the south. They also probably carried on a trade by sea. In 325 B.C., Pythias, the first explorer of Britain known to fame, was sent at the head of an expedition from Massilia, working his way along the Atlantic coast and wintering somewhere near Dover. From this point he sailed to the Orkneys and Scandinavia, returning by way of the amber coast at the mouth of the Elbe. The Greek influence was also felt from the northern borders of Greece through Germany. In Britain a coinage which was copied from the Stater of Philip of Macedon marks the close of the prehistoric Iron Age, when the Greek influence was dominant. In Ireland, it is worthy of note, none of these coins have been met with, and it is likely, therefore, that the Greek influence was never felt in that island.

From this outline it is clear that the principal artistic development in Britain, in the Bronze and prehistoric Iron Ages, was due to the art of the south, and that it was derived mainly from the Mediterranean civilisation, including under that term Mycenæan, Ægean, Etruscan and Dalmatian art, and that in later times it was aided by intercourse with the Greeks.

W. BOYD DAWKINS.

THE MOVEMENTS OF PLANTS.[1]

IT is sometimes asserted that the power of movement is a character distinguishing animals from plants. This statement arises to some extent from an obvious confusion of thought. Trees are stationary, they are rooted to one spot; but they are not, therefore, motionless. We think them so because our eyes are dull—a fault curable with the help of a microscope. And when we get into the land of magnification, where the little looks big and the slow looks quick, we see such evidence of movement that we wonder we do not hear as well as see the stream of life that flows before our eyes.

In speaking of the cells of which plants are built, Mr. Huxley said that a plant is "an animal enclosed in a wooden box, and Nature, like Sycorax, holds thousands of delicate Ariels imprisoned in every oak." It is this delicate prisoner, the living protoplasm, that we may watch pacing round its prison walls. And we may see it stop as though frightened at our rough usage, and then, after a hesitating twitch or two, we see it recover and once more flow round the cell. Or we can see under the microscope minute free-swimming plants rushing across the field of view, all one way, like a flock of little green sheep that we can drive to and fro with a ray of light for a sheep dog.

But I am not going to speak to-night of microscopic matters, but rather of things on a bigger scale which can be seen with the naked eye. I will begin by trying to show that very obvious movements are to be seen in every kitchen garden or in every garret window where a scarlet runner is grown for its red flowers' sake.

If you will examine a scarlet runner, you see that the shoot is not completely vertical, but bends over to one side. To record the movements of the plant a series of photographs may be taken vertically from above the plant, so that the end of the shoot shows like the hand of a watch against a sort of clock-face on which the points of the compass are marked. These photographs will show how the shoot swings round in its instinctive search for another stick to climb up.

This well-known movement is performed by a co-ordinated series of curvatures the exact nature of which need not trouble us now. Let us rather consider the less obvious power of coordination which enables a plant to grow upwards in a straight line. Think of a forest of pine trees, hundreds of thousands of them, all growing vertically up towards the sky. Here is a clear case of movement, for the leading shoots were once but a few inches from the ground, and now they are crawling along vertical lines 100 feet up in the air. It may be said that this is mere increase in size, not movement in the ordinary sense. But I can show you that the trees could not grow in this way had they not a power of curvature to which the name of movement cannot be refused.

As it is not easy to experiment on pine trees, we will use a pot of mustard seedlings, which represents in miniature a forest of vertical stems. Now suppose the flower-pot upset and left lying on its side for a few hours: the seedlings will be found to have all recovered the vertical position, and they have done so by a bend which is just as much a case of movement as the flexure of a man's arm, though it is effected by a very different mechanism. Not everyone realises how rapid this movement is. Fig. 1 is from a diagram made in the ordinary course of class-work at Cambridge, and illustrates this point. A shoot of *Valerian* was placed horizontally at 2.17 and a black line painted like a silhouette on a vertical sheet of glass to record its position at 2.30; similar lines were painted at intervals, forming a record of fairly rapid movement. If greater delicacy of observation had been practised, it would have been easy to show that the plant begins to curve up within a few minutes of being placed horizontally.

It is a remarkable fact that the plant should be stimulated, or stirred up, to a definite curvature by merely placing it horizontally. The curvature tends to bring the plant into the upright position, and when the whole stem has reached the vertical, the stimulus ceases to exist. It is as though the plant were in a condition of content when vertical and of discontent in any other position, and as though the discontent expressed itself in curvature.

