CLASSICS OF SCIENCE:

Role of Chlorophyl in Plants

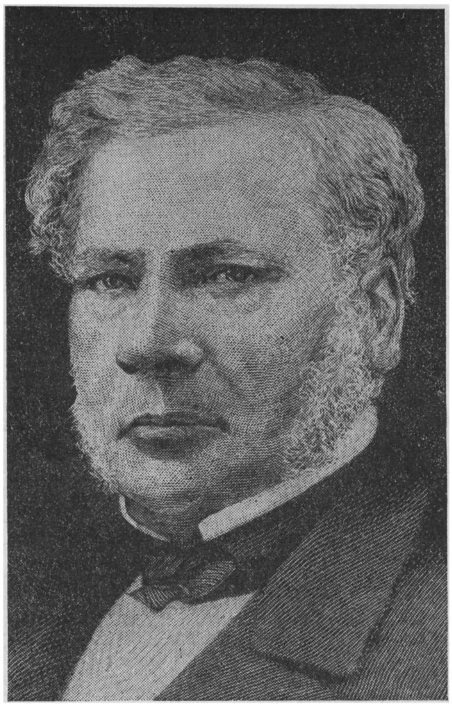
Botany

In addition to the several experiments suggested here by Boussingault, the student will find it interesting to seal up a small green seedling with a little earth and air in an electric light bulb and watch it grow, proving for himself the self-sufficiency of the plant.

RURAL ECONOMY, in its relations with Chemistry, Physics and Meteorology; or, An Application of the Principles of Chemistry and Physiology to the Details of Practical Farming. By J. B. Boussingault, Member of the Institute of France, etc., etc. Translated with an introduction and Notes, by George Law, Agriculturist. London, 1845.

Germination

If some seeds, sufficiently moistened, are placed under a bell glass containing atmospheric air confined over quicksilver, all the signs of germination will soon be perceived. In the course of a few days, provided the temperature has been sufficiently high, germination will have made a certain progress. Supposing that the temperature of the bell glass has not varied and that the atmospheric pressure remains the same, we generally find that the air, in which germination has been proceeding, has not changed its original volume; but it has been modified in its composition; a notable quantity of carbonic acid has been formed and a portion of oxygen has disappeared. The volume of carbonic acid produced represents for the most part the volume of oxygen which has disappeared. Now we know that carbon being burnt in a certain volume of oxygen gas, produces sensibly an equal volume of carbonic acid gas. It was the knowledge of this fact that induced M. de Saussure to say, that in germination carbonic acid is produced by the combustion of a portion of the carbon which enters into the composition of the seed. . . .



J. B. BOUSSINGAULT

In the first period of its germination, therefore, wheat, like trefoil seed, experiences a loss which may in great part be referred to elimination of the carbonic oxide. The chemical composition of these two kinds of seed at more advanced periods of their germination, no longer presents relations so simple. We easily discover that carbon continues to be eliminated; but the loss no longer corresponds with that which the oxygen of the seed ought to suffer, in order that the total loss should be represented by a definite compound of carbon. The phenomenon, in fact, becomes extremely complex; and we can even perceive that it must be so, when we reflect that in proportion as the green parts are evolved, a new chemical action is set up entirely different from that which takes place in the earliest periods of the germination; the green matter of vegetables having, as we shall find, the singular faculty of decomposing carbonic acid gas, and assimilating its carbon under the agency of light.

The action of the green matter begins to be manifested long before the first phases of germination have entirely ceased; so that during a certain time two opposite forces are at work simultaneously. One of these, as we have seen, tends to discharge carbon from the seed; the other tends to accumulate this element within it. So long as the first of these forces predominates, the seed loses carbon; but with the appearance of the green matter the young plant recovers a portion of this principle; finally, when by the progress of the vegetation, the second force surpasses the first in energy, the plant grows, increases, and advances to maturity.

The presence of light is indispensable to the manifestation of the chemical force by which the green parts of plants appropriate the gaseous elements of the atmosphere. Germination, on the contrary, may take place in absolute darkness; and it would be curious to inquire into the issues of vegetation begun and ended under such circumstances, in which the organs produced by the seed would have no power to fix any of the principles of the atmosphere to repair the loss of carbon which the seed suffers. It is evident that this loss of carbon must have a limit, which is probably that of germination. . . .

Evolution and Growth of Plants

As germination advances, we see those organs acquiring shape and size which had appeared at first in the rudimentary state. The roots extend in length, and increase in number, and their extremities become covered with capillary fibres. The stem as it rises puts forth branches in all directions which become covered with leaves. The cotyledons which had nourished the young plant during the first days of its existence, wither and fall. Under the influence of the solar light, the vegetation progresses amain, and the organic matter, which finally constitutes the plant when it has attained maturity, weighs vastly more than the same matter which existed previously in the seed. To quote a single instance from the family of annual plants, a seed of field beet of the weight of .06175 of a grain, may by the end of the autumn give birth to a root which with its leaves shall weigh 162099 grs., or upwards of 28 lbs.

This immense and rapid assimilation can have no other source than the soil, the air and water. Without, at this time, pausing to consider the useful influence which the soil, and the substances it contains, exert upon the entire development of vegetables, we shall here assume it as a general principle that water and the air of the atmosphere alone, are capable of furnishing them with all the elements which enter into their composition, to wit—carbon, hydrogen, oxygen, and azote. In other words, a seed may germinate, vegetate, give birth to a plant which shall attain to complete maturity by the mere concurrence of water and the gases, or vapours which are diffused through the atmosphere. This fact is demonstrated by the following experiment:

In a sufficient (*Turn to next page*)

Chlorophyl in Plants—*Continued*

quantity of properly moistened roughly pounded brick-dust (which had been heated to redness in order to destroy every trace of organic matter), a few peas were sown on the 9th of May, and the pot was transferred to a green-house in order to protect the plants from the dust and impurities which always fly about in the open air.

