ANIMALS

CONTAINING

CHLOROPHYLL

Compiled by

Campbell M Gold

(2008)

(This material was compiled from sources in the United States public domain)

--()--

Introduction

Are there animals, on planet earth, that contain chlorophyll?

Isaac Asimov, in his book, 'Facts and Trivia', writes: *There are one-celled creatures that have the properties of both plants and animals. An example is the flagellate Eugena, which propels itself rapidly through water like an animal by means of undulating, snakelike appendages. Moreover, it contains **chlorophyll**, a substance as characteristic of plants as blood is of animals.*

--()--

Scientific American

The theme of animals containing chlorophyll is explored in the *'Scientific American Supplement No. 324, March 18, 1882'*, and is presented in its entirety below:

SCIENTIFIC AMERICAN SUPPLEMENT NO. 324

NEW YORK, MARCH 18, 1882

Scientific American Supplement. Vol. XIII, No. 324.

Scientific American established 1845

Scientific American Supplement, $5 a year.

Scientific American and Supplement, $7 a year.

*   *   *   *   *

BIOLOGY, ETC.--Researches on Animals Containing Chlorophyl. --Abstract of a long and valuable paper "On the Nature and Functions of the Yellow Cells of Radiolarians and Coelenterates," read to the Royal Society of Edinburgh. By PATRICK GEDDES.

The Hibernation of Animals, An interesting review of the winter habits of some of our familiar animals, insects, etc.

*   *   *   *   *

RESEARCHES ON ANIMALS CONTAINING CHLOROPHYL.

[Footnote: Abstract of a paper "On the Nature and Functions of the 'Yellow Cells' of Radiolarians and Coelenterates," read to the Royal Society of Edinburgh, on January 14, 1882, and published by permission of the Council.--_Nature_.]

--()--

It is now nearly forty years since the presence of chlorophyl in certain species of planarian worms was recognized by Schultze. Later observers concluded that the green color of certain infusorians, of the common fresh water hydra and of the fresh water sponge, was due to the same pigment, but little more attention was paid to the subject until 1870, when Ray Lankester applied the spectroscope to its investigation. He thus considerably extended the list of chlorophyl containing animals, and his results are summarized in Sachs' Botany (Eng. ed.). His list includes, besides the animals already mentioned, two species of Radiolarians, the common green sea anemone (_Anthea cereus_, var. _Smaragdina_), the remarkable Gephyrean, _Bonellia viridis_, a Polychæte worm, _Chætoperus_, and even a Crustacean, _Idotea viridis_.

The main interest of the question of course lies in its bearing on the long-disputed relations between plants and animals; for, since neither locomotion nor irritability is peculiar to animals; since many insectivorous plants habitually digest solid food; since cellulose, that most characteristic of vegetable products, is practically identical with the tunicin of Ascidians, it becomes of the greatest interest to know whether the chlorophyl of animals preserves its ordinary vegetable function of effecting or aiding the decomposition of carbonic anhydride and the synthetic production of starch. For although it had long been known that _Euglena_ evolved oxygen in sunlight, the animal nature of such an organism was merely thereby rendered more doubtful than ever. In 1878 I had the good fortune to find at Roscoff the material for the solution of the problem in the grass-green planarian, _Convoluta schultzii_, of which multitudes are to be found in certain localities on the coast, lying on the sand, covered only by an inch or two of water, and apparently basking in the sun. It was only necessary to expose a quantity of these animals to direct sunlight to observe the rapid evolution of bubbles of gas, which, when collected and analyzed, yielded from 45 to 55 per cent. of oxygen. Both chemical and histological observations showed the abundant presence of starch in the green cells, and thus these planarians, and presumably also _Hydra spongilla_, etc., were proved to be truly "vegetating animals."

Being at Naples early in the spring of 1879, I exposed to sunlight some of the reputedly chlorophyl containing animals to be obtained there, namely, _Bonellia viridis_ and _Idotea viridis_, while Krukenberg had meanwhile been making the same experiment with _Bonellia_ and _Anthea_ at Trieste. Our results were totally negative, but so far as _Bonellia_ was concerned this was not to be wondered at since the later spectroscopic investigations of Sorby and Schenk had fully confirmed the opinion of Lacaze-Duthiers as to the complete distinctness of its pigment from chlorophyl. Krukenberg, too, who follows these investigators in terming it _bonellein_, has recently figured the spectra of Anthea-green, and this also seems to differ considerably from chlorophyl, while I am strongly of the opinion that the pigment of the green crustaceans is, if possible, even more distinct, having not improbably a merely protective resemblance.

