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IX.—*The President's Address.* By H. J. SLACK, F.G.S.

(*Read 12th February, 1879.*)

I AM, unfortunately, quite unable to follow in the footsteps of Mr. Sorby, who, upon two occasions, brought before you in his Annual Addresses important original work, highly gratifying to those who value and desire to increase the scientific standing of this Society. Failing in this, it seemed most desirable to select a few points of interest for your consideration, arising out of recent invention and observation.

First, I would mention the introduction of the oil lenses suggested by Mr. Stephenson, and constructed under the direction of Professor Abbe by Herr Zeiss, of Jena. The objects of this invention are twofold; first, to do away with the troublesome necessity for making corrections with the screw collar introduced by Andrew Ross, and secondly, to obtain the largest angle of aperture with a good working distance. By selecting an oil, or mixture of oils having the same refractive power as the covering glass, it was expected that a fixed correction would suffice for any thickness. When the cover was thicker, as the working distance of the objective remained unchanged, there would be a thinner stratum of oil used upon the immersion principle, and when the cover was thinner the oil stratum would be thicker. After many trials, Professor Abbe found oil of cedar wood had very nearly the requisite properties when the illumination was with oblique light, and was improved for direct light by an admixture with oil of fennel seed. The glass made for Mr. Stephenson fully answered expectation. It had according to his description a balsam angle of 113° , its power was rather more than one-ninth, and the only correction it needed was a change in the length of the Microscope tube from 10 inches to 12 when very thin covers were employed. One result of using objectives of this construction, taken in connection with Professor Abbe's account of the way in which

lined objects can be viewed, or lined appearances produced, has been to throw fresh doubt as to the correspondence between actual structure, and optical effects of this description; and we are thrown back, as I pointed out in reference to insect scales long ago, upon the necessity of making various experiments, and of reasoning from the best analogies we can obtain in the interpretation of the appearances we see. Amongst those who have experimented with the oil lenses I may mention Dr. Pigott, who speaks of a No. 15 as a "magnificent glass."

It was not found by Mr. Dallinger, whose researches require the highest and most efficient optical aid, that the oil objectives showed anything he could not see with the Powell and Lealand glasses he usually employed, but he at once admitted and praised the great facility with which they could be used. He has since obtained excellent effects by using oil of cedar wood with Powell and Lealand's newest $\frac{1}{8}$, $\frac{1}{12}$, and $\frac{1}{16}$, and expresses great admiration for a new wet and dry $\frac{1}{50}$ by the same makers.

By the kindness of Mr. Baker, I had an opportunity of trying an $\frac{1}{8}$ and $\frac{1}{12}$. The latter I found a splendid glass, remarkable for the ease with which it displayed difficult objects, and requiring only a film of oil to connect it with the slide cover. The $\frac{1}{8}$ had such a large working distance that it required a little puddle of the oil, and on this account could only be employed with the Microscope in a vertical position. I am told that these glasses are not all alike in this respect.

The 'American Quarterly Microscopical Journal' for January, 1879, contains a letter from Professor Abbe, explaining that owing to a mistake several $\frac{1}{8}$ ths have been made with a balsam angle of 107° to 109° only, instead of 114 to 116 , as they should have been. He also states these objectives are composed of "four separate lenses," and not three, as Professor H. L. Smith supposed.

It seems probable, from Mr. Dallinger's experiments, and a few made by myself, that opticians may be able to furnish us with objectives that can be corrected for either oil or water; but if this cannot be satisfactorily accomplished, it is not likely that the oil lenses will supersede the water ones, though they have obviously some decided advantages for special purposes.

The fine performances of the large-angled glasses of the best makers, and the results obtained with the extreme angles of the oil lenses, have led in some quarters to a belief that great angles are good for all purposes; but there can be little doubt that this will be found a mistake, and that glasses of small and moderate angles, with fine corrections, will still be needed for much, and probably for most, valuable work.*

* See Dr. Pigott's paper "On the Invisibility of Minute Refracting Bodies caused by Excess of Aperture," 'M. M. J.,' February, 1875, p. 55.

