nock, where a good load factor may be found in a small area, but in this case the consumers are chiefly mills, which require current for many hours daily.

There is no golden rule to secure cheap electricity. The most favorable size, locality and number of generating stations in each area can only be arrived at by a close study of the local conditions, but there is no doubt that, generally speaking, to secure cheap electricity a widespread network of mains is in most cases a very important, if not an essential, factor.

The electrification of tramways and suburban railways has been an undoubted success where the volume of traffic has justified a frequent service, and it has been remarkable that where suburban lines have been worked by frequent and fast electrical trains there has resulted a great growth of passenger traffic. The electrification of main-line railways would no doubt result in a saving of coal; at the same time, the economical success would largely depend on the broader question as to whether the volume of the traffic would suffice to pay the working expenses and provide a satisfactory return on the capital.

Municipal and company generating stations have been nearly doubled in capacity during the war to meet the demand from munition works, steel works, chemical works, and for many other purposes. The provision of this increased supply was an enormous help in the production of adequate munitions. At the commencement of the war there were few steel electric furnaces in the country; at the end of last year 117 were at work, producing 20,000 tons of steel per month, consisting chiefly of high-grade ferro alloys used in munitions.

Charles A. Parsons

(*To be concluded*)

PHYSIOLOGICAL ISOLATION BY LOW TEMPERATURE IN BRYOPHYLLUM AND OTHER PLANTS

In axiate plants a physiologically active growing tip inhibits more or less completely the development of other growing tips or axes of the same plant within a certain distance which varies to some extent with the intensity of physiological or metabolic activity in the inhibiting tip. This physiological correlation is not specific for the growing tips of stems and roots, but other parts of the plant, *e. g.*, leaves, may exert the same inhibiting effect to a greater or less degree. Removal of the growing tip or other inhibiting part, or a sufficient decrease in its metabolic activity abolishes its inhibiting action upon other parts. These facts have long been known, much experimental work has been done upon this problem of physiological correlation and various hypotheses have been advanced. As regards the manner in which such an effect of one part upon another at a greater or less distance may conceivably be produced, there are apparently three possibilities: first, the growing tip may inhibit indirectly by obtaining through its greater physiological activity the greater proportion of nutritive materials necessary for growth and development; second, the growing tip or other inhibiting part may produce substances which are transported by the fluids of the plant and which exert a specific inhibiting effect upon other parts; and third, the metabolic activity of the growing tip may produce dynamic changes which are conducted through the protoplasm of the plant and influence the physiological condition of the parts which they reach.

As regards the first of these possibilities it is difficult to conceive how in the bean seedling, to take a concrete case, the growing tip can so completely deprive the buds in the axils of the cotyledons of nutrition that they are unable to grow at all, although they are very much nearer the source of both inorganic and organic nutrition than the tip. The attempt to interpret this inhibition solely in nutritive terms has proven unsatisfactory.

The second possibility, the production of more or less specific inhibiting substances, which are transported to other parts of the plant, also presents certain difficulties and inconsistencies. In the first place every growing tip must be immune to the inhibiting substances which it produces, yet these substances inhibit other growing tips; second, in the normal growth of most plants new growing tips of stems usually arise from previously existing growing tips: it is not their origin but their later development which is inhibited; third, the correlation exists in many simple plants, such for example as algæ, where there is, so far as we know, no mechanism for the transportation of such substances through the plant body; fourth, the inhibiting action is not a specific function of growing tips of stems for a leaf may inhibit a bud. In short when we attempt to interpret the facts in terms of inhibiting substances inconsistencies and contradictions began at once to appear.

The third possibility, that of a dynamic change of some sort, transmitted through the protoplasm, has been suggested by various authors, but the problem of the mechanism by which such a transmitted change produces an inhibiting effect has not been adequately considered.

Most experimental work along this line has consisted either in removing, or stopping or retarding the physiological activity of the inhibiting tip or other part, or in physical isolation of the inhibited part from its action. Another method of attack upon the problem which has been but little used consists in attempting to block the correlative factor somewhere along its path in the intact plant.[1] If it is possible to accomplish this blocking without injury to the plant and to make it temporary, *i. e.*, reversible, the nature of the conditions which bring about the block and the behavior of the parts of the plant on the two sides of the block may be expected to afford at least some basis for conclusions concerning the nature of the correlative factor which is blocked.

