A power of 500 horses will be at the disposal of exhibitors, and this will be furnished by several steam engines, and one gas engine of 30 horse power. The steam will be furnished by a series of large Collet boilers, arranged for marine service.

Electricity will be largely represented. The building, its facade, its garden and its main galleries, will be lighted by electricity for the night fetes.

The new works of the port, which are nearly finished, will likewise offer considerable attraction, and, along with the exhibition itself, will mark the immense progress made by our chief port on the Channel. —*Le Genie Civil.*

THE TELEPHONE AND PHOTOPHONE.*

By Professor A. GRAHAM BELL.

It was my intention to give a description of the elements involved in the transmission of speech to a distance, but after a look at the munificent equipment of your physical laboratory, it may not be well to linger over some of the more elementary propositions with which you are, no doubt, already familiar.

In attacking any problem it is best to have it clearly formulated. What is our problem, and what is the process by which we are to solve it?

First—What is speech? Speech is like sound itself, a mere sensation in the breath. Outside of ourselves there is no sound. Speech requires a brain to formulate, and a brain to receive; it is, therefore, a mere sensation in the brain, caused by a movement of air on parts of the ear. The movement of the air is thus the object to be reproduced, and causes sound or speech. How may this then be brought about to produce an air movement to effect the sensation of sound upon the brain? What is this movement of the air? Perhaps one of the easiest of general considerations is to compare it with water. If we throw a stone into a body of water, waves in the form of circular rings go forth. Thus, if we disturb air, circular rings of waves are propagated, but with this difference—the rings are circular in all directions, or spherical like a soap bubble, rapidly expanding, but with a velocity which can be measured, but not appreciated. If we observe the flash of a cannon, and note the time required for the sound to reach the ear, we can, knowing the distance, calculate the velocity of the sound.

When a succession of air impulses is caused to strike the ear, a musical sound is produced, if the impulses are more frequent than thirty-two per second, just as in a dark room the light of a cigar can easily be distinguished if it have a slow movement, whereas if it be moved rapidly, owing to the persistence of vision, a continuous line will be produced. Thirty-two times per second being then the least number of vibrations which constitute a musical note, the tone increases from this as a lower limit up to about four thousand vibrations, after which it ceases to be pleasurable. This existence of sound waves is not mere theory, but can be easily demonstrated experimentally. That air can be moved in waves no one can well doubt, especially after observing the oily effect when light passes through heated air, such an effect as we have often observed when watching a heated stove, or a chimney outlined against the sky, pouring out oftentimes no smoke, but this oily substance of the air, or, perhaps, we have noticed it as the heat rolls up from a heated street on a sultry day. But by sound waves do not gather the idea that the waves mean an actual transference of air particles, nor by waves the idea that they, as waves, strike our ears. They are more correctly sound spheres. What is the action then? Let us take an example of a large wheat field. As the breezes strike it, we see the waves most beautifully roll over it, precisely as the billows on a larger sea. But no grain of wheat is transferred from one part of the field to another. The action of the grain waves is as the action of the sound waves in air. The air particles do not move, *i. e.*, are not transferred, but simply vibrate back and forth in an extremely minute distance.

What causes sound? What is the nature of that vibration which is so extremely small? Wherein does sound vibration differ in properties from other vibrations? These are the propositions we have to deal with in the transmission of speech. Sound being a vibration, in order that we may communicate sound to a person, we must vibrate his ear. In order that speech may be made and apprehended, a marvelous process is going on. A mind conceives the thought, the nerves call upon the vocal muscles; the muscles pronounce with audible speech, that is, certain air vibrations are produced. These vibrations fly to a hearer, act upon the muscles of the ear, the nerves carry these muscular tremors to the brain. Thus is the thought in my mind transferred to your mind. Why is the thought in my mind transferred to your mind? Why is it that certain sounds produce certain ideas in the brain? What is it that causes a difference in the quality of the sounds? This is then the problem.

The ear consists of a highly drawn membrane free to pulsate under the sound vibrations. How then can this membrane distinguish the ever varying differences in sound?