Mr. Dallinger has pointed out that fine dry lenses are still necessary for many cases in which the use of fluids is objectionable, and this brings us to the consideration of the direction in which we must look for further progress.

It is now several years since Dr. Pigott called attention to the practical importance of the residual errors of the best objectives then made, and he proved experimentally that with the existing materials it was possible to reduce them. Since then important advances have been made, both with dry and wet lenses, and it is probable that for a further advance, to any important extent, the optician must be supplied with fresh materials.

Professor Abbe says, "The impossibility of removing each chromatic difference of spherical aberration has its root in the circumstance that, in the kinds of crown and flint glass at present provided, the dispersion always goes hand in hand with the mean index of refraction, in such a way that the higher dispersion is attached to the highest index. The outstanding aberrations might be completely, or very nearly, compensated, if an optical material were provided in which a relatively lower refractive index were united with a higher dispersion, or a higher refractive index with a relatively smaller dispersion. It would then be possible by combining such materials with the ordinary crown and flint glass to remove the chromatic and spherical aberrations which are partly disconnected, and thus fulfil the essential conditions arising from the chromatic difference." *

Professor Abbe also remarks upon the very small number of persons engaged in the manufacture of glass for optical purposes, and upon the few substances that have hitherto been employed in its preparation. Looking to the present conditions of manufacturing industry, which offer the largest gains to those who can produce at the lowest price articles required in great quantities, it is not probable that purely commercial considerations will induce anyone to devote attention to the demands of science for new kinds of glass or substitutes for glass, and the task is not likely to be undertaken unless through the help of private munificence, or State aid.

Besides glasses, which are chiefly silicates of potash, soda, and lead, with a little alumina or lime, &c., there seems a probability that a class of compounds resembling precious stones may come into optical use. M. Feil, a celebrated manufacturer of optical glass, and M. Fremy have succeeded in artificially producing rubies and sapphires, alumina minerals of high refractive power, and it is not impossible some quite new compounds may be formed. When Sir David Brewster experimented with jewel lenses, he spoke very highly of garnet, which is a compound of three or four silicates, chiefly of

* 'Die Optischen Hilfsmittel der Mikroskopie,' von Dr. E. Abbe, Professor an der Universität zu Jena. Braunschweig, 1878.

alumina and lime. If the optician were supplied with fresh substances possessing the requisite properties, we might not only have objectives of more perfect corrections, but higher powers with flatter curves and larger lenses.

Passing from objectives to their employment and performance, we find Professor Abbe dealing with the conditions necessary for the resolution of close-lined and analogous objects, Mr. Dallinger measuring the flagella of *Bacterium termo* and finding them less than the 200,000th of an inch, and Dr. Pigott exhibiting, by remagnification, the image of a spider line diminished to the one-millionth of an inch.

If we consider the application of high powers to natural history, it is an interesting question how far the existing optical means enable the structure and rank of many of the minuter organisms to be discovered, and how far down in the scale sexual generation can be affirmed, or, with probability, assumed.

Professor Haeckel places amongst his Protista, eight classes of creatures, including Amœba, Flagellata, Diatoms, &c., and affirms of the whole list "that the most important physiological characteristic of the kingdom Protista lies in the exclusively non-sexual propagation of all the organisms belonging to it."* With regard to this statement, it may be mentioned that in 1863 Dr. Wallich published a remarkable series of observations on the form of Amœba he discovered in a Hampstead pond, and named *villosa* from its having a permanent villous organ protruding from one part. He stated that "one of the most remarkable amongst the most novel and varied characters of the Amœbæ consists in the vesicle, in which the true nucleus is contained, having been found to be distinctly membranous in some individuals." He noticed also "a clear nucleolus," and inquired whether the appearances presented justified the belief that the creature possessed "a germ cell and sperm cells."†

