On the Origin of the Thermal Flora.

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The American naturalist, W. H. Weed, was the first who pointed out the possibillity that plants found in hot springs might be the oldest organisms on the earth. In his paper on »The Vegetation of Hot Springs« printed already in 1889., he said:

»The ability possessed by the vegetation found in such waters to withstand such extreme and adverse conditions of environment shows the possible existence of this form of life during the early history of our globe, when the crust of the earth is supposed to have been covered with hot and highly mineralized waters. Such plants may thus represent the earliest links in the chain of evolution.«

This idea of Weed made B. M. Davis so enthusiastic that he added the following refrain in his song to the Thermal-Flora of Yellowstone:

»Children of steam and scalded rock,
What is the story you have to tell,
Our legends are old, of greater age
Than the mountains round about.«

The Weed's idea became eventually one of the main problems investigated by the biologists working in this field, and is now known by the name of Relic-Hypothesis.

I pointed out already in 1923 in a paper given at the hundredth-anniversary meeting of the Society of German Naturalists and Physicians in Leipzig that the Relic-Hypothesis is not well-founded and gave several important facts which opposed it.

Molisch during his last stay in Japan devoted some of his time to a biological investigation of the hot springs there, on which occasion he spoke in his last book :Pflanzenbiologie in Japan auf Grund eigener Beobachtungen« (1926) of the Relic-Hypothesis. Molisch accepts this Hypothesis as follows:

»Bei dieser Sachlage drängt sich einem eigentlich die Ansicht förmlich auf, dass die ersten Pflanzen, die unseren Erdball besie-

delten, wahrscheinlich thermophile, höhen Temperaturen des Wassers angepasste Cyanophyceen und gewisse Bakterien waren, dieselben Organismen, die noch heute die Thermen bewohnen. Die gegenwärtig in den heissen Wässern vorkommenden Cyanophyceen können als die Nachkomen, als Relikt jener Blaualgen betrachtet werden die einst weite, mit noch warmen und heissen Wasser bedeckten Erdstriche bewohnten und die nach eingetretener Abkühlung der Erdrinde in den aus der Vorzeit zurückgebliebenen oder neuentstandenen Thermen eine willkommene Zuflucht gefunden und sich bis auf den heutigen Tag erhalten haben.«

Molisch connected the relic-hypothesis with the question of the origin of the first organisms on the earth. He thinks that the thermophile Schizophyceae were the first organisms that appeared on the crust of the earth.

The main idea of the relic-hypothesis appears very obvious and because of that it was very deceiving for the biologists. There are now, however, several reasons which seem to justify me to abandon my previous undecided position towards the hypothesis and to come out against it. That position was already taken for the case of ***Mastigocladus***. It was shown that this alga is not a relic form but that it is only an organism adapted to high temperature. At present the reasons seem to be conclusive enough for a general inference that all thermal vegetation consists of a flora adapted to high temperature. The above mentioned reasons are:

In making the hypothesis, Weed assumed that the flora of different widely distributed therms is in general the same. That this is not the case has already been shown by West and later confirmed by Elenkin. My own investigations on the thermal flora of Croatia revealed that very closely located hot springs have different vegetation. It has been shown that the thermal vegetation depends not only on the temperature but on other factors also, especially on the chemical composition of the water.

It was shown by Elenkin that the thermal flora of Kamtchatka is very rich in different Cyanophyceae, consisting of:

1. A very few cosmopolitan species, found in hot springs throughout the world.
2. A considerable number of species found in hot springs of the moderate and artic regions.
3. Forms known as yet only from cold waters.
4. Many new forms.

Wilhelm found also that the vegetation of the thermal waters of Czechoslovakia consists of a large number of forms which are common to cold waters.

Molisch has not as yet given the list of algae of Japan thermal-springs but from his biological paper it can be seen that in the therms of Japan occur many Cyanophyceae normally found in cold waters. He is of the opinion that the number of cosmopolitan

forms among the thermal algae is much higher than assumed by Elenkin.

It was already mentioned by Weed that Archer observed in the therms of the Azores algae common to fresh water of Great Britain. West also found a different algal flora in different hot springs of Iceland. He compared this flora with that of tropical Africa as described by Schmiedle, and found two species to be identical (*Mastigocladus laminosus* and *Phormidium laminosum*), While the comparison with the flora of Yellowstone revealed only one (*Phormidium laminosum*). For a better understanding of this question it will be necessary to make an extensive comparison of different lists of thermal flora. It is already possible now to state as follows:

1. The thermal floras differ in the species of algae they contain.

2. Most of these species are also commonly distributed in cold waters.

3. There are, however, certain thermophillous forms which are found in many therms. But they are, to my knowledge, not specific genera or species limited to thermal waters only. Also, the much spoken of *Mastigocladus* has cold woter forms as its closest relative.