Each vocal sound has three different characteristics—pitch, loudness, character, or as the French term it, *timbre*. The *pitch* depends upon the frequency of vibration, a note high in pitch being one in which the number of sound vibrations are very great. The *loudness* of a sound depends upon the amplitude of the vibrations. Recurring again to our wave theory, if we on our pond of water have the waves succeeding each other with great rapidity, we have the effect corresponding to pitch, but if the waves are high we have the effect of loudness; although both the rapidity and the height, and therefore the pitch and the loudness, may be independent of each other. Upon what does the character or *timbre* of the sound depend? We have both the rapidity and amplitude of the sound wave, now what other effect can take place of this nature in order to effect what we term *timbre*? May not the wave itself be changed between intermediate points, or smaller waves be produced on the waves?

For illustration take the case of two boys running a race between two points. They as it were make an oscillation. The more times they run back and forth, the more oscillations. The number of oscillations corre-

sponds to the pitch. Then will also the character be indicated by the mode in which the combatants run. Thus one may run with a sideways swaying motion, another forges straight ahead, while perhaps a third falls alternately behind, then spurts ahead. The same thing may be shown more graphically by having a board, representing say the race way, held by two persons. I hold at one end, in my hand a piece of chalk. Those holding the board walk along a short distance with it, and as they do so I move my hand in various manners, but always up or down, when on the board will appear more or less regularly shaped wavy curves. The character or *timbre* of these curves will be indicated when these waves have on them, or rather as part of them, a smaller wave curve.

In Boston some years since I was led to make a study of the anatomy of the human ear, and wished to discover just how sound affected it. So under an eminent anatomist of that city I was furnished with that portion of a dead man's skull having an ear and all the adjacent parts. The bone work was then so sectioned that it could be readily adapted to a position on my apparatus conveniently arranged. To the hammer of the ear a very light piece of hay was attached, this projected outward and was arranged to just touch a plate of smoked glass. The glass plate was capable of having a lengthwise movement, by being placed upon slideways. When this ear was spoken into, the piece of hay attached to the hammer of the ear was caused to vibrate to and fro. The smoked glass plate was then drawn along. It was then found a continuous wavy line had been formed on the glass. A number of experiments were conducted, but the most interesting are those showing the waves corresponding to the vowel sounds.

Having thus the speech portrayed graphically in the form of curves, and thus knowing that for each wave on the diagram there had been a corresponding vibration of the hammer and tympanum of the ear, the question then presenting itself was, In an artificial ear how can this vibration be produced, and when produced how can it be transmitted to a distance? This was accomplished by the telephone. It is unnecessary to go into an elaborate description of telephonic apparatus. New forms and improvements have so rapidly multiplied that one can scarcely acquaint himself with them. With many inventions their first forms were complexity itself, then later followed simplicity and refinement of construction. But with the telephone it appears to be different, first simplicity then later complexity. The first form was almost the simplest, because it was the carrying out of a single idea, and that one of great simplicity.

Faraday was the first to point out that a current of electricity could be developed by the motion of a piece of iron in front of an electro-magnet. This idea, simple as it is, is nothing more than the embodiment of the telephone. The piece of movable iron in the instance of the telephone is a thin iron disk. We cause this disk to move or vibrate under the influence of sound by speaking near it. These vibrations of the iron disk cause corresponding electrical movements in the coil of wire surrounding the magnet. These electrical pulsations can then be carried off to a distant receiving station. The currents of electricity generated by the iron disk are proportioned exactly to the movement of the iron plate. The disk moves as we have seen, precisely in the same manner as the tympanum of the human ear, consequently the pitch, tone, and *timbre* are taken up by the telephone and converted into electrical currents. The wave lines which we had produced by our experiments on the human ear were seen to be continuous curves of an undulatory character. The electric current thus taking up these sounds must, therefore, have a similar nature, and therefore the name, *undulatory current*, I have applied to it.

This current, as it proceeds from a distant station, traveling along a shorter or longer distance of wire, arranged similarly to a telegraph wire, is received into a receiving telephone, termed the receiver, one perhaps in all respects similar to the telephone which forwarded the words. The undulatory current passes into the instrument through the coil of wire surrounding the magnet, and then out to its return or ground connection. But during the passage of the undulating current it has produced corresponding varying effects upon the magnetism of the magnet. The diaphragm is thus correspondingly attracted and repelled by the magnet, or controlled by the current, moulded as it were, and the same sound waves are reproduced as were spoken at the sending station.

