

ALGAE AND THEIR MODE OF LIFE IN THE BARADLA CAVE AT AGGTELEK

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The flora of caves has been studied ever since the middle of the 18th century. Fungi of various caves were described by SCOPOLI as early as in 1772, by HUMBOLDT in 1793, and by HOFFMANN in 1811. One of POKORNY'S works (1853) also deals with the flora of caves and, later, the plant life in more than a hundred caves in France was studied by MAHEU. Between 1910 and 1916, LÄMMERMAYER undertook similar investigations in the caves of the Eastern Alps, while ZMUDA examined the cave-flora in the Tatra mountains and the Galician Plateau in Poland. Studies of this kind were made by Gams in the South of Switzerland, as also in the North of Bavaria.* At the present time, many similar investigations are being carried on and in Hungary. A. BOROS is occupied with the search for cave plants and the examination of their ecology.

Prof. E. DUDICH was the first to make biological studies in the Baradla cave. We find the following passage in his work giving a comprehensive account of his investigations of many years: (p-66); «Es muss betont werden, dass ich weder gelegentlich meiner früheren Excursionen, noch zu meiner letzten Forschungszeit höhere Pflanzen, also etwa Moospflanzen, Farnpflanzen in der Höhle gefunden habe. Sogar in den Eingängen nicht, geschweige denn in der ewigen Finsterniss der eigentlichen Höhle . . . Auch Algen sah ich in den Eingängen nicht, obwohl ich sie, mindestens im Eingang I, erwartet hätte. Ich muss aber jedoch bemerken, dass Herr Prof. ALEXANDER MÁGÓCSY-DIETZ, Professor i. R. der Botanik an der Universität zu Budapest, mir nach dem Abschlusse meiner Untersuchungen erwähnt hat, dass er einst Algen in der Region des Einganges I beobachtet hatte, und zwar in den an Höhlendecke hängenden Sickerwassertropfen. An diesem Punkt muss also die Arbeit eines Algologen einsetzen und die Sachlage aufklären.»

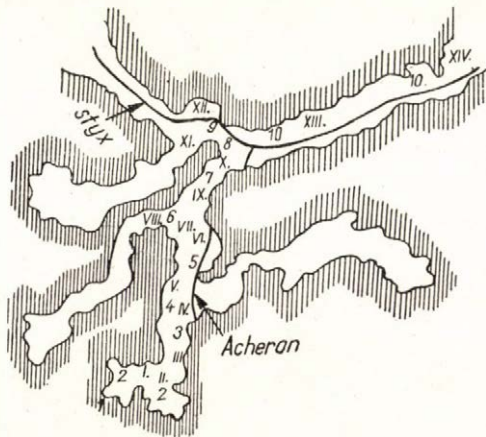
It was this remark of Prof. DUDICH that induced us to start algological studies in this cave.

* See MORTON p. 1-6.

Geographical conditions

The stalactite cave of Baradla lies in North Hungary, in the counties Gömör and Abaúj-Torna, the area being known as the Torna-Karst. Karst is a limestone formation; the limestone beds found in the area under review belong to the alpine facies of the Upper Trias. It is a gently rolling country where only the «Poronya Roof» exceeds the height of 500 m., the cave lying everywhere else beneath hills of lower elevations.

The known sections of the cave are about 22 km. long; as regards length and dimensions in general, it is the largest stalactite cave in Europe. Origin-



nally, there was but a single opening to the surface. The cave was a so-called «sac cave», to which several artificial entrances were made subsequently. The one natural opening at Aggtelek lies 332 m. above sea level, at the foot of a 25 m. high cliff facing south. It is 180×100 cm.

Two underground streams, «Styx» and «Acheron», flow through the cave, the former emptying into the latter. The natural outlet of the Acheron was unknown for a long time but recent speleological explorations have shown it to flow through a lately unearthed lower cave, where its water becomes clear and then spouts to the surface as the spring at Jósvalő. The pH value of these spelean waters varies between 7 and 7.4. Their conductance extremes are from 3,861 to $5,320 \times 10^{-4}$ mho. Their temperature agrees with that of the cave, the annual mean of which is 10°C , with extremes of $4,5^{\circ}\text{C}$ and $11,5^{\circ}\text{C}$, respectively. (Meteorological Niche.)

The relative humidity of the air is from 84 to 100% throughout the cave (cf. DUDICH, p. 130, tab. 6). With the exception of the immediate vicinity of the entrances the cave is completely dark.

According to JAKUCS (p. 16) «The steep cliff at Aggtelek is the fault plane of the dislocation of a 50 m. high vertical crust of the earth. Recent observations made in the cave have shown that the dislocation occurred not prior to but after the formation of this cave system. Once the entire known part of the cave must have been at a lower level, and the main branch between Jósvalfő and Aggtelek probably continued to the west and possibly had twice the length of the sections known to us. The cave end as it seems today at the entrances at Aggtelek must have been but the middle portion of what was then the main branch, which was cut off in the fault plane at the time of the great upheaval that produced the hanging wall rock, and was displaced upwards to a distance of 50 m., thus severing the present end of the cave from its continuation now hidden the earth. The Aggtelek entrances of the Baradla cave are therefore not the products of water erosion (although water may have streamed through them into the cave in the Ice Age); they are of tectonic origin, and give direct access to the well developed halls and corridors of the chopped-off former middle section.»

Methods

The respective Institutes for Botanical and Zoological Taxonomy of the Loránd Eötvös University made a field trip on July 11, 1953, to the Baradla cave under the guidance of Prof. E. DUDICH. Algological investigations were supervised by Miss P. PALIK. The investigations covered about 500 m. from Entrance I. Except in the immediate vicinity of the entrance, no algae were found. Test material was nevertheless collected by taking scrapings from the cave walls at different heights, and also by scraping, chipping or breaking off small bits of dripstone from the roof. Additional material was taken from the cave streams by means of plankton nets specially made for the purpose, and also from the «Aquariums» and by drawing too. No test material was collected from the floor of the cave as it is constantly contaminated by the boots of visitors. The collected material was placed in sterile glass boxes labelling the places of collection thereon.

A second trip to the cave was made on June 22, 1954; its object was partly to collect fresh material, partly to bring back to and leave in the cave the cultures grown in light in the Institute of Botanical Taxonomy from the originally collected material; it was intended to ascertain after 6 and 12 months, respectively, the changes undergone by the algae in the utter darkness. The glass boxes with the cultures were put down at a distance of from 500 to 600 m. from Entrance I in the following places: 1st box: half way down Nádor street, left side, at the broadening of the way, in a recess of the wall, at a height of 2 m. 2nd box: further along Nádor street, on the left side, about 15 m. after the projection, at the posterior side of a big stalactite, at a height of 2,5 to 3 m. 3rd box: on the left side of Nádor street, at the second projection, in a wall recess after the Terrace, at a height of 2 m.

The following is a list of the places of collection, Arabic numerals indicating the first, and Roman numerals the second trip. (See also figure.)

First trip (July 11, 1953)

1. Immediate vicinity of entrance.
2. Porch. Meteorological niche (45 m.). Charnel house.
3. Right side of the street between Bridge I and King's Well.
4. Left side of the street between Bridge I and King's Well.
5. Ramp of Cathedral (208 m.). Cathedral.
6. Neighbourhood of entrance to Bat Cave.
7. Neighbourhood of Bridge 3 (312 m.).
8. Water of Acheron (330 m.). Interior of Aquariums.
9. Walls of surrounding Aquariums, up to a height of about 160 cm.
10. Nádor street (400 to 500 m.).

Second trip (June 22, 1954)

- I. 10 m. from entrance.
- II. Porch. Meteorological niche (45 m.).
- III. Charnel house + roof above street.
- IV. Right side of street from Bridge 1 to King's Well.
- V. King's Well.
- VI. Right side of street from King's Well to Cathedral (209 m.).
- VII. Left side of street from King's Well to Cathedral (209 m.).
- VIII. Neighbourhood of entrance to Bat Cave.
- IX. Neighbourhood of Bridge 3 (312 m.).
- X. Entrance side of Acheron. Exterior walls of Concert Hall.
- XI. Interior of Aquariums.
- XII. Walls surrounding Aquariums up to a height of 160 cm.
- XIII. Nádor street (400 to 500 m.).
- XIV. Further down Nádor street, after the second projection (600 m.).

Figures in brackets indicate distances from Entrance I.

While collecting our material we found a number of mycelia and even thalluses of fungi. A yellow coloured colony of *Monilia aurea* Gmel. was most conspicuous. Many other bacteria and fungi are mentioned in Prof. DUDICH's work (p. 67).