In April, 1875,‡ Messrs. Dallinger and Drysdale described a series of facts in the life-history of certain flagellate monads, including a sexual union, a division of nucleus, and formation of germs at first so minute as to be separately invisible, and then developing by several changes into the parental form. A magnification of 2600 diameters sufficed for watching these processes, and made the nuclei appear about one-eighth of an inch in their shortest diameter. One of the creatures in its most globular condition had, with that power, an apparent longest diameter exceeding one inch, and the shorter diameter a little under an inch. If we compare these dimensions with those of *Bacterium termo* magnified 4000 diameters, in Mr.

* 'History of Creation,' vol. ii, p. 69.

† 'Ann. N. H.,' May, 1863.

‡ 'M. M. J.,' May, 1875.

Dallinger's drawing represented in the September number of the new Journal,* we find the latter creature's body composed of two oval beads, each one seeming only about the size of the nucleus of the just mentioned flagellate monad, though the magnification is 1400 diameters greater. How much smaller living creatures may exist it is not possible to say, but with those of these dimensions we can scarcely expect any mode of vision furnished by the Microscope to enable the processes of their germ formation to be traced. Another difficulty of dealing with these organisms arises from the fact that it is only by unintermittent watching for a long time and under a variety of conditions that the whole cycle of their life changes can be made known. Mr. Dallinger has shown in the case of monads that the same species in different stages of development present very different aspects and behave in very different ways. The minute bacteria found to be capable of producing in animals the splenic disease which the French call *sang de rate*, has been found by other observers able under certain conditions to branch like the mycelium of a mould; and in M. Pasteur's book '*La Bière*' will be found many illustrations of dissimilar growths of ferments, and fungi under different circumstances. After recounting many interesting experiments, M. Pasteur remarks that in the dust of a laboratory in which fermentations are studied, there are many germs which give rise to organisms which it is impossible to distinguish from alcoholic ferments, although they do not possess the properties of those bodies.

In endeavouring to avoid the error of lumping together a number of small organisms under a common heading, implying a very low stage of development, attention should be paid to any indications that may be obtained from their external organs, although their internal structure may defy scrutiny. An organism furnished with cilia in constant vibration is in that respect, and may be in others, below another in which ciliary motion, to use the words of the '*Micrographic Dictionary*,' "is interrupted at intervals, apparently under the influence of a will." Of course, the term "will" is only employed to express a remote analogy. The difference appears to be that the ceaseless motion in one case responds to some continuous necessity, possibly that of respiration, while the intermittent one responds to a less frequent need, such as going in search of food. The "springing monad" of Messrs. Dallinger and Drysdale,† so called from its peculiar habit of coiling and uncoiling one of its flagella with a darting motion, not unlike the vorticella, carrying the body with it, evidently possesses an instrument superior to the simple cilium, and the same may be said of the "hooked monad" of these observers, a creature "with a persistent hook-like flagellum." The "calycine monad," to

* '*Journal R. M. S.*,' vol. i. No. 4.

† '*M. M. J.*,' vol. x. p. 245.

which reference has already been made, is in its normal state like a cup, terminating in a slender pointed stem. It has nuclear bodies and two large "eye spots," with the strange "rhythmical opening and shutting" seen by these observers in some other monads. It is provided with four long flagella, and the authors say, its mode of locomotion is "a graceful gliding through the water, the flagella moving so often and so rapidly as to render their detection impossible when the monad is at its swiftest. They could roll over on their long axis, and change the direction of their motion with lightning-like rapidity, and, however crowded the field, not the slightest approximation to collision occurred." In this case the creature is big enough for some important internal organs to be seen, but had it been too small for this, or had none been open to detection, would not its remarkable and varied powers of locomotion have afforded fair ground for suspecting that it ought not to be ranked among the simplest unicellular bodies?