The telephone, as an instrument, is not one of great delicateness. The wonder is that we can hear speech at all. Our ear, which interprets the sound, is the organ of marvelous delicacy. In fact, the operation of the telephone is so simple, that some of even the most crude apparatus serves to transmit distinguishable speech. A telegraph instrument may be made to talk, or a hammer head. In the Hughes transmitter, simply two nails answered the purpose.

Telephones for commercial use are required to be more powerful, and to effect this compound magnets are often employed. Although the hand telephone is not the most powerful, yet its greater convenience has caused it to survive.

Telephonic receivers remain much the same as when introduced, but numerous changes have been made in the transmitters. The one now in most general use is the Blake transmitter, and instruments of its class are known as carbon transmitters. A number of forms have been invented by Blake, Edison, Berliner, and others. In these forms of carbon transmitters a current of electricity from a battery is kept flowing through a carbon button attached to the diaphragm. As the diaphragm, actuated by the voice, is vibrated to and fro, it causes a varying amount of compression to take place in the carbon. Carbon has the peculiar property of offering a greater resistance to the passage of the electric current when submitted to pressure. Thus when the carbon telephone is spoken into, the voice, as it were, simply cuts off more or less electricity. This undulating current, as in the previous case, passing to the receiver, it produces sound in the same manner.

In the case of carbon, we have a variable electric resistance produced by pressure, but are there no other means by which this variation of electric resistance may be produced than by pressure? It has been found that selenium has its resistance altered by the presence of light. If then we can vary the intensity of light which is acting upon selenium, to correspond

to our wave vibrations of sound, we can, therefore, accomplish the wonderful result of transmitting speech by light instead of electricity. The chief difficulty in the use of selenium has been found to be its enormous electrical resistance, which is something like 14,000 megohms, or the resistance of a telegraph wire from the earth to the moon. The discovery of this wonderful property of light on selenium is due to Siemens, who, in some cabling experiments, found that the selenium, which he was using on account of its high resistance, varied greatly in its electric resistance during the day time and at night. Quite a number of experiments had been conducted on this strange material by investigators.

It then suggested itself to my mind that this substance might be made a valuable aid in telephoning. An insuperable difficulty seemed apparently to lie in the way—its enormous resistance—and how could it be reduced? Siemens partially effected it by arranging the selenium in a spiral of platinum wire. We tried many experiments with this spiral, but were obliged to discard it; then was tried the plan of placing the selenium in a sort of grating, also as suggested by Siemens, but this also failed to give much more satisfactory results.

At last I was led to devise a method which seemed to more perfectly fill the requirements. The apparatus, which might be described as a selenium rheostat, is constructed of a number of thin disks of brass. These are separated from each other by placing between them sheets of mica of somewhat smaller diameter. The plates are then tightly clamped together, and the interstitial spaces filled with melted selenium. Every other brass plate is connected to form one pole of the apparatus, while the other plates are connected to form the other pole. Thus is it made possible to have a large surface of selenium exposed to the light, and also to have a moderate resistance. The apparatus is also in a convenient form, so that it may be readily used in the focus of a parabolic reflector.

We are, therefore, ready for the *photophone*. If undulating waves of light, corresponding to sound vibrations, are projected into a parabolic reflector in which is placed this selenium cell, the light vibrations will produce variations of resistance in the selenium. Consequently a passing current of electricity will be correspondingly increased or decreased. The result being precisely the same as in the carbon telephone, and it needs only the ordinary telephone to translate into audible sound these currents of electricity.

But how is this variation of light corresponding to the sound vibrations produced? The photophone's transmitter, the means whereby this is accomplished, is simply a diaphragm silvered at its back, and free to vibrate under the action of sound. This is so placed that a ray of light striking it, the light is so concentrated and directed that it can be brought to bear upon the distant photophone receiver—the parabolic reflector. These rather curious results—telegraphing speech by light—we did not come upon at once, but only after long and tedious delays, experimenting with unmanageable selenium.