Back in the Institute, the glass boxes were filled with KNOP's culture medium and left to stand on the inner sills of windows facing north. After 3 to 4 weeks the contents of the boxes began to colour, a greenish-bluish and brownish coating appeared on the bottom and the sides of the vessels, as also on the surface of the wall scrapings and the chipped-off pieces of dripstone. Soon there appeared the *Helminthosporium* sp., and was followed first by a foliaceous moss (classified by A. BOROS under the genus *Bryum*), and then by the liverwort.

The coating on the wall scrapings was strikingly found to consist of a single algal species. Most probably, a single cell had found its way to and multiplied in that particular piece of wall.

The material collected on the two trips has been determined to consist of 69 species, varieties and forms of algae distributed as follows:

Cyanophyta group: 44 species, varieties and forms. *Euglenophyta* group: 1 species. *Chrysophyta* group: 12 species and varieties, of which *Xanthophyceae*: 1 species, *Chrysophyceae*: 1 species, *Bacillariophyceae*: 10 species and varieties. *Chlorophyta* group: 12 species, all belonging to the *Chlorophyceae*. Three species, one variety and one form of those enumerated are new, and many of them are new to Hungary.

In the taxonomic part that follows the occurrences of the respective species are shown in brackets; these data were taken from the algologic keys and manuals in use, and merely serve to give a general idea of the habitat of the individual species. In respect of each species listed it is specially mentioned whether the cultures grown from the first or from the second collection yielded more of it. This is admittedly of no great significance since it is quite possible that KNOP's nutrient medium, or the light conditions, or the temperature of the rooms, while favouring the growth and propagation of some of the species in our cultures represented conditions detrimental to the development of others. The cultures furnish a clue to the species only that lived at the different points of collection in the cave but allow of no conclusions as to the masses in which they occurred at them.

Taxonomy

CYANOPHYTA Chroococcaceae

1. *Microcystis parasitica* Kütz. (In stagnant waters, frequently attached to water plants or algae.) Very few in collection 4. A few in collections II, IV, and XI.
2. *Gloeocapsa mellea* Kütz. (On humid soil and humid walls.) Very few in collection 10. A few in collection IX.
3. *Gloeocapsa granosa* (Berk.) Kütz. (In bogs and hothouses.) Very few in collection 4. More in collection I.
4. *Gloeocapsa punctata* Näg. (Frequent everywhere on moist rocks.) A few in collection 10.
5. *Gloeothece vibrio* N. Carter. (On rocks and treetrunks.) Very few in collection 5.
6. *Synechococcus elongatus* Näg. (On humid soils and aged treetrunks.) More in collection 1 and I, less in collection 2.

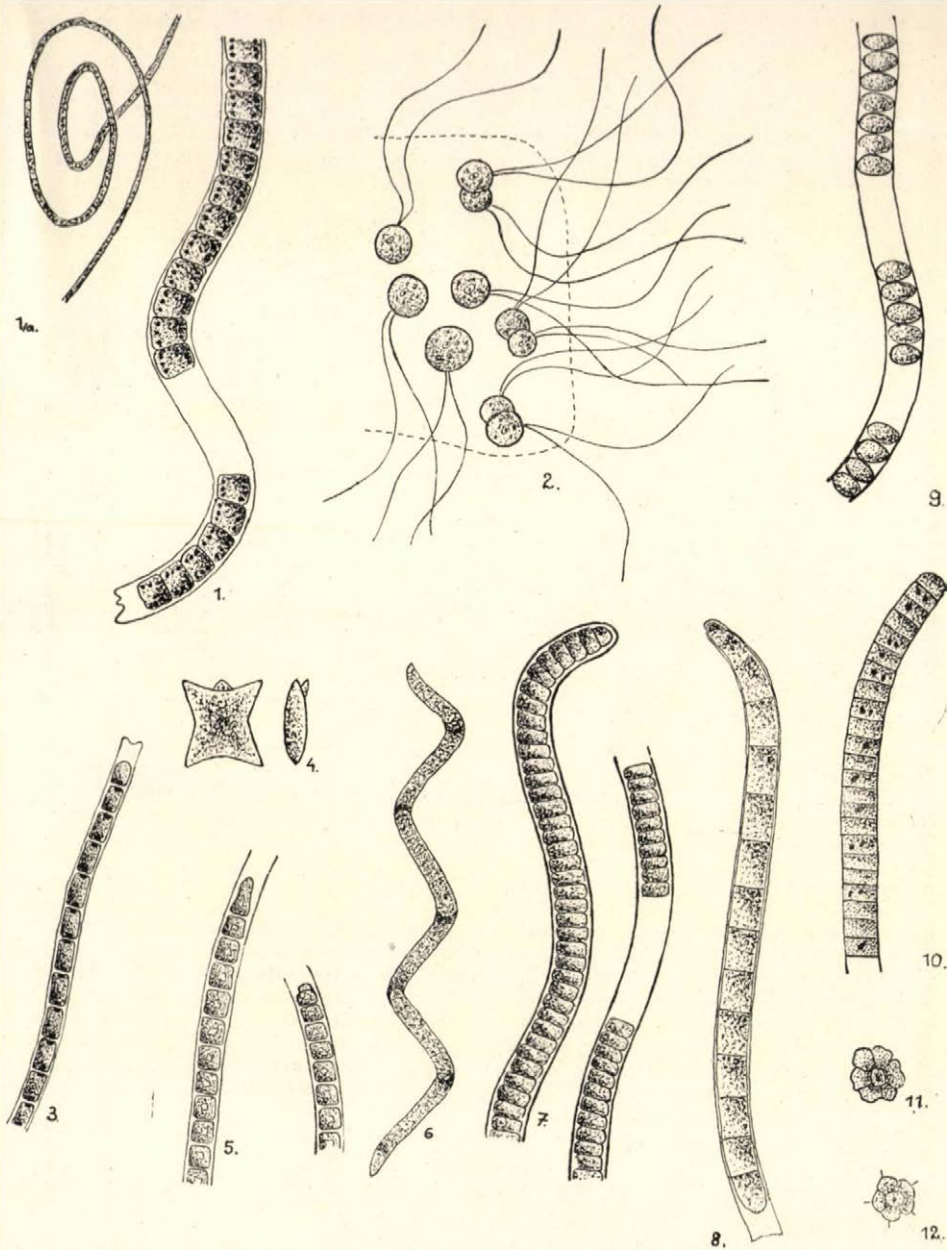


Fig. 1. *Lyngbya palikiana* n. sp. Strong magnification from the right hand side. Fig. 2. *Tetraspora tarnayana* n. sp. Fig. 3. *Phormidium frigidum* Fritsch. Fig. 4. *Tetrapedia reinschiana* Arch. f. *aggtelekienses* n. f. Frontal and lateral view. Fig. 5. *Phormidium dimorphum* Lemn. Fig. 6. *Spirulina laxa* Smith. Fig. 7. *Phormidium pristleyi* Fritsch. Fig. 8. *Oscillatoria dudichiana* n. sp. Fig. 9. *Lyngbya erebi*. Fig. 10. *Oscillatoria pseudoangusta* var. *brevicellulata*. Fig. 11. *Sorastrum simplex* (a form found in the cave). Fig. 12. *Sorastrum simplex* according to Wille's drawing

7. *Tetrapedia reinschiana* Arch. f. *agtelekiensis* nova forma. Cells more or less quadratic, 3,5 to 4 μ wide, pointed at the apices. One pair of opposite walls concave, the other triangular. Lateral view barrel-shaped. Colour bluish green. They differ from the species by being smaller in size and having a fifth apiculus on the cell surface. (The species occurs in peaty bogs.) A few in collection 10. (Fig. 4)
Cellula plus minusve quadrata, 3,5—4 μ lata, angulis acuminatis. Duo latera opposita concava, altera duo latera autem forma triangulari excavata. Cellula a latere visa dolioliformis, colore glaucescentiviridis. A typo mensuris minoribus necnon in margine superiore praeter angulos apiculo quinto differt. (Typus in paludibus sphagnetosis invenitur.)

Chlorogloeaceae

8. *Chlorogloea microcystoides* Geitl. (Occurring on well-curbs in dripping water, occasionally in stagnant waters.) A fair number in collection 5. More in collection I, less in XIII.

Stigonemataceae

9. *Hapalosiphon intricatus* W. et G. S. West. (In stagnant waters attached to water plants or among the moss, sometimes on humid soils. Europe, Africa, and Antilles.) Described by Magdeburg from several Swiss caves as a stalactite-forming species. By dissolving the limestone with 5% HCl, the filaments can be brought to light undamaged from the minute dripstones. We found it in minute stalactites all over the examined area.

