phenomena in a shower is the following: It begins with a short and light shower, and this is followed by a longer or shorter cessation of rain, after which comes the first heavy downpour. After this the intensity of precipitation alternately decreases and increases but, on the whole, gradually diminishes until the shower is over.

This discovery of the periodic character of rain furnishes a striking confirmation of the theory enunciated by Helmholtz and other physicists, according to which a shower is the result of a change in an air wave analogous to the combing of breakers on a sea beach. A wave of this sort must traverse an extensive field and produce rainfall of the same character in every part of it. This fact may be demonstrated by the aid of the self-registering apparatus described above. Comparison of the intensity curves obtained at various points should show clearly the path of the air waves, their possible modification by local influences, etc. Fallenkamp has made an attempt in this direction by comparing the records obtained at Nuremberg and at Fuerth, about four miles away, during the violent cloudburst of June 3, 1903. Although there was a difference of an hour between the times of beginning of rain at the two places the curves agree so closely in all their details as to make it very probable that both showers were caused by the same air wave.

The field of observation that awaits exploration by this apparatus is very extensive. The differences, often very great, between rainfall at places at no great distance from each other, the relations between rainfall and electrical discharges, the forms of clouds, etc., and many other things may find explanation when the present method of measuring only the total amount of rainfall shall have been replaced by a method which records the phenomena in detail.

THE RADIATION OF LIGHT BY PLANTS.*

By Prof. Dr. HANS MOLISCH.

SIXTY-TWO years ago, at a session of the twenty-first Congress of German Naturalists and Physicians, in Graz, over which the famous chemist, Justus von Liebig, presided, an Austrian naturalist, J. F. Heller, described the radiation of light by decaying wood, and expressed the opinion that the light emanated, not from the wood itself, but from a fungus by which it was infested. Not long afterward Heller submitted the luminosity of decaying plants and animals to a thorough investigation. He found that the radiation of the flesh of dead marine animals and of various decaying parts of plants represents a biological rather than a purely chemical process, and that it is always due to a fungus. The light proceeds, not from the meat, fish, or wood, but from the fungus which grows upon it and causes its decomposition.

As Heller's investigations fell into complete oblivion and there remained until I recently brought them to light, the priority of this discovery, which unquestionably belongs to Heller, has been erroneously attributed to the distinguished physiologist, E. Pflüger.

The recognition of the biological character of the problem gave a firm basis for further investigation. Soon after Robert Koch had enriched science with his biological methods and pure cultures such cultures were made of various luminous bacteria, to which luminous fungi of higher organization have recently been added. Now it became possible to distinguish the various species, to study conveniently the conditions of radiation and the nature of the light and to attack the problem of luminosity with success.

If we except the luminous peridinea, which have

TOP, OR REPRODUCTIVE PART, OF AGARICUS MELLEUS.

The mycelium, or vegetative part, which grows under the bark of trees, is luminous, the top is not.

been classed alternately with animals and with plants and which play a prominent part in the beautiful spectacle of the phosphorescence of the ocean, and also except the so-called "flashing" of many flowers—a phenomenon first observed by Linnaeus's daughter and probably of purely physical character and analogous to St. Elmo's fire—we may assert that all luminous plants belong to two classes of fungi, filamentous fungi and bacteria. To prevent misunderstanding I should explain that when I speak of

luminous plants I always refer to light produced by the plant itself and not to reflected light, which is known to be the cause of the splendid iridescent colors of many marine algae, the wonderful emerald green glow of the pro-embryo of *Schistostega osmundacea*, and the sheen, resembling molten gold, of *Chromophyton Rosanoffii*.

Already some thirty species of bacteria and about

PURE CULTURE OF AGARICUS MELLEUS.

This is photographed by reflected light. The mycelium, or base, alone is self-luminous.

half as many of other fungi are recognized as luminous.

This number is exceedingly small in comparison with the whole number of known species of plants. Nevertheless, as some of the luminous fungi are among the commonest of plants, we are often surrounded by luminous objects in nature, and even in our houses, as the following examples will show.

