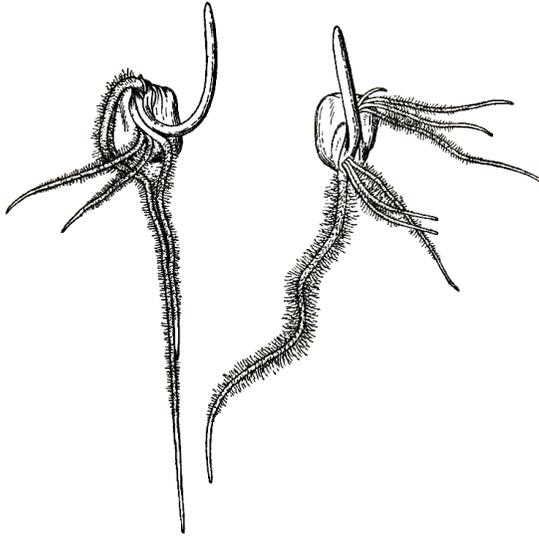


FIGURE 20. *Sill* later stage of Figure 18.

placed in different positions. When the roots have grown an inch or more in length, sketch some of the different positions. Is there any advantage to the plant in having this first root grow downward?

How the pumpkin plant gets out of the seed coat.

As the root grows out of the small end of the seed, it acts like a wedge and often splits the shell or seed coat part way, but not enough for the rest of the plant to escape. The little plant develops a curious contrivance to assist it in getting out. There is formed on one side of the stem a “peg” or “heel.” This is formed on the underside of the stem, when the seed is lying on its side, at the point in the opening of the seed. This peg presses against the end and helps to split the seed coat further open. The stem now elongates above this peg, presses against the other half of the seed coat, and pries

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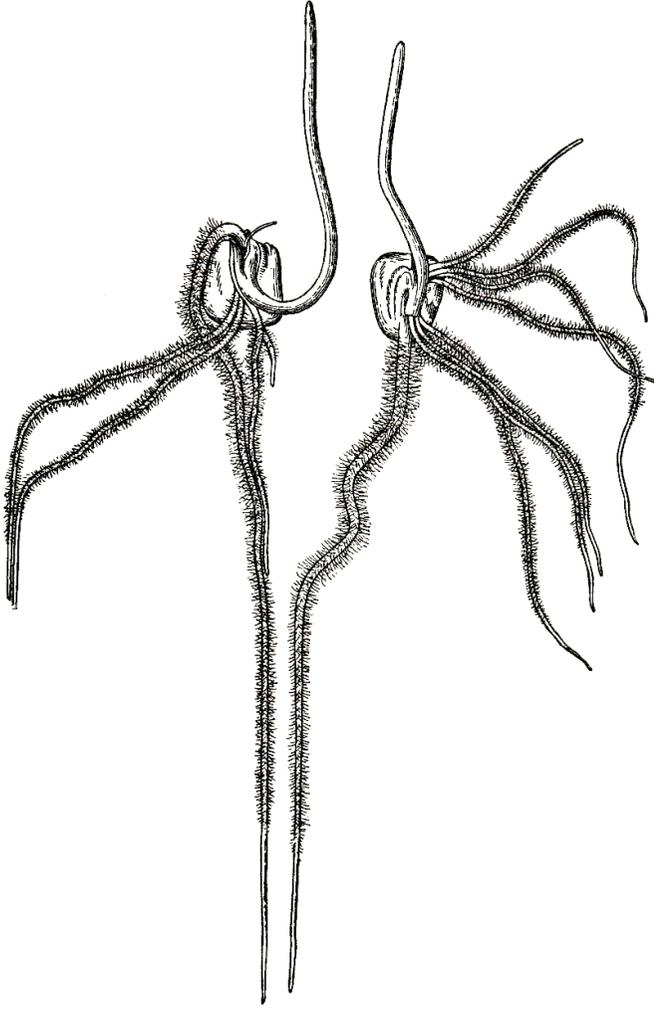


FIGURE 21. *Still later stage of Figure 18. Note root hairs in all.*



FIGURE 25. *Sunflower seed germinating.*

HOW THE SEEDS BEHAVE

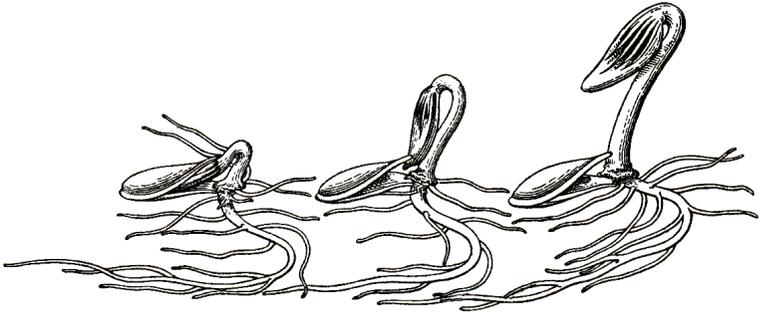


FIGURE 22. Pumpkin seedlings casting the seed coats. Note the "peg."

the two halves far apart so that the plant readily slips out, as shown in Figure 22.

Germination of the bean. After the root comes out of the bean on the concave side, the two halves

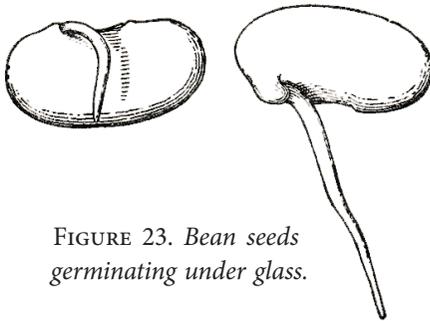


FIGURE 23. Bean seeds germinating under glass.

of the bean swell so that the outer coat is cracked and begins to slip off. We can then see that the stem is a continuation above from the root, joined to one end of the two thick parts or

cotyledons. This part of the stem now grows rapidly, arches up in a loop, and lifts the bean upward.