Before passing to another topic, a protest may be admitted against a not uncommon practice of describing some of the lowest living things as composed of a little mass of "homogeneous protoplasm." Is it not true, whenever magnification reasonably proportioned to the size of any organism can be applied, its protoplasm, so far from being "homogeneous," exhibits granulation, or particles differing in refractive power, and presumably in chemical properties from the mass?

The progress of discovery certainly leads to the belief that the processes and functions of the higher animals are developments of what is found low down in the scale. In a lecture "On the Phenomena of Life common to Animals and Plants,"* Claude Bernard said, "the principle of vital unity dominates in the entire history of animals and plants," and he characterized "nutrition" as "continuous generation." In another passage he said, "At the origin of every nutritive or generative phenomenon there is an organized agent, egg, germ, cell," and up to the present time the Spontaneous Generation Controversy has resulted in showing that there are no known means of obtaining any manifestations of new life, excepting as the products and results of previous life, acting, and acted upon, by appropriate surroundings. There is, however, another controversy still going on, in which the Microscope is indispensable, which has very wide and important bearings upon a variety of scientific questions, and which has a better chance of being finally settled.

This controversy relates to M. Pasteur's explanation of certain facts and appearances belonging to fermentation. In 1861, and since, M. Pasteur has been led by various experiments to divide a group of living organisms into two classes, which he designates *aerobies* and *anaerobies*, the former requiring for their existence

* 'Revue Scientifique,' 26th September, 1874.

and growth the presence of free oxygen, and the latter able to dispense with it, provided they are brought in contact with a fermentable substance from which they can obtain the oxygen they need by a process of decomposition—the latter, he affirms, to be ferments. Septic vibrions he finds killed by free oxygen, and these come under his designation of *anaerobies*. In other cases, and notably in yeast plants, he notices a capability of living in either state; and in the last or *anaerobic* one, they act as ferments.

Before proceeding further with M. Pasteur's researches, it will be well to bear in mind what takes place in the life processes of the higher chlorophyll-containing plants, and we shall then be able to see what relation these *aerobies* and *anaerobies* bear to them.

The experiments and observations of M. Corenwinder, extending and confirming opinions expressed by M. Th. de Saussure, and supported thirty years ago by M. Garreau,* show that the respiratory process of plants is constant, and like that of animals carried on by absorption of oxygen and exhalation of carbonic acid, and that the absorption of carbonic acid with retention of carbon and emission of oxygen is "a veritable digestion." The respiratory acts belong to the nitrogenous matter of the plants, and the carbon digestion to the chlorophyll, and it depends essentially upon the influence of light, being most active during direct exposure to solar rays and diminishing as the light is weakened. The carbon carried off in the respiratory action comes from the supply obtained by the digestive and assimilative processes.

We learn from M. Pasteur that the moulds *Penicillium* and *Aspergillus*, and the "mother of wine," *Mycodermi vini*, are capable of living in either of the states named, and he describes a variety of experiments showing these facts, and he remarks upon them, "We are constrained to admit that the production of alcohol and carbonic acid with the help of sugar, in a word, alcoholic fermentation, are chemical acts connected with the plant life of cells of very divers natures, and that they appear at the moment these cells are no longer able to burn freely the materials of their nutrition by the effect of respiration, that is to say, by absorption of free oxygen, and that they accomplish their life by utilizing oxygenated substances like sugar and combustible bodies, which give out heat in their decomposition. The ferment character then presents itself to us, not as peculiar to this or that being, or this or that organ, but as a general property of the living cell; a character always ready to manifest itself, and actually doing so when its life is no longer accomplished under the influence of free oxygen, or of a quantity of that gas sufficient for all the acts of nutrition." †

M. Pasteur gives drawings of the appearance of various cells

* See 'Revue Scientifique,' 1st August, 1874.