Until recently luminous meat was regarded as a rare and remarkable curiosity and its occurrence was attributed to unknown conditions, seldom to be met with. When I undertook to investigate the subject I had no material and, although I communicated with a number of persons and establishments likely to come into possession of luminous meat, I could not, in two years, obtain a single specimen. I was about to abandon the undertaking when it occurred to me to examine the meat bought for household use. To my astonishment I found that this meat, after being kept from one to three days in a cool room, often began to radiate light spontaneously. In the course of my investigation I learned that the radiation was most likely to occur in meat about half immersed in a 3 per cent solution of salt. Of the specimens examined in the course of three months, not less than 87 per cent were found to be luminous, that is, 89 per cent of the specimens of beef and 65 per cent of the specimens of horseflesh. The source of the light was proved, by the method of pure culture, to be, in every case, the same intensely luminous *Bacterium phosphoreum* (Cohn) Molisch. As I have now continued my investigations for several years, not only in Prague, but also in other cities, and have always obtained substantially the same results, the spontaneous luminescence of meat must be regarded as a very common phenomenon.

The cause of the radiation, the *Bacterium phosphoreum*, must therefore be one of the commonest of bacteria. It occurs on meat in the cold storage room, the slaughter house, and the market, and even infests the kitchen. Such an assumption is necessary to account for the astonishingly large proportion of specimens of meat that radiate light spontaneously.

In the last few years I have met with another phenomenon of luminescence which, though of very common occurrence, has been entirely ignored. I mean the radiation of light by decaying leaves. In my nocturnal strolls in the tropics, especially in Java, I often found dead leaves of *Bambusa*, *Nephelium*, *Aglaia*, and other plants, which glowed in the dark. Since my return to Europe I have followed up the subject and discovered that luminous dead oak and beech leaves are very abundant in central Europe. The leaves must be in a moderately damp condition and in a particular stage of decomposition. Especially fine luminescence is exhibited by leaves which have acquired, in the course of decay, a pale yellow tint, with or without brown markings. Usually they glow in spots, but sometimes throughout their whole extent, with a soft, white, steady light. Here, also, the source of the light is not the decaying substance of the leaf, but the fungus that infests it.

It appears from my observations that a considerable proportion of fallen leaves in oak and beech forests is luminous in summer, and that the ground in the forest is everywhere illuminated by the light of decaying leaves which, though faint, is clearly discernible at night. Unfortunately, I have not yet succeeded

in identifying the fungus which causes the luminescence.

On the other hand, I have successfully applied the method of pure cultures to the fungi which cause the luminescence of wood, and have identified them, in most cases, as *Agaricus melleus* and *Mycelium X*. At the same time I have learned that certain cryptogams, including *Xylaria hypoxylon* and *Trametes pini*, must be stricken from the list of photomycetes, or luminous fungi, in which they have generally been included.

Bacterium phosphoreum (Cohn) Molisch and *Mycelium X* (provisionally so named because it cannot be induced to reproduce itself even after several years' culture) are particularly favorable objects for study and experiment, because of the comparatively great intensity of their radiation and its very long duration.

Beijerinck has made a very thorough and valuable investigation of the relations between the luminosity and the nutrition and growth of luminous bacteria. He was the first to show how these bacteria may be employed for the detection of extremely small quantities of oxygen and of certain enzymes. These physiological methods rival, and even surpass in sensitivity, the best physical and chemical methods of analysis and prove that the living organism is able to render, as an instrument of research, inestimable services to science.

In order to make clear the nature of the radiation, it is necessary to presume that the presence of free oxygen is indispensable. The light is due to oxidation. In popular lectures I demonstrate this fact in the following way:

A glass tube from three to five feet long and one-third of an inch in diameter, closed at one end, is filled to within one-half inch, or less, of the top with bouillon made strongly luminous by *Bacterium phosphoreum* or *Pseudomonas lucifera*. After the tube has stood about fifteen minutes the light vanishes from lack of oxygen, except at the extreme top, where the bacteria are in contact with the air. If the tube is then closed with the thumb and inverted the rising bubble of air makes the whole tube luminous again.