The pea. The pea germinates in a different way. After the root begins to grow the pea swells, so that the thin coat is cracked. The stem, just as in the bean, is joined at one side to the two thick cotyledons of the pea. But this part of the stem of the pea does not grow longer, so the pea is left in position in the ground. The stem grows

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on from between the two thick cotyledons, arches up in a loop, pulls out the young and tender leaves from the ground, and then straightens up.

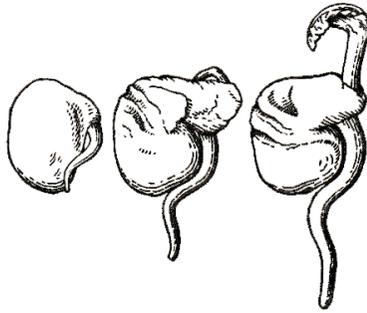


FIGURE 24. Pease germinating under glass.

To compare the germination of the bean with that of the pea. This can be done very easily by first soaking beans and peas for twenty-four hours in water. With the finger or with the knife split the bean along the line

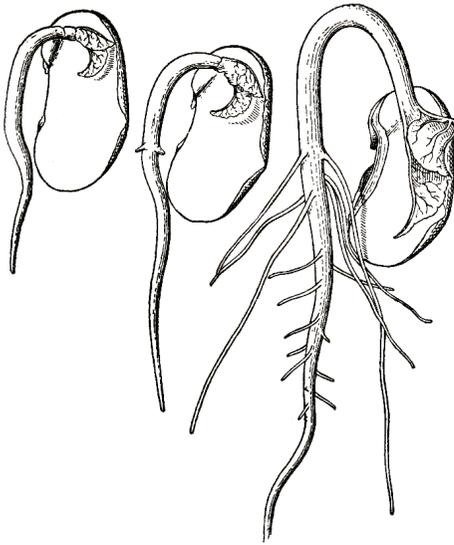


FIGURE 26. Beans with one cotyledon removed to see how the cotyledons are raised up from the ground.

of the convex side and pull the halves apart. The young embryo plant lies attached to one of these halves, having broken away from the other. Split several beans in the same way and place the half which has the embryo bean plant under glass, in position as shown in Figure 26.

Take one of the peas and, by a slight rubbing pressure between the fingers, remove the thin outer coat. The split between

HOW THE SEEDS BEHAVE

the halves is now seen. Carefully break away one of these halves and split several more peas in the same way; those pieces which have the embryo attached should be planted under glass near the beans, in position as shown in Figure 27. From day to day observe the growth in each case. That part of the bean stem below the cotyledon can be seen to elongate, while in the pea it is the stem above the attachment of the cotyledon which grows.

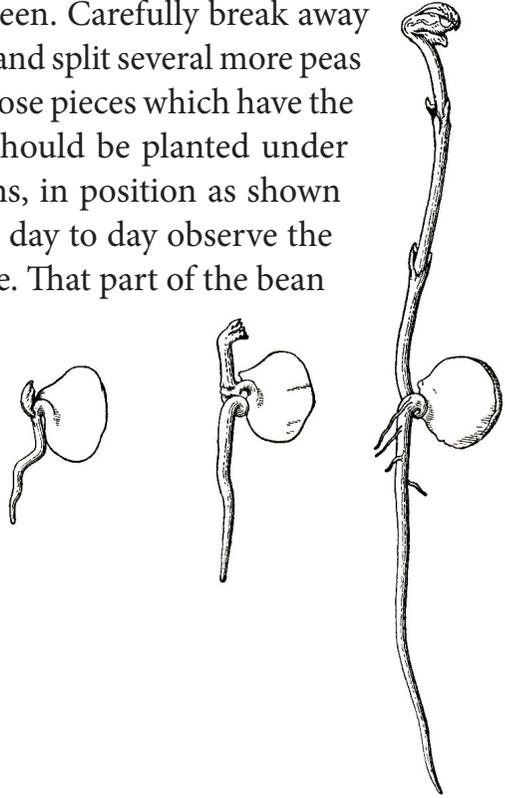


FIGURE 27. Peas with one cotyledon removed to see how the cotyledons are left in the ground.

The oak seedling. The young oak plant comes out of the acorn in a curious way. It is easy to get the acorns to see how they behave. Visit a white oak tree in late October several weeks after the acorns have been falling from the tree. If the tree is situated by the roadside, or in a field where there is some loose earth which is damp and shaded, many of the acorns will be partially buried in the soil. Or you may collect the acorns and half bury them in a cool, damp soil, which should be watered from time to time.

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The root is the first to appear, and it comes out of the small end of the acorn, splitting the short point on the end of the seed in a star-shaped fashion. The root immediately turns downward, so that if the acorn is not buried the root will soon reach the soil. This can be seen in Figure 28.

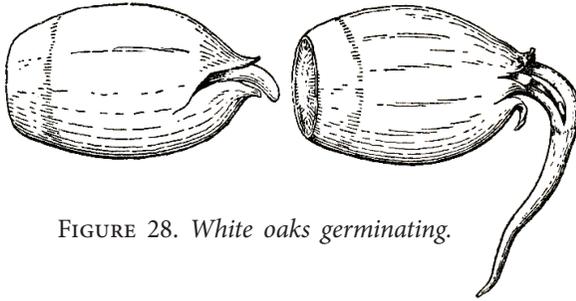


FIGURE 28. *White oaks germinating.*

How the oak seedling escapes from the acorn. If you look for sprouted acorns, you will find them in different stages of growth. Some with the root just emerging will be found, and others with the “tail” an inch or more long. In these larger ones we can see that the part next the acorn is split into two parts. As it curves, this split often widens, so that we can see in between. In such cases a tiny bud may be seen lying close in the fork of the two parts. This bud is the growing end of the stem, and we now see that the tiny plant backed out of the acorn.