It is now necessary to pass to the discussion of a widely distinct subject--the long outstanding enigma of the nature and functions of the "yellow cells" of Radiolarians. These bodies were first so called by Huxley in his description of _Thallassicolla_, and are small bodies of distinctly cellular nature, with a cell wall, well defined nucleus, and protoplasmic contents saturated by a yellow pigment. They multiply rapidly by transverse division, and are present in almost all Radiolarians, but in very variable number. Johnnes Muller at first supposed them to be concerned with reproduction, but afterward gave up this view. In his famous monograph of the Radiolarians, Haeckel suggests that they are probably secreting cells or digestive glands in the simplest form, and compares them to the liver-cells of Amphioxus, and the "liver-cells" described by Vogt in _Velella_ and _Porpita_. Later he made the remarkable discovery that starch was present in notable quantity in these yellow cells, and considered this as confirming his view that these cells were in some way related to the function of nutrition. In

1871 a very remarkable contribution to our knowledge of the Radiolarians was published by Cienkowski, who strongly expressed the opinion that these yellow cells were parasitic algæ, pointing out that our only evidence of their Radiolarian nature was furnished by their constant occurrence in most members of the group. He showed that they were capable not only of surviving the death of the Radiolarian, but even of multiplying, and of passing through an encysted and an amoeboid state, and urged their mode of development and the great variability of their numbers within the same species as further evidence of his view.

The next important work was that of Richard Hertwig, who inclined to think that these cells sometimes developed from the protoplasm of the Radiolarian, and failing to verify the observations of Cienkowski, maintained the opinion of Haeckel that the yellow cells "fur den Stoffwechsel der Radiolarien von Bedeutung sind." In a later publication (1879) he, however, hesitates to decide as to the nature of the yellow cells, but suggests two considerations as favoring the view of their parasitic nature--first, that yellow cells are to be found in Radiolarians which possess only a single nucleus, and secondly, that they are absent in a good many species altogether.

A later investigator, Dr. Brandt, of Berlin, although failing to confirm Haeckel's observations as to the presence of starch, has completely corroborated the main discovery of Cienkowski, since he finds the yellow cells to survive for no less than two months after the death of the Radiolarian, and even to continue to live in the gelatinous investment from which the protoplasm had long departed in the form of swarm-spores. He sum up the evidence strongly in favor of their parasitic nature.

Meanwhile similar bodies were being described by the investigators of other groups. Haeckel had already compared the yellow cells of Radiolarians to the so-called liver-cells of _Velella_; but the brothers Hertwig first recalled attention to the subject in 1879 by expressing their opinion that the well-known "pigment bodies" which occur in the endoderm cells of the tentacles of many sea-anemones were also parasitic algæ. This opinion was founded on their occasional occurrence outside the body of the anemone, on their irregular distribution in various species, and on their resemblance to the yellow cells of Radiolarians. But they did not succeed in demonstrating the presence of starch, cellulose, or chlorophyl. The last of this long series of researches is that of Hamann (1881), who investigates the similar structures which occur in the oral region of the Rhizostome jelly-fishes. While agreeing with Cienkowski as to the parasitic nature of the yellow cells of Radiolarians, he holds strongly that those of anemones and jelly-fishes are unicellular glands.

In the hope of clearing up these contradictions, I returned to Naples in October last, and first convinced myself of the accuracy of the observation of Cienkowski and Brandt as to the survival of the yellow cells in the bodies of dead Radiolarians, and their assumption of the encysted and the amoeboid states. Their mode of division, too, is thoroughly algoid. One finds, not unfrequently, groups of three and four closely resembling _Protococcus_. Starch is invariably present; the wall is true plant-cellulose, yielding a magnificent blue with iodine and sulphuric acid, and the yellow coloring matter is identical with that of diatoms, and yields the same greenish residue after treatment with alcohol. So, too, in Velella, in sea-anemones, and in medusæ; in all cases the protoplasm and nucleus, the cellulose, starch, and chlorophyl, can be made out in the most perfectly distinct way. The failure of former observers with these reactions, in which I at first also shared, has been simply due to neglect of the ordinary botanical precautions. Such reactions will not succeed until the animal tissue has been treated with alcohol and macerated for some hours in a weak solution of caustic potash. Then, after neutralizing the alkali by means of dilute acetic acid, and adding a weak solution of iodine, followed by strong sulphuric acid, the presence of starch and cellulose can be successively demonstrated. Thus, then, the chemical composition, as well as the structure and mode of division of these yellow cells, are those of unicellular algæ, and I accordingly propose the generic name of _Philozoon_, and distinguish four species, differing slightly in size, color, mode of division, behavior with reagents, etc., for which the name of _P. radiolarum, P. siphonophorum, P. actiniarum_, and _P. medusarum_, according to their habitat, may be conveniently adopted. It now remains to inquire what is their mode of life, and what their function.