The first successful experiment was made in Washington. The transmitter with its source of light was placed in a window of my laboratory. I placed myself with the parabolic reflector in one of the uppermost windows of a public school building, 500 yards distant, far enough in order that no speech might be heard without instrumental means. With the telephone attached to the connections on the reflector I waited. I did not have long to wait. Soon my assistant, in my laboratory, spoke into his mirror transmitter. Instantaneously the words were flying over the beams of light. Here is the first message ever transported by this new servant of man: "Mr. Bell, if you hear what I say, come to the window and wave your hat." It is unnecessary to say that I waved with vigor, and with an enthusiasm which comes to a man not often in a lifetime. The feelings which arise within one when, after some vast labor, a great problem is solved, or invention produced, and fraught with so much success, no one can express. They are moments worth a life to live for.

Thus was brought into existence the photophone, and no longer may it be remarked that electricity is the only messenger which will carry our voice to distant hearers.

On experimenting with this new instrument, at one time I happened to take up a piece of hard black rubber which was lying on the laboratory table. Placing it in front of the mirror transmitter in the direct ray of the light between the mirror and the parabolic receiver, I of course thought, as any reasonable being would, that as soon as the waves of light were shut off the sounds in the receiver would cease. Surprisingly to all, such did not seem to be the case. Although the rubber was opaque to light, it was transparent to radiant energy.

Many other substances were experimented with, and yielded curiously varying results, each substance giving forth peculiar musical notes characteristic of itself when thus placed in the intermittent beam of light. In order to hear these sounds it was also, strangely enough, found that the selenium receiver might be dispensed with altogether, the material itself acting as a receiver.

Thus it appears that we have a new property of matter—sonority under intermittent light.

The substances experimented with were of every conceivable kind, gases, solids, and liquids, each having its peculiar characteristics. The substance found to give the most pronounced audible effect was *soot*. In fact its notes could be heard over a good sized room or even a hall.

Taking advantage of this strange property of soot, I have recently devised what we may call a *soot photophone*. The transmitter is the same in principle as that employed for the selenium photophone, *i. e.*, a silvered mirror, but the selenium rheostat and parabolic receiver is replaced by a simple funnel shaped ear piece, the mouth of the funnel being stretched across by very fine wire gauze coated with soot, as well as are the interior sides of the funnel. This apparatus being placed at the ear, the loudness of the sounds produced by the intermittent beam is really uncomfortable.

As it was seen that these causes were not so much due to light as to radiant energy, these new developments in photophonic apparatus might be more properly termed *radiophones*, and the science *radiophony*.

The lecture was illustrated throughout by a large

* Abstract of a lecture lately delivered at Sibley College, Cornell University, by Prof. Bell, inventor of the telephone.—*From the Crank.*

number of admirable drawings thrown on the screen by the large lantern of the physical lecture room. Some of the views of early apparatus were not only interesting, but valuable for their historical value. The speaker throughout carried his audience with him, as his manner was easy and withal intensely interesting. As he described the steps leading up to the invention of the photophone, he held the attention of his hearers transfixed with the same expectancy that the good reader awaits the *denouement* of the plot. On arriving at the lecture room, he may well have expressed surprise, by his introduction: "I scarcely thought in getting in, that I should be able to hear my own lecture;" for never before, indeed, has such a dense mass of humanity collected in that hall. His audience were agreeably surprised to find a man of so modest mien, when he has the distinction of having such exalted honors.

THE CONDUCTION OF ELECTRICITY BY GASES AT HIGH TEMPERATURES.

M. R. BLONDIOT has presented to the *Académie* a memoir entitled "Recherches upon the Transmission of Electricity of Low Tension by Hot Air," of which the following is an abstract: In the year 1853, M. E. Becquerel discovered that a gas at a high temperature became a conductor of electricity, and stated that the phenomenon could be observed even with a single cell. Some doubt has been thrown in later years upon the accuracy of the statement, but it has been fully confirmed by the experiments which are about to be described. The apparatus employed consisted of a sort of double bell jar placed with its mouth downward; between the outer and the inner lining a stream of coal gas was caused to ascend, and being mixed with air in its passage a powerful flame could be produced around the inner lining, which soon raised it to a state of incandescence. Within this heated jar, but entirely free from contact with any part, were placed two platinum disks, about 3 cm. in diameter. These served as electrodes. By means of this arrangement the air could be raised to a very high temperature, while currents of convection were as far as possible avoided.