But the plant does not gain the vertical by a single continuous curvature; at first it overdoes the thing (see Fig. 1) and the end of the shoot may pass beyond the vertical by 20°–30°. But this new position, inasmuch as it is not vertical, originates a new stimulus, and the new curvature which follows brings the shoot back towards the upright position. It may again overshoot the mark, but by repeated corrections it finally attains the normal upright posture.

It is this power of correcting the line of growth whenever it deviates from the upright that enables the pine tree to grow

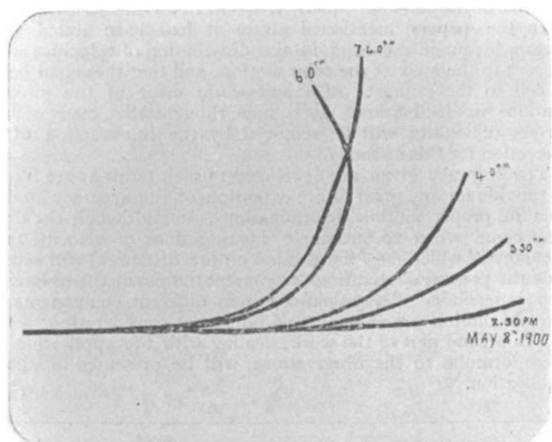


FIG. 1.—A *Valerian* stem curving geotropically.

straight upwards. And this is what I meant when I said that its habit of growth depends on regulated curvature to which no one can refuse the name of movement.

The pine and the seedling have, in fact, a wonderful kind of sensitiveness—a sensitiveness to the force of gravity. To those accustomed to think of Mimosa as the sensitive plant *par excellence* my words may sound strange. But the sensitiveness of Mimosa is crude by comparison with that of the seedling. A plant with a perception of the position of the centre of the earth and a power of growing along the line so perceived is a much greater miracle than a leaf that closes its leaflets when burnt or cut or shaken.

I hope I shall be able to prove to you that we can point to certain parts of the plant which have the special quality of the perception of gravitation, but we are at present ignorant of how the act of perception is effected. We know something of the machinery of hearing or vision in animals, but in plants we can only guess that when a cell is placed horizontally a resulting change of pressure on the protoplasm produces that loss of equilibrium which is translated into curvature.[1]

The use of this gravitational sensitiveness is clear enough. It is to the pine tree what a plumb-line is to the builder, for

[1] Evening lecture delivered at the Glasgow meeting of the British Association, September 16, by Francis Darwin, F.R.S.

[1] It is, however, probable that Nemec and Haberlandt are right, and that the stimulus depends on the pressure of solid particles, *e.g.* starch-grains, on the protoplasm. See their papers in the *Deutsch Bot. Ges.*, 1900.

neither plant nor man can build high unless he builds straight. A man has a general perception of the verticalness of his body and of surrounding objects, but he does not trust to this sense in placing brick on brick to make a house. He uses a plumb-line which tells him through his eye the precise line along which he must pile his bricks. The tree has also to pile one over another the cells or chambers in which its protoplasmic body lives, and this too must be done along a vertical line; but the plant does it by the sensitiveness to gravity of which I have spoken.

It must be clearly understood that gravity does not act directly on the growth of plants. It does not act as a magnet acts on iron, or to take a better example, it does not simply act as gravity acts on the plumb-line in which the string is kept in a vertical straight line by the weight. It might be supposed that in some occult way the stem was mechanically kept straight like the string, and this indeed was the view formerly held about such roots as grow straight down into the earth. But it is not so; the thing is not explicable mechanically. Gravitation is nothing more than a sign-post or signal to the plant—a signal which the plant interprets in the way best suited to its success in the struggle for life, just as what we see or hear gives us signals of the changes in the exterior world by which we regulate our conduct.

You will say that this is hard to prove, and indeed, like other biological hypotheses, it can only be shown to be true by explaining a number of facts. It is interesting to try to explain the facts without the assumption in question. If gravity does *not* act indirectly as a signal it must act directly, and we must find a reason why, in the case of the mustard seedling above referred to, the stem has grown up and the root down. There is absolutely nothing in their structure or manner of growth to help us to see why this difference of behaviour under identical conditions should exist. And if, instead of placing the mustard seedling in the dark we had grown it near the window, we should have come across another remarkable phenomenon, namely, that the stem grows towards, the root away from, the light—and this is equally inexplicable on a mechanical basis.