Scytonemataceae

10. *Plectonema puteale* (Kirchn.) Hansg. (On well structures; in rivulets, attached to stones and pieces of wood, or free-floating. Central Europe and Alaska.) A few in collection 1.
11. *Plectonema schmidlei* Liman. (On humid walls.) A fair quantity in collection 4 and I.
12. *Tolypothrix distorta* (Fl. Dan.) Kütz. (In stagnant, seldom in slowly flowing waters.) Very few in collection 2.

Nostocaceae

13. *Nostoc punctiforme* (Kütz.) Hariot. (In stagnant waters, attached to water plants.) Many in collection 10.

Oscillatoriaceae

14. *Spirulina laxa* Smith. Filaments 2,0 to 2,8 μ wide and bluish-green. Spirals 4,5 μ wide, placed at 15 to 20 μ intervals from one another. Cells shorter than wide. Colony a dark bluish-green. (Wisconsin, North America. According to the latest Soviet key to Algae (HOLLERBACH: p. 465), it occurs, though rarely, also in the stagnant waters of the Ukraine. Fig. 6). A few in collections 10 and XIII.
15. *Pseudanabaena tenuis* Koppe. (On putrescent mud, in humus, further on the banks of the Holstein lakes.) A few in collection 1.
16. *Oscillatoria dudicsiana* nov. sp. Colony jelly-like and yellowish green. Filaments darkviolet-brown, 7,5 to 11,3 μ wide, with a well-developed, tight, colourless sheath. They are not articulated at the septa, the apices are thinning out and curved. Cells 6 to 8 μ long, plasm not granulated. Very many in collection 2. The species is closely related to *O. borneti* Zukal, but the plasm is not keritomized, and the sheath is well developed (Fig. 8).
Filamenta stratum gelatinosum luteo-viridem formantia, ipsa filamenta obscure violaceo-fusca, 7,5—11,3 μ lata, vagina crassa, stricte adhaerente, hyalina circumdata, ad septa non constricta, apicem versus attenuata, incurva. Cellulae 6—8 μ longae; plasmate non granulato. Ad *O. borneti* Zukal vergens, ab ea plasmate non keritomisato et vagina crassa differt.
17. *Oscillatoria chlorina* Kütz. (In mud and even in saline waters. Europe, North America, Africa, Antarctis.) Many in collection I.
18. *Oscillatoria tenuis* Ag. (Fixed or swimming in stagnant waters; cosmopolitan.) Great masses in collection I.
19. *Oscillatoria tenuis* Ag. var. *symplociformis* Hansg. (In flowing waters.) Many in collection 5.
20. *Oscillatoria irrigua* Kütz. (In stagnant and flowing waters, or even on damp rocks; cosmopolitan.) Many in collections II and III.

21. *Oscillatoria neglecta* Lemm. (On humid walls and in waters containing putrescent matter.) Many in collection 5.
22. *Oscillatoria limnetica* Lemm. (In the plankton of lakes, frequently in sewage, mud, and occasionally in the gelatinous capsule of other algae.) Many in collection 3, less in collection 4, more in XIII.
23. *Oscillatoria geminata* Menegh. (In peaty bogs, hothouses, thermal springs.) Very many in collection 10.
24. *Oscillatoria pseudoangusta* Claus *var. brevicellulata nov. var.* Filaments solitary, 0,6 μ wide, bluish-green or almost colourless, not articulated along the septa. Length of cells 0,3 μ , width about 0,6 μ . Some cells with one or two luminous grains. The variety differs from the species in its dimensions. (The species occurs in the thermal spring at Bükkszék.) A few in collection 4 (Fig. 10).
Filamenta 0,6 μ lata, solitaria, glauco-iridica vel subhyalina, ad septa non contracta. Cellulae dimidio breviores quam latae, 0,3 μ longae. In cellulis nonnullis punctumunicum vel duo puncta fulgentia visibilia. (Typus in thermis Bükkszékensibus inventus.)
25. *Oscillatoria pseudogeminata* G. Schmid. (On grimy, damp walls.) Many in collection V.
26. *Oscillatoria profunda* Kirchn. (On lake muds.) A few in collection XII.
27. *Oscillatoria guttulata* van Goor. (Fixed on lake muds, or freely swimming.) Great masses in collection I.
28. *Oscillatoria agardhii* Gom. (In lake planktons.) A fair amount in collection I.
29. *Oscillatoria woronichinii* Anissim. (In mineral water lakes in the Ukraine.) Many in collection XIII.
30. *Oscillatoria animalis* Ag. (In cold or warm stagnant waters, on the walls of hothouses; cosmopolitan.) Very few in collection 8.
31. *Phormidium frigidum* Fritsch. Colony thin, skin-like. Filaments bent, entangled. Sheath slimy, diffuse. Filaments strongly articulated along the septa, ends not tapered, their width 0,8 to 1,2 μ . Apical cells rounded. Cells twice as long as wide, faintly bluish-green, each with a luminous grain by the side of the septa. An interesting occurrence. It is described in two of GETTLER's works (1932, p. 997; 1925, p. 377) as occurring in the antarctic regions and in the High Tatra, while according to HOLLERBACH, KOSSINSKAIA, POLJANSKII, it can also be found occasionally in various parts of the Soviet Union, both in flowing and stagnant waters. (1952, p. 477). (Fig. 3) Many in collection 3. Few in collection II, V, VIII and XII.
32. *Phormidium foveolarum* (Mont) Gom. (On humid soils, damp lime rocks, and also in sewage.) A few in collection 10.
33. *Phormidium henningsii* Lemm. (On peat-moss; in wash-houses.) A fair number in collection 1.
34. *Phormidium molle* Gom. (In stagnant waters; on humid soils.) A few in collection I.
35. *Phormidium pristleyi* Fritsch. Colony soft and of a bright bluish-green, easily falling to pieces on pressure. Filaments coiled and densely intertwined. Sheath tight. Filaments articulated at the septa, fragile, non-tapering, 3,3 μ wide; apical cells rounded. Cells half as long as wide, faintly bluish green; no grains by the side of the septa. An interesting occurrence. GETTLER, 1925, p. 378. Antarttis. 1932, p. 1008 «Im Süßwasser Antarktiss» (Nähere Standortsangaben fehlen). HOLLERBACH does not mention it (Fig. 7).
36. *Phormidium dimorphum* Lemm. Colony skin-like, extended, blackish, bluish-green. The straight or bent filaments frequently take parallel courses, they are strongly articulated along the septa, 3,5 to 5 μ wide, bright bluish-green, tapering, or else widely rounded off at the end without thinning out. Sheath tight, colourless, thin, not layered, and fails to stain with chlor-zinc-iodine. Cells mostly quadratic, occasionally shorter but at the ends of filaments usually longer than their width; their length varies from 2 to 5,6 μ , but is mostly 3 μ . No grains by the side of the septa. Apical cells the shape of an elongated rounded-off cone, or that of a somewhat flattened hemisphere with a cap about 2 μ wide and 1,5 μ long. GETTLER, (1925, p. 381 and 1932, p. 1011) «Salinen in Kissingen». HOLLERBACH (p. 481) claims its occurrence in West Siberia, in saline basins and even in the soil. The present author has found it in the thermal spring at Bükkszék. A great number of both forms in collection 2, and a fair number in 7 (Fig. 5).
37. *Lyngbya amplivaginata* van Goor. (In river muds in Holland.) Many in collection V.
38. *Lyngbya erebi* W. et G. S. West. Colony flatly extending, from 3 to 5 mm. thick and of shades varying from dark bluish-green to colourless. Filaments entangled, 0,9 μ thick, strongly articulated along the septa. Sheath thin and tight. Filaments non-tapering. An interesting occurrence. GETTLER (1925, p. 394 and 1932, p. 1056) «In stehendem Wasser Antarktiss». HOLLERBACH does not mention it. A few in collection 6 (Fig. 9).

