logical and botanical collections. For two months we had lived at an altitude of over 15,000 feet, soaked by the rains and blinded by the snow and hail, with little or nothing to eat, and nothing to drink but tea, and yet not one of us had a moment's illness from the day we left till we reached our homes again."

GASES IN LIVING PLANTS.[1]

PLANTS are permeated by the same gases that make up the atmosphere surrounding them: oxygen, carbon dioxide and nitrogen. Nitrogen in the form of a gas is neither used nor generated by any part of plants, unless we except the tubercles of certain roots, and so it occurs in about the same percentage inside the plant as outside of it. On the other hand, both oxygen and carbon dioxide enter into combination with, and are liberated from, the plant tissues in varying amounts at different times. The percentage of these two gases in the cavities of the plant vary through a considerable range. In a series of determinations made by Lawes, Gilbert, and Pugh, in England, the oxygen ranged from 3 to 10 per cent., and the carbon dioxide from 14 to 21 per cent. in plants which had been for some time in the dark, while plants which had been standing in sunlight reversed these figures, and gave 24 to 27 per cent. of oxygen and 3 to 6 per cent. of carbon dioxide. The two gases, therefore, bear a somewhat reciprocal relation, their sum usually being about 25 to 30 per cent. of the total gas in the plant.

The variations in the relative amount of oxygen and carbon dioxide are due to two independent processes incident to the life of plants. One of these processes is assimilation, by which all green cells of plants in the presence of sunlight, or its equivalent, such as a strong electric light, absorb carbon dioxide and liberate oxygen. This process goes on with great rapidity in healthy cells, but is entirely checked upon the withdrawal of light, or when it reaches a certain low intensity. Of course it never takes place in roots, flowers, the central portion of large stems, or other parts which are not green, nor in any fungi or other plants not possessed of green colouring matter.

The other great cause of disturbance in the relation of oxygen and carbon dioxide in the plant is the process of respiration.

Respiration in plants is essentially the same as in animals, and consists in a fixation of oxygen and the liberation of carbon dioxide. It takes place in every living cell, whatever the kind of plant, whatever the part of the plant, and whatever the conditions of active existence. The rate of respiration varies with the temperature, the age of the cell, and the nature of the chemical transformations. In normal respiration the amount of oxygen absorbed is approximately the same as the amount of carbon dioxide evolved. There are, however, certain modified forms of respiration in which this does not hold true.

If living plants be placed in a vacuum, or in an atmosphere deprived of oxygen, it is found that they can still carry on life processes for some time, accompanied with an evolution of carbon dioxide. The oxygen necessary for this process is obtained from the breaking up of compounds in the cells, and it is therefore called intramolecular breathing.

The germination of seeds, which contain a large amount of oil, is somewhat the opposite of this last process. In order to convert the fat into a more directly serviceable food material for the plant, a large amount of oxygen enters into the new combination, for which there is no equivalent amount of gas liberated. It consequently comes about that oily seeds in germinating absorb a far larger amount of oxygen than they liberate of carbon dioxide. This is known as vincular breathing.

Another variation from normal respiration is known as insolar breathing, and which, with still some other modifications, I need not stop to explain. To this brief statement of plant respiration must be added that much yet remains to be discovered regarding the details of the processes.

Assimilation and respiration are the two great causes which disturb the relative volume of the two variable gases in plants.

We shall now turn to the movement of the same two gases, oxygen and carbon dioxide. There has never been a disposition as in the case of many other plant phenomena, to explain the movement of gases upon any other than purely physical principles. We have therefore to do simply with the question of the aids and hindrances to the establishment of an equilibrium between the gases inside and outside the plant, irrespective of whether the cells are alive or dead.

It has already been stated that the relative amounts of oxygen and carbon dioxide inside the plant are usually very different, and that within a few hours the relation of the two may be completely reversed. To this may be added that the pressure of the gases inside the plant is sometimes more, sometimes less than that of the atmosphere outside the plant, almost never the same. Hales observed in his early work that a mercury gauge connected with the inside of the trunk of a tree showed an internal pressure when the hot rays of the sun warmed the trunk. This was largely due, undoubtedly, to an expansion of the gases in the trunk, by the heat. Such an excess of pressure in water plants is very common, although due to other causes. It may readily be shown by breaking stems under water, when bubbles of gas will be liberated, as undoubtedly many have noticed in gathering water lilies, or other water plants.

On the other hand, the pressure of the gas inside the plant may be less than on the outside. This has long been recognised, but was best demonstrated by Von Höhnel in 1879, to whom it occurred to cut off stems under mercury. In doing so the mercury rose to a considerable height in the vessels of the stem, and as mercury is without capillarity, this can only be ascribed to the greater pressure of the outside air, or in other words, to a partial vacuum in the plant.