In the dark, the appearance is that of an ascending rocket. In another quarter of an hour or less the light vanishes again and may be reproduced as before.

The nature of the light has recently been studied by E. Pflüger, Radziszewsky, Dubois, F. Ludwig, Katz, Tollhausen, Lehmann, Beijerinck, McKenney, Nadson, and others, with discordant results. As our knowledge of the subject increases, however, increased support is won for the view that there is produced within the cell a hypothetical substance, photogen, which becomes luminous in presence of free oxygen. This theory is confirmed by the discovery of Radziszewsky that many organic substances become luminous in presence of alkalis and free oxygen. Furthermore, there are certain observed facts which, in my opinion, compel us to assume the existence of a photogen. Characters written with the luminous matter of *Luciola italica* may be brought to renewed luminescence by moistening. The luminous organs of the glow-worm (*Lampyris noctiluca*), when thoroughly dried and kept *in vacuo* do not emit light; but if (even after a year, according to Bongardt) they are exposed to the air and moistened with a drop of distilled water, the light reappears. Filter paper impregnated with a secretion of certain millipedes may be made luminous by wetting after being kept two months. In these cases we can not speak of living cells or cell constituents, for the luminous organ of

DECAYING BEECH LEAF.

The light-colored (pale yellow) part is luminous.

an insect which has been kept desiccated *in vacuo* for a year cannot be regarded as living. We have to do, not with a vital, but with a purely chemical process, and with a substance that becomes luminous in presence of water and free oxygen.

In the luminous plant there is no luminous secretion (as has been erroneously assumed), for the light is developed only in the interior of the cell. It has also been observed, hitherto, only in the living cell, and to this extent it may be regarded as a true vital light. But the alcoholic fermentation was, until recently, believed to be inseparably connected with the living yeast cell, and we now know, thanks to Buchner's discovery, one of the most brilliant in the history of biochemistry, that fermentation is due solely to a definite, lifeless, chemical substance, the ferment

* An address delivered before the Congress of German Naturalists and Physicians, at Meran, September 24-30, 1905, and translated for the SCIENTIFIC AMERICAN SUPPLEMENT. Comprehensive data and a bibliography of the subject may be found in Dr. Molisch's book "Leuchtende Pflanzen." (G. Fischer, Jena, 1904.)

zymase, which causes fermentation even when isolated. This suggests an analogy for photogen. The fact that no such luminous substance has yet been isolated is due in all probability to the very small quantity in which it exists, its great instability and its immediate change on the death of the cell. It is not yet possible to describe the nature of photogen or to say whether or not its light is produced by a fermentative process. Further study is needed to decide these questions. To prove, directly or indirectly, the existence of photogen, to isolate it, if possible, and bring it to luminous emission outside of the cell appear to me as very fascinating and, in view of other biochemical discoveries, not altogether hopeless objects of endeavor.

Everyone who has beheld swarms of fireflies darting through the blackness of night like living stars or has regarded, with well rested eyes, brightly luminous cultures of bacteria and higher fungi, must have been strongly impressed by the peculiar character of this "living light." It is therefore easy to understand that at an epoch when physicists are surprising us with new and unsuspected radiations, great attention should be directed to the nature of these radiations from living creatures and to their physical, chemical, and physiological effects.

In the first place, I wish to point out a remarkable difference between the character of the light emitted by animals and plants. If we disregard the peridinae, which are possibly to be classed as animals, and confine our attention to the fungi, we may assert that the light of plants is always long continued, for the bacteria and higher fungi shine for days, weeks, months, and with abundant nutriment and other favoring conditions even for years, continuously, day and night, while animals, with few exceptions, radiate only during relatively short periods, usually of a few seconds or minutes, and usually in response to an external stimulus, so that the light appears as a flash or spark.