But it may be said that it is not fair to compare a root and a stem which are structurally unlike. Let us, therefore, stick to roots. When the root of a bean has grown vertically down into the soil for some distance it begins to bud forth into side roots. These are exactly like the primary root from which they spring; there is no difference in structure or in machinery of growth. Yet the secondary roots do not grow vertically down, but obliquely, or in some cases horizontally. There is one more striking fact about the roots of the bean. The secondary, like the primary roots, give off branches, and these—the tertiaries—behave differently from both primary and secondary roots. For instead of directing themselves vertically or horizontally, they simply treat the force of gravity with contempt and grow just where fancy leads them. The point on which I wish to insist is that it is impossible to explain on any theory of the direct action of gravity why the three orders of roots have three distinct modes of growth. They may remind us of three generations, grandfather, father, and son, all of one blood and yet behaving towards the universe in three distinct ways—a fact not unknown in human society.

On the other hand, it would not be difficult to show that the behaviour of the three orders of roots is well suited to the plant's needs, and therefore we can understand how the power of behaving in three different ways to the same signal has been evolved. The main root takes the shortest course to the deeper layers of earth; the four or five ranks of secondary roots divide the world between them and push forth all round, keeping slightly below the horizontal; the tertiaries take it for granted that their predecessors have done the usual thing and that they can satisfactorily occupy the spaces left among their elders by random growth. The fact that the tertiary roots have no specialised sensitiveness of gravitation shows that their unregulated growth is good enough for the necessities of the case. For among organised beings necessity is the mother of development, and what their brethren of second rank have developed they too could assuredly have gained. To this point of view I shall return, but first I should like to give a few more instances of actions carried out in response to the signal of gravity; and these examples shall be from stem-structures.

The flower-heads of a clover (*T. subterraneum*) bury themselves in the ground, thus effectually sowing their own seeds, and they are guided to the ground by their unusual capacity of curving down and directing themselves like a primary root towards the centre of the earth.

Other flower-stalks are guided by gravitation for quite different purposes. Take, for instance, a common narcissus. In the young condition there is a straight shaft piercing the ground

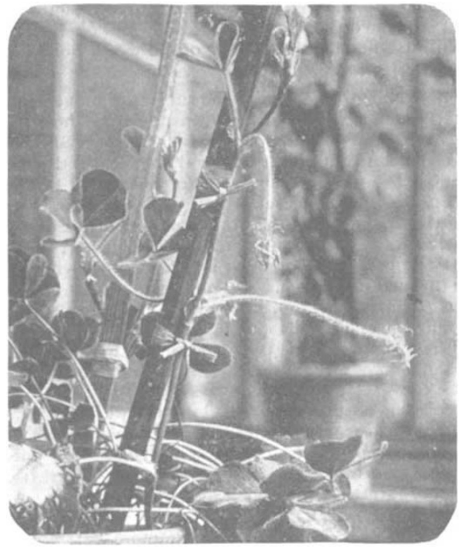


FIG. 2.—*Trifolium subterraneum.* Two flower-heads in the fruiting condition: the upper one has bent sharply and is growing vertically downwards.

with its compact pointed flower bud; but as the flower opens the stalk bends close to the top and brings the flower-tube into a roughly horizontal position, where it shows off its brightly coloured crown to the insects that visit it. The flowers are guided to the right position by the gravitation sense, and they increase or diminish the angular bend in their stalk till the right position is attained, as shown in Fig. 3. The same thing

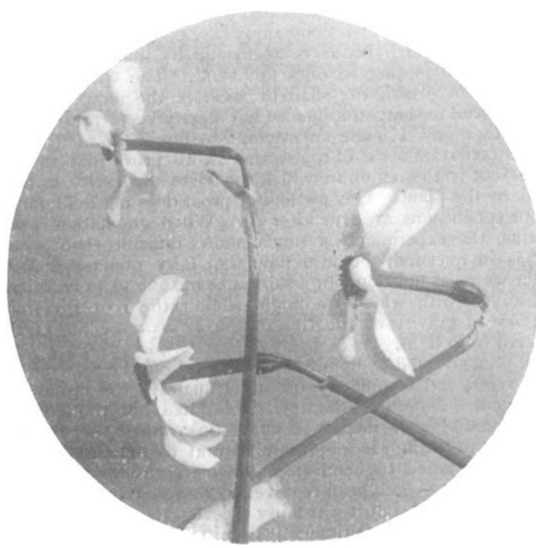


FIG. 3.—Narcissus flowers.

may be easily seen in the larkspur. So long as the plant is left to itself the flower-stalk remains quiescent, but if the stem is displaced so that the flower makes the wrong angle with the vertical, the stalk is stimulated to curve, and bends until the flower is once more in its proper position.