An observation was made by Hales, which we may use to illustrate how such a negative pressure, as it has been called, can be brought about. He cut off a branch, fastened an empty tube to the cut end, and plunged the other end of the tube into a liquid. He found that as evaporation of moisture from the leaves took place, the liquid was drawn up into the empty tube. This phenomenon can now be explained more satisfactorily than could be done at that early day. By evaporation the liquid water inside the plant escapes in the form of vapour, and the space it occupied is filled by the gases, thus rarifying them. This rarifaction may go on in uninjured plants until the internal pressure is greatly reduced. But in the experiment, the pressure is equalised by the rise of the liquid in the tube. A later modification of Hales' experiment is to use a forked branch, place the cut end in water to give a continuous supply of moisture for transpiration, and attach the empty tube to one of the side forks of the stem, cut away for that purpose.

It is self-evident that such condensation and rarifaction of the gases in the plant could not take place if the cell walls were readily permeable to gases. Thus it comes about that one of the most important topics in connection with the movement of gases in the plant, is the permeability of tissue walls of various kinds, and especially those constituting the surface covering of plants.

I shall not attempt to conduct you through the tangle of supposition and fact, errors in experiments, correct and incorrect conclusions, and the general confusion which has come from the labours of physicists, chemists and botanists for the last twenty-five years, during which the subject has received particular attention. The results of the later work have been to cast grave doubts upon the correctness, or at least the interpretation of some of the experiments most relied upon heretofore. Nevertheless many points still lie open for verification, and untouched parts of the subject await investigation.

In the earlier days it was found that the leaves and young stems of plants have their epidermis more or less well supplied with minute openings, called stomata, or breathing pores, which communicate with small air cavities inside, which in turn branch out among the cells into a network of minute passages rarifying throughout the plant. This intricate network of intercellular passages affords an air communication throughout the whole plant, and connects directly with the outside atmosphere through the stomata. Subsequent to the discovery of stomata, it was ascertained, that in stems more than one year old, the stomata are replaced by another kind of opening, known as lenticels, which in some form are doubtless to be found in the bark of shrubs and trees of whatever age.

Gases stream into and out of the plant through the stomata and simpler lenticels, according to the law governing the movement of gases through minute openings in thin plates. The rate of movement is accordingly proportional to the square roots of the density of the mixing gases. Such a movement of gases is known as effusion.

The movement by which gases pass from one part of the

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[1] Reprinted from the *American Naturalist* for February.

plant to another, through the intercellular spaces, is governed by other laws. It was at first thought that the rate of movement would correspond to that in capillary tubes, according to the well-known law of Poisenille, that it is proportional to the fourth power of the diameter, divided by the length of the tube. But upon testing the matter two years ago, Wiesner found that owing to the extreme minuteness of the intercellular spaces, and their zigzagged and branched condition, this law does not hold, neither does the movement prove to be proportional to the density of the gases. The discovery of the law of the rate of movement of gases in intercellular spaces, that is, the transpiration of gases, is, therefore, yet to be discovered, together with other interesting facts pertaining to the subject. Poisenille's law does, however, hold good for the movement of gases in the woody ducts, but here it is of limited application, for these do not connect with one another, with the intercellular spaces, or with the exterior of the plant.

The walls of most cells, ducts, and surface covering of plants, except as already mentioned, are imperforate, that is without any openings that can be demonstrated by the microscope. If gases pass through them, it must be in accordance with some law of diffusion, or osmosis. Many experiments in this line have been tried, and the results have been of the most diverse character. It is impossible to give a fair idea of the subject in the time at my disposal, and it must suffice to mention a few bare facts.

The most astonishing and important results were obtained by Wiesner, in experiments conducted at Vienna, two years since. It would be a most natural interpretation, it seems to me, to think that the gases are forced from one cell to another, through the cell walls by differences in pressure. Wiesner found, however, that it is impossible to force gases through cell walls of any kind whatever, by any pressure they will stand, acting for any length of time. For instance, a bit of grape skin held up a column of mercury, 70 centimetres high, for seventy-five days, and a piece of cherry skin withstood a pressure of 3 atmospheres for twenty-four hours. Similar experiments were tried with cuticularised, suberised, liquefied and simple cellulose tissues from many sources, and with uniformly the same results, whether the tissues were moist or dry, alive or dead.

But in the same set of experiments it was found that if gases cannot be forced through cell walls, they will readily pass through by simple osmotic diffusion. All cells permit the passage of gases by diffusion when moist, dependent upon the coefficient of absorption and the density of the gas. Cuticular and corky formations also permit the passage of gases when dry. Thus we see that gases may be forced through the stomata, or breathing pores, by varying pressure, but can only pass through the epidermis and bark of plants by diffusion. We therefore arrive at the conclusion that the gases inside and outside of the plant are brought to an equilibrium by direct interchange through the stomata and intercellular spaces, aided by the comparatively slow process of diffusion through the whole surface of the plant, both above and below ground.

