Isamu UMEZAKI*: The life history of *Nemastoma nakamurae* Yendo (Nemastomataceae, Rhodophyta) in culture

梅崎 勇*: 紅藻ヒカゲノイトの生活史に関する研究

(Plates XIV-XV)

Since the publications of Magne (1961, 1964) in which he doubted the existence of haplobiontic species in the Rhodophyta, life history studies have been carried on in a number of species, especially in the Nemaliales. Until recently, these studies have led to the supposition that for most members of the Florideophyceae the life history is of the *Polysiphonia* type. In the orders Cryptonemiales and Gigartinales a diversity of life history however has been shown from recent works (Dixon *et al.* 1972; Dixon 1973).

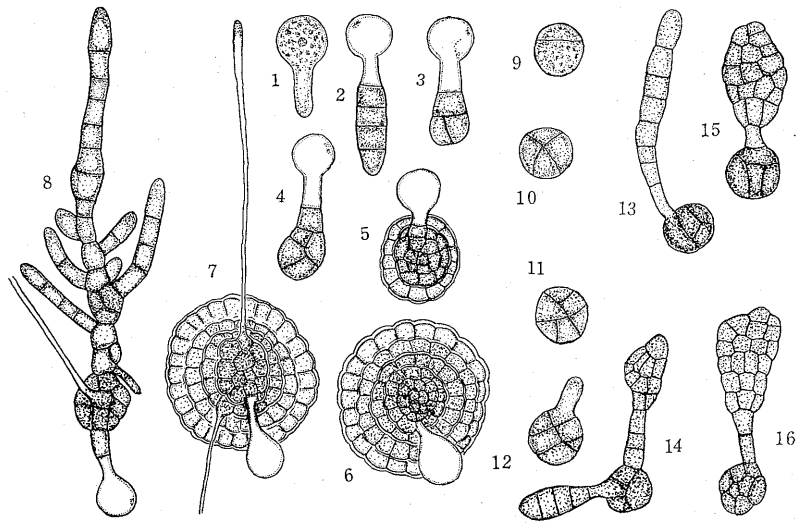
The genus *Nemastoma* belongs to the Nemastomataceae, Gigartinales. Hoek and colleagues (1972) have made an interesting observation from their culture study of *Nemastoma dichotoma* that on germination the carpospores give rise to branched filaments which reproduce by monospores. However, they had not completed the life cycle of the alga. There have been few attemps to culture other species of *Nemastoma*. Kuckuck's illustration (1912) of *Platoma bairdii* shows that erect filaments of the crustose thallus give rise to an erect thallus bearing tetrasporangia. Inoh (1947) observed only early stages in germination of carpospores of *Schizymenia dubyi*. No one has studied the life histories of other members of the Nemastomataceae, as far as the writer knows.

Materials and methods On September 1, 1972, the writer collected both the gametophytes and tetrasporophytes of *Nemastoma nakamurae* Yendo, both of which grew together on rocks at a depth of 1-1.5 meter, from Seihama, Obama Bay, Fukui Prefecture. Both the gametophytes and tetrasporophytes were fertile in August and in the beginning of September. The materials collected were brought to Kyoto University at Kyoto and

* Department of Fisheries, Faculty of Agriculture, Kyoto University, Kyoto 606. 京都市左京区北白川追分町. 京都大学農学部水産学教室.

were put into unialgal cultures. The cultures were grown under day light fluorescent lamps of light intensity of 4,000 lux for 16 hours per day at temperature of 20±1°C.

Results The discharged carpospores and tetraspores are 13.5–16.0μm (mean 14.4μm) and 10.5–13.5μm (mean 12.2μm) in diameter respectively, the former being a little larger than the latter. There are two types in the early process of spore germination. After fastening to the substratum the spore, which was enveloped in a cell wall, pushes out a germ tube into which the entire spore protoplast migrates. In the next stage, divisions occur in the tube to produce a uniseriate row of two to five cells. The terminal cell divides to produce a disc composed of several cells. This type of germination belongs to Inoh's typus discalis mediatus (Inoh 1947) (Figs. 1–8; Plate XIV, figs. 2–3). In the other type, the spore divides directly into two unequal cells, followed by a 4–8 celled germling by the second and third divisions (Plate XIV, fig. 1). One or two cells of the germling elongate towards its outside to produce a branch. On the tip of

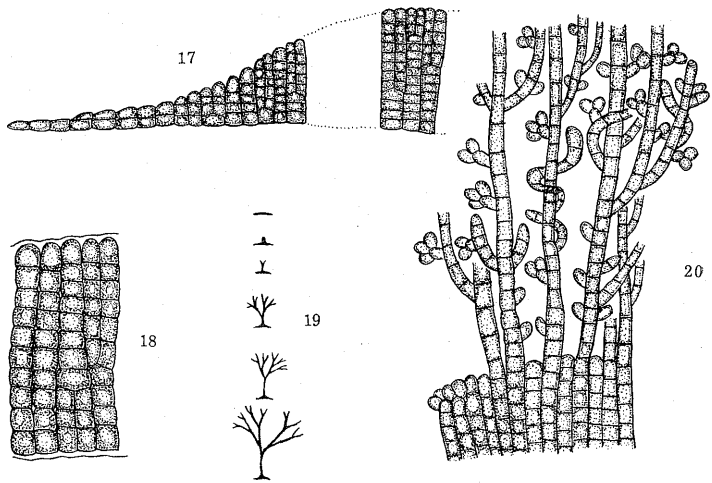


Figs. 1–16. *Nemastoma nakamurae* Yendo. 1–8. Indirect germination type in which the spore pushes out a tube on which a disc is produced. ×130. 9–16. Direct germination type in which spore body divides directly to produce a disc. ×130.