All these cases of plants executing certain useful curvatures which occur when the plant is displaced as regards the vertical and cease when the habitual relation is reached, all these, I say, seem to me only explicable on the theory that gravitation does not act as a mechanical influence, but as a signal which the plant may neglect entirely, or, if it notices, may interpret in any way; that is, it may grow along the indicated line in either direction or across it at any angle. You may say that this is no explanation at all, that it only amounts to saying that the plant can do as it chooses. I have no objection to this, if you will first define the meaning of the word "choice."

I AM now going to deal with the subject of movement from a somewhat different point of view, namely, to show that it is possible to discover the part of the plant which reads the signal, and this is not necessarily the part that executes the correlated movement. In the reflex movement of an animal (for instance, a cough produced by a crumb going the wrong way), we distinguish the irritation of the throat and the abdomen, and further, the nervous machinery by which the stimulus is reflected or switched on, by way of the central nervous system, from throat to coughing muscles. In the plant, too, if we are to compare its movements to the reflexes of animals (as has been done by Czapek), we must distinguish a region of percipience, another of motility, and the transmission of an influence from the percipient to the motor region.

Transmission of a stimulus has long been known in Mimosa, but in the far more important curvatures which we are now considering it was not known to exist before the publication of the "Power of Movement in Plants." There is an experiment of Rothert's[1] which we do in class work at Cambridge, and which only differs from my father's classical experiment in the fact that a much more perfectly adapted plant is employed. The plant in question is a grass, *Setaria*, which has a remarkable form of seedling. When the grain germinates it does not send up a simple cylindrical sprout like an oat, but a delicate stem terminating in a pointed swollen part which looks like a little spear-head. When a group of *Setarias* is illuminated from one side, they bend strongly over, with their little spear-heads all pointing straight at the light. The spear-heads do not bend; the whole movement is carried out by the stalk on which the head is supported. But the remarkable thing is that it is the spear-head and not the stalk which perceives the light. This is easily proved by covering the heads of a few *Setarias* with opaque caps. For the result is that the blindfolded seedlings remain vertical while their companions are pointing to the light. Thus the part which bends is unaffected by illumination, and the part which is affected does not bend. The spear-head is the percipient organ, the shaft or stalk is the motor region, and from head to shaft an influence has clearly been transmitted.

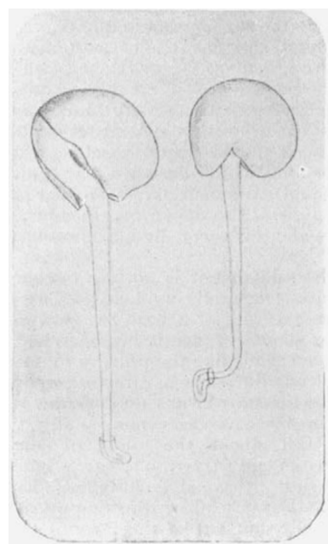
My father and I made an attempt to prove the same thing for the gravitation-sense of roots, that is, to prove that the tip of the root is the region in which the force of gravity is perceived by the plant. Our method of proof does not hold good, but our conclusions are true after all. When gravitation is the stimulus, the experiment is much more difficult than when light is in question, because now that fairy godmothers are extinct we must not hope for a substance opaque to gravitation, a substance with which we might shelter the root-tips from the force of gravity as the tips of the *Setaria* seedlings were sheltered from light.

The plan adopted by us was simply to cut off the extreme tip of the roots, and fortunately (or unfortunately) the result was just what was expected—the tipless roots had lost the sense of gravitation and were unable to curve downwards towards the centre of the earth. It was surely natural to believe that the tipless roots failed to bend because their sense-organs—their percipient parts—had been removed. As a matter of fact they had been removed, but it was fairly objected that the operation of removing the delicate tissues at the tip of the root is a severe one, and that the roots which refused to grow downwards were suffering from shock and not from the absence of their sense-organs.