4. So far no algae or any other organism has been found with distinct characteristics of a relic form, as would be expected according to the relic-hypothesis.

5. Most investigations on thermal biology agree that the Cyanophyceae are most important among the organisms found in thermal waters. Moreover, in some thermal waters they are almost the only plants present. On the other hand, in some thermal waters of the Azores, Iceland, Kamtchatka, Yellowstone, Diatomaceae and also Desmidaceae are found in abundance. Chlorophyceae and Characeae are rare and limited to the springs of low temperature. It is not justified, therefore, to attribute the thermophilic property to Cyanophyceae only. As far as the degree of thermophily is concerned, the Cyanophyceae and Bacteriaceae can be placed first. To judge the age of the evolution according to the degree of thermophily, would be going too far, and in my opinion not at all warranted.

The main argument for the hypothesis that the Cyanophyceae are the oldest inhabitants of the earth follows:

1stly. Their apparent low organisation.

2ndly. Striking disjunction of several forms through the widely distributed thermal waters of the earth: and

3rdly. The above mentioned property of the thermophily.

If we consider the degree of organisation of the Cyanophyceae we know to-day that although their cellular structure shows differences, their nature is nevertheless very complex, and has really never been fully analysed. Even at the present time views

concerning their structure are not yet definitively established (Baumgärtner, Cowdry, Prat, Geitler). Whether the Cyanophyceae represent a specialized group or a very reduced developmental type is difficult to determine. It appeared that several Cyanophyceae already existed in the archaic age (Gruner, Tampelajo), however, these reports are mere assumptions. There seems to be no doubt that the Cyanophyceae do not represent original organisms of the remainig plants.

Secondly we must consider the apparent disjunction of several Cyanophyceae. If we take into consideration for example the typical form... *Mastigocladus laminosus*... it seems strange that this alga is found in most thermal regions of the earth and in order to explain this fact, the idea of relics has arisen. According to this view this alga showed at one time a general distribution, but at that time the entire surface of the earth was apparently covered with hot waters. Today the alga is found only in very distant places which are considered as »relic stations«. My own physiological investigations have taught me that in order to explain the disjunction it is not necessary to resort to the theory of relics. I have found that *Mastigocladus laminosus* in its latent condition at ordinary temperature of the water, or even under dry condition is able to exist for months or even years without losing its active life, growth or reproduction. This goes to prove decidely the wide distribution possibility of these algae and it explains also the accidental disjunctions. That the distribution possibilities at places of juvenile springs is greater becomes also clear.

If we consider the above discussed thermophily I only wish to add to what has been said before that these ability is also a property of other algae although in a much smaller degree. If Diatoms, Desmidiaceae, Chlorophyceae, and also Characeae exist in higher temperature we consider it as an adaptation phenomenon. I find no reason not to affirm this for the Cyanophyceae, also. The progress of the Cyanophyceae in the thermophily becomes explainable if we consider the generally known extraordinary wide range of adaptation ability of the Cyanophyceae for the most extreme conditions of life. The Cyanophyceae an the Bacteria, if we may say so, are in every respect the most euriphilous organisms.

From what has been said above I am of the opinion that it would come nearer the truth, if I venture to say that the property of thermophily of the Cyanophyceae is of a secondary nature, i. e., that the entire present thermal vegetation is only an adaptation flora of waters of higher temperature. To conclude from previous biological investigations of the thermal waters that the thermophilous Cyanophyceae are the first living organisms of the earth is not permissible.

Since these considerations force me to give the thermal flora only an adaptive character, I must also raise the question con-

cerning the time in the history of the earth when this adaptation occurred. In answering this question I believe I am right to assume that the migration of forms of fresh water algae from cold regions occurred at different times and this also explains that the thermal flora is composed of so different elements as far as thermotolerance is concerned. It is also possible that certain Cyanophyceae represent the oldest immigrants, but it is impossible to say at what time of the development of the earth this migration occurred since we have not a single important fact to go by.

IMPORTANT LITERATURE.

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