The root hairs. In this study of the seedlings grown under a glass, or in a box or vessel where there is no soil for the root to bury itself, you will see that the root soon becomes covered, a little distance back of the tip, with a dense white woolly or fuzzy growth. You will see that these are like very tiny hairs, and that the root

HOW THE SEEDS BEHAVE

bristles all around with them. They are the *root hairs*. They help the root to do its work, as we shall see in a later study.

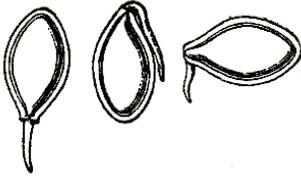


FIGURE 29. *Pumpkin seeds germinating under glass, turned in different positions.*

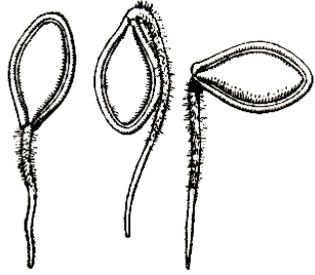


FIGURE 30. *Same as Figure 29, but later stage.*

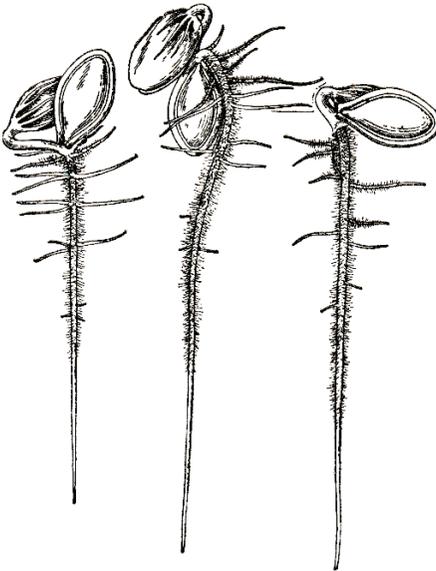


FIGURE 31. *Later stage of Figure 29.*

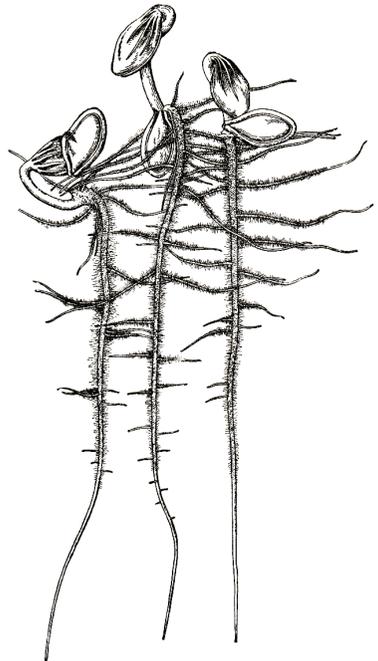


FIGURE 32. *Later stage of Figure 29.*

CHAPTER III

THE PARTS OF THE SEED

Are the parts of the seedling present in the seed?

Since the root comes from the seed so soon after planting, when the soil is moist and the weather warm, and the other parts quickly follow, one begins to suspect that these parts are already formed in the dry seed. We are curious to know if this is so. We are eager to examine the seeds and see. The dry seeds might be examined, but they are easier to open if they are first soaked in water from twelve to twenty-four hours. When they are ready, let us open them and read their story.

The parts of the bean seed. The bean seed can be split, as described on page 14, into halves by cutting through the thin coat along the ridge on the rounded or convex side. Spread the two parts out flat and study them. The two large white fleshy objects which are now exposed we recognize as the two cotyledons which were lifted from the soil by the loop. The thin coat which enclosed them is the *seed coat*. Lying along the edge near the end of one



FIGURE 33. *Bean showing scar.*

THE PARTS OF THE SEED

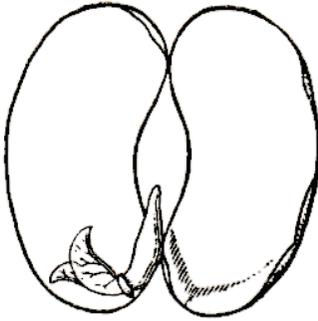


FIGURE 34. *Bean seed split open to show plantlet.*

of the cotyledons is a small object which looks like a tiny plant. Is this the *embryo* of the bean plant? The pointed end is the root, and we see that it lies in such a position that when it begins to grow it will come through the seed coat near the scar on the bean.

At the other end of the plantlet are two tiny leaves, pointed, and set something like the letter V. We know that they are leaves because there are veins on them like the veins on the leaf. Between these leaves and the pointed end or root lies the stem. It is short and stout, and there is *no distinct dividing line between it and the root*. *Root and stem in the embryo are called the cau-li-cle*. The upper end of the stem just below the tiny leaves is joined to the

FIGURE 35. *Cross section of bean showing situation of plantlet.*



cotyledon, one cotyledon breaking away as the bean was split open. *The part of the stem below the cotyledons, that is, the part between them and the root, is called the hy'po-cot-yl.*

The parts of the pea seed. The position of the

FIRST STUDIES OF PLANT LIFE

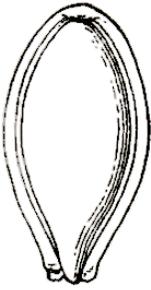


FIGURE 36. *Pumpkin seed.*

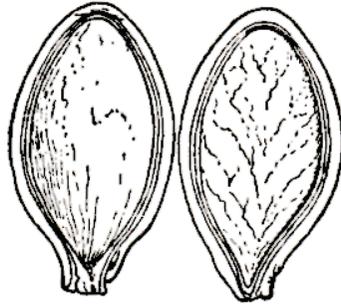


FIGURE 37. *Pumpkin seed split open; in right-hand half the papery covering shown which surrounds the "meat."*

plantlet can be seen on one side of the rounded pea, below the scar, after the pea has been soaked in water. By a slight rubbing pressure between the thumb and finger the thin seed coat can be slipped off. The two thick cotyledons can now be separated. If this is done carefully, the embryo plant remains attached to one of them. Sketch this, as well as the embryo of the bean; compare them and indicate in the drawings the names of the parts.