The subsequent history of the inquiry is an instance of the unwisdom of prophesying unless you know. In 1894 an able summary of the question was published in a German journal, in which the impossibility of solving the problem of the gravitational sensitiveness of the root-tip was dwelt on, and immediately afterwards Section K of this Association had the satisfaction of hearing Pfeffer read a brilliant paper giving the long-hoped-for proof that the tip of the root is a sense-organ for gravitation.[1]

Like many other experiments, it depends on a deception or trick played on the plant. The root is forced to grow into a glass tube closed at one end and sharply bent in the middle, resembling, in fact, a little glass boot. The extreme tip is thus kept at right angles to the main body of the root; if the theory we are testing is the right one, a root with its motor region horizontal and its tip vertical ought to continue to grow horizontally, because the tip being vertical is not stimulated by gravity; it is in a quiescent, or, as it were, a satisfied condition, and no bending influence is being sent to the motor region. And this is what Pfeffer and Czapek found. Fig. 4 A, if turned through a right angle, will represent such a root. On the other hand, if the main body of the root points vertically down while the sensitive tip is horizontal, a curvature results, because as long as the tip is horizontal it is stimulated, and the stimulus is transmitted to the motor region. Fig. 4 A shows the tip horizontal; B shows the curvature which brings the tip into the vertical once more.

This experiment proves not only that the tip of the root is the sense-organ for gravity, but also that the motile part is not



A B

FIG. 4.—Roots in glass boots (from *Pringsheim's Jahrbücher*).

directly sensitive; in other words, that gravitation is perceived exclusively in the tip of the root. Since the publication of Pfeffer's and Czapek's papers I have been lucky enough to hit on another way of testing the theory that the tip is the percipient organ for gravitation,[2] and I am not without hopes that botanists may become in this question as fertile as Cyrano with his seven ways of flying to the moon.

There is a certain kind of inverted action familiarly known as the tail wagging the dog, and it is on this principle of inversion that my experiment is designed. Inversion may in some cases be practised without altering the final result. For instance, it does not much matter whether the thread goes to the needle (the rational masculine plan) or *vice versâ*, as in the orthodox feminine way of threading a needle. In other cases you create what is practically a new machine by inversion, as in a certain apparatus in which the hand of a clock stops still while the clock itself rotates. The effect is still more striking with my plants, for the inversion practised on them entirely changes the character of their movement.

The result may be shown with the seedling *Setarias* of

[1] Cohn's *Beiträge*, 1894.

[1] Pfeffer, in the *Annals of Botany*, September 1894. Further details in Czapek's paper in *Pringsheim's Jahrb.*, 1895.
[2] F. Darwin, *Annals of Botany*, December, 1899.

which I have spoken, or with *Sorghum*, as in Fig. 5. If one of these is supported by its seed with its stem projecting freely in the horizontal plane, the gravitation stimulus makes it bend upwards until the tip is vertical, when the stimulus ceases to act and the curvature comes to an end. If the conditions are reversed, if the seedling is supported in a horizontal position *by its tip*, while the seed projects freely, the result is at first the same, though finally it comes to be strikingly

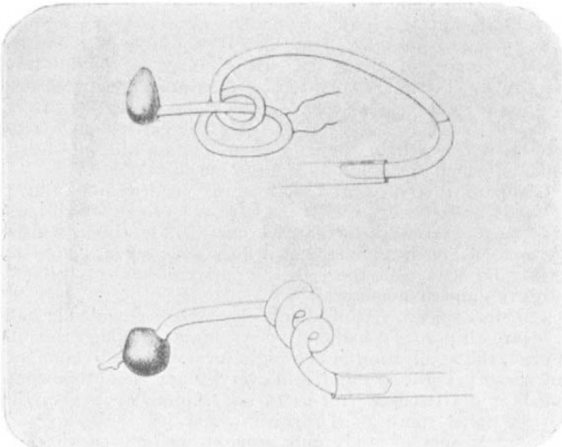


FIG. 5.—Seedling *Sorghums* supported by their tips in horizontal glass tubes. (From the *Annals of Botany*.)