In accordance with M. Becquerel's announcement, it was found that in this case no current would pass until a red heat had been attained. On the other hand, when a column of air is allowed to rise by convection from a heated body, a current may be obtained with a single element when a thermometer indicates a temperature of only 70° C. The explanation suggested is that the convection current contains many particles which are themselves far hotter than the mean temperature of the air, as shown by the thermometer, and it is these hotter particles which are alone concerned in conducting the current.

In the present apparatus, as soon as a red heat had been attained, an E.M.F. not exceeding one-thousandth of a volt produced a measurable current. It was, however, discovered that this current does not obey the law of Ohm, as on increasing the E.M.F. the current increases more rapidly than the difference of potential. This result, which has been well established, appears to be one of considerable importance as throwing light on the differences between the conduction of electricity in solids, liquids, and gases. It follows that gases, properly speaking, have no specific resistance, as the quantity so measured will depend upon the E.M.F. employed in the experiment. It is probable that the explanation of the phenomenon is to be found in the conduction by convection currents already alluded to. When the air is at the normal temperature, it is known that all bodies are coated with a kind of atmospheric film, which therefore serves as an effective insulator. But when the temperature is sufficiently raised, this film is driven off, and the gaseous molecules then come into sufficiently close contact with the surface of the metal to carry off a charge of electricity.

ELECTROLYSIS OF COPPER AND ZINC.

By ALEXANDER SHAND.

THE separation of copper from zinc or any other metal is much more easily and quickly conducted by electrolytic deposition than by the ordinary wet process. As the result of some experiments recently conducted, I have found that the electrolytic method is also much more accurate. In order to determine the accuracy of the process, 0.5033 gramme of pure copper and 0.5031 gramme of pure zinc were dissolved in a little dilute sulphuric acid, and the solution made up to 1000.5 grammes with distilled water at 15° C.

Of this solution, 100 grammes, calculated to contain 0.050304 gramme of copper and 0.05028 gramme of zinc, were weighed into a tared platinum basin, and the current from one Bunsen cell passed through the solution, the positive electrode being a platinum disk. The Bunsen cell exposed 140 sq. in. of zinc to dilute sulphuric acid, specific gravity 1.12 at 15° C. The current was allowed to continue all night, the total time being about eighteen hours.

The solution in the basin was now poured into a beaker, and the deposited copper washed three times with distilled water, then three times with alcohol, and finally three times with ether. It was then dried in an air bath at 80° C., allowed to cool in a desiccator, and weighed.

RESULTS OF TWO ESTIMATIONS.

1st	0.0504	Theory requires	0.0503
2d	0.0503	"	0.0503

A large number of experiments showed that the most accurate results, in zinc estimations, are obtained by the following process. The zinc, being in the form of sulphate, is nearly neutralized, if necessary, with potassic hydrate, free from aluminum; then add ammonium oxalate in excess. Maintain the solution at a temperature of 80° C. or 90° C. by heating with a steam or water bath, and pass the current from two Bunsen cells similar to the one used for the copper estimation. In a few hours the whole of the zinc is deposited as a pale bluish-white coating on the basin; which is washed with water, alcohol, and ether, as in the case of copper, and then dried and weighed.

RESULTS OF TWO ESTIMATIONS.

1st	22.19	per cent.
2d	22.09	"

There are a number of practical details and precautions, most of which will occur to any who may be disposed to investigate this process. It is absolutely necessary that the analysis be carried out exactly as described above, and that the platinum basin be chemically clean. If the basin is heated directly with a flame during the process, the zinc is deposited in a black powdery condition, and gives too high results. Should the acid in the battery be too dilute, the zinc comes down in a crystalline state. In this condition it is very difficult to wash without loss, as some of the crystals become detached and are easily washed away. From 0.4 to 0.9 gramme of the metal is the most convenient quantity to work with, as too large a quantity takes much longer to deposit; 1.5 gramme of copper, for instance, takes thirty hours to completely deposit with the current from a single Bunsen cell.

The accompanying wood cut will show a suitable arrangement of the apparatus for conducting the process.