The experiments briefly described below were undertaken because it was believed that this method of temporarily blocking the correlative factor in its passage would prove particularly fruitful in plants and would afford a means of testing still further the general conception of physiological axiation which has been formulated by one of us on the basis of many different lines of zoological and botanical evidence.

These experiments are concerned with the effect of low temperature as a block to the action of the growing tip upon other parts of the plant. The method of experimentation consists in subjecting to a low temperature some portion of the plant between the inhibiting growing tip and the part which it inhibits, while the inhibiting growing tip and the inhibiting part which it is desired to isolate remain at the usual temperature. More specifically a portion, two centimeters or more in length of the stem, petiole, runner, etc., is surrounded by a coil of tubing through which flows a current of water, at a low, controlled temperature. In order to avoid injury, the diameter of the coil is made large enough so that it does not touch the plant, the portion to be inclosed is wrapped in tinfoil, the space between it and the coil is lightly packed with damp absorbent cotton, and finally the coil, together with the portion of the plant surrounded by it, is wrapped lightly with a bandage of dry raw cotton. In this way a localized region can be maintained at any desired temperature above zero with very slight variation, provided the temperature of the water flowing through the coil is kept constant. In the apparatus used in these experiments the temperature variation inside the coil can be controlled within one degree Centigrade. The plants are kept in a greenhouse at a temperature ranging from 20° to 25° C., while the region surrounded by the coil is kept at a much lower temperature, in most experiments at approximately 3° C., though in some cases temperatures as high as 5° or even 6° have been found effective.

The results of these experiments with low temperature are briefly as follows: It is a familiar fact that in *Bryophyllum* new plants develop from the notches of the leaves when

[1] McCallum, *Bot. Gaz.*, XL., 1905, attempted to block the correlative action by means of localized anesthesia and obtained results of great interest.

the leaves are separated from the parent plant and placed in water or in a saturated atmosphere. We have found that when a length of 2 to 3 centimeters of the petiole is kept at a temperature 2.5° to 3° and the leaf immersed in water at room temperature, the notches, or some of them, will develop into new plants, while the leaf is still attached to the parent plant. The low temperature does not visibly injure the petiole and after its removal the development of the notches may again be inhibited or retarded. Moreover, it can be shown in this way that each leaf exerts a correlative action upon the leaf opposite and to some extent upon other leaves near it, this action extending farther down the stem than upward. For example when the petiole of one leaf is kept at low temperature, development occurs not only in the notches of this leaf but in at least some of those of the opposite leaf and sometimes in some of the notches of the next pair above and of one or two pairs below, if these leaves are immersed in water. In general the effect upon other leaves of the physiological isolation of one leaf apparently decreases with increasing distance from the isolated leaf and more rapidly upward than downward.

Very commonly the development of the notches is less rapid in the leaf with the low temperature zone on its petiole than in the opposite leaf, although the two leaves themselves are at the same temperature. This difference in rate of development is probably due to the fact that the low temperature zone brings about some disturbance in the movement of nutrition to the leaf and so delays somewhat the development of its buds.

Young plants of the scarlet runner bean *Phaseolus multiflorus,* and Lima bean, *Phaseolus macrocarpus* have also been much used in these experiments with even more satisfactory results than *Bryophyllum.* In these species buds are present in the axils of the cotyledons, but in normal plants these buds never develop beyond minute outgrowths. When a length of 2 or 3 centimeters of the stem above the cotyledons and below the first pair of leaves is inclosed in a coil at 3°, 4° and usually even 5° C., these buds develop, although the plant above the zone of low temperature shows no wilting and at most only a slight retardation of growth for two or three days. Moreover, the development of all axillary buds above the zone of low temperature is inhibited as in normal plants, but the inhibiting factor is blocked by the low temperature zone, although water and nutritive substances obviously pass it. When the low temperature coil is removed from the stem the growth of the buds in the axils of the cotyledons may be again inhibited, and may be again started by replacing the low temperature. If, however, the physiological isolation by low temperature is maintained long enough to permit these buds to develop into shoots several centimeters long, they often continue to grow more or less rapidly after the low temperature is removed and in some cases may even inhibit the further growth of the chief tip. In these bean seedlings the effect of the low temperature zone is visible in the growth of the buds within one to two days.

