courses. The polishing was accomplished by movement in the water-courses, aided by the carbonic acid and the calcium carbonate carried in solution. (The polishing work of such waters may be seen in certain caves in the Copper Queen mine at Bisbee, Ariz.)

The topography of the region, the character of the pebbles, their depth below the surface, their relation to the water-courses, the smallness of the joint openings at the surface and the absence of similar pebbles on the surface all make it improbable that the pebbles came from the surface.

R. D. GEORGE

SPECIAL ARTICLES

UPON THE TEACHING OF THE SUBJECT OF RESPIRATION [1]

AT least three totally distinct definitions of the term respiration are expressed or implied in current literature. These and varying shades of meaning are often confused even in the same discussion, and the result is very unsatisfactory.

The first definition occurs in works upon the physiology of the higher animals. Among the different senses in which respiration is there used, one refers to the functions of lungs and gills, processes essentially secondary and which take place far away from the cell.

A second definition is found in general works and especially in botanical ones, namely, that respiration is an exchange of gases, a sort of commerce between the cell and its environment. A majority of our botanical text-books give a categorical definition something as follows. "Respiration is the taking in of oxygen and the giving out of carbon dioxid and water." To this is often joined the idea that the amount of carbon dioxid given off is equal to that of oxygen absorbed, that in fact the oxygen which enters is the same as that which reappears immediately as carbon dioxid, and not seldom, some emphatic and sweeping statement that the living substance must obtain oxygen somehow all the time.

A third and entirely distinct meaning is given to the word in more scientific works such as Pfeffer and in at least two American text-books, namely, that respiration is a vital operation taking place within the cell, a metabolic process in which energy is released and which is ordinarily indicated by the gaseous exchange mentioned in the last definition. The steps of this process are not well known, but any discussion of them seems to include also anaerobic or intramolecular respiration and certain kinds of fermentation.

The confusion in words is inconvenient enough, but there is back of it a confusion of ideas which is more serious, and by which the teaching of the subject is more or less impaired. From the standpoint of the teacher it is imperative that the subject be cleared up somewhat. However, before dealing with the appropriateness of definitions, let us briefly look over the phenomena which we have to deal with. The most common forms of apparatus used by teachers in this country in the study of respiration are U tubes or thistle tubes in which flowers or germinating seeds are placed. The end holding the seeds is sealed and the other end placed in some reagent which will absorb carbon dioxid or oxygen, or both, or in mercury which will absorb none of the atmospheric gases and serve as a control. With such arrangements it is easy to obtain satisfactory and instructive proof that oxygen is absorbed and carbon dioxid given off. If the idea were carried no further all would be well, but there is a temptation to bring in also quantitative results, and, pointing out the fact that caustic potash rises about one fifth of the volume of the tube, to imply that the oxygen contained has been combined in the activity of the plant into an equal amount of carbon dioxid. Remarkable quantitative result is it not, that if in an enclosed space there is a plant absorbing oxygen and a reagent absorbing carbon dioxid, the result should be a reduction of volume to that of the nitrogen present?

Ordinary experiments and bright pupils are a combination which is likely to cause a disturbance in formal ideas of respiration. Suppose, for instance, that three U tubes with germinating peas in the sealed end are set up,

[1] Read before the Botanical Society of America at the New York meeting, December, 1906.

the open ends being in pyrogallol, caustic potash and mercury, respectively. The pryo rises rapidly by absorption of oxygen till it occupies about one fifth of the volume, the potash slowly does the same as the plants absorb the oxygen and give off carbon dioxid till it also reaches the one-fifth mark and the mercury does not rise at all. After some days the experiment looked upon as a perfect success is ready to be taken down. Theoretically, over the mercury also the oxygen has been absorbed and its place taken by carbon dioxid. Some student, not knowing any better, concludes to demonstrate that fact by introducing potash solution through the mercury. At once the mercury begins to rise in the tube, carrying the potash before it. The student watches to see it stop at the one-fifth mark and is astonished to see it continue to mount until it has reached two fifths or even more. Then the best the teacher can do is to clumsily explain that here is something he had not meant to demonstrate; that this is *intramolecular respiration,* that carbon dioxid has been produced in quantities and that the mixture of carbon dioxid and air has bubbled out through the mercury, some of the nitrogen thus escaping. Now it will at once be urged that some other seeds than peas should have been used for the experiment. But one may at least inquire why. Peas are living things and they are convenient. Moreover, if seeds in any considerable bulk are employed over mercury, the teacher must choose the seeds very carefully indeed if the idea of an equal exchange is not to suffer. If a series of objects are used, alterations of volume will occur in nearly all. In chrysanthemum flowers and peas the volume increases. In beet, turnip and timothy seed the volume diminishes. Facts such as these have long been known. It is well known, for example, that in oily seeds generally, oxygen absorption at first outruns production of carbon dioxid. Now after such a brief and fragmentary consideration of the experimental side, let us take up the question of definitions.