39. *Lyngbya digueti* Gom. (In stagnant waters.) Many in collection 4.
40. *Lyngbya palikiana* nov. spec. Colony bright bluish-green, forms a membrane floating on the surface of the water; sometimes settles at the bottom of the experimental flask. Filaments form bundles, and are either straight or irregularly bent, 2 to 3 μ wide, bright bluish-green, markedly articulated along the septa. Sheath thin and adhesive. Cells quadratic or somewhat shorter than wide. Grains on the side walls. Apical cells rounded off. Great masses in collection 7, many in 5 (Figs. 1 and 1a).
Stratum membranaceum glauco-viride in superficie aquae formans, nonnunquam in vitro substrato adhaerens. Filamenta fascicularia, recta, vel irregulariter curvata, 2—3 μ lata, laete glauco-viridia, ad septa valde constricta. Vagina tenuis, stricte adhaerens. Cellulae quadratae, vel parum breviores quam longae. Membranae cellularum) laterales granulatae. Cellula apicalis rotundata.
41. *Lyngbya martensiana* Menegh. (In stagnant and flowing waters, hothouses; cosmopolitan.) A fair number in collections 5 and 8. (It was not found when the test material collected on the first trip was examined but there was a great number of it in the glass box which had been put back into the cave with the contents of collections 5 and 8). We shall come back to this point.
42. *Schizotrix fragilis* (Kütz.) Gom. (On the border of puddles, on damp walls.) A few in collection 5.
43. *Schizotrix cyanea* Näg. (On damp rocks.) Many in collection 3. Colony black. It occurs in the soot-like deposits in the cave.
(It is noteworthy that the black coatings occurring in different caves have given rise to contradictory theories since the beginning of the last century. RAISZ (1807) believed them to have been produced by the fire of primeval men, while KYRLE (1923) attributed them to the torches of visitors. Lately it is assumed they are colonies of iron bacteria (MAGDEBURG, DUDICH, JAKUCS). No iron bacteria were found during our two trips to the Baradla cave, while a number of algae could be shown forming blackish or black colonies, e. g. *Gloeocapsa punctata*, *Phormidium foveolarum*, *Phormidium henningsii*, *Phormidium dimorphum* and *Schizotrix cyanea*. It can therefore be assumed that some of the black coatings consist of colonies of algae.)

Chlorobacteriaceae

44. *Tetrachloris inconstans* Pascher. (On putrescent mud, in stagnant and flowing waters.) A fair number in collection 7, many in XII.

EUGLENOPHYTA

Euglenaceae

1. *Trachelomonas* sp. Capsule covered with bristles, elliptic, 8,4 long and 7,5 μ wide, brownish yellow. Two specimens were found in collection 10.

CHRYSOPHYTA

Xanthophyceae Sciadaceae

1. *Ophiocytium parvulum* (Perty) A. Braun. (Very frequent; great masses in some places.) A few in collection 5.

Chrysophyceae Ochromonadaceae

2. *Ochromonas ovalis* Dofl. (Occuring in great masses.) Many in collection 10.

Bacillariophyceae Fragilariaceae

3. *Diatoma vulgare* Bory. (Cosmopolitan. In stagnant and flowing waters, on damp rocks, well-curbs, etc.) Two chains found in collection X.
4. *Diatoma elongatum* Ag. var. *minor* Grun. (Cosmopolitan. In stagnant and flowing waters, on damp rocks, well-curbs, etc. but rather pelagic.) Many in collection XIII.
5. *Fragilaria virescens* Ralfs. (Frequent in mountain waters, springs, sometimes also in lowlands.) A fair number in collection 8.

6. *Fragilaria brevistriata* Grun. (Frequent on banks of lakes.) A few in collections 3 and II, many in 10.

Naviculaceae

7. *Navicula mutica* Kütz. var. *nivalis* Kütz. (In fresh waters, on damp rocks; an epiphyte.) A few in collection 6.
 8. *Amphora ovalis* Kütz. var. *pediculus* Kütz. (Frequently attached to large-sized Bacillariophyta or water plants.) A fair number in collection 9, many in VII and XII.
 9. *Gomphonema angustatum* (Kütz.) Rabenh. (Cosmopolitan. In stagnant and flowing waters, on damp rocks, curbs of wells, etc.) (Very many) in collection III.
 10. *Gomphonema bohemicum* Reichelt et Fricke. (In Tyrol, in the neighbourhood of Wiesenegg. Ecology not indicated.) Great masses in collection XII and XIV.

Nitzschiaceae

11. *Hantzschia amphioxys* (Ehr.) Grun. (In lakes, brooks, springs; cosmopolitan.) Many in collection V.
 12. *Nitzschia thermalis* Kütz. var. *minor* Hilse. (Frequent.) A fair number in collection 8.

CHLOROPHYTA

Chlorophyceae

Palmellaceae

1. *Gloeococcus schroeterii* (Chodat.) Lemm. (Very frequent in planktons, katharobe.) Many in collections 1, 3, 10, V.

Tetrasporaceae

2. *Tetraspora tarnayana* nov. spec. Mucous colony of irregular shape, bright or dark green. Diameter of cells 13 to 15 μ . The two flagella 10 to 12 times the cell diameter. More than half of the flagella hanging out of the gelatinous capsule. It differs from *T. gelatinosa* (Vauch.) Desv. sp. in the size of the cells and in the marked protrusion of the flagella from the capsule. It differs from *T. limnetica* W. et G. S. West sp. in colour and size of the cells. A fair number in collection 10, less in 6 (Fig. 2).

*Colonia mucosa irregulariter formata, laete vel obscure viridis. Cellulae 13—15 diametientes. Flagella mucosa duo adsunt, longitudine latitudinem cellulae 10—12 \times superantia. Pars major flagellorum e capsula mucosa exstans. A *T. gelatinosa* (Vauch.) Desv. in magnitudine cellularum et flagellis capsula valde exsertis, a *T. limnetica* W. et G. S. West in colore et dimensione differt.*

Chlorococcaceae

3. *Chlorococcum infusionum* (Schrank) Menegh. (Frequently in stagnant waters attached to plants; occurs also on humid soils.) A few in collection 3, more in XIII.

Chlorellaceae

4. *Chlorella simplex* (Artari) Migula. (Basel. No ecological details available.) A fair number in collection 9.
 5. *Chlorella miniata* (Näg.) Oltmanns. (Frequent on walls and flower pots.) Very many in nearly all collections.

Oocystaceae

6. *Oocystis pusilla* Hansg. (On damp rocks.) Many in collections 10, IV and XI.

Coelastraceae

7. *Sorarstrum simplex* Willeä According to Wille (in LEMMERMANN, BRUNNTHALER, PASCHER: Die Süßwasserflora . . . 1915, p. 200) coenobia round and consisting of 7 cells, which have the shape of elongated eggs ending in 3 μ long spinules. Seen from their apical side

they are round. Inclusive of spinules, cells $12\ \mu$ long and $13\ \mu$ wide. (Novaia Zemlia) (Fig. 11). The colonies found in the cave at Aggtelek greatly resemble Wille's drawing (Fig. 12), the only difference being their size and the absence of spinules in our specimens. Diameter of the colony $20\ \mu$, that of the individual cells 6 to $7\ \mu$. Several colonies were found in collection 4.

Protococcaceae

8. *Protococcus anulatus* Pasch. (Found only in elevated regions.) It was present in all collections except 8 and 10, and in a very great number in 2.

Ulotrichaceae

9. *Hormidium flaccidum* A. Br. *forma typica* Heering. (Occurring in the most diverse habitats: on ice, in stagnant and flowing waters, humid soils, on the bark of trees.) Many in collections 2 and I, less in 3 and 4.
10. *Stichococcus bacillaris* Näg. *forma minor* Näg. (Everywhere.) Many in collections 2 and I, less in X and XIII.

Chaetophoraceae

11. *Chaetophora elegans* (Roth) Ag. (Widely distributed in stagnant and flowing waters, attached, to water plants, shells and stones, or freely swimming.) Two thick bundles were encountered in collection III.

Cladophoraceae

12. *Rhizoclonium hieroglyphicum* (Ag.) Kützing. (Occurs both in fresh and seawater.) A single bundle developed in collection I, several bundles were found in I and V.

Ecology

On examining the algal material collected from the cave of Aggtelek a number of questions arises:

1. How do the specified algal species come to be in the cave?
 2. How are they able to live there?
 3. How can there the presence of arctic and antarctic species be explained?
- Several theories are possible in connection with the first question.

1. The algae are being carried into the cave by the streams that flow through them. This assumption fails to explain the presence in the cave of the species that were found in scrapings taken from elevated points on the walls, and from the roof of the cave, to which the water of the streams now never rises. The cave being itself the product of water erosion it is conceivable that some algal colonies have subsisted for millions of years in a more or less unchanged condition on the spot of their original settlement. To this point we propose to revert later in this paper.

2. Individual algal cells are being carried into the cave by currents of air. Satisfactory as this assumption at first appears, it is vulnerable from two points of view. First, although the entire cave is pervaded by strong air cur-

rents, the great number of breaks makes it impossible for the cells or spores to travel further than 20 to 30 m. from the entrance without striking against and becoming attached to some wall. Secondly, owing to the 100% relative humidity of the atmosphere in it, cells swept into the cave will, like dust particles, form nuclei of condensation and precipitate in the very foreground of the cave. Incidentally, this phenomenon accounts for the purity and almost complete sterility of the air within the cave.

3. The algal organisms are deposited on the higher spots on the walls by animals to which they attach, e. g. by bats. This, however, is inconsistent with the fact that whereas bats are known to dwell exclusively in certain definite parts of the cave system, algae have been collected from the walls of other parts. By another hypothesis, algae are spread in the cave by animals of lower orders, such as arthropoda, insects, etc. While this would well explain the distribution of the different algae within the cave, it still leaves open the question as to how they get into the cave at all, since the host animals never leave the cave and mostly occupy its more remote parts.

