The relation $\frac{\text{respiration}}{\text{anion absorption}}$ shows high values when the salt concentration in the medium is low, and decreases with increasing concentration. The potential difference between the root and the medium decreases also with increasing salt concentration. In one series the relation $\frac{\text{K absorb.}}{NO_3 \text{ absorb.}}$ attained the values 0·77 in a 0·001 *N*. KNO_3 solution and 0·43 in a 0·01 *N*. solution. The initial potential difference was *ca.* – 70 mv. in the diluted and *ca.* – 25 mv. in the more concentrated solution. More energy is needed to absorb anions in the former case.

Extensive experiments[3] indicate a sort of quantitative relation between the amount of anions absorbed by the root and the respiration intensity during the same period. The following equation was formulated:

$$R_t = R_g + k.A,$$

where R_g is a fundamental or 'minimum' respiration that occurs independently of the mechanism of anion absorption; $k.A$ is the anion respiration, which is a multiple k of the anion absorption A; R_t is the total respiration measured in the experiments. The existence of a 'fundamental respiration' is proved by the fact that its intensity is unaffected by agents, for example, potassium cyanide, which check the anion absorption. The anion respiration is an oxidation mechanism which is regulated by the negative electrical charge of the protoplasmic membrane and it supplies apparently the energy for the absorption of anions against the potential gradient.

The above equation represents only the outlines of the process, for other factors also influence the surface potential of the protoplasm. Thus the coefficient k is a constant only if other factors, for example, the kind of cations in the solution, are constant too. From what has been said about salts and surface potential of the protoplasm, it is evident that the exchange power of the cations partly determines this potential. Bivalent ions have a larger exchange power than monovalent ones, and therefore, in equimolar concentration, depress the potential difference more. On the other hand, ions of high exchange power are less mobile in the protoplasmatic colloids; their retention in the solution increases again the negative potential in the protoplasmic membrane. It requires more energy, of course, to absorb anions from a solution if cations are held back than if they are absorbed in similar amounts too. Consequently absorption experiments show that the relation $\frac{\text{anion respiration}}{\text{anion absorption}} = k$ gives higher values for salts of bivalent cations, for example, Ca^{++}, than for potassium salts. For the same reason, k is higher in a barium salt than in a calcium salt (Ba^{++} is less mobile than Ca^{++}).

If the mechanism of the anion respiration is regulated by the negative charge in the protoplasmic membrane, and if this charge, as measurements show, is a product of the relation $\frac{c\text{H of protoplasmic membrane}}{c\text{H of the medium}}$, the cH value of the medium and all factors which determine this will be included in the complex of conditions which determine the value of the coefficient k in the above equation. Apart from the relative absorption velocity of cations and anions just mentioned, one end-product of the respiration, HCO_3-ions, is an important regulator of the pH of the medium. The aeration of the medium will consequently be an important factor, apart from the fact that the oxygen supply which controls the respiration also depends upon the aeration. The somewhat curious situation will then occur that a very effective aeration is a drawback for intensive anion uptake, because the carbon dioxide left in the solution helps the protoplasm to overcome the resistance to anion absorption.

The theory of anion respiration of which we have here given an outline refers to cells with a pronouncedly acid protoplasmic membrane. Such a membrane seems to be characteristic of plant roots. Other kinds of cells might behave differently. I recall in this connexion the interesting observations on the skin of frogs[4]. If the charge of the root cells is changed to positive by holding them in a *ca.* $10^{-2 \cdot 5}$ *N*. solution of a strong acid, they die within a few minutes. Also in very concentrated salt solutions ($> 10^{-1}$ *N*. KCl) the charge of the membrane will be changed into positive; but the cells then live longer. Such media are by no means normal. On the other hand, one can easily conceive that cells of a normally positive charge relatively to the medium might exist. Such cells will be able to absorb anions without any extra energy supply, but the absorption of cations needs energy supply. This is a speculation so far, because our experience of the interference of reduction processes in ion absorption is very limited. From the point of view of electro-chemistry, reduction processes diminish the positive charge. Attention is here directed to the interesting results of Arens in the polarity of leaf cells during photosynthesis[5]. Potential gradients in protoplasmic boundaries are probably of fundamental importance both in the metabolism and in the translocation of substances within the organism, as well as in the absorption and excretion of ions. From this point of view the investigations in the ion absorption of plant roots may have a wider application.

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Reduction of Carbon Dioxide with Molecular Hydrogen in Green Algæ

A VIGOROUSLY growing pure culture of the alga *Scenedesmus* sp. D.3 is suspended in a hundredth molar (1/100 *M*.) solution of potassium bicarbonate and kept for six hours in the dark in an atmosphere of hydrogen containing 2 per cent carbon dioxide. Shortly before the last traces of oxygen in the vessel have disappeared by way of respiration, the cells begin to absorb hydrogen. The amount of hydrogen absorbed in this reaction varies with the condition of the algæ. After this absorption has stopped, practically no further gas exchange is observed. If the light is now turned on, no evolution of oxygen can be detected but the algæ begin to absorb hydrogen instead. The process has a measurable induction period, but thereafter it proceeds at a steady rate. This phenomenon is strikingly similar to the reduction of carbon dioxide with molecular hydrogen brought about by purple bacteria. That this absorption of hydrogen by the green algæ is connected with the reduction of carbon dioxide can be shown by the same method which enables one to establish the ratio H_2/CO_2 in purple bacteria[1]. The algæ are suspended in a slightly acid phosphate buffer, treated with hydrogen in the dark, and then illuminated until all carbon dioxide stored or produced by fermentation has been used up in photosynthesis. Addition of a known amount of carbonate at this point is followed by a rapid uptake of hydrogen, the quantity of which exceeds the ratio $2H_2$ for $1CO_2$ found in purple bacteria. In *Scenedesmus* this ratio often reaches a value of about 3.