In regard to the first definition (that respiration refers to the functions of lungs and gills) it may be merely noted that it is of application only in the case of differentiated animals and the question of use must therefore be left to students in that field. It may be pointed out in passing, however, that respiration in this sense is so firmly imbedded in literature that it will probably retain the meaning it has, and that this meaning is so distinct that it will be little source of confusion. For the botanist the discussion must be between the following definitions and here confusion of thought arises very easily.

In regard to the second definition (that respiration is taking in oxygen and giving out carbon dioxid) it may be observed that it is easy of demonstration and is remarkably clear of statement and these features have probably given it its wide currency. But when we press for the conception lying back of the definition, for the idea which the words convey, it seems to be little more than a physical process of diffusion. On this account a telling objection can be raised. Granting that the gaseous exchange is easy to demonstrate and that the definition is exceedingly clear, which the writer is freely willing to do; granting that only aerobic respiration need be referred to in general teaching, which the writer is unwilling to do, it is still open to the fundamental criticism that it turns the student's attention away from the vital and really important process to a superficial and physical one. For far and away the most important idea in the teacher's subject matter is this: The living substance must have energy; it can get it only by working changes in the compounds within reach in such a way as to release energy. If oxygen is at hand these changes are largely those of oxidation. If oxygen is lacking the cell will find another way. To define respiration then as a gaseous exchange is to turn away from the all-important process. In this connection it may also be noted that to imply in addition that the carbon dioxid produced is equal to the oxygen absorbed amounts to positive error as does also the hard and fast statement that all living matter must obtain constant supplies of oxygen.

In regard to the third definition it may be observed that it refers to processes which are somewhat obscure and which are, after all, covered by the term metabolism. Nevertheless, it points to the really important vital process and it is broad enough to be in harmony with all the facts we know. (If respiration is taking in one gas and giving out another, 'intramolecular respiration' is an absurdity in words.) There seems scanty warrant for the custom of setting aside anaerobic respiration as though it were something entirely different or pathological or unusual. That aerobic and anaerobic respiration and even fermentation are closely connected, has for some time been recognized and has been brought out with especial clearness by Barnes.[2]

It may be urged that respiration in this sense is too abstract and complex to be a profitable subject for general teaching. With this view the writer does not agree. Certainly no amount of obscurity or complexity in an essential process can warrant the adjustment of definitions and teaching so as to lay the emphasis on the superficial accompaniments of that process. It seems to him that fundamental conceptions are the very ones to strive for in general teaching. Teaching may not go very far, but it ought to point in the right direction.

The suggestion made by Barnes[3] that a new term 'energesis' be adopted would be an admirable one, but the word respiration has so long been prominent that it seems unlikely that it will ever be permanently associated with a minor meaning. Moreover, as already stated, some of the best authorities already use it in referring to the metabolic process of energy release. For these reasons the writer thinks it probable that this third definition is the one which will stand. If this opinion is well founded, it becomes the duty of teachers to adopt the latter definition forthwith. Whatever is done, the vital process is to be kept in the foreground in teaching.

The subject of respiration certainly deserves a more adequate treatment in our courses. The writer knows as well as anyone that topics are many and hours are few, but are there not subjects in all our courses that might better be omitted than a fair consideration of a process which is essential and universal? Fundamental ideas penetrate the student's mind but slowly, and the writer feels that two or three experiments on the great question of respiration are not too many. After an experiment of some kind bringing out clearly but only quantitatively the fact that oxygen is absorbed and carbon dioxid given off, let another be set up which shall take some account of quantities—of different phases of respiration. Peas and oily seeds are valuable objects for this purpose. Explanation of the real nature of respiration and of the different kinds of respiration—anaerobic, fermentation, etc., will then follow quite naturally.