4. The cells are carried into the cave by the water that seeps into it from above and appears in the form of droplets at the point of stalactites. This assumption is untenable because before reaching the cave the water penetrates several thick layers of rock which act as ultrafilters and free it of all even microscopic impurities. Prof. MÁGÓCSY-DIETZ claims to have seen algal cells in water drops at the point of stalactites but this is no proof of the cells having reached the cave with the seeping water (DUDICH, p. 66).

All our theories having failed, there seems to be no definite answer to the first of our questions unless we assume that the algae have existed in the cave ever since its formation.

As regards the second question, it is known that the algae (except saprophytes and a few parasites) require a certain moisture, heat and light to subsist. While the first two of these requirements are satisfied in the cave, the third factor, i. e. light, is absent. It was shown by MORTON (p. 6) that as little as a 2500th part of normal sunlight intensity sufficed for certain *Cyanophytae* to exist, and so it is conceivable that the light shed by the lamps of visitors, or the guards making their daily rounds, is sufficient for the algal organisms in the cave to complete their assimilative processes. Comparisons with the light requirements of deep-sea algae may help to clear up this point.

It was observed by FELDMANN in 1937 (SMITH, p. 315) that certain green algae are able to live in depths (200 m) to which practically no light can penetrate. It was found by members of the deep-sea exploring expedition «Albatros» (Biebl, p. 37) that even the comparatively very short waves (310 m μ) of ultraviolet rays are completely absorbed before reaching such depths. Experiments prove that, beyond a depth of 20 m, every meter absorbs 90% of the residual radiation. Although rays with a still shorter wave length (about

200 m μ) penetrate somewhat deeper, they are no longer capable of producing biological effects. Lately it has been discovered that the reason why there are no algae in the lower regions of the oceans is not the absence of light but deficiency in nitrogen. The problem of assimilation in deep-sea algae is still far from being solved.

Soil algae may furnish another basis for comparison. In 1919 MOORE and CARTER found certain *Cyanophyta* 1 m. below the surface of the soil. D. FEHÉR, the recently deceased eminent academician, undertook detailed and precise investigations in this respect (Soil Biology, p. 325). He says: «When placed under the microscope, all our soil samples brought up from considerable depths unfailingly revealed the presence of intact algae which had retained the green colour of their chlorophyll even in depths over 1 m. In 1935 we started experiments that stretched over a number of years. Flourishing algal cultures, grown in light, were placed in suitable vessels and buried in depths of 1 to 1,5 m. On unearthing and re-examining them after 1 to 2 years, it was found that in spite of having been cut off from any source of light in the soil these microorganisms retained their green colour, and that, accordingly, their chlorophyll remained unimpaired». Summing up the result of his investigations performed during many decades, Prof. FEHÉR reaches the following conclusion (I, p. 696—698): «Our results do not allow us to put forward the transition to a heterotrophic mode of life as the sole explanation for the problem of nutrition and assimilation in algal organisms that live in darkness and are able to conserve their green chlorophyll». Prof. FEHÉR failed to achieve an increase in the weight of his algal cultures and, because of methodological difficulties, to attain precision in his assimilation experiments. Nevertheless, he regarded intact retention of the chloroplasts as not quite perfect yet sufficient proof of continued algal life. Our own studies in this respect will be reported later.

Since the end of the last century various views have been developed on how some algal species can tolerate the total absence of light. MAHEU (1860)* believed that even the very little light emitted by phosphorescent fungi was sufficient to be utilized by algae. To this it must be observed that algae have been found in many caves where there were no luminous fungi. MORTON (p. 4—6) attributed an assimilatory effect to such infinitesimal light as is imperceptible not only to the human eye but even to the most sensitive instruments of today. If we use the word «light» in its physically accepted wider sense, there may be some truth in this hypothesis; it is therefore to be regretted that MORTON omitted to state to which range of the electromagnetic waves he referred when using the term «light» (gamma, ultraviolet, infrared rays, radio waves).

* See Morton p. 2.

SMITH (p. 315) refers to the long-known phenomenon that in want of light some of the *Cyanophyta* change over to heterotrophic nutrition, provided there is suitable organic matter or abundant anorganic nitrogen at their disposal. They even retain their colour, whereas Chlorophyta lose it in darkness to regain it when coming to light again. It is repeatedly emphasized in Prof. FEHÉR's work that he only supplied his cultures with anorganic nutrition, and so the possibility of an adoption of a heterotrophic mode of life was from the outset out of question.

In MAGDEBURG's view, substantiated by observations made in Swiss caves, Chlorophyta too retain their colour in darkness, even if they adopt there a saprophytic mode of nutrition. At the same time, he points out sharply how highly improbable it is that the existing chloroplasts should live forth in the cells as functionless rudiments. In setting up his new theory he gives, however, no answer to the question of the real part played by the chloroplasts. In his conception, some of the *Cyanophyta*, or *Chlorophyta*, and the autotrophic iron bacteria that are «never lacking» in caves enter into a state of symbiosis. Equally interesting are MAGDEBURG's attempts to explain the life processes of a stalactite-forming blue alga, the *Hapalosyphon intricatus*, which was first described by him out of caves. He found, this alga lived in the interior of small stalactites comparatively near the entrance and so still received some light; it secreted a considerable amount of calcium and therefore played an important role in the formation of stalactites but, by doing so, it cut itself off from the light. In a section made from a stalactite of this kind, MAGDEBURG observed regular algologic zonation: in the outer part and covered with but a thin layer of calcium there were colonies of *Chroococcus*, *Dactylococcopsis*, which in his view supplied nutriment to the *Hapalosyphon* species occupying the dark interior of the stalactite. He substantiated his opinion by the observations of CHOLODNY who, too, described phenomena believed to be symbiosis of iron bacteria and *Cyanophyta* and of different kinds of *Cyanophyta*, respectively. A number of objections can be made to MAGDEBURG's theory, viz.:

1. Iron bacteria do not live in great masses in all caves, nor do they in the Baradla cave. It is quite possible that they do occur in certain periods and in certain places but not more than three specimens were found during our collections, and these at places from where we were unable to obtain algal cells in cultures.

2. Not only some primitive blue algae but also *Chlorophyta* were found to exist in the entire area where we collected, and it is hardly conceivable that these cells attached to stalactites or walls should all subsist on organic matter. Even MAGDEBURG makes no mention of a state of symbiosis between iron bacteria and *Chlorophyta*, or between *Cyanophyta* and *Chlorophyta*.

3. Experiments to be described below have proved that in the present case there can be no question of any symbiosis either of *Cyanophyta* inter se, or of these and iron bacteria.

4. Using MAGDEBURG's method, we found *Hapalosyphon intricatus* in nearly every one of our collections, also in collections made at a distance of approximately 600 m. from the entrance, in complete darkness. At the same time, we saw no traces of any algal zonation in the cross section of the minute stalactites. This precludes symbiosis of this species and *Chroococcus* or other *Cyanophyta*. MAGDEBURG probably mistook some alga cells attached to the surface of a stalactite for the symbiont of the *Hapalosyphon*.

All hypotheses attempting to solve the problem by attaching special significance to ultraviolet and infrared radiation, or gamma rays emitted by the soil, yielding equally unsatisfactory results, one is bound to say that none of the theories gives a reliable explanation of the active algal life in the cave. It needs to be pointed out that, with the exception of a few isolated cases, the algae in the cave do not appear in an akinetic state as assumed by some but show definite signs of active existence that can be substantiated by the following facts.

a) Microscopical examinations started on the day following that of the collection (especially the second) permitted of the determination of several algal cells and filaments in an unimpaired and assimilatively active condition. It would be practically impossible to demonstrate without cultures all the species described from the cave: it occurred, for instance, that one of the cultures, grown from a particular collection, turned out to be a monoculture, probably because only a single cell, or at most a colony composed of but a few cells had found its way into the vessel. The suspicion may of course arise that the collected material became contaminated: this possibility appears to be excluded by the above-described absolute sterility of the air in the cave as also by our use of sterile implements in collecting. Nor does it seem probable that the *Protococcus anulatus* (grown in the said monoculture), a rather rare alpine species, got into the vessel with the air of the room when the vessel was filled with sterile culture medium in the Institute; this would have been the sole opportunity, as the vessel was opened on no other occasion.

b) The presence of the species *Hapalosyphon intricatus* offers a clear evidence of an active mode of life, as in this species secretion of calcium and assimilation are closely correlated processes. Even MAGDEBURG is convinced that this is not a case of a passive «embedding in stalactite».