ARRANGEMENT OF APPARATUS FOR ELECTROLYSIS.

A is a Bunsen cell with zinc carbon couple. B B are the conducting wires, and the direction of the current is indicated by the arrows. C is a metallic rod fixed in

a circular base; an ordinary retort stand does very well. D is a copper rod having a ring at the end on which the platinum basin, E, is supported. F is a platinum wire supported by the rod, G, and insulated by a piece of glass in the center of the rod. At the lower end of the platinum wire, F, is a small platinum disk which dips under the surface of the solution in E, containing the metal to be deposited. The other end of F is attached to the positive conducting wire, and the arrangement is complete.—*Pharmaceutical Journal*.

LIFE ENERGY, OR THE DYNAMICS OF HEALTH AND DISEASE.

By NATHL. ALCOCK.

SINCE it is admitted that matter is indestructible, it is obvious that life can be only the manifestation of that energy which is set free by the reduction of compounds embodying more energy to states of combination which embody less energy.

Life therefore is the result of the continuous interchange of partners between the compound molecules constituting chemical and organic compounds.

"In any transformation which takes place without the application, or the giving out, of work, the heat developed is the equivalent of the excess of the original over the final potential energy due to the chemical affinities involved. The final state of every combination is that in which the potential energy of chemical affinity is a minimum." (Tait.)

If these words formulate the law which governs those combinations of elementary substances known as inorganic compounds, how much more must they refer to the combinations of the same elementary substances which go to form organic compounds?

Life thus becomes an expression for the sum of the difference between the original potential energy of the food and the final potential energy of the excretions. All change in the configuration of matter, whether physical or chemical, must be accompanied by either the evolution of, or the absorption of, energy.

Energy, as far as is known, has but one source, the sun.

Whether that energy act by direct impingement of solar rays producing the ascending scale of effects from genial warmth to fatal sunstroke, or whether it be second hand, from the decomposition of vegetable matter, or third hand, from the decomposition of animal substances which obtained it from vegetable substances, its origin is still the same.

Assuming then the universality of this energy, which shows itself in all the intangible forms of life, and growth, and all organic change, it will be the effort of the writer to adduce evidence to prove that much which is still mysterious in both health and disease is due to its subtle action too.

The vibrations of direct solar energy which fall upon the optic nerve give rise to those molecular disturbances which produce the subjective sensation of light.

Physical change is thus originated by an immaterial agent. Work is done, and cannot continue to be performed without renewal of the material acted on.

But when the vibrations of direct solar energy fall upon the tissues of a growing plant, energy is incorporated into those tissues. This energy so attunes the atomic vibrations in the plant molecules as to bring them into combining harmony with the carbon and hydrogen atoms present in the forms of carbonic acid and water.

The hydrocarbon compound starch is formed, and embodies within itself the energy which made it starch.

Each molecule of starch maintains its individuality as starch only so long as it retains within itself that solar energy under the influence of which it became starch. As soon as part of that energy is lost, the starch is degraded to its original condition of carbonic acid and water. Yet that energy which works such molecular miracles is sought for among the products of decomposition in the form of heat only, and if not recognizable as such is put out of count in the world's work.

While it is thus evident that the vegetable kingdom lives a constructive life, storing up energy from an extra-terrestrial source, it is equally demonstrable that the animal kingdom lives a destructive life, unable to

add aught to the sum of energy required for the work of the planet. Consequently an approximate expression for the value of the energy incorporated in the plant may be found in the work done, as a result of its consumption, by the animal.

4,500 grains of plant carbon are daily excreted by every average man in the form of carbonic acid. Carbon and oxygen independently embody a greater sum of original energy than is found in the compound formed by their union. Therefore the result of their combining together must be a loss of energy. The value of this energy is estimated by the heat evolved. The heat recognizable on the combination of 4,500 grains of carbon with the required equivalent of oxygen amounts to 118 units, and represents in foot pounds the raising of 40 tons one foot high.

Such, then, is the enormous supply of solar energy obtained by a man when he compels the elementary atoms of carbon and oxygen to enter into a combination of greater stability and less energy, and to surrender their surplus energy that he may live.