In the same way other axillary buds at higher levels of the stem may be physiologically isolated and induced to develop, while the chief growing tip continues to grow and to inhibit all buds above the zone of low temperature. In most plants a temperature of 5° or 6° C., constitutes an effective block to the inhibiting action of the chief growing tip for several days, but these temperatures are near the upper limit of effectiveness for this species, and adjustment or acclimation of the cooled zone gradually occurs to such a degree that the buds which were at first physiologically isolated are again inhibited and cease to grow even before the low temperature is removed. When lower temperatures are used such acclimation may occur to some extent, but is less rapid.

Physiological isolation of the runner-tip of *Saxifraga sarmentosa* may also be brought about by low temperature. The runners of this plant, like those of the strawberry and various other forms, grow to a certain length, and then the bud at the tip of the runner develops into a new plant, and growth in length of the runner ceases. The more active the parent plant, the longer the runner grows before its tip develops. When the plants are in good condition the runners attain a length of 20 to 30 centimeters or even more before development of the tip occurs. When the length of 2 to 3 centimeters of a growing runner is kept at a temperature of 3° to 4° C., development of the new plant usually begins within two to four days, and very little further growth in length of the runner occurs, even though its length is much less than the normal length of runner produced by the same plant. Since each plant produces numerous runners in succession, and since the normal length of runner at any given time is very definite, several runners, of both earlier and later origin than the experimental runner and from the same plant, may be used as controls. There is no wilting of the runner distal to the low temperature zone, and the tip evidently receives nutrition, for the growth and development of the new plant take place as rapidly as in normal runners which have attained their full length. It should be noted, moreover, that these runner-tips are not permitted to touch the ground and become rooted, but are kept suspended in air.

Work with this method is being continued and further results will be reported and apparatus and technique more fully described in later papers. The results already obtained, together with certain conclusions to which they point are summarized as follows: first, the inhibiting action of the growing tip of the plant upon other buds, or of a leaf upon buds on other leaves, as in *Bryophyllum,* can be blocked by a zone of low temperature which does not prevent the flow of water and nutritive substances; second, the block produced by the zone of low temperature does not involve any visible or permanent alteration of the tissues, but is wholly reversible; third, a temperature which is at first an effective block may become ineffective after a few days, because of acclimation of the cooled zone to that temperature; fourth, in view of the above facts it appears at least highly probable that the inhibiting action of growing tip, a leaf, or other active region of a plant, depends for its passage from point to point upon metabolically active protoplasm, rather than upon purely physical transportation in the fluids flowing through "preformed channels" in the plant. In other words, the mechanism of this physiological correlation appears to possess at least certain of the characteristics of a transmissive or conductive, as distinguished from a purely transportative mechanism.

C. M. CHILD,
A. W. BELLAMY

SCIENTIFIC EVENTS

THE BRITISH NATIONAL PHYSICAL LABORATORY

SIR RICHARD GLAZEBROOK, as already recorded in SCIENCE, resigned the directorship of the National Physical Laboratory, Teddington, which he has held since its inception in 1899 on September 18, his sixty-fifth birthday.

Sir Richard was principal of Liverpool University when he received the appointment to the laboratory, which was founded by the Royal Society, and was originally intended as an extension of Kew Observatory. When the new buildings were opened at Teddington in 1902 it had but two departments and a staff of twenty-six. At the present time the staff numbers about 600, and building operations are still in progress for the accommodation of new departments in research work.

As already announced Richard Glazebrook is succeeded by Professor Petavel, professor of engineering and director of the Whitworth Laboratory in the University of Manchester.

The London *Times* writes:

Sir Richard Glazebrook, who retires from the directorship of the National Physical Laboratory, has controlled its fortunes from its small beginnings in 1899 to its present great place in the scientific organization of the nation. It was first intended merely to carry out investigations required in connection with the manufacture and testing of instruments of precision, and in 1902, when it was moved to new buildings at Teddington, it had only two departments and a staff of twenty-six. It has now seven scientific departments, a secretariat, and a staff of over 600 persons. These deal with heat, optics, acoustics and molecular physics, with electricity, metrology, engineering, metallurgy, the forms of ships and aerial machines, and aero-dynamics. It is the supreme