c) Powerful and apparently very virulent filaments of *Chantransiae*, covering a surface of several square decimeters and reaching a height of 10 cm. were found in the cave at Abaliget, and there is no reason why one should not suppose similar vitality in existence at Aggtelek.

d) FEHÉR failed to demonstrate an increase in the weight of his buried alga cultures, nor was he successful in performing measurements of assimilation, so that it was in an indirect way, from the unimpaired subsistence of the chromoplasts, that he inferred the existence of a flourishing life activity in his algae. We used the following method: test material collected in the cave was cultured in light, and the flourishing cultures were then taken back to the cave. There sterile Petri dishes were filled with water taken from the cave streams, then inoculated with our cultures by placing into the dishes tiny particles of stalactite or fragments of the wall «green with algae». As the water of the streams contains but a minimum of organic matter, this procedure precluded the possibility of a heterotrophic mode of nutrition. Nor was symbiosis with iron bacteria possible, since our cultures were devoid of such bacteria. By placing our glass boxes at a distance of about 600 m. from the entrance of the cave, it was made impossible that any one *Cyanophyta* that may still have received some little light should become the symbiont of the other, for there reigned the same utter darkness in this part of the cave. The glass boxes were deposited at approximately $1\frac{1}{2}$ to $2\frac{1}{2}$ meters above the floor, in more or less closed wall recesses, partly in order to put them beyond even the highest level of possible floods, and partly to protect them from the possible effect of the light shed by the lamps of visitors or those of the guards making their daily rounds.

It merits mentioning that we also succeeded in collecting algae from the «Peace Cave», a part of the system which is visited but rarely; the material in question is now being worked up. This fact apparently disproves two assumptions: (i) that it is the lamp of visitors which supplies the light required for the process of assimilation; and (ii) that the algae are carried into the cave on the boots of the visitors. We collected algae by «climbing» parts of the Peace Cave where no man had trodden before us.

The dishes left in the cave were examined after 6 months and found to be teeming with algae that floated on the surface of the water in the shape of thick membranes, or had climbed up the sides of the dishes covering even their lids. Although we too refrained from measuring weights, yet we believe the facts just described sufficiently prove the active metabolism of these algae. The vitality of some of them is well illustrated by the following example. When first examined, none of our collections appeared to contain *Lyngbya marteniana*. Yet, on re-determining the contents of our dishes after 6 months of exposure in the cave we were surprised to find a great number of these algae in one of them. It must be supposed that either there was such a small number in the collection at the first inspection that it escaped attention or, else, our cultures were contaminated by the water of the cave stream. In any case, the algae must have been in our material in very small numbers at the outset, and have yet grown to a considerable colony by the time of the second inspection.

The following list shows the specific composition of the cultures taken back into the cave and re-determined after an exposure of 6 months.

It is known that chlorophyllous plants need radiant energy to perform assimilation. Visible light is generally regarded as the principal and almost

Species	No. of dish			After 6 months
	I.	II.	III.	
<i>Cyanophyta</i>				
<i>Synechococcus elongatus</i>			+	+
<i>Plectonema puteale</i>			+	
<i>Nostoc punctiforme</i>	+			
<i>Spirulina laxa</i>	+			+
<i>Pseudanabena tenuis</i>			+	+
<i>Oscillatoria tenuis</i>		+		+
<i>Oscillatoria neglecta</i>		+		
<i>Oscillatoria limnetica</i>			+	+
<i>Oscillatoria geminata</i>	+			+
<i>Oscillatoria agardhii</i>			+	+
<i>Phormidium foveolarum</i>	+			+
<i>Phormidium henningsii</i>			+	
<i>Phormidium dimorphum</i>		+		+
<i>Lyngbya digueti</i>			+	+
<i>Lyngbya martensiana</i>			+	+
<i>Schizothrix fragilis</i>		+		
<i>Schizothrix cyanea</i>		+	+	+
<i>Chrysophyta</i>				
<i>Ophiocythium parvulum</i>		+		+
<i>Ochromonas ovalis</i>	+			+
<i>Fragilaria virescens</i>		+		
<i>Navicula mutica</i> var. <i>nivalis</i>		+		+
<i>Nitzschia thermalis</i>		+		+
<i>Gloeococcus schröteri</i>	+		+	+
<i>Chlorophyta</i>				
<i>Tetraspora tarnayana</i>	+			
<i>Chlorococcum infusionum</i>	+	+		+
<i>Chlorella miniata</i>		+	+	+
<i>Oocystis pusilla</i>	+			
<i>Protococcus anulatus</i>		+	+	+
<i>Hormidium flaccidum</i>		+	+	+
<i>Stichococcus bacillaris</i> f. <i>minor</i>			+	
<i>Rhizoclonium hieroglyphicum</i>			+	+

the only source of such energy. Biebl observed that certain pelagic algae absorb considerable amounts of ultraviolet rays ($\lambda = 200$ to $400 \text{ m}\mu$); these rays can, however, play no part in the assimilatory process of cave algae since — as has been demonstrated by FEHÉR, FRANK, SZELÉNYI and SCHEITZ (FEHÉR 1953. p. 205) — they are stopped even by quite thin layers of soil. X-rays of still shorter wave lengths generally exert a bactericide, destructive or growth-inhibiting effect, although they have no practical importance in soil biology, as was stated by FEHÉR (1953. p. 209). Investigations into the effect of infrared rays on soil algae proved that, while these rays may somewhat heat up the surface of the soil, they exert no assimilative action, and it is sure that this applies to cave algae as well. As regards MORTON's above-mentioned theory about the invisible rays, only the long radio waves and the various very short gamma waves have still to be considered. As radio waves exercise no physiological effect, there is no need to speak of them. There remain the gamma rays, and it was to be seen whether there existed in the Aggtelek cave a gamma radiation strong enough to be utilized by the algae for assimilatory purposes. Such supposition was justified by the fact that, in the thirties, STOKLASA and PENKOVA (p. 413) observed certain algae which while kept in radium light, multiplied and increased in weight.

To settle the problem, the Institute of Botanical Taxonomy organized, on December 12, 1954, a third trip to Aggtelek under the guidance of Miss P. PALIK which was joined by Z. TÁRCZY-HORNOCH of the Technical University who equipped himself with GEIGER-MÜLLER counting tubes taken from the Central Physical Research Institute. Our gratitude is due to Prof. K. SIMONYI, director of the Department of Atomic Physics of that Institute, for having facilitated these investigations by his valuable advices and by lending the necessary instruments.

The measurements gave negative results in as much as it was found that, far from reaching even the mean value of the gamma radiation in Budapest, the intensity of the gamma rays was not more than one fifth of that value in some places of the cave. (The appendix contains a detailed report on the local distribution of the radioactivity and the method of assessment.)

We are now again faced with two moot questions:

1. Is the slight emission of gamma rays found in the cave and due probably to cosmic radiation, sufficient for the assimilation of algae, or in other words are the alga cells able to take up at all the existing quanta which are few in number but large in size?

2. If it is not from this minimal but still demonstrable radiation that the algae take up the energy required for their assimilative function, what do they utilize for this purpose?

Because of technical difficulties, it is for the time being impossible for us to decide the first problem.

The method that will at one time have to be employed is briefly this: the cultures must be placed in rayproof cases of lead with walls of 15 to 20 cm thickness. A stoppage in their growth or their death would prove that the slight radiation existing in the cave, as measured by us, suffices for the algae there to assimilate CO_2 . Increasing doses of radioactive substances, emitting known quantities of radiant energy, will then have to be added to the cultures in the cases, in order to ascertain the minimum amount of radiation required for a continued metabolistic activity of the algae. Even after that the problem of how the cells are able to take up rays of such a high energy and, consequently, of such a high power of penetration, and to utilize them for assimilative purposes, will remain unsolved. STOKLASA and PENKOVA did not deal with this question.

It is known that gamma rays are stopped only by heavy metals and their salts, and it is also known that these metals have a toxic effect on plasma colloids: proteins are precipitated while complex is formed. The question has been evaded by the introduction of the concept of «hits». GLOCKER defines «hit» in the following manner (FEHÉR 1953, p. 207 — the original work was, unfortunately, not available): „«hit» means the penetration of a photo- or Compton-electron through the «ray sensitive» mass of the cell or bacterium, and its ionizing action therein.“

Recent researches have shown this «ray-sensitive» space to be but a small fraction of the entire mass of the bacterial body. GLOCKER (1949) found that the «ray-sensitive» space of a bacterium of medium size consists of about 250 spherules with diameters hardly exceeding 12 $\text{m}\mu$ or 120 Å. A single quantum if it hits this comparatively small area may destroy it, while all other quanta of the ray will pass ineffective.