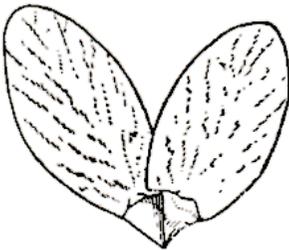


FIGURE 38. "Meat," the embryo, with one cotyledon turned to one side.

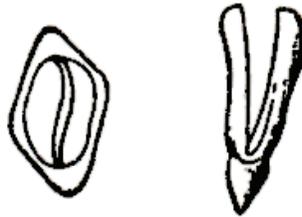


FIGURE 43. *Cross section of sunflower seed at left; at right, side view of embryo taken from seed.*

THE PARTS OF THE SEED

The parts of the pumpkin seed. The scar on the pumpkin seed is found on the smaller end. The seed coat can be split by cutting carefully part way around the edge of the flattened seed and then prying it open. The “meat” inside is covered with a very thin *papery layer*. The pointed end of the meat is the *caulicle (root and stem)*. It lies, as we see, in the small pointed end of the seed coat. The meat is in halves, as shown by a “split” which runs through to the point where they seem to be joined. *These halves of the meat are the cotyledons of the pumpkin.* Pry them apart so that one is broken free. At this junction of the cotyledons will be found a tiny bud on the end of the stem attached to one cotyledon after



FIGURE 39. Long section through a pumpkin seed.



FIGURE 40. Cross section of pumpkin seed.

the other is broken off. The stem is very short in the pumpkin plantlet. We have found in the pea and bean that it lies between the cotyledon and the root. So it does in the pumpkin. Is it so in all seeds?

Cut a pumpkin seed through the cotyledons, but lengthwise of the seed. Make a sketch of one part showing the seed coat, the position of the *papery lining*, the cotyledons as well as the short root and stem. Cut a seed in two, crosswise, and sketch, showing all the parts.

FIRST STUDIES OF PLANT LIFE

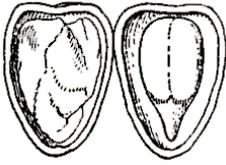
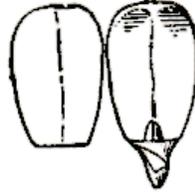


FIGURE 41. *Sunflower seed split open showing "meat," the embryo in right and papery covering in left hand of seed coat.*

The sunflower seed. The sunflower seed can be split open to remove the seed coat in the same way as the pumpkin seed. The meat occupies much the same position, and is covered with a papery layer. While the proportions are different, the general shape of the plantlet reminds one of that of the pumpkin or squash.

FIGURE 42. *Embryo of sunflower with one cotyledon removed.*



The root and stem are more prominent. There are two flat cotyledons. As we spread them apart we see that they are joined to the end of the stem; we can also see between them the tiny bud. If we cut the seed in two, as we did the pumpkin seed, we shall see that the relation of the parts is much the same.

Structure of the corn seed. In the germination of the corn we have seen that the root comes out at the small end of the kernel in the groove on one side, while the leaves first appear on the same side at the other end of this groove. If the tiny plant is present in the seed, then it should be found in the groove. Split the soft kernel lengthwise through this groove. Just underneath the seed coat at the small end will be seen the end of

THE PARTS OF THE SEED

the root and stem (caulicle). Near the other end of the groove there may be seen several converging lines running as shown in Figure 44. These lines represent several leaves cut lengthwise while they are rolled round each other. The stem lies between the leaves and

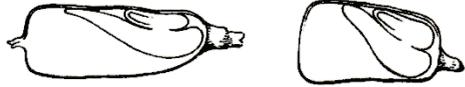


FIGURE 44. Section of corn seed; at upper right of each is the plantlet, next the cotyledon, at left the endosperm.

root; it is now very short, and cannot be distinguished

from the root. On the opposite side of the stem from the groove is a small curved object. This is the **cotyledon** cut through. There is only **one** cotyledon in the corn seed, while in the other seeds studied there are **two**.

The meat in the corn seed. In the pea, bean, pumpkin, and sunflower seeds the cotyledons form nearly all the meat inside the seed coats. In fact, *the whole seed inside the seed coat in these plants, except the papery lining, is the embryo, for the cotyledons, being the first leaves, are part of the tiny embryo plant.* We have found something very different in the corn. *The embryo is only a small part of the inside of the seed.* After the seed has germinated, the *food substance* is still there. Did you ever examine a kernel of corn after the seedling had been growing some time? There is scarcely anything left but the old and darkened seed coat. It is nearly hollow within. *The meat which formed most of the inside of the kernel has disappeared.* What has become of it? I think every one who has examined the corn in this way can tell. *It has gone to form food for the young corn plant. The substance which is used by the embryo for food is*

called **endosperm**.

Is there endosperm in the seeds of the pumpkin, the bean, the pea, and the sunflower? That is perhaps a hard question for you to answer. It is a difficult matter to explain without taking a good deal of time. But I will ask a few more questions, and then perhaps you can guess. Where does the germinating pumpkin, sunflower, bean, or pea seedling find its food before it can get a sufficient amount from the soil? If from the cotyledons, or first leaves, where did they obtain the food to become so big in the seed? What about the papery lining in the squash and sunflower seed?

FIGURE 45. *Long section of buckwheat seed showing one view of embryo surrounded by the endosperm.*



FIGURE 46. *Another section showing another view of embryo of buckwheat in seed.*



FIGURE 47. *Cross section of buckwheat seed showing coiled cotyledons.*



CHAPTER IV

GROWTH OF THE ROOT AND STEM

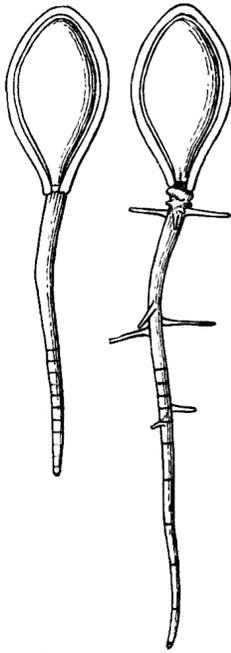


FIGURE 48. *Pumpkin seedlings, the root marked in left. Right one showing where growth took place in twenty-four hours.*

The part of the root which lengthens. One of the interesting things about the root is the way it grows in length. We know that as the root becomes longer the tip moves along. But does this take place by a constant lengthening of the extreme tip of the root? Or is the tip pushed along through the soil by the growth or stretching of some other part of the root? We can answer this if we examine the seedlings which are growing in germinators, as in the lamp chimney, where the roots are not covered with soil.