I next exposed a quantity of Radiolarians (chiefly _Collozoum_) to sunshine, and was delighted to find them soon studded with tiny gas-bubbles. Though it was not possible to obtain enough for a quantitative analysis, I was able to satisfy myself that the gas was not absorbed by caustic potash, but was partly taken up by pyrogallic acid, that is to say, that little or no carbonic acid was present, but that a fair amount of oxygen was present, diluted of course by nitrogen. The exposure of a shoal of the beautiful blue pelagic Siphonophore, _Velella_, for a few hours, enabled me to collect a large quantity of gas, which yielded from 24 to 25 per cent. of oxygen, that subsequently squeezed out from the interior of the chambered cartilaginous float, giving only 5 per cent. But the most startling result was obtained by the exposure of the common _Anthea cereus_, which yielded great quantities of gas containing on an average from 32 to 38 per cent. of oxygen.

At first sight it might seem impossible to reconcile this copious evolution of oxygen with the completely negative results obtained from the same animal by so careful an experimenter as Krukenberg, yet the difficulty is more apparent than real. After considerable difficulty I was able to obtain a large and beautiful specimen of _Anthea cereus_, var. _smaragdina_, which is a far more beautiful green than that with which I had been before operating--the dingy brownish-olive variety, _plumosa_. The former owes its color to a green pigment diffused chiefly through the ectoderm, but has comparatively few algæ in its endoderm; while in the latter the pigment is present in much smaller quantity; but the endoderm cells are crowded by algæ. An ordinary specimen of _plumosa_ was also taken, and the two were placed in similar vessels side by side, and exposed to full sunshine; by afternoon the specimen of _plumosa_ had yielded gas enough for an analysis, while the larger and finer _smaragdina_ had scarcely produced a bubble. Two varieties of _Ceriactis aurantiaca_, one with, the other without, yellow cells, were next exposed, with a precisely similar result. The complete dependence of the evolution of oxygen upon the presence of algæ, and its complete independence of the pigment proper to the animal, were still further demonstrated by exposing as many as possible of those anemones known to contain yellow cells (_Aiptasia chamæleon, Helianthus troglodytes_, etc.) side by side with a large number of forms from which these are absent (_Actinia mesembryanthemum, Sagastia parasitica, Cerianthus_, etc.). The former never failed to yield abundant gas rich in oxygen, while in the latter series not a single bubble ever appeared.

Thus, then, the coloring matter described as chlorophyl by Lankester has really been mainly derived from that of the endodermal algæ of the variety _plumosa_, which predominates at Naples; while the anthea-green of Krukenberg must mainly consist of the green pigment of the ectoderm, since the Trieste variety evidently does not contain algæ in any great quantity. But since the Naples variety contains a certain amount of ordinary green pigment, and since the Trieste variety is tolerably sure to contain some algæ, both spectroscopists have been operating on a mixture of two wholly distinct pigments--diatom-yellow and anthea-green.

But what is the physiological relationship of the plants and animal thus so curiously and intimately associated? Every one knows that all the colorless cells of a plant share the starch formed by the green cells; and it seems impossible to doubt that the endoderm cell or the Radiolarian, which actually incloses the vegetable cell, must similarly profit by its labors. In other words, when the vegetable cell dissolves its own starch, some must needs pass out by osmose into the surrounding animal cell; nor must it be forgotten that the latter possesses abundance of amylolytic ferment. Then, too, the _Philozoon_ is subservient in another way to the nutritive function of the animal, for after its short life it dies and is digested; the yellow bodies supposed by various observers to be developing cells being nothing but dead algæ in progress of solution and disappearance.

Again, the animal cell is constantly producing carbonic acid and nitrogenous waste, but these are the first necessities of life to our alga, which removes them, so performing an intracellular renal function, and of course reaping an abundant reward, as its rapid rate of multiplication shows.

Nor do the services of the _Philozoon_ end here; for during sunlight it is constantly evolving nascent oxygen directly into the surrounding animal protoplasm, and thus we have actually foreign chlorophyl performing the respiratory function of native hæmoglobin! And the resemblance becomes closer when we bear in mind that hæmoglobin sometimes lies as a stationary deposit in certain tissues, like the tongue muscles of certain mollusks, or the nerve cord of _Aphrodite_ and Nemerteans.