PIETSCHMANN (p. 128) made similar experiment on green algae, and found that doses of 100 to 200 roentgen were lethal to *Chlorella*, although they were but one twentieth part of the resistance as measured in *Escherichia coli* units. We have thus succeeded in getting round the problem by introducing the concept of the ray-sensitive space but only at the price of having raised another problem: if *Chlorella* and other green algae are so sensitive to radiation, how was it possible that, far from being killed, the cells exposed to direct radium energy in STOKLASA and PENKOVA's experiments were able to multiply? Although it was demonstrated in PIETSCHMANN's later experiments that some algal cells survived even radiations of 10 000 roentgen that lasted from 5 to 10 minutes, the said contradiction does not seem to be fully explained.

In any case, the experiments of STOKLASA and PENKOVA seem to confirm that radioactivity is being utilized by algae, if they stood it at all; it remains nevertheless an open question whether it is this source which is used by the algae or rather some other as yet unknown kind of energy. This leads

us to the other problem: if algae are able to exist in «absolutely rayproof space» where does the energy they utilize come from? The only explanation which offers itself is Prof. FEHÉR's theory to the effect that every substance emits rays of very short wave lengths and a great power of penetration of which, so far, only their supersensitive biological detectors are known.

It has been known since the nineties of the last century that a certain radiation is emitted also by inactive, i. e. non-radioactive, metals. ELFVING (1890) discovered this effect on *Phycomyces nitens*; the problem was treated, later by THEILE and WOLF (1899), LUGER and SPÄT (1920), RIED (1931) LAGRANGE and BOUCHER (1932); RIVERA and his collaborators studied the question on plants of higher orders in 1935-39; having experimented in the Leningrad Roentgen Institute since 1933, NADSON and STERN succeeded in arranging the ray-emitting metals in a progressive series.* Yet, only Prof. FEHÉR and his collaborators (from 1938 to our days) have been able to demonstrate the existence of strict quantitative relations between the mass of the radiating substance on the one side and the biological effect of the radiated energy, further its absorption by heavy metals, on the other side. By a stroke of genius this prominent worker generalized his experimental findings and extended his studies on the phenomenon to the non-metallic substances, and thereby started a series of new and fertile investigations in nuclear physics concerning the structure of matter. No satisfactory physical interpretation of the phenomenon has yet been found but there is no doubt as to its existence, and it has been pointed out by HOLLERBACH, the eminent Soviet scholar, (1953, p. 108) that FEHÉR's biophysical conception is in perfect harmony with the quantum theory of today.

It will be seen from the above that we are not yet in a position to give a satisfactory answer to the second question either; it is to be hoped that a solution will be found within the next few years.

As regards our third problem, that is, how the presence of arctic and antarctic algae in the cave can be explained, we must be content with more assumptions. If we attempt to draw a parallel between the cryobiont organisms and the species enumerated below we shall find only three species, i. e. *Horridium flaccidum* and *Stichococcus bacillaris f. minor* that play a constant part in the formation of coloured snows. The two latter are cosmopolitan; although *Phormidium frigidum* too has been found in the Soviet Union, its habitat is not reliably stated. So a comparison with cryobiont organisms does not help us in solving the problem. It is probable that in the present case we have to do with glacial relics; these settled in the cave when it was formed, and habituating themselves to the cave's constant temperature of about 10° C, they found there a refuge from the rising temperatures of the interglacial

* (See Fehér, 1953. p. 253.)

epochs. These warm epochs killed the glacial hardy algae not only in the neighbourhood of the Baradla cave but in all lower regions throughout Europe, and only those few species managed to survive the intervening higher temperatures which took shelter in the caves or high mountains.

The following list gives the alpine arctic and antarctic algal species, indicating the mean annual temperature of their habitat. The forms marked with asterisk are ubiquitous to which the above arguments do not fully apply.

Name of species	Occurrence	Annual mean temperature °C
<i>Plectonema puteale</i> * ...	Alaska Southeast Region of the River Yukon	5,6—6,4 —3,5— —5,1
<i>Spirulina laxa</i> *	Wisconsin Lake shore Plateau	4,5 7,3
<i>Oscillatoria chlorina</i> *	Antarctica	
<i>Phormidium frigidum</i>	Antarctica High Tatra Árvaváralja 501 m Kőrösmező 652 m	6,2 6,0
	European high mountains (500—1200 m) Engelberg 1018 m St. Beatenberg 1148 m	5,2 6,0
<i>Phormidium pristleyi</i> ..	Antarctica 50° of latitude 55° « « 60° « « 65° « « 70° « « 75° « «	5,8 1,3 —3,4 —8,2 —13,6 —20,2
<i>Lyngbya erebi</i>	Antarctica as above	
<i>Protococcus anulatus</i> ..	Central European high mountains see <i>Phormidium frigidum</i>	
<i>Sorastrum simplex</i> ? ..	Novaya Zemlya Markowo 64° of lat. Kola peninsula 68° Narwik 68° of lat. Sodankylä 67° of lat.	—9,1 —0,7 —1,7 +0,6
<i>Hormidium flaccidum</i> *	Central European high mountains see <i>Phormidium frigidum</i>	
<i>Stichococcus bacillaris</i> <i>f. minor</i>	Antarctica see <i>Phormidium pristleyi</i>	

Our work is far from being completed, the problems are manifold, and their solutions require further prolonged but very intriguing research work.

Our acknowledgement is due to Miss. P. PALIK who, besides drawing our attention to the problems in question, spared neither efforts nor pains to lend her assistance throughout our investigations; we are also indebted to Prof. R. SOÓ, who supported our efforts during the whole of the two years not only by his valuable advices and his devotion to our problems but also

by having arranged the material aid required ; we must thank also Prof. E. DUDICH for giving us constant advice, making much of the pertinent literature available, and taking an active interest in our algological investigations.

APPENDIX

REPORT ON THE MEASUREMENTS OF RADIOACTIVE RADIATION IN THE STALACTITE CAVE
OF AGGTELEK, PERFORMED BETWEEN DECEMBER 10 AND 12, 1954

By

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In the course of the investigation the following instruments were used : A rate meter of type GK2 for β and γ -radiation built by the Central Research Institute for Physics, and a battery-operated counter equipped with a counter-tube of type NG 101, made by the Geophysical Institute.

The investigation was made mainly for the qualitative determination of the radioactive radiations in the cave. The time at our disposal, altogether 13 hours of working in the cave, could not have been sufficient for the accurate radioactive mapping of a cave system several kilometres long, even if the most elaborate instruments had been used. If that object is to be achieved, systematic and several times repeated sets of measurement will have to be made involving much longer periods of investigation.

After a preliminary deliberation on the above circumstances I decided to choose as the primary objective the study of those parts of the cave only, whose radiation promised to be the most interesting, and then, by way of compromise, to investigate there at as many points as possible contenting myself with a lesser accuracy. Assuming, namely, a constant radioactive source in a fixed position, the average relative error in a separate counting of n γ -photons is given by the Poisson formula

$$h_1 = \frac{\sqrt{n}}{n}$$

which means that for ensuring an accuracy of 3% roughly thousand impulses are to be counted.

From this point of view, it would seem that GM tubes with the greatest possible effective surface are desirable, for their use increases the number of impulses registered during a fixed time interval, which means increased accuracy. However, on taking into account the finite resolving power, τ , of the counter, we find that the greater the number of impulses in unit time, the

greater is the probability of two consecutive impulses being separated by a time shorter than τ and leading to faulty recording. In first approximation the average relative error due to this effect is given by

$$h_2 = \frac{\tau}{t}$$

where τ is the resolving power mentioned above and t the *average* interval between two consecutive impulses. Contrary to the former one, this last effect recommends the use of GM tubes of smaller dimensions, by which it can be achieved that the error h_2 be small; and if the error h_1 is to be kept low at the same time, the duration of the observation must be considerably lengthened.

These considerations have led to the selection of the tube NG 101, the zero effect of which at Budapest, averaged from many measurements, amounts to 94 impulses per minute. The same tube covered by a lead shield 4 cm thick gives a zero effect of 37 counts/minute. Each observation was scheduled for 5 minutes. In this manner it was possible to keep the average error of the entire set of measurements in the neighbourhood of 15%, not once exceeding 20%. (It can easily be understood that reducing the error to only 13% by using a tube with a zero effect of one fourth the one used, would have claimed a duration of measurement five times as long, i. e. 25 minutes in each case, which was entirely out of question.)

It needs to be mentioned that other sources of errors may also have impaired the measurements, such as radioactive contaminations imported into the cave (e. g. AUER burners), variations in the battery voltage caused during several hours by the 100% relative humidity, leakage currents of the cable and leads caused by moisture, etc.