The light emitted by fungi is white, green, or blue-green in tint and, contrary to earlier assertions, it is never wavering, like that of phosphorus, but always steady and uniform, whether observed with the naked eye or with microscope. Its apparent intensity, as a rule, is slight, though the light of some bacteria is discernible, even with the unaided eye, in the darkest corner of a room in broad daylight. An excellent object in this respect is the *Bacterium phosphoreum* (Cohn) Molisch, the luminous bacterium of butcher's meat, and a still better one is *Pseudomonas lucifera* Molisch, which I discovered in sea fish two years ago, and which surpasses all other known luminous bacteria in intensity of radiation.

The spectra of fungi are continuous, without dark lines, and attain their maximum brightness in the green. The spectra of the strongly luminous bacteria mentioned above extend further toward the violet than those of the higher fungi. In the spectrum of *Pseudomonas lucifera* Molisch I could distinguish green, blue, and violet. This is the first authenticated case in which colors have actually been seen in the spectrum of the light radiated by a plant.

The composition of the fungus light suggests the possibility of photographing with it, and this has actually been done by Von Haren Noman, Forster, Barnard, B. Fischer, and, in particular, R. Dubois. With the strongly luminous bacteria at my disposal colonies can be clearly photographed by their own light with an exposure of five minutes and good pictures of such objects as statuettes, thermometers, and print can be obtained by the use of bacterial lamps. In the latter case an exposure of several hours is required for sharp definition. On the other hand, an exposure of one second is sufficient to give a visible impression of a linear luminous culture laid directly on the plate. All pictures yet produced have been made by the light of colonies or extended cultures; but, in view of the almost infinite sensitiveness of the photographic plate, it seems to me that we may hope, some day, to photograph a single bacterial cell by its own light, as we have succeeded in photographing stars invisible to the naked eye.

The discovery of the Roentgen and Becquerel rays and the radiations of radioactive substances justified the suspicion that rays of a peculiar kind might be present in the light of bacteria, but Dubois's assertion that bacterial light penetrates such opaque bodies as wood and cardboard is based on self-deception, induced by the direct action of the wood and cardboard on the photographing plate. I can explain in the same manner the remarkable and puzzling discoveries of the Japanese investigator Muraoka, in regard to the light of the firefly. The light of fungi and of fireflies acts like ordinary daylight on the photographic plate and cannot traverse opaque bodies.

The physiological effects of bacterial light on plants are not without interest. The heliotropic sensibility, or the tendency to grow toward the light, of the seedlings of certain plants sprouted in darkness, has been shown by Wiesner to be astonishingly great. The plant detects, better than our eyes, very slight differences in brightness, and may be regarded as an excellent physiological photometer. This extraordinary sensitiveness to light induced me to test experimentally the heliotropic power of bacterial light, which I found able to produce positive heliotropism in seedlings of lentils, peas, and vetches, and in the fungi *Phycomyces* and *Xylaria hypoxylon*. It is a wonderful thing to see one plant influencing the movements of another, the bacteria compelling, by the emission of radiant energy in the form of light, the stalk of a plant to grow almost directly toward

the source of light. On the other hand, the bacterial light, probably because of its faintness, does not appear able to induce the formation of chlorophyll.

We now come to the question, whether so striking a phenomenon as the development of light in a plant is of any recognizable advantage to the plant. All zoologists appear to agree that the light produced by animals is beneficial to them, for when we consider the lightning-like, explosive emission of light, the sudden explosion of a luminous secretion and the marvelous construction of the luminous organs of animals living in the black depths of the sea, we cannot doubt that these appliances exist for the service of the organism and that many animals derive definite benefit from their power of radiating light, either because they thus attract or frighten each other or are aided in catching their prey by the illumination of their environment.

In the case of plants, the question is far more difficult to answer. The opinion has been expressed that the luminosity is an aid to their dissemination. The light emitted by bacteria living on stranded and decomposed marine animals is supposed to attract various beasts of prey which carry off the flesh and thus scatter the bacteria. I agree with Beijerinck, however, in maintaining that this view is untenable, because ocean currents, waves, and shifting sands amply suffice to account for the dissemination of the bacteria.