To tell where the root elongates. Take a fine pen and some indelible or water-proof ink. Beginning at the tip of the

root, mark off on one side very short spaces, as close together as possible, the first 1 mm. from the tip, and the others 1 mm. apart, as shown in Figure 48. Now place the seedling back in the germinator in position, the root pointing downward. In twenty-four hours see the result. The spaces between the marks are no longer

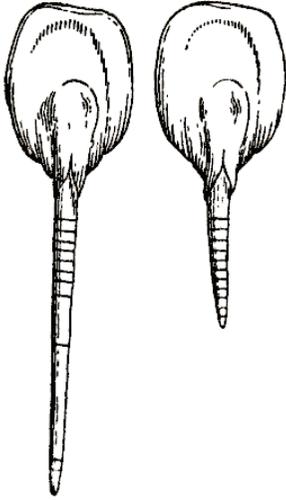


FIGURE 49. Corn seedlings marked to show where growth takes place in the roots.

equal, showing that stretching of the root takes place over a limited area. Figures 48 and 49 show the result with corn and pumpkin seedlings. The root has not grown perceptibly at the tip, for the space marked off by the first line does not appear to be any greater than it was twenty-four hours ago. *Growth in length occurs in a region a short distance back of the tip.* The spaces between the marks back of the tip, especially those between the third, fourth, fifth, and sixth marks, are much

wider. This is the place, then, where the root stretches or grows in length. The stretching is greatest in the middle of this region.

Direction of the roots of seedlings. The first root from the seedling grows downward, as we have seen. In the germinating seed, what advantage is there to the plant in this downward direction of the first root? The roots which grow out from this first or primary root are called lateral roots. What direction do they take?

GROWTH OF THE ROOT AND STEM

What advantage is there to the plant in the direction which the lateral roots take? Look at the root system, as a whole, of the seedling when well developed. What are the advantages to the plant of the distribution of the roots which you observe?

Growth of the stem. In a similar way the region over which growth extends in the stem may be shown. As soon as the seedlings come above the ground, or as soon as a new portion of the shoot begins to elongate above the leaves, mark off the stem with cross lines. The lines on the stem may be placed farther apart than those on the root. They may be put as indicated in Figure 50. A rule may be used to locate the marks on the stem, and then, after several days, if the rule is placed by the side of the stem, the amount of growth will be determined.

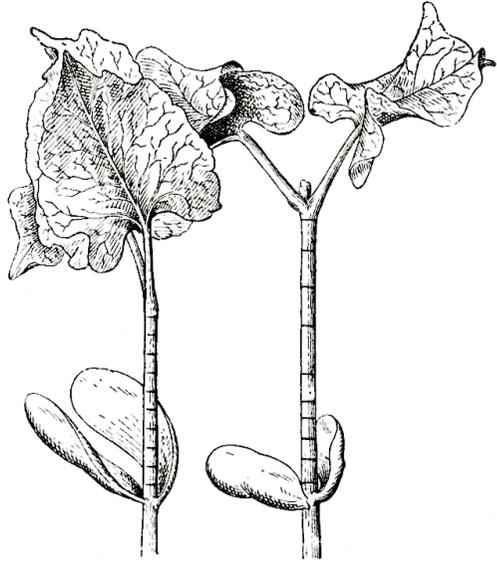


FIGURE 50. Stems of bean marked to show where growth takes place in stem.

CHAPTER V

DIRECTION OF GROWTH OF ROOT AND STEM

In our studies of the seedlings we cannot fail to observe that the *first root grows downward* and the *stem upward*. No matter which way the seed is turned, as soon as the root comes out it turns downward. It grows toward the earth, or if it is in the ground it grows toward the

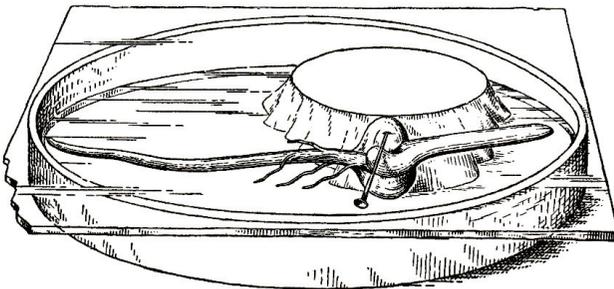


FIGURE 51. *Corn seedling pinned in a horizontal position.*

center of the earth. So we say that the root grows toward the earth, while the stem grows away from the earth, or upward. It is interesting to notice how persistently the root and stem grow in these directions. To see how persistent they are in this, change the positions of the seedlings after they have begun to grow.

DIRECTION OF GROWTH

Downward growth of the root. Take any one of the seedlings germinated in moss or sawdust or behind glass. Place it in a horizontal position. This may be done behind a pane of glass in a box, or a pin may be thrust through the kernel into a cork which is then placed as in Figure 51, with a little water in the bottom of the vessel to keep the air moist. In several hours, or on the following day, observe the position of the root.

The greater part of it remains in a horizontal position, but the end of the root has turned straight downward again.

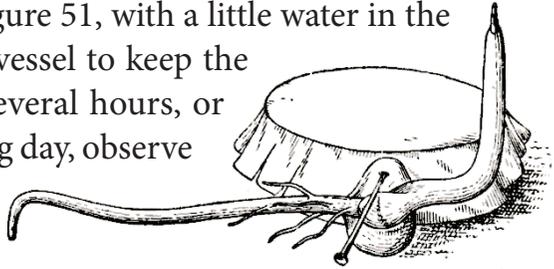


FIGURE 52. Same corn seedling as shown in Figure 51, twenty-four hours later.

