

Mountain States are entirely distinct from the real lignites, or brown coals. They are not lignites in chemical composition, in color, or in physical characteristics, and as they lie between the lignites, or brown coals, and the true bituminous coals, the term sub-bituminous has been adopted by the United States

Geological Survey to designate them. In the production of this variety of coal Wyoming leads, Colorado is second, and New Mexico is third. A part of the product of California and Oregon should also be included under this head. The principal producers of true lignite are Texas and North Dakota.

The comparatively small production of cannel coal was obtained from nine States in 1905 and seven in 1906, of which Kentucky, Indiana, and West Virginia are the principal ones. West Virginia is also credited with nearly all the splint coal production, while Indiana is the leading producer of block coal.

THE BREATHING OF PLANTS.*

THE NECESSITY OF RESPIRATION TO ALL LIFE.

BY DR. C. STUART GAGER.

THERE is probably no scientific question concerning which erroneous notions are more widespread than the one regarding the difference between animals and plants. Ask the "average man" what this difference is and he will tell you, in the first place, that animals have motion while plants have not; or, if he is especially conservative, that animals have locomotion while plants have not; and second, that plant respiration is just the reverse of animal respiration. Animals, he says, "breathe-in oxygen and breathe-out carbon dioxide, while plants breathe-in carbon dioxide and breathe-out oxygen." It is with the latter of these "differences" that we are concerned in the following paragraphs.

By way of a gentle introduction it may be stated at once that plants breathe precisely as do animals, and, second, that they do not "breathe" at all. This seeming contradiction is explained when we remember that, as we think more accurately, our terms must be more carefully defined. In ordinary conversation "breathing" refers to the inspiration of fresh air into the lungs, and the expiration of the air that has been used. Obviously, plants have no lungs. We cannot see them breathe.

But this exchange of fresh and foul air is only incidental to respiration. Not all animals have lungs. Earthworms, insects, jelly-fish, and others may be mentioned as familiar examples of this fact. The real process, to which the physiologist applies the term respiration, has to do with the use that is made of the inspired air. From the lungs this air, in man for example, is taken up by the blood. Part of it the blood uses in its own respiration, the remainder it carries to all the tissues of the body, and delivers it to the individual protoplasmic units or cells. These cells take up the oxygen according to their needs, use it in performing their work, and return to the blood the carbon dioxide that results. Carried by the blood back to the lungs, the carbon dioxide is given off to the air in expiration. All of this is common knowledge. Respiration refers to that part of this process which goes on in the individual cells, while the term breathing may be to advantage restricted to the work of the lungs. Respiration, then, is a cell-process, and every organism that is alive and every living cell of that organism must respire. All plants are built up of cells, some of which are alive and some not. All the living cells of plants respire, just as truly as do those of animals.

It is difficult to demonstrate the cell processes, but the outward manifestation of them—the absorption of oxygen and the evolution of carbon dioxide—is very easily shown.

Into each of six fruit jars place portions of the different parts of plants as follows: into the first fresh roots, into the second stems, into the third leaves, into the fourth flowers, into the fifth germinating seeds, and into the sixth nothing. A lighted candle will continue to burn when placed in any of the jars. Seal them all air tight. If, at the end of twelve hours, a lighted candle is thrust into each of the jars, it will be extinguished in each of the first five, but will continue to burn as usual in the sixth. This shows us that the air in the five jars has become poorer in oxygen, while that in the sixth jar is apparently unchanged. If now we pour clear lime-water into each of these jars, the water will become milky in each of the first five, but will remain clear in the sixth. This indicates that in the first five the amount of carbon dioxide has been increased, but not so in the sixth.

Since the only difference between the first five jars and the sixth is the presence, in the former, of parts of living plants, we must conclude that the change in the air is due to the vital activities of the roots, stems, leaves, flowers, and seeds. But an absorption of oxygen and an evolution of carbon dioxide, we have learned, is the outward indication of the cell process called respiration. In this, and in many other ways, it may be shown that plants respire.

It will be seen here that plant respiration is not confined to the leaves. Nothing can be more misleading than to speak of leaves as the "lungs of plants." If any comparison at all is to be made they could better be called the stomachs of plants, for in them processes of digestion go on with as much, if not more, vigor than does respiration. Moreover many kinds of plants

such as bacteria, algæ, fungi, liverworts, and others, have no leaves, but respiration goes on in them notwithstanding, and trees in winter, after all the leaves have been dropped, continue still to respire.

No vital activity is as important as respiration. Food may be supplied, water and air may be abundant, but without respiration life is impossible. The power to respire marks the chief difference between the living and the non-living. In the realm of living things it is universal and incessant. It is always, in all essentials, the same process, whether in plants or in animals. The failure to recognize this fact gave rise in the latter half of the last century to the doctrine of vital dualism. Because of the supposed difference between animal and plant respiration, it was argued that there were two kinds of life. A clearer understanding of the vital processes of animals and plants, however, has taught us that life is one. No clearly defined line can be drawn between the two kingdoms. As great differences exist between certain animals, and between certain plants, as are found between animals and plants. But the process of respiration is everywhere the same. Even dry seeds respire.

In regard to the amount and rate of respiration the supposed difference between animals and plants breaks down. Under favorable conditions the process may be even more active in plants than in animals. In man the carbon dioxide produced in twenty-four hours equals about 1.2 per cent of the body weight, but in some of the molds the amount has been found to equal 6 per cent of the dry weight of the plant. Bulk for bulk, very active bacteria may consume oxygen 200 times more rapidly than man. In both kingdoms respiration is accompanied by an evolution of heat.