different. The basal end of the seedling is carried upwards by the curvature of the stem; but according to the theory we are testing, the tip of the seedling is the only part of the plant which feels the gravitational stimulus, and the tip of the seedling remains horizontal in spite of the curvature of the stem. Therefore the tip of the seedling is not freed from stimulation as it was in the first case, where the curvature brought the tip into

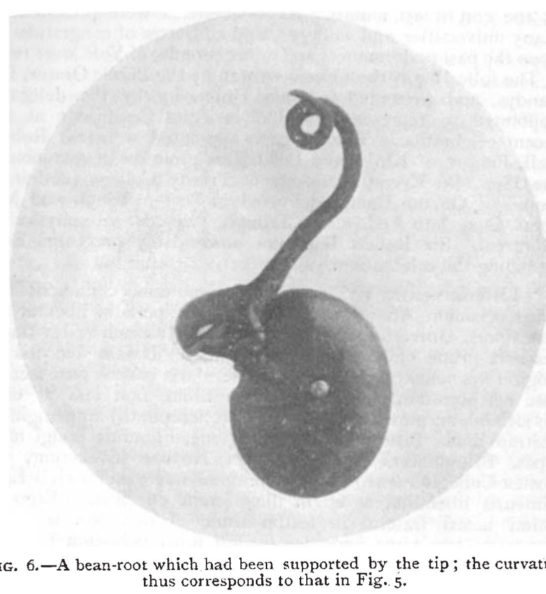


FIG. 6.—A bean-root which had been supported by the tip; the curvature thus corresponds to that in Fig. 5.

the vertical position. The horizontal tip therefore continues to send commands to the stem to go on curving, in a way I can best explain if I am allowed to make the plant express its sensations in words. The tip says to the stem, "I am horizontal, therefore you must bend upwards"; and when this order has been obeyed the tip says, "It is of no use, I am still horizontal—go on bending." The result is that the stem curls up into a spiral like a corkscrew or a French horn, as shown in Fig. 5. I have also been able to get the same result with the roots of beans and peas, as shown in Fig 6.[1]

These unfortunate plants are in the position of a convict on the treadmill; their movements are, from their own point of view, absolutely ineffectual and meaningless. The results are, however, of some importance from our point of view, since they give clear support to the theory which I have now attempted to place before you, namely, that the percipient region is at the tip of the *Setaria* seedling or of the bean root (as the case may be), and that by what corresponds to a reflex action the stimulus perceived by the tip is transmitted to the motor region. I think I may quote my father's words and say that it is hardly an exaggeration to say that the tip acts like the brain of one of the lower animals.

I should like to add a few words on the question how far the movement of plants can be placed under the general laws deducible for the movements of animals. Unfortunately, as soon as we attack this question we are liable to enter regions where for the ignorant there are many pitfalls. We are, in fact, face to face with the question whether in plants there is anything in which we may recognise the faint beginnings of consciousness, whether plants have the rudiments of desire or of memory, or other qualities generally described as mental.

If we take the wide view of memory which has been set forth by Mr. S. Butler[2] and by Prof. Hering, we shall be forced to believe that plants, like all other living things, have a kind of memory. For these writers make memory cover the whole phenomena of life. Inheritance with them is a form of memory, or memory a kind of inheritance. A plant or an animal grows into the form inherited from its ancestors by passing through a series of changes, each change being linked to the preceding stage as the notes of a tune are linked together in the nervous system of one who plays the piano. Or we may compare the development of an animal or plant to the firing of a train of gunpowder, which completes itself by a series of explosions each leading to a new one. To use the language I have been employing, each stage in development acts as a signal to the next.

In the same way the characteristic element in what is done by memory or by that "unconscious memory"[3] known as habit is the association of a chain of thoughts or actions each calling forth the next.

What I wish to insist on is that the process I have called action by signal is of the same type as action by association, and therefore allied to habit and memory. The plants alive to-day are the successful ones who have inherited from successful ancestors the power of curving in certain ways when, by accidental deviations from their normal attitude, some change of pressure is produced in their protoplasm. With the pianist the playing of A has become tied to, entangled or associated with the playing of B, so that the playing of A has grown to be a signal to the muscles to play B: similarly in the plant the act of bending has become tied to, entangled or associated with, that change in the protoplasm due to the altered position. There is no mechanical necessity that B should follow A in the tune; the sequence is owing to the path built by habit in the man's brain. And this is equally true of the plant, in which a hereditary habit has been built up in a brain-like root-tip.