These possible sources of errors were constantly kept in mind and by performing control measurements, the evidently faulty data were immediately discarded. The attached table contains only data regarded as correct. It shows the date, time, and approximate site of each observation, followed by an indication of its peculiar circumstances. The measurements performed in air, stalactite, limestone, clay, and pebbly sediment are designated by the letters a, st, lst, cl, and ps, respectively. For all the measurements, except for those performed in air, the position of the GM tube is also given [— horizontal, / vertical, / obliques] with an indication of the degree of covering of the tube by the material investigated, given by the angle of contact in a plane perpendicular to the tube axis.



Radioactive radiation measurements in the stalactite cave at Aggtelek

Serial No.	Date and time	Site where measurement was made	Peculiar circumstances of measurement	Impulses per 5 min.
1.	Dec. 10	Mountain lake hotel	a	487
2.	16 ⁴⁰	Entrance to cave	a	427
	17 ⁰⁵			
3.	17 ¹⁵	First stairs: about 180 m	a	236
4.	17 ³⁰	About 460 m	a	277
5.	18 ⁰⁰	In the middle of Concert Hall	a	520
6.			a	537
7.			a	361
8.	18 ²⁵	At sign No. 36	a	364
9.			st. 270°	178
10.			st. — 200°	243
11.			lst. — 180°	226
12.	19 ¹⁰	At sign No. 30	a	410
13.			st. — 180°	176
14.	19 ⁴⁵	On the way back: Concert Hall	a	410
15.			st. — 180°	176
16.	22 ¹⁵	Mountain lake hotel	a	419
17.	Dec. 11.			
	14 ⁰⁰	Cave hotel	a	352
18.			a	355
19.	14 ²⁵	Charnel house	a	140
20.			st. — 200°	103
21.			st. 300°	70
22.	14 ⁵⁰	After King's Well	st. 300°	63
23.	15 ⁰⁰	Cathedral	a	189
24.	15 ¹⁵	Concert Hall behind Aquarium	st. 180°	244
25.		In the middle	a	191
26.			a	165
27.	15 ⁴⁰	Nádor street, the place of first glass box	st. 270°	182
28.	15 ⁴⁵	In the place of second glass box	st. 90°	183
29.	16 ⁰⁵	In the place of third glass box	st. 270°	164
30.	16 ¹⁵	Nádor memorial tablet	st. 270°	112
31.	16 ²⁵	Bridge behind flood lock Sign No. M I 1926 ...	ps. — 270°	321
32.	16 ⁴⁵	Staggered dentation	ps. — 180°	241
33.			st. 270°	135
34.	17 ⁰⁰	20 m from cement ramp	cl. — 180°	392
35.		1,5 m further	st. 270°	263
36.		Farther from clay	st. — 270°	67
37.		20 m, on clay again	cl. — 180°	505
38.	17 ⁴⁵	Two ramps	a	222
39.		On the highest point	a	220
40.	18 ²⁰	Dining room	ps. — 180°	327
41.			st. — 180°	208
42.	19 ⁴⁵	Vöröstó exit	st. ps. 180°	327
43.			slt. ps. — 180°	263
44.		Gangway	a	241
		<i>Control measurements*</i>		
45.	14 ¹⁰	Aggtelek cave Concert Hall on concrete	a	452
			— 180°	466
47.	14 ²⁰	On the way out, about 460 m	cl. 180°	460
48.			1 st./180°	225
49.	15 ²⁵	Railway station	a	430
			a	470
		Mean in Budapest	lead — 360°	185

* 1' measurement converted to 5' measurements.

This separate treatment of the observations performed in the air, resp. on the surface or in a hole of rock was necessary, because already the very first observations showed that the radiation of the cave atmosphere was rather inhomogeneous and the radiations measured in air were merely the resultants of those of the rocks around. The figures in the last column of the table give the intensity of the radiation expressed in the number of impulses counted in five minutes. In two rows at the foot of the table are given the numbers of impulses calculated to a five minute observation at Budapest, with (2) and without (a) lead shield.

The contents of the table can be summarized in the following statements :

1. No appreciable radioactivity can be observed in the stalactite cave of Aggtelek. In some places, e. g. in the Charnel House, the radiation is rather remarkably low and, within the experimental errors, is nowhere above the average of Budapest.

2. The radiation minima are invariably to be found in places where there is no sediment. The basic limestone and the stalactites and stalagmites were found to have zero activity, within the errors. On the other hand, the sediments, mainly the clay, showed everywhere slight γ -activity.

The question as to what amounts of radioactive materials did give rise to the observed activity and whether uranium, thorium or potassium emits it, cannot be decided unless by lengthy and costly laboratory determinations.

In conclusion, it needs to be mentioned that nowhere in the cave was β -activity observable.

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О ФЛОРЕ ВОДОРΟΣЛЕЙ ПЕЩЕРЫ БАРАДЛА В АГГТЕЛЕК

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Резюме

Изложены результаты альгологических и радиологических исследований, проведенных в пещере Барадла у с. Аггтелек в течение двух лет.

Было установлено, что в сталактитовой пещере Барадла — расположенной в северной части Венгрии на территории, известной под названием Торнаи Карст, длиной приблизительно в 22 км., со среднегодовой температурой в 10°C, и относительной влажностью воздуха в 80-100%, — произрастает значительная флора водорослей.

Сборы проводились следующим образом:

Исходя из входа № 1. на территории, распространяющейся до 500 м., были взяты со стен соскобы до высоты в 160 см. Кроме того проводился сбор планктона в ручейках пещеры и в аквариуме. Из полученного материала в стерильных чашках Петри на питательной среде, изготовленной раствором Кюппа, выводились водоросли, исследование которых дало следующие результаты.

44 вида, разновидности и формы относятся штамму *Cyanophyta* (синезеленые водоросли), 1 вид к штамму *Euglenophyta* и 12 видов и разновидностей к штамму *Chryso-phyta* (точнее 1 вид к классу *Chryso-phyceae* 1 вид к классу *Xanthophyceae*, и 10 видов и разновидностей к классу *Bacillariophyceae*) а остальные 12 видов и разновидностей — к классу *Chlorophyceae* штамма *Chlorophyta*. Из вышеприведенных видов новыми для науки являются следующие: *Tetrapedia reinschiana* Arch. f. *aggtelekiensis* n. f., *Oscillatoria dudichiana* n. sp., *Oscillatoria pseudoangusta* Claus var. *brevicellulata* nov. var., *Lyngbya palikiana* n. sp. *Tetraspora tarnayana* n. sp. а многочисленные виды новые для Венгрии.

Из результатов исследований можно сделать следующие выводы:

I. Было установлено, что все гипотезы, выдвинутые относительно вопроса, каким образом водоросли попадают в пещеру, как например гипотеза, согласно которой клетки переносятся в пещеру воздушным потоком, водой или пещерными животными, неудовлетворительны. На основании нам ныне известных фактов нельзя выдвинуть гипотезу, удовлетворяющую все требования, разве только на основании предположения, что водоросли произрастают там уже со времени возникновения пещеры. Эта теория подтверждалась бы существованием в пещере следующих видов, известных ныне только в Арктике или же Антарктике: *Oscillatoria chlorina*, *Phormidium pristleyi*, *Lyngbya erebi*, *Sorastrum simplex*.

II. Несмотря на полное отсутствие света водоросли ведут в пещере не латентную, а активную жизнь; это доказывается:

1. видом *Hapalosiphon intricatus*, выделяющим кальций в ходе ассимиляции, и тем обстоятельством, что в пещере обнаружены как этот вид, так и многочисленные конкреции извести;

2. исследованием так называемых «черных покрытий» пещер, которые долго считались колониями железобактерий, или же сажой. Удалось выявить, что эти «черные покрытия» в значительной мере состоят из следующих водорослей: *Gloeocapsa punctata*, *Phormidium foveolarum*, *Ph. dimorphum*, *Ph. Henningii* и *Schizothrix cyanea*;

3. наконец, повторным исследованием возвращенных в пещеру культур. Выявилось, что виды, культивируемые на свете, не погибали в темноте пещеры, а в значительной степени размножались.

Ввиду того, что проведенные в пещере радиологические исследования выявили наличие в пещере лишь минимального гамма-излучения (часто примерно одна треть надземного излучения), что в пещере вовсе нельзя выявить бета-излучения, далее, что при данных условиях нельзя рассматривать источником энергии для ассимиляции пещерных водорослей никакое излучение, относящееся к одной из известных до сих пор областей электромагнитных волн, — то остается открытым вопрос, какой же энергией пользуются эти, содержащие хлорофилл и живущие в темноте растения для своей продукции. До окончательного выяснения этого вопроса следует принять известную теорию Д. Фехера о микроволновой радиации.

III. На основании присутствия арктических и антарктических видов можно предположить, что эти водоросли в качестве гляциальных реликтов сохранились в пещере при постоянной температуре воздуха в 10°C еще из ледникового периода, то есть со времени возникновения пещеры.