The importance of this respiratory function is best seen by comparing as specimens the common red and white Gorgonia, which are usually considered as being mere varieties of the same species, _G. verrucosa_. The red variety is absolutely free from _Philozoon_, which could not exist in such deeply colored light, while the white variety, which I am inclined to think is usually the larger and better grown of the two, is perfectly crammed. Just as with the anemones above referred to, the red variety evolves no oxygen in sunlight, while the white yields an abundance, and we have thus two widely contrasted _physiological varieties_, as I may call them, without the least morphological difference. The white specimen, placed in spirit, yields a strong solution of chlorophyl; the red, again, yields a red solution, which was at once recognized as being tetronerythrin by my friend M. Merejkowsky, who was at the same time investigating the distribution and properties of that remarkable pigment, so widely distributed in the animal kingdom. This substance, which was first discovered in the red spots which decorate the heads of certain birds, has recently been shown by Krukenberg to be one of the most important of the coloring matter of sponges, while Merejkowsky now finds it in fishes and in almost all classes of invertebrate animals. It has been strongly suspected to be an oxygen-carrying pigment, an idea to which the present observation seems to me to yield considerable support. It is moreover readily bleached by light, another analogy to chlorophyl, as we know from Pringsheim's researches.

When one exposes an aquarium full of _Anthea_ to sunlight, the creatures, hitherto almost motionless, begin to wave their arms, as if pleasantly stimulated by the oxygen which is being developed in their tissues. Specimens which I kept exposed to direct sunshine for days together in a shallow vessel placed on a white slab, soon acquired a dark, unhealthy hue, as if being oxygenated too rapidly, although I protected them from any undue rise of temperature by keeping up a flow of cold water. So, too, I found that Radiolarians were killed by a day's exposure to sunshine, even in cool water, and it is to the need for escaping this too rapid oxidation that I ascribe their remarkable habit of leaving the surface and sinking into deep water early in the day.

It is easy, too, to obtain direct proof of this absorption of a great part of the evolved oxygen by the animal tissues through which it has to pass. The gas evolved by a green alga (_Ulva_) in sunlight may contain as much as 70 per cent. of oxygen, that evolved by brown algae (_Haliseris_) 45 per cent., that from diatoms about 42 per cent.; that, however, obtained from the animals containing _Philozoon_ yielded a very much lower percentage of oxygen, e.g. _Velella_ 24 per cent., white _Gorgonia_ 24 per cent., _Ceriactis_ 21 per cent., while Anthea, which contains most algæ, gave from 32 to 38 per cent. This difference is naturally to be accounted for by the avidity for oxygen of the animal cells.

Thus, then, for a vegetable cell no more ideal existence can be imagined than that within the body of an animal cell of sufficient active vitality to manure it with carbonic acid and nitrogen waste, yet of sufficient transparency to allow the free entrance of the necessary light. And conversely, for an animal cell there can be no more ideal existence than to contain a vegetable cell, constantly removing its waste products, supplying it with oxygen and starch, and being digestible after death. For our present knowledge of the power of intracellular digestion possessed by the endoderm cells of the lower invertebrates removes all difficulties both as to the mode of entrance of the algæ, and its fate when dead. In short, we have here the relation of the animal and the vegetable world reduced to the simplest and closest conceivable form.

It must be by this time sufficiently obvious that this remarkable association of plant and animal is by no means to be termed a case of parasitism. If so, the animals so infested would be weakened, whereas their exceptional success in the struggle for existence is evident. _Anthea cereus_, which contains most algæ, probably far outnumbers all the other species of sea-anemones put together, and the Radiolarians which contain yellow cells are far more abundant than those which are destitute of them. So, too, the young gonophores of Velella, which bud off from the parent colony and start in life with a provision of _Philozoon_ (far better than a yolk-sac) survive a fortnight or more in a small bottle--far longer than the other small pelagic animals. Such instances, which might easily be multiplied, show that the association is beneficial to the animals concerned.

The nearest analogue to this remarkable partnership is to be found in the vegetable kingdom, where, as the researches of Schwendener, Bornet, and Stahl have shown, we have certain algæ and fungi associating themselves into the colonies we are accustomed to call lichens, so that we may not unfairly call our agricultural Radiolarians and anemones _animal lichens_. And if there be any parasitism in the matter, it is by no means of the alga upon the animal, but of the animal, like the fungus, upon the alga. Such an association is far more complex than that of the fungus and alga in the lichen, and indeed stands unique in physiology as the highest development, not of parasitism, but of the reciprocity between the animal and vegetable kingdoms. Thus, then, the list of supposed chlorophyl containing animals with which we started, breaks up into three categories; first those which do not contain chlorophyl at all, but green pigments of unknown function (_Bonelia<, Idotea_, etc.); secondly, those vegetating by their own intrinsic chlorophyl (_Convoluta_, _Hydra_, _Spongilia_); thirdly, those vegetating by proxy, if one may so speak, rearing copious algae in their own tissues, and profiting in every way by the vital activities of these.

PATRICK GEDDES.

*   *   *   *   *

End

--()--

18112008