The capacities of plants of which I have spoken have been compared to instincts, and if I prefer to call them reflexes it is because instinct is generally applied to actions with something of an undoubted mental basis. I do not necessarily wish it to be inferred that there can be nothing in plants which may possibly be construed as the germ of consciousness—nothing psychic, to use a convenient term; but it is clearly our duty to explain the facts, if possible, without assuming a psychological resemblance between plants and human beings, lest we go astray into anthropomorphism or sentimentality, and sin against the law of parsimony, which forbids us to assume the action of higher causes when lower will suffice.

The problem is clearly one for treatment by evolutionary method—for instance, by applying the principle of continuity.[4] Man is developed from an ovum, and since man has consciousness it is allowable to suppose that the speck of protoplasm from which he develops has a quality which can grow into consciousness, and by analogy that other protoplasmic bodies, for instance those found in plants, have at least the ghosts of similar

1 F. Darwin, in *Proc.* Cambridge Phil. Soc., xi.
2 "Life and Habit," 1878.
3 Mr. S. Butler's term.
4 See James Ward, "Naturalism and Agnosticism," i. 283.

qualities. But the principle of continuity may be used the other way up—it may be argued that if a lump of protoplasm can perform the essential functions of a living thing to all appearances without consciousness, the supposed value of consciousness in Man is an illusion. This is the doctrine of animal automatism so brilliantly treated by Mr. Huxley.[1] He is chiefly concerned with the value of consciousness to an organism—a question into which I cannot enter. What concerns us now is that, however we use the doctrine of continuity, it gives support to belief in a psychic element in plants. All I contend for at this moment is that there is nothing unscientific in classing animals and plants together from a psychological standpoint. For this contention I may quote a well-known psychologist, Dr. James Ward,[2] who concludes that mind "is always implicated in life." He remarks, too (*ibid.* p. 287), "it would be hardly going too far to say that Aristotle's conception of a plant-soul . . . . is tenable even to-day, at least as tenable as any such notion can be at a time when souls are out of fashion."

This is a path of inquiry I am quite incapable of pursuing. It would be safer for me to rest contented with asserting that plants are vegetable automata, as some philosophers are content to make an automaton of Man. But I am not satisfied with this resting-place. And I hope that other biologists will not be satisfied with a point of view in which consciousness is no more than a bye-product of automatic action, and that they will in time gain a definite conception of the value of consciousness in the economy of living organisms. Nor can I doubt that the facts we have to-night discussed must contribute to the foundation of this wider psychological outlook.

1 "Science and Culture," Collected Essays, i.
2 *Loc. cit.* p. 288.

LESSONS FROM GERMANY.

WE are glad to see that many public men are directing attention to the relationship between scientific investigation and industrial progress, and urging reforms which were advocated in these columns, and by men of science generally, long before the present position was reached. There is no question now that resolute efforts must be made if Great Britain is to hold her own during the twentieth century. Already we have lost supremacy in several branches of industry, and we shall probably be surpassed in others by America and Germany unless our commercial men learn to realise that science is the source of energy of all sustained industrial movements.

It is the business of scientific research to extend natural knowledge, and the investigator is not usually concerned with the commercial aspects of his work. The application of scientific results to industrial developments is for the manufacturer and merchant to consider, but they are unable to appreciate the possibilities of such results unless they have themselves had a scientific education. A discovery which to one man appears trivial may be made by another the nucleus of a great industrial development. Commercial history can afford numerous instances of the connection between science and prescience and the influence which the two combined exert upon progress. Mr. R. B. Haldane, M.P., mentions a few cases of this kind in an article in the November number of the *Monthly Review*. He selects the brewing industry as one instance of a change which should cause national concern. Thirty years ago Germany exported no beer, to-day she exports almost as much as Britain. The advance is due to the discovery and application of scientific method. When the "Brauerbund" was formed, it was definitely decided to make science with practice and practice with science the principle to work upon. Scientific stations were established in which technical problems confronting the practical brewer could be studied, brewing schools were founded, each with laboratories, experimental maltings and a brewery attached to them, and every effort was made to provide for the education of brewers with scientific as well as technical knowledge. The result of this thorough provision for educating scientific brewers is that German beer is a very active rival of English beers in our own country, and in France it almost monopolises the market.