When students are using U tubes or thistle tubes there is always a possibility that the sealed end is not perfectly air tight. Eudiometers over mercury are an admirable form of apparatus, for here the question of leakage is removed from discussion, and quantitative readings can be made readily and with accuracy. The seeds are held in the upper end of the tube by glass wool, and in starting the experiment the mercury column is introduced some distance into the tube so that either increase or decrease in volume can be noted. The carbon dioxid evolved can later be directly and accurately measured by introducing caustic potash through the mercury.

After a well-planned series of experiments it is not difficult to question a class till most of them perceive that the various phenomena can be understood only in the light of the fact that in each case energy is set free. The content of the teacher's explanations would then be something as follows: By respiration we understand the changes brought about by the cell whereby energy is released. A supply of energy is a *sine qua non,* for life and reactions which yield energy are universally carried on by living substance. Ordinarily respiration is a process of oxidation, indicated both by an absorption of oxygen and a production of carbon dioxid. A supply of free oxygen seems to be necessary for protoplasmic movement and growth, and for con-

[2] 'The Theory of Respiration,' SCIENCE, February 17, 1905.

[3] *Loc. cit.*

tinued existence in most of the higher plants. The carbon dioxid given off is sometimes equal in amount to the oxygen taken in, but this ratio is a variable one. Most plants are able to respire for limited periods without taking in oxygen. Some of the lower plants are able to do this for prolonged periods—perhaps for a whole life cycle. This phase of the process is called intramolecular or anaerobic respiration and is much the same as certain kinds of fermentation. The steps of the processes of respiration are imperfectly known.

Charles H. Shaw

QUOTATIONS

'NEWSPAPER SCIENCE'

In the last number of Science, a correspondent, dealing with 'fakes and the press,' urges Congress "by some legal enactment to check the publication of all items that convey erroneous impressions relative to matters in which the whole community is interested." The immediate occasion of this somewhat sweeping recommendation is the wide publication late in January of a paragraph to the effect that the Jamaica earthquake, by disturbing the subterranean strata, had increased the flow of oil from the wells of northern Texas and Louisiana, while diminishing that from the southern counties of both states. The tale, it appears, was not true, and certain geologists declared at the beginning that it could not possibly have been true. Nevertheless, the writer is unfortunate in having illustrated his arraignment of 'newspaper science' by an example of a plain 'fake,' which is not typical of 'newspaper science' at all.

If the term has any meaning, it applies not to malicious stock-market rumors, or to wild fantasies which no one would pretend to take seriously, but to the journalistic treatment of matters that have really a scientific status. Just now 'newspaper science' is concerned chiefly with the weight of the human soul. Two days ago some Boston physicians announced that they had demonstrated a loss in weight of from one half ounce to one ounce at the moment of death, or a little later in the case of very slow-witted persons. This morning 'an eminent physiological chemist' adds the information that 'a group of German students' determined years ago that a mouse lost a milligram of weight when it died in an open vessel, but not when in an hermetically sealed bottle. We feel sure that this is not the last, but confidently await the story of the Indiana investigator who found some years ago that the soul of a lizard could be made to keep for years in any climate when contained in a bottle of pink glass. All this will be very interesting, it harms nobody, and at the beginning of the serial story there was some definite information furnished by men of standing.

There is much less guile about newspaper science than the laboratory scientists would have us believe. For instance, last fall, if we may infer causes from results, a newspaper correspondent at a small western lake resort picked up on the beach a defunct specimen of the common 'mud puppy.' He had never seen such a creature before, and took it to a local naturalist, who told him something about its amphibious habits and superabundant breathing apparatus. He also gave the generic name, *Necturus,* which the correspondent or the telegraph operator afterwards misspelled in the account of the monster—its size was a detail not mentioned—which possessed both lungs and gills, four legs, a mouthful of sharp teeth, a long tail, and was 'believed to be the Nocturis.' The finding of a mud puppy would have been no news at all, yet by means of this ingenuous dispatch, some perfectly correct and remarkable bits of scientific information were brought within the reach of a million newspaper readers.

By and large, there are probably quite as many commonplace and elementary scientific facts thus exploited as there are outright fabrications. Set any layman to report the lecture of a scientist who, in going over the field of his own specialty, mingles old with new matter, and he is just as likely to hit upon the former as the latter. If he is looking simply for sensation, he will send out an account, like so many which have emanated from the University of Chicago, bearing very little relation to anything a competent scientist could have