What part of the root bends when it turns from the horizontal position? We should now determine

what part of the root it is which bends when it grows downward in this fashion. To do this the root of another seedling should be marked and placed in a horizontal position. With a fine pen and India ink, mark spaces as close together as possible, about 1 mm. apart, beginning at

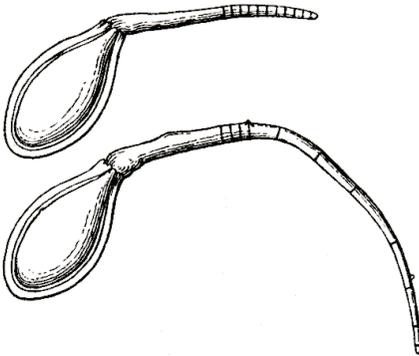


FIGURE 53. Pumpkin seedling placed horizontally and marked to show where the root bends when turning downward.

the tip of the root. Mark off ten such spaces, as shown in Figure 53, and leave the root in a horizontal position for a day. Now observe where the curve has taken place. It has not taken place at the tip, for the mark made near the tip is still there. The curve has taken place back from the tip, in the region of mark 3, 4, or 5, probably, if the marks were close together at first. These marks on the bent region of the root are now far apart.

You remember that when the root was measured to see where growth in length took place, we found that the

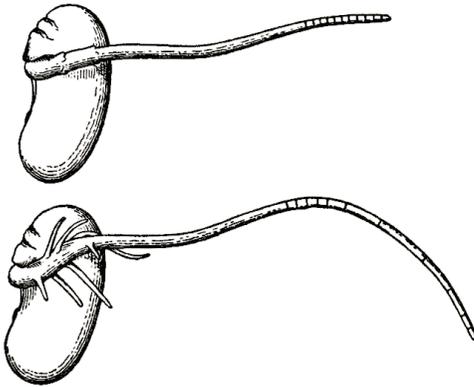


FIGURE 54. *Bean seedling placed horizontally and marked to show where the root bends.*

root grew in this same region, just back of the tip. This is an interesting observation, and I think you can understand why the root can bend easier in the region where it is stretching than in the region where elongation has

ceased. The region of elongation is called the *motor zone*, because this is where the root moves.

What causes the root to turn downward? This is a question that is difficult, perhaps, to demonstrate to your satisfaction. It can be shown, however, that gravity influences the root to turn toward the earth. Gravity, you know, is the force which pulls an apple or a stone toward the earth when either is let fall. We must bear in

DIRECTION OF GROWTH

mind, however, that gravity does not pull the root down in the same way in which it acts on the stone or apple. It only influences or stimulates, we say, the root to turn. (If desirable the teacher can explain or demonstrate for the pupils, that when the influence of gravity is neutralized, the root does not turn downward but continues to grow in the direction

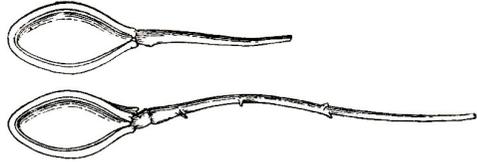


FIGURE 55. *Pumpkin seedling placed horizontally and root tip cut off to show that without the root tip the root will not bend.*

in which it was placed. This may be demonstrated by the well-known experiment of fastening, in different positions, several seedlings on a perpendicular wheel

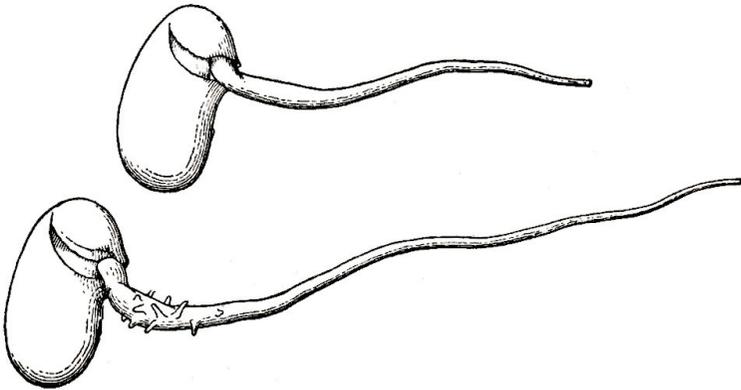


FIGURE 56. *Bean seedling treated as the pumpkin seedling in Figure 55.*

or disk which revolves slowly. The position of the root with reference to the earth is constantly altered, and the influence of gravity is neutralized.)

If the tip is removed, will the root turn? Now place some more seedlings with the roots in a horizontal

position, or, if you choose, this experiment can be carried on along with the others. With sharp scissors, or a very sharp knife, cut off the extreme tip of the root. In twenty-four hours afterwards observe the roots. *They have elongated, but they have not turned downward.* They have continued to grow in the horizontal position in which they were placed, although the motor zone was not cut away. Why is this? It must be that the tip of the root is the part which is sensitive to the influence or stimulus of gravity. For this reason the tip of the root is called the *perceptive zone*.

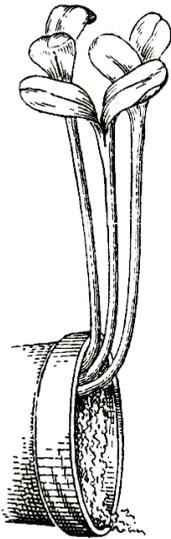


FIGURE 57.
*Sunflower
seedlings
turning
upward.*

The upward growth of the stem.