On the 16th of July, the peas, which looked extremely well and healthy, were in flower. Each seed had sent forth one stem, and each stem, abundantly covered with leaves, bore a flower.

On the 15th of August the pods were ripe; no more water was given, and by the end of the month plants were dry. The length of the stalks varied from about three feet three inches to five feet; but they were extremely slender, and the leaves not more than one third the ordinary size. The pods were 1.3 inch, by from 0.3 to 0.4 of an inch broad. They generally contained two peas each; one contained a single pea only, but this was almost twice the size of any of the others.

In the course of three months, therefore, these peas came to perfect maturity—ripe seeds were gathered. The analysis of the crop, which I shall give by and by, in connexion with another question which we shall have to discuss, showed that the harvest obtained under the conditions indicated, contained a considerably larger proportion of each of the elements found than was originally contained in the seed from which which it sprung.

Carbon being the predominating principle in plants, it is our first duty to inquire into the origin of so much of this element as is assimilated in the course of vegetation.

Carbon is met with in a very small quantity in the atmosphere in the state of carbonic acid, and as this is one of the most soluble of the gases which enter into the constitution of the air, water always contains a considerable quantity of it in solution. Carbonic acid may therefore be in relation with plants by the medium of the air amidst which they live, and of the water which is no less indispensable to their existence. We have now to ascertain in what way this gas evolves and sets free its carbon in favour of living vegetables. . . .

In giving the grand features in the history of this brilliant discovery of the eighteenth century, it may be said that Bonnet was the first who observed the phenomenon of the gaseous evolution effected by the leaves of vegetables; that Priestley anounced that the gas disengaged was oxygen; that Ingenhousz demonstrated the necessity of the solar light to the production of the phenomenon; finally, that it was Sennebier, to whom was reserved the honour of showing that the oxygen gas obtained under these circumstances is the product of the decomposition of carbonic acid. . . .

Green Leaves Take Up Oxygen

The necessity of oxygen gas in the decompounding action which plants exposed to the light exert so energetically upon carbonic acid, leads us to study particularly the phenomena which oxygen exhibits in connexion with growing plants. When a number of freshly gathered and healthy leaves are placed during the night under a bell glass of atmospheric air, they condense a portion of the oxygen; the volume of the air diminishes, and there is a quantity of free carbonic acid formed, generally less than the volume of oxygen which has disappeared. If the leaves which have absorbed this oxygen during their stay in the dark, be now exposed to the sun's light, they restore it nearly in equal quantity, so that all corrections made, the atmosphere of the bell glass returns to its original composition and volume. . . .

Saussure applied the names of inspiration and expiration of plants to these alternate effects, led by the analogy,—somewhat remote, it must be confessed, which the phenomenon presents with the respiration of animals.

The inspiration of leaves has certain limits; in prolonging their stay in the dark, the absorption becomes less and less: it ceases entirely when the leaves have condensed about their own volume of oxygen gas. And let it not be supposed that the nocturnal inspiration of leaves is the consequence of a merely mechanical action, comparable, for example, to that exerted by porous substances generally upon gases. The proof that it is not so is supplied by the fact that the same effects do not follow when leaves are immersed in carbonic acid, hydrogen or azote. In such circumstances there is no appreciable diminution of the atmosphere that surrounds the plant. The primary cause of the inspiration of oxygen by the leaves of living plants is, therefore, obviously of a chemical nature.

With the facts which have just been announced before us, it seems very probable that during the nocturnal inspiration, the carbonic acid which appears is formed at the cost of carbon contained in the leaves, and that this acid is retained either wholly or in part, in proportion as the parenchyma of the leaf is more or less plentifully provided with water. A plant that remains permanently in a dark place, exposed to the open air, loses carbon incessantly; the oxygen of the atmosphere then exerts an action that only terminates with the life of the plant: a result which is apparently in opposition to what takes place in an atmosphere of limited extent. But it is so, because in the free air the green parts of vegetables can never become entirely saturated with carbonic acid, in as much as there is a ceaseless interchange going on between this gas, and the mass of the surrounding atmosphere; there is then, incessant penetration of the gases, as it is called. There is a kind of slow combustion of the carbon of a plant which is abstracted from the reparative influence of the light.

The oxygen of the air also acts, but much less energetically, upon the organs of plants that do not possess a green colour.

Jean Baptiste Joseph Dieudonne Boussingault was born in Paris, February 2, 1802, and died in the same city May 11, 1887. But between those dates he had had a varied career, having gone to South America as a mining engineer for an English firm at the age of twenty and become attached to the staff of the famous General Bolivar. Upon his return to France he became interested in agricultural experiments and in 1839 was appointed professor of agricultural and analytical chemistry at the Conservatoire des Arts et Métiers in Paris. He took an active part in politics also, and was elected to the National Assembly in 1848. A number of discoveries in plant physiology stand to his credit. He proved that plants cannot make direct use of the nitrogen of the air, and, in the extract quoted above, showed the importance of the *green* parts of the plant in the oxygen-carbon dioxide reactions which are dependent on the energy obtained from sunlight.