In plants, as in animals, the rate of respiration varies with the age of the organism, and with external conditions. Breathing, which is the expression of respiration in man, is most rapid with infants, and decreases with the approach of old age. So it is with plants, for germinating seeds and young seedlings respire more rapidly than mature plants. Increase of work is accompanied with increase of respiration in animals; in trees, also, the process is more vigorous in the spring, during the work of bud-opening and the putting forth of new leaves and flowers. Under bodily pain or mental excitement we breathe more rapidly, so also does a plant that has been cut, or otherwise injured, or subjected to any stimulus, as, for example, violent shaking. A thermometer placed in a dish of cut onions, for example, will indicate the existence of a fever (due to the wounding of the tissue), just as surely as if placed in the mouth of a typhoid patient.

This question is far from having a merely academic interest. Practices that have been in vogue since man first began to till the soil, and that must be continued as long as agriculture is carried on, depend, in part, upon the respiratory function of plants. I refer to plowing the soil and hoeing the crops. It is not alone to get the soil into a suitable physical condition that it is broken up by the farmer. The roots and other underground parts must have air to respire, just as much as the parts above ground, but if the soil is hard and compact this need is but poorly met. The plow, the spade, and the hoe facilitate the thorough aeration of the ground. For the same reason it is desirable frequently to loosen the surface of the soil in flower pots, and this, in part, is why flower pots are made of porous material.

Emphasis has been laid upon the fact that only living things respire. While this is perfectly true of the physiological process, it is not true of the mechanical act which may be designated as breathing. The entire soil area of the globe is subject to great inspirations of atmospheric air, and expirations of the gases resulting from life processes underground. This process is necessary to the healthful respiration of soil-organisms, and of the underground portions of all land plants. Without it land vegetation would perish and the world would become a desert.

The "breathing" or aeration of the soil is accomplished in a variety of ways. In all regions where it has a depth of fifty feet or more, the ground at a certain distance below the surface is soaked with water, so that all the spaces between the soil particles are completely filled. The upper surface of this moisture is called the water-table, and above it the soil contains only capillary water. The interspaces between the soil particles are filled with air, and only the sur-

faces of the grains are wet. The level of water in a well marks the level of the water-table in the soil. In the spring, and in other wet seasons, this water-level stands at a greater height than in periods of dry weather, and, as it falls, air from above ground enters the soil. When the water-table rises, gases are forced out.

The gradual heating of the soil during the day causes the soil-air to flow out, while the nocturnal cooling is accompanied by a current in the opposite direction. Wind blowing over the surface causes an outflow, the calm that follows an inflow. Thus the great soil-breathing goes constantly on.

It is in this way that fresh air is continually supplied, not only to roots, but also to the soil-bacteria, some of which are able to convert the nitrogen of the air into a form available to other plants, others of which are able to convert the ammonium-compounds into nitrates and the nitrates into nitrites, in which form they may be utilized by higher plants. For bacteria respire as truly as ourselves.

The question as to what becomes of all the roots, and why the soil never becomes clogged, may possibly never have occurred to some of us. Several causes explain this, one of which is the process of putrefaction, which is explained by the respiration of a certain kind of microscopic plants. These plants are called *anaerobes*, because they normally respire anaerobically, that is, without the presence of free external oxygen. Some of them are unable to respire at all if free oxygen surrounds them. If, therefore, the aeration of the soil is interfered with, these plants find ideal conditions for their growth and activity, and the soil becomes "sour," and unfit for crops.

From the above considerations it becomes clear that agriculture, the most fundamental of all human industries, depends for its successful pursuit upon practices whose whyfore is found in the fact that plants respire.

But husbandry is not the only point where the respiration of plants touches our daily lives. Upon the respiration of the yeast-plant depends the enormous brewing industry of our own and other countries, and upon the respiration of another yeast-plant we are dependent for the lightness of our daily bread, for the fermentation involved in "raising" dough is a kind of respiration. The difference between a "good" and a "bad" cigar is partly attributable to a similar cause, for the difference is connected with the curing of the tobacco, and this process involves the respiration of bacteria. So, too, does the tanning of hides, and the separation of flax and hemp fibers from the plants that produce them.

Cold storage warehouses and refrigerator cars are made necessary, in part, because of the respiration and universal presence of myriads of microscopic plants that float in the air, for, whereas heat accelerates respiration, cold retards it. The turning rancid of butter, the souring of milk, the formation of vinegar from cider, are all dependent upon the same process. If plants did not respire, canned fruits and meat would seldom spoil. That a hen's egg is a miniature botanical garden is a bit of that truth that is stranger than fiction. The ovophytic flora enters the egg in the body of the fowl, before the formation of the shell, and the respiration of the entombed plant is one reason why eggs will not always remain "strictly fresh," and why cold storage will prolong the period of their freshness.

Someone may raise the question of the value of plants in the sick room. It may be at once recognized that they have the same kind of an effect on the air of a room that a person or a burning gas jet would have, though possibly not to the same degree. If the plants were abundantly supplied with green leaves, and were well exposed, even to bright diffused sunlight, they would supply an insignificant amount of oxygen to the air. But at the same time they would be sources of carbon dioxide. And when we recall that the "plants" in a sick room are usually cut flowers, often not over fresh, and that flowers respire more vigorously than any other part of a plant except germinating seeds, we do not need to be further enlightened as to their power of purifying the air. Our scientific knowledge, however, should not, as it is often liable to do, get the better of our "sense uncommon, men call common sense," for the brightness and cheer that flowers bring to the sick need never be sacrificed for fear of their evil effects upon the air.

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