If the stem is well developed in any of the seedlings placed in a horizontal position, we see that the stem turns up while the root turns down. The corn seedling shows this well in Figure 52. It is more convenient in studying stems to take seedlings grown in pots. Squash, pumpkins, corn, bean, sunflower, etc., are excellent for this study. Place the pot on its side. In twenty-four hours observe the plants. They have turned straight upward again, as shown in Figures 57 and 58. In the case of the stems the part which turns is at a much greater distance from the end than in the root. This is because the *region of elongation or motor zone in the stem is farther from the tip than in the root.*

DIRECTION OF GROWTH

How gravity influences the stem. It may seem remarkable that gravity, which influences the root to grow downward, also influences the stem to grow upward. It is nevertheless true. The lateral roots and lateral stems are influenced differently. What are the advantages to germinating seeds from this influence of gravity on root and stem?

Behavior of the roots toward moisture. Test this by planting seeds in a long box, keeping the soil in one end dry and in the other end moist. The root grows toward moist places in the soil. If the soil is too wet, the roots of many plants grow away from it. Sometimes they grow out on the surface of the soil where they can get air, which they cannot get if the soil is too wet.

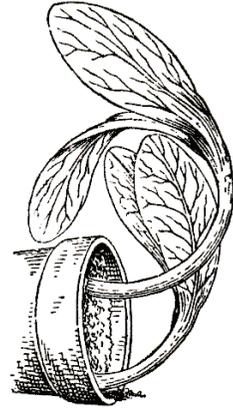


FIGURE 58. *Pumpkin seedlings turning upward.*

CHAPTER VI

BUDS AND WINTER SHOOTS

Do buds have life? When the leaves have fallen from the trees and shrubs in the fall the forest looks bare and dead, except for the pines, spruces, cedars, and other evergreens. The bare tree or shrub in the



FIGURE 59. *Winter condition of trees and shrubs.*

yard looks dead in winter. But examine it. The slender tips of the branches are fresh and green. If we cut or break a twig, it is not dry like a dead stick. It is moist. It seems just as much alive as in the summer, when the trees are covered with green leaves. But look at the tip

BUDS AND WINTER SHOOTS

of the twigs, and on the sides, just above where the leaves were! What do the buds mean? Do they have life?

How the buds look inside. On the shoot of the horse-chestnut see the overlapping “scales” on the bud. Take a pin and remove them one after another. Observe how they are seated in the bud. On this side is one, and on the opposite side is another. How are the next two seated? And the next? They are not very easy to remove, and our hands are “stuck up” if we handle them. This sticky substance helps to hold the scales close together and keeps out water.



FIGURE 60.
*Shoot of
horse-
chestnut.*

When the brown scales are removed, see the thin chaff-like ones! Then come scales covered with long woolly hairs. These scales are green in color, and in shape are like miniature leaves! They are alive even in the fall or winter! How are they kept from being killed? The long woolly hairs are folded round them like a scarf, and all are packed so tightly and snugly under the close-fitting brown scales that they are well protected from loss of water during dry or cold weather, or after freezing. They lie “asleep,” as it were, all winter. In spring we know they awake!



FIGURE 61.
*Shoot
of lilac.*



FIGURE 62. *Opening bud of hickory.*

How the bud looks when split. With a sharp knife we will split the bud down through the end of the stem. We see how closely all the scales fit. Near the center they become smaller and smaller, until there is the soft end of the stem, which seems to be as much alive as in the summer, but it is resting

now. The leaves in the bud are winter leaves. How convenient it is for the tree or shrub that in the fall it can put on this armor of brown scales and wax to protect the tender end of the stem!

The lateral buds.

There are several large buds on the side of the shoot, larger near the terminal bud. If we examine these, we find that they look the same inside as the terminal bud. The lateral buds are smaller,



FIGURE 63. *Long section of horse-chestnut bud—scales and woolly scale leaves inside.*