The case of the luminous mushroom-shaped fungi is rather more doubtful. The eminent biologist Kerner has expressed the opinion that the light of these plants attracts the flies and beetles that lay eggs in their mycelia and spore-cases and incidentally carry away and disseminate the spores of the fungi. This view is attractive at first glance, but closer examination discloses certain insuperable objections. For example, it is difficult to understand why, in *Agaricus melleus*, the receptacle, which bears the spores and is easily accessible to insects, is not luminous, while the mycelium, which grows in the wood of the host, under the bark, and usually contains no spores, is luminous. Even if the light of the mycelium did attract insects or their larvae, the result could only be injurious to the fungus, which would be destroyed, and not disseminated. Its luminosity would therefore prove its ruin. If the function of the light of plants is to attract insects at night, it is not easy to understand why it is emitted also in the daytime, when it is invisible. The case of luminous plants is essentially different from that of luminous animals and therefore I prefer to refrain from bold speculations and to admit that at present it is impossible to give any plausible ecological explanation of the luminescence of fungi, probably because it is merely a necessary result of the metabolism of these plants.

Finally, when we regard the problem from the standpoint of energetics, it appears that radiant energy in the form of light may be developed in plants, in addition to chemical and electrical energy and heat. This is a wonderful fact! In its microscopically small laboratories, the chlorophyll grains, the green cell receives the radiant energy of the sun and transforms it into chemical energy, by building up, out of atmospheric carbon dioxide, the organized tissue which is a storehouse of energy. These organic substances serve as food for luminous animals and luminous plants and thereby reproduce heat and light. Within vegetable life, therefore, there is a complete cycle from light to light! In every case—the radiation of the glow worm, the sudden flash of *Noctiluca* or the *Peridinae* when lashed by the waves or stirred by a ship's keel, the illumination of the sea bottom by luminous crustacea, the soft radiance of a fungus in the forest or of bacteria in decaying flesh—the light emitted by living organisms is essentially nothing but the radiant energy of the sun, received and transformed by plants.

It is sunlight born anew.

TURPENTINE STAINS AND WATER STAINS.

THE purpose of this article is to set forth the advantages and disadvantages of these two kinds of stain, and to correct the idea, prevalent among painters and cabinet makers, that water stains are of little value or even impracticable for staining wood.

Turpentine stains are chiefly solutions of oil-soluble coal-tar dyes in turpentine-oil, with small quantities of wax also in solution; they do not roughen the wood, making a final polishing unnecessary, a great advantage, and they enter the wood slowly, a further advantage, whereby a more even stain, especially on large surfaces, is secured. The disadvantages of turpentine stains are the lack of permanence of the coloring, when exposed to light and air, and their high price, consequent upon the present increased price of turpentine oil. The lack of permanence is a great fault, and cannot be remedied, since there are not at present upon the market any coal-tar dyes, soluble in turpentine oil, which, in point of fastness to light, meet the requirements for staining wood, itself so durable. Furthermore, the price of turpentine oil will not fall, since the demand for it is increasing constantly, and the supply from America, the chief producer, is becoming limited.

Water stains are solutions of chemicals, dye extracts, astringent substances, and coal-tar dyes in water. They roughen the wood, a disadvantage, however, which can be remedied to a large extent by previous treatment of the wood, as follows: It is moistened with a wet sponge, allowed to dry, and then rubbed

with sandpaper, or made smooth by other agencies. This almost entirely prevents roughening of the surface by the stain. Another disadvantage of these stains is that they are very rapidly absorbed by the wood, which makes an even staining of large surfaces difficult. For this too there is a remedy. The surface of the wood is rubbed all over evenly with raw linseed oil, applied with a woolen cloth, allowed to dry, and then thoroughly smoothed with sandpaper. The water stain, applied with a sponge, now spreads evenly, and is but slightly absorbed by the wood.