† 'La Bière,' pp. 113, 114.

grown under the two conditions. They might be taken for different species, and no mere microscopic examination would suffice to show what they were.

Speaking of the peculiar effects of yeast and other ferments, he observes that "there is only a slight relation between the weight of the yeast formed and the weight of sugar decomposed; with all other known beings the weight of the nutritive matter assimilated is of the same order of quantity as the weight of the aliments brought into play. The discrepancy where it exists is relatively slight. Such is not the life of yeast. For a weight a of yeast formed, the weight of the sugar decomposed is $10a$, $20a$, $100a$, and even more."

The growth and generation of ferments in mineral media are regarded by M. Pasteur as having "a great physiological interest." He says, "They demonstrate, among other results, that all the protein matter of yeasts may have their origin in the vital activity of cells putting in action hydrocarbonous substances without the influence of light or free oxygen—or with free oxygen in the case of the aerobies—together with salts of ammonia, phosphates, and sulphates of potash and magnesia. It might even with rigour be admitted that a similar effect is produced in the higher plants. What serious reason can be invoked in the present state of science for not considering this effect as general? It would not be illogical to extend the results we speak of to all plants, and to believe that the protein matters of plants, and perhaps even of animals, are formed exclusively by the activity of cells acting on the ammoniacal salts and the mineral salts of the sap, or of the plasma of the blood and the hydrocarbonous matters, of which the formation in the higher plants only requires the aid of the chemical forces of green light.

"According to this view the formation of protein substances is independent of the great act of reduction of carbonic acid under the influence of light. . . . As in plant production by a hydrocarbonous matter in a mineral medium, the hydrocarbonous matter may vary greatly, and we comprehend with difficulty how it reduces itself to its elements before serving for the composition of the protein matters, we may hope to obtain as many distinct protein bodies, and even celluloses, as there are hydrocarbonous matters." M. Pasteur states that he is engaged in experiments of this description. He further remarks that if solar radiation is indispensable for the decomposition and formation of the proximate principles of the larger plants, certain lower ones can do without it, and still form a variety of the most complex substances, so that life in inferior forms might exist even if sunlight disappeared.

Objections have been made to M. Pasteur's theory of the action of ferments by various authorities, and the controversy is still going

on in the French Academy. Schützenberger, in his work on Fermentation, says, "Yeast sets up alcoholic fermentation in a solution of pure sugar in the absence of all trace of oxygen, but without developing; this is contrary to the affirmation of M. Pasteur that fermentation is bound up with the organization of the yeast, or is a phenomenon correlative to the vital activity of the cells."

Full explanations on this point are given by M. Pasteur in 'La Bière.' I will cite one passage (p. 239), in which he says, "In order to multiply itself in a fermentable medium, without the presence of oxygen gas, the cells of yeast must be extremely young, full of life and health, still under the influence of the vital activity they owe to the free oxygen which assisted to form them, and which perhaps they have stored up for a time. When older they have much difficulty in reproducing themselves without air, and they age more and more quickly: if they continue to multiply, it is under a *bizarre* and monstrous form. When still older they remain absolutely inert in a medium deprived of free oxygen. It is not that they are dead: usually they rejuvenesce rapidly if sown in the same liquid after it has been aerated."

The lines of inquiry suggested by M. Pasteur may lead to many valuable results. It is obvious that the chemist can compose a great variety of nutrient fluids in which many of the lower organisms can be grown. Certain mineral matters, compounds of ammonia to supply nitrogen, and hydrocarbons that may be varied to almost any extent, offer the means of experiments presenting different conditions and likely to lead to different results.

Unless new methods can be devised, it will evidently be a waste of time to seek amongst the simplest organisms for any transition, or change of dead matter into living matter without the intervention of a living cell; but as the highest organisms are orderly and co-ordinated aggregations of simple ones, the smallest living particle capable of growth, reproduction and decay, may, when rightly questioned, elucidate some of the profoundest problems with which the biologist has to deal.