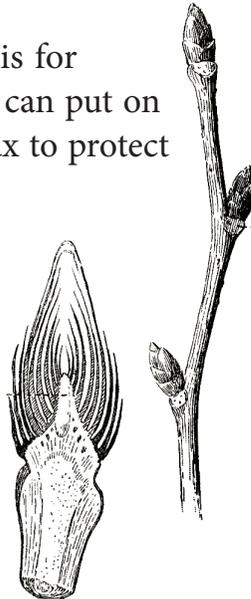


FIGURE 64. *Bud of European elm in section, showing overlapping of scales.*

BUDS AND WINTER SHOOTS

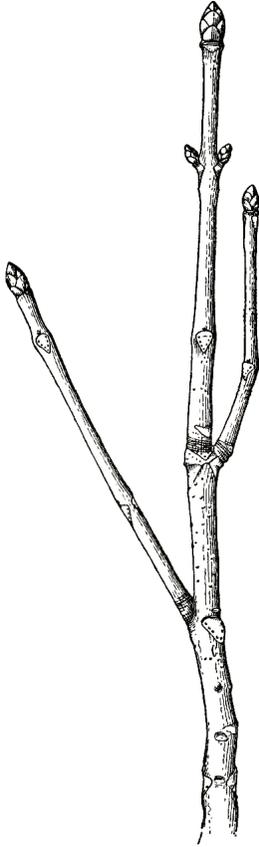


FIGURE 65. *Shoot and buds of horse chestnut.*

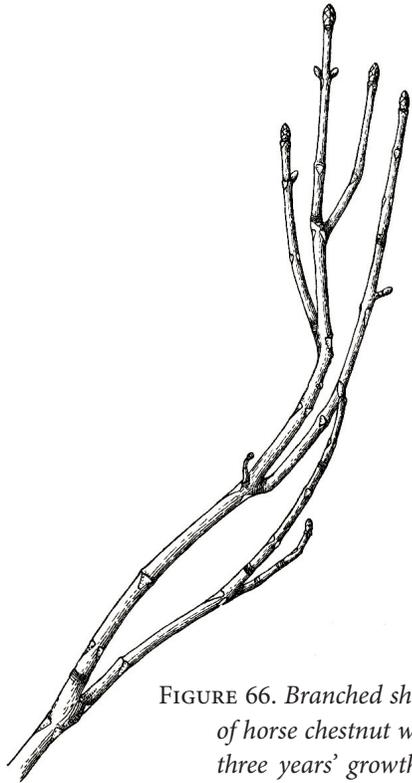


FIGURE 66. *Branched shoot of horse chestnut with three years' growth.*

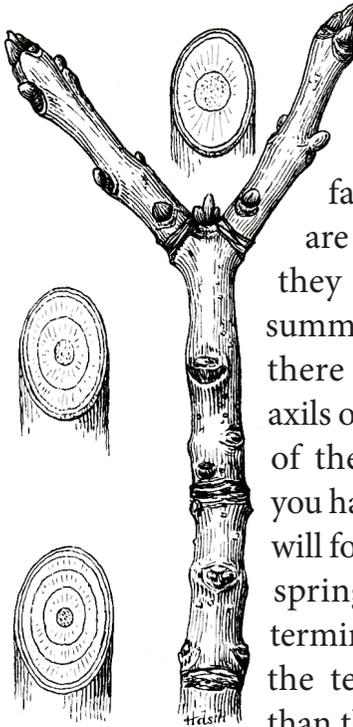


FIGURE 67. Shoot and buds of horse-chestnut.

perhaps. Where are the buds seated on the shoot? The lateral buds are seated just above the scar left by the falling leaf. We say that they are in the axils of the leaves, for they began to form here in the summer, before the leaves fell. Are there buds in the axils of all the leaves of the shoot which you have? Which buds will form branches next spring? What will the terminal bud do? Why is the terminal bud larger than the lateral buds?

The winter shoot. You should have a shoot two or three feet long, branched, if possible. See how it is marked. *The leaf scars.* These are very large, and are in pairs opposite each other, just as the scales are seated in the bud, only the different pairs are farther apart on the stem. Who can tell what the row of pin holes in the scar means? Perhaps you can tell better later on. What else do you see on the shoot? *There are the scale scars, or girdle scars.* What do they mean? When the bud begins to grow in the spring, the winter scales and leaves are thrown off. Each

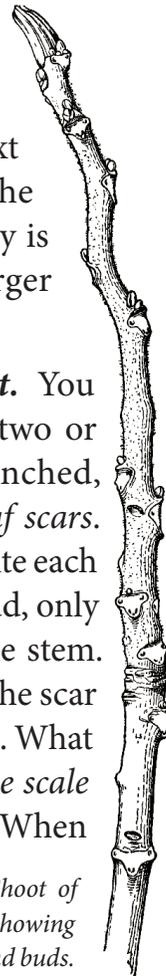


FIGURE 68. Shoot of butternut showing leaf scars and buds.

BUDS AND WINTER SHOOTS

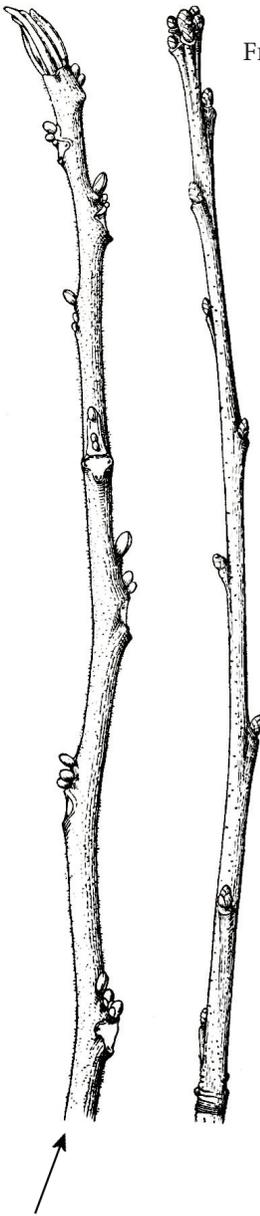


FIGURE 70. *Shoot and bud of white oak.*

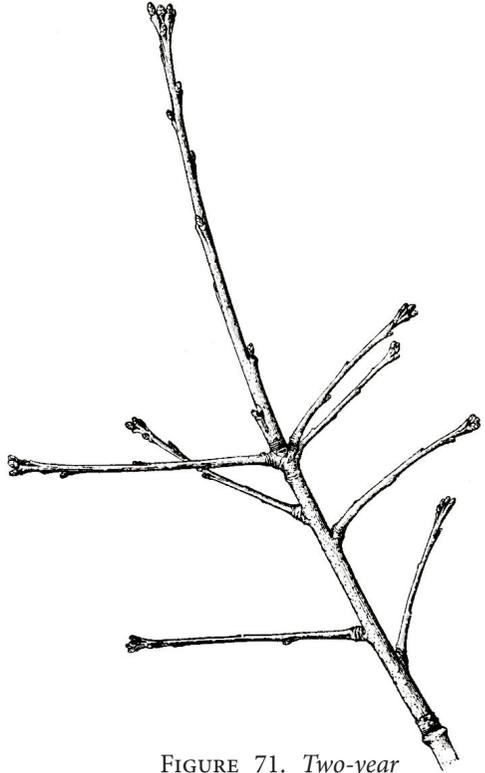


FIGURE 71. *Two-year old shoot of white oak showing where the greater number of branches arise.*

FIGURE 69. *Shoot of butternut showing leaf scars, axillary buds, and adventitious buds (buds coming from above the axils).*

FIRST STUDIES OF PLANT LIFE

tiny scale and winter leaf leaves a scar on the shoot just as the large summer leaves do, only it is a tiny scar. But there are many scars close together all round the shoot, for, as we have seen, the winter scales and leaves are seated so in the bud. Each year, then, a girdle of scale scars is formed on the shoot. How old is the branch you have? Get a shoot which has several girdle scars on it. Cut it through, between the girdle scars. How many rings show in the cut surface of the wood? What does this mean?

Other buds and shoots. Gather other shoots and study the buds, the leaf scars, and their arrangement. Good ones to study are the ash, ailanthus, walnut or butternut, oak, elm, birch, dogwood, peach, apple, willow, poplar, etc.

Some buds may be made to open in the winter. Bring in shoots of dogwood, willow, poplar, ash, oak, etc. Rest the cut ends in water and see what will happen after several weeks or months.