Some of the water stains upon the market leave much to be desired in point of fastness to light; but there is a small number of dyes and chemicals, readily soluble in water and very fast, and these are the colors to be chosen. Among these may be named the long-known Cassel brown and nut brown, in granules; catechine is recommended for brown shades, with tannin or pyrogallol acid and green vitriol for gray; for bright-colored stains the tar-dyes azine green, croceine scarlet, Parisian red, tartrazine, water-soluble nigrosine, walnut, and oak brown are very suitable. With proper mixing of these dyes, all colors except blue and violet can be produced, and prove, according to W. Zimmerman's experiments, very fast to light and air, and superior to turpentine stains. Only the blue and violet dyes, methyl blue, naphthol blue, and pure violet, do not come up to the standard, and require a second staining with tannin.

A very simple method of preparing water stains is as follows: Solutions are made of the dyes most used, by dissolving 500 grammes of the dye in ten liters of hot water, and these are kept in bottles or casks. Any desired stain can be prepared by mixing proper quantities of the solutions, which can be diluted with water to make lighter stains, and quickly made ready for use.

There is a third kind of wood stain, viz., spirit stain, but it is not greatly in favor. It contains the same color constituents as the turpentine stains, and shares their lack of fastness to light. Spirit stains have no advantages over turpentine stains, and should be entirely excluded from real wood staining, and used only for coloring spirit varnishes and polishes.

Zimmerman recommends to the consumers of wood stains to make experiments in regard to the fastness of the stains most used, by means of exposing stained surfaces to the light of summer, under burnished glass, and comparing the results with those of similar exposure of stains known to be fast. Institutions for teaching the industrial arts should test all the new chemicals and dyes which appear, for their value as wood stains, and communicate the results to persons engaged in such work. The old formulas for stains should also be revised.—Translated from the *Maler Zeitung*.

SENSE OF HEARING IN FISH.

READERS of Brehm's "Tierleben" (Animal Life) will recall a statement to the effect that the carp inhabiting a pond in a certain Continental town are accustomed to come up to the landing steps at the sound of a bell to be fed. And from this and other circumstances it has been commonly held, at least up to the middle of the last century, that fishes possess the sense of hearing.

In the year 1851 were discovered, however, the so-called organs of Corti in the internal ear of mammals, which there is good reason to believe alone receive and transmit to the brain the vibrations giving rise to the sense of hearing. Now, these organs of Corti, together with the bony "labyrinth" of the internal ear in which they are contained, are absent in fishes alone among the whole group of vertebrates, and it accordingly seems highly probable that these creatures lack the power of hearing, more especially since there seems reason to believe that the aforesaid organs of Corti are absent in such few members of the other classes of vertebrates as are deaf. If this be so, it follows, of course, that the so-called otoliths (the familiar solid white bones in the head of a cod, for instance) in the ears of fishes have nothing to do with the sound of hearing.

The whole question has recently been discussed in an exceedingly interesting manner by Prof. O. Kerner, director of the ear hospital at Rostock. The learned professor says that nature is never wasteful, and since fishes possess keen power of sight, smell and touch (in the so-called lateral line on the side of the body) it is improbable that they are also provided with the sense of hearing. He incidentally cites as a proof of this the presence of numbers of sharks at the battle of Aboukir Bay and other naval battles, pointing out that if those fishes had heard the roar of the cannon they would scarcely have swum about in their usual unconcerned manner, intent only on business.

Another argument urged is that the sense of hearing would be useless to fishes, since the enemies by which they are attacked rush silently upon them in the waters or swoop down upon them from above. The vibrations caused by the breaking of the waves on the beach are probably communicated by the lateral line system, so that fishes are warned in this manner of the proximity of land.

Brehm's anecdote of the carp coming to be fed does not by any means imply that these fishes hear the sound of the bell; and it is much more likely they feel the vibrations communicated to the water by the fact of the person coming up to the landing steps.

Moreover, according to the German professor, it appears as the result of direct experiment that while fish are able to take cognizance of numerous rapid vibrations in water, such as those communicated by