The reaction between molecular hydrogen and carbonic acid in green plants is affected in a peculiar manner by the light intensity. Up to a certain threshold the rate of hydrogen absorption is proportional to the light intensity and at constant intensity, when both reactants are present in excess, the reaction proceeds at a constant rate. If, however, the light exceeds a certain limit of intensity, the absorption of hydrogen stops and after a few minutes normal photosynthesis is in full activity with the production of oxygen.

This effect of light of too high intensity cannot be reversed merely by subsequent reduction of that intensity; a slow dark reaction is necessary to re-establish the bacterial type of light metabolism in green plants.

In the absence of light, 'hydrogen-treated' algæ are able to catalyse the 'oxyhydrogen' reaction, provided the tension of oxygen is held below a certain limiting value. Oxygen at a higher pressure inhibits the oxidation of hydrogen completely; once it has been inhibited, the reaction cannot be immediately restored by lowering the oxygen pressure. For reactivation an incubation period under anærobic conditions is necessary. The inhibiting effect of oxygen on the 'oxyhydrogen' reaction in *Scenedesmus* is very similar to the phenomenon in *Acetobacter peroxidans*[2].

These two observations in *Scenedesmus* supplement each other inasmuch as the reduction of carbon dioxide with hydrogen can be explained by the oxyhydrogen reaction, the catalytic system of the latter reaction being apparently able to use the molecular oxygen produced in photosynthesis at low light intensities. The reaction rates, however, suggest an alternative explanation. Under the conditions of the experiments the oxyhydrogen reaction in green plants may be catalysed by the same enzyme system which normally liberates oxygen in photosynthesis. When completely reduced, the enzyme would not react as a catalase but as an oxidase and a peroxidase. This action of the catalyst would be practically the same in green plants and in purple bacteria. The alternative explanation therefore brings photosynthesis by purple bacteria into accord with that in green plants. Added support to this hypothesis is found in the papers of Keilin and Hartree[3] and of Stern[4] on hydrogen peroxide catalase, from which it appears that catalase will occasionally act as a peroxidase.

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Further Evidence for the Lamarckian Theory of the Cause of Evolution

The death of Prof. William McDougall marks the end of an epoch in the history of biology. Prof. McDougall attained world-wide fame as a brilliant experimental psychologist, but his equally important work on the heritability of acquired habit has been, I think, for the most part overlooked. He experimented on rats, and he showed that when rats were forced by unpleasant experience to acquire a habit, they produced offspring which acquired the habit more readily than did their parents until, at the end of nine years, they acquired the habit at the first contact with the unpleasant experience.

The late Miss Dorothy Sladden (whose work has periodically been noted in Nature) also, like McDougall, was engaged in experiments on the heritability of acquired habit, though she knew nothing of McDougall's work. When she died her work, like that of McDougall, was complete, but the final and conclusive part of it was embodied in jottings in note-books and columns of figures. My former colleague, Mr. H. M. Hewer, has edited these notes and published his results, which were noted in Nature[1].

As Miss Sladden's experiments were of a much simpler type than those of McDougall, a very brief account of them may be given here. She used the stick-insect *Carausius morosus*, a native of South India, which in Great Britain normally feeds on privet. This insect was subjected to periods of semi-starvation, each lasting two days, when it was offered ivy for food which it detested. At the end of each period it was revived by a leaf of privet. Each of these ordeals was called a 'presentation'. The overwhelming majority of the insects would not accept ivy until the fifth presentation, and some even held out until the tenth presentation. These insects are parthenogenetic and when their eggs were collected and bred from, it was found that they accepted ivy at an earlier presentation than did their parents until at the end of five years they took ivy at the first opportunity. Thus Miss Sladden and Prof. McDougall between them have adduced evidence in support of the hypothesis that the acquired habits of one generation are passed on to the next.

Of this I may give two examples. The Didsbury Institute informs me that the effort to transplant sea-island cotton from islets off the coast of Carolina to other parts of the world has resulted in failure. In a few years the transported cotton reverts to the native stock. On the other hand, Marquis wheat, which has doubled the Canadian wheat crop owing to its ability to survive 'summer frosts', has been proved to be a northern Russian race which has gradually adapted itself to the rigours of a subarctic climate. 'Mutants' only persist when cultivated under the exact conditions of soil in which they made their appearance; further, they become progressively weaker and liable to disease.

The alternative hypothesis as to the origin of species has been that these originated from the sports familiar to us in the garden and farmyard which are the source of some of our most valuable domesticated animals and plants. But there are two difficulties about this hypothesis: first, Mohr, whom the late Dr. Bateson called the first geneticist in Europe, has shown that all sports are physiologically weaklings and could never survive in the open; and secondly, that when such sports are returned to the wild in a