J. C. ARTHUR.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—The Curators of the Hope Collections will proceed to the election of a Hope Professor in Trinity Term 1893. Candidates for the Professorship, of which the emoluments are £480 per annum, are required to send in their applications, together with such evidence of their qualifications as they may wish to submit to the Curators, on or before May 1, 1893, to the Registrar of the University, Clarendon Buildings, Oxford. The duties of the Hope Professor are, to give public lectures and private instruction on zoology with special reference to the Articulata, to arrange and superintend the Hope collection of annulose animals, and to reside in the University for the term of eight months in every academical year between October 1 and July 15.

Physiological Department.—It is satisfactory to note that the number of students in this department is greater than in any previous corresponding term. The increase is due not only to the larger number of candidates for the M.B. degree, but also to a larger number of candidates for honours in Physiology in the Honour School of Natural Science. The course of study during the term has comprised lectures on the general subjects of the Honour School by the Waynflete Professor on the physiology of nutrition, by Dr. J. S. Haldane: and on the nervous System, by Dr. E. Starling. Mr. Leonard Hill has undertaken the course of lectures on elementary physiology. Practical instruction has been carried on under the superintendence of Dr. Haldane and Mr. M. S. Pembrey.

SCIENTIFIC SERIALS.

Bulletin of the New York Mathematical Society, Vol. ii. No. 4 (New York, 1893).—The contents of this number are an abstract of a paper (read before the Society, June 4, 1892) by Prof. W. Woolsey Johnson, entitled "On Peters's Formula for Probable Error" (pp. 57-61). A clear abstract of Engel and Sophus Lie's Theorie der Transformationsgruppen, by C. H. Chapman (pp. 61-71), and a similar account of U. Dini's work on the theory of functions of a real variable, by J. Harkness (pp. 71-76). Notes and new publications complete the number.

Bulletin de l'Académie Royale de Belgique, No. 12.—An unpublished corollary of Kepler's laws, by F. Folie. A deduction of Dewar's empirical formula for the ratios of the mean velocities of the planets from Kepler's third law.—On the common cause of surface tension and evaporation of liquids (preliminary note) by G. Van der Mensbrugghe. The author endeavoured to show in 1886 that the particles of a liquid are at distances apart which increase as we approach the surface, and that therefore the tension is greatest at the surface. Following up this view, he regards surface tension as the elastic force due to tangential displacement of surface particles, and evaporation as produced by molecular displacement beyond a certain limit in a direction normal to the surface. He predicts that a liquid of high surface tension will be able to evaporate across another liquid which has a lower density and surface tension, and does not mix with the former.—On a new optical illusion, by M. J. Delbœuf.—On the reduction of invariant functions in the system of geometric variables, by Jacques Deruyts.—Construction of a complex system of straight lines of the second order and the second class, by François Deruyts.—Contribution to the study of diastase, by Jules Vuylsteke.—Pupine, a new animal substance, by A. B. Griffiths.—Two experimental verifications relative to refraction in crystals, by J. Verschaffelt. Billet has calculated that if refraction takes place on a cleavage face of a crystal of Iceland spar, the angle of refraction for the extraordinary ray corresponding to normal incidence is 6°12′, and that the ray is normal with an incidence of 9° 49′. M. Verschaffelt has determined these angles experimentally, and found them to be 6° 9′ and 9° 45′ respectively, thus showing a close agreement with the theoretical values.—On the bacterian fermentation of sardines, by M. A. B. Griffiths.—On prejudices in astronomy, by M. F. Folie.—On the constitution of matter and modern physics, by P. de Heen.

Ann. dell' Ufficio Cent. Meteor e Geodinamico, ser. secund., part iii. vol. xi. 1889. Roma, 1892.—Fumo di Vulcano veduto dall' Osservatorio di Palermo durante l'eruzione del 1889, by A. Riccò.—From the obervatory terrace (72m. above sea level) the summits of some of the Lipari islands are visible, but that of Vulcano (140km. distant) is not so. Any smoke or vapour that exceeds 300m. in height can, however, be seen. The author was not successful in either photographing or measuring the dimensions of the smoke cloud, which were, however, estimated by comparison with the size of Alicuri, which had been carefully determined. At the commencement of the observations (January 6, 1889) the smoke column reached a height 10½km. and had the form of the pine tree. Several drawings are given, and the form assumed in some cases is very curious. The paper terminates with some thermodynamical calculations, which are very interesting, but unfortunately based on false premises. The author supposes that the eruption was caused by the access of the sea-water. He supposes this to be at sea level, and calculating the pressure at this point, concludes the vapour was produced from water heated to 196° C. only. He seems to be unacquainted with the solution of H_2O in the fluid volcanic glass, the vesiculation and escape of vapour from it, involving so many data with which the physicist has not yet supplied us, as to make any calculations of such a nature of a highly romantic rather than of practical use.