This is one example given by Mr. Haldane to show how the industrial life in Germany is in close contact with the academic life. The case of the aniline dyes is too well known to need to be described here again, but our loss may be understood by the fact that 80 per cent. of the coal-tar colours used by the Bradford Dyers' Association now comes from Germany.

It is, however, not only through the school that the man of science in Germany comes to the aid of industry, but also through the experiment stations or central bureaus of scientific opinion. The German, remarks Mr. Haldane, "is aware of the enormous extent to which he is dependent upon high science, and, further, that the best high science cannot be bought by the private firm or company. Accordingly the rival German explosives manufacturers several years ago combined to subscribe about 100,000*l.* and to found close to Berlin what they call their Central-Stelle. This establishment, which is maintained by subscription at a cost of about 12,000*l.* a year, is presided over by one of the most distinguished professors of chemistry in the University of that city, with a staff of highly-trained assistants. To it are referred as they arise the problems (in this industry these abound) by which the subscribers in their individual work are confronted. By it is carried on a regular system of research in the field of production of explosives, the fruits of which are communicated to the subscribers."

Compare this organised system of determining the best methods and processes with the narrow spirit in which most of our commercial work is carried on. Trade rivalry exists in Germany as much as here, but it does not prevent combination having for its object the scientific study of subjects related to industries and manufactures.

The universities, technical schools and other academic institutions are all part of an organised system, and though the aim is culture, the application of the highest knowledge to commercial enterprise is borne in mind, and everything is done to encourage it. It is not necessary for us to copy Germany in everything, but we need more of the spirit which has built up such a splendid system of study and brought science, education and industry into such close relationship. It is the duty of the State to do far more than it has hitherto done to promote this connection by assisting research, organising and extending scientific education, and encouraging men to devote their lives to the extension of natural knowledge.

THE BICENTENNIAL OF YALE UNIVERSITY.

THE two hundredth anniversary of the foundation of the University was celebrated by a series of imposing ceremonies at the end of last month. Representatives were present from many universities and colleges, and addresses of congratulation upon the past performances and future promise of Yale were read.

The following is the address written by the Public Orator, Dr. Sandys, and presented to Yale University by the delegates appointed to represent the University of Cambridge at the recent celebration. The delegates appointed were Sir Robert Ball, Fellow of King's and Lowndean professor of astronomy, the Hon. W. Everett, formerly of Trinity College (author of lectures "On the Cam," delivered in Boston, 1865), and Mr. John Cox, late Fellow of Trinity, professor of physics at Montreal. Sir Robert Ball was unavoidably prevented from attending the celebration.

"Litteris vestris, viri nomine non uno nobis coniunctissimi, trans oceanum Atlanticum ad nos nuper perlatis libenter intelleximus, Universitatem vestram, inter Musarum sedes transmarinas prope omnium vetustissimam, annis iam ducentis ab origine sua feliciter exactis, sacra saecularia paucos post menses esse celebraturam. Trans oceanum illum, non iam ut olim dissociabilem, plus quam sexaginta (ut accepimus) ante originem vestram annis, Insulae Longae e regione, Fluminis Longi inter ripas, Britannorum coloni Portum Novum invenerunt, ubi postea Collegio vestro antiquo nomine novo indito civis Londiniensis liberalitatem etiam illustriorem effecistis. Ergo et animi nostri fraterni in testimonium, et diei tam fausti in honorem, tres viros amicitiae foederi novo vobiscum feriundo libenter delegimus, primum Astronomiae professorem nostrum facundum, quem quasi nuntium nostrum sidereum, velut alterum Mercurium Pleiadis filium Atlantis nepotem, trans maria ad vos mittimus; deinde, e vestra orbis terrarum parte, non modo Universitatis Cantabrigiensis utriusque alumnum, cuius eloquentia olim Cami nostri nomen Angliae Novae inter cives magis notum reddidit, sed etiam Universitatis nostrae alumnum alterum, qui provinciae Canadensis Universitatum inter professores numeratur. Has igitur litteras a legatione nostra ad vos perferendas Mercurio nostro tradimus, in quibus Universitati vestrae florentissimae propterea praesertim gratulamur, quod