But the converse of this is also true, viz., that when a plant proceeds to utilize this carbonic acid for the reproduction of 4,500 grains of carbon, it can do so only by obtaining from some external source energy equivalent to the raising of 40 tons one foot high and adding this to the rates of vibration already existing in the carbonic acid. Thus the condition of energy of the carbonic acid is altered till finally the oxygen and carbon atoms are compelled to dissociate themselves and to resume their elementary forms of less stability and greater energy. They then become available for plant assimilation, and fix in its tissues the energy which forced them apart.

If, then, the union of oxygen and carbon in the human body sacrifices such energy that man can live thereby, is it not obvious that under whatever circumstances that union takes place, the same energy must appear? If that be so, the question must arise whether in estimating the effect of vegetable decomposition upon the health of man, too much notice has not heretofore been taken of the carbonic acid and kindred stable products given out, and too little attention paid to the energy evolved. In fact, whether from the surface of every seething swamp there be not poured forth streams of that powerful energy which originally fed the growing plants, and which when eliminated within the body of man is known by the name of life. To assume that such energy is powerless is to assert that the mother's heat is not the force that hatches out the egg.

That the theory which attributed all noxious influence to the gaseous resultants of decomposition did not satisfy the requirements of science is shown by the greedy acceptance of the germ theory which now prevails. But this, after all, is but coming one step nearer to the action of that universal energy which is the inseparable concomitant of all material interchange. For has not Dr. Burdon Sanderson well said, "Bacterial life is a middle term between chemical antecedents and consequents"? They reduce all unstable compounds in the world to final stable products, and live with vigor or in apathy in proportion to the effect upon themselves of the energy evolved from the medium they destroy. Thus, too, is produced much of that form of secondary energy recognized as heat of decomposition; and while this heat is known to possess marvelous influence over vegetable germination, it has up to the present been credited with but little action on the life of man.

The gaseous consequents and the bacterial agents have borne the blame of every human ill, while that energy which ruled the universe before the first vegetable cell had varied toward animal functions is allowed to go unchallenged.

If, then, suspicion can be legitimately directed toward this heat as a factor in physiological change hitherto overlooked, it becomes necessary to pursue the subject of heat in all its latest developments.

Dr. Doherty, in his "Organic Philosophy," says: "Light is nothing but the velocity of a force which in slow motion is called heat." From the facts that are known in relation to light it may be possible to deduce by analogy much that is yet unproved with regard to heat.

It has been shown that light consists of certain colors which, when taken together, produce the sensation of light. Each of these colors acts upon certain specialized molecules of the optic nerve, and not upon the remainder, just as Professor Tyndall has shown that the invisible heat rays, "powerful as they are, and sufficient to fuse many metals, can be permitted to enter the eye and to break upon the retina without producing the least luminous impression."

May it not therefore be inferred that heat consists of a series of velocities of force which when taken together produce the sensation of heat, yet each of which is capable of acting upon certain specialized molecules of the nerves of sensation, while being unperceived by the remainder?

Light has been proved by Captain Abney to be the visible velocities of wave lengths from 38,000 to the inch to 60,000, and within this range from 38,000 to 60,000 to the inch all the varied sensations of color are produced. Nevertheless, by the higher velocities, from 60,000 to 120,000 wave lengths to the inch, the great chemical actions of the world are performed. Is it not evident, then, that if the recognition of wave lengths from 38,000 to the inch and upward depended solely upon the subjective sensation of light, all appreciation of them must cease at the 60,000 wave lengths, and that the great powers of the ultra-violet wave lengths must have remained in darkness for ever?

But Captain Abney has also shown that there are measurable wave lengths extending downward from 38,000 to 10,000 to the inch; if, therefore, these are credited with such action only as is recognizable by the subjective sensation of heat, is it not equally possible that powerful influences which change for good or ill the configuration of the molecules of the nerves of sensation may be left unregistered?

It is therefore allowable to infer from this analogy that in the dark region descending from the fading red to the cold of zero there may be many rates of velocity, some of which, harmonizing with some phase of life, produce the most potent physiological effects without at the same time exciting the molecular resistance which corresponds to the sensation of heat.

In other words, is it not probable that in estimating the actions of the forces of nature upon the animal sys-