the branch a disc is produced by the method of the first type (Figs. 9–16). Most of the discharged spores, both carpospores and tetraspores, germinated by the first type.

When the disc grew to a size of about 50μm, it produced one to several colourless hairs with a diameter of 2μm and a length of 100–200μm on its upper surface (Fig. 7; Plate XIV, fig. 3). They were produced only on young discs. The disc continued to produce new cells towards its marginal and upper sides, thus increasing its diameter and height, respectively. The margin of the disc is one-celled and its cells are 5–10μm in size, while its middle part is composed of 2–3-celled layer whose cells are polygonal, being about 5μm. When the cultures had been kept under a poor nutrient condition and under the lower illumination less than 1,000 lux, the discs continued to grow without erect thalli. After one year in culture they developed into a prostrate system with a diameter of 1.5 cm and with a layer of 10–15 cells (Figs. 17–18). The appearance in vertical section is similar to that of *Hildenbrandia*. The lower surface of the system did not produce rhizoids. Sometimes, the system enlarged in irregular outline and became highly lobed. Or they horizontally produced new branches from their marginal part and produced new discs on the tips of the branches (Plate XIV, fig. 4). By these methods the crust increased vegetatively during this phase without involving any reproductive organs such as monospores.

After three months the prostrate system began to shoot out numerous upright filaments each of which originated from the upper surface cells of the system. The filaments branched repeatedly to produce a compact mass in which they paralleled upwards and adhered to each other laterally. At an early stage the upright filaments separated under slight pressure (Figs. 19–20; Plate XIV, fig. 4). With growth the filaments increased in number and coalesced more tightly by becoming twisted with each other, thus developing into an erect thallus (Plate XIV, figs. 5–6). Three months later, the erect thalli branched dichotomously and grew to a height of 3–4 cm (Fig. 19; Palte XV). The plants derived from tetraspores and ones from carpospores were both similar in superficial appearance and also had resemblance to plants in nature. Unfortunately these cultured plants did not produce any reproductive organs on them. The crustose system without



Figs. 17–20. *Nemastoma nakamurae* Yendo. 17. Part of vertical section of disc. ×100. 18. Vertical section of middle part of disc. ×200. 19. Successive stages in development of erect thalli from disc. ×2/9. 20. Part of vertical section of disc showing upgrowing erect filaments. ×130.

producing erect thalli remained alive even after it grew to a diameter of 2 cm.

Discussion The carpospores of *Nemastoma dichotoma* on germination give rise to *Acrochaetium*-like plants which reproduce by monospores (Hoek *et al.* 1972). In some members of the Florideophyceae the carpospore germlings develop also into *Acrochaetium*-like plants which reproduce by monospores, namely, *Liagora farinosa* (Stosch 1965), *Pseudogloiophloea confusa* (Ramus 1969), *Dermonema pulvinata* (Umezaki 1972; as *Nemalion pulvinatum*, Umezaki 1967), and *Nemalion helminthoides* (Martin 1969). In *Halymenia floresia* of the Cryptonemiales the same curious stage was also found (Hoek and Cortel-Breeman 1970). In the Rhodophyta the monospore formation has been reported in the Bangiophyceae and the Nemaliales and Ceramiales of the Florideophyceae. However, such a phenomenon has been also found in some genera of the Cryptonemiales by recent works. For example, in *Halymenia floresia* (Hoek and Cortel-Breeman 1970), in *Thuretellopsis peggiana* (Richardson and Dixon 1970) and in *Pikea californica* (Scott and Dixon 1971). In the Rhodophyta the product of germination of a

monospore does not develop into a succeeding phase of life history, but repeats the parent phase. Because of this it appears that monospore formation of Rhodophyta is a special kind of reproduction repeating the same phase. In *Nemastoma nakamurae* the tetraspores and carpospores germinated to give rise to crustose thalli on which erect thalli developed without inserting an *Acrochaetium*-like stage. And the prostrate disc did not produce any reproductive organs such as monospores. As mentioned above, when the prostrate system was under conditions of poor nutrient and weak illumination, they grew without proceeding into the next phase and increased in size and in number. It is possible to say that the prostrate system of *Nemastoma nakamurae* is a stage by which it remains vegetative until the beginning of the next growing season and also during which it reproduce vegetatively. As has been pointed out by Dixon *et al.* (1972) it seems that the prostrate system of the Florideophyceae is an important stage of reproducing vegetatively and a phase of life history, although it does not involve spore formation and release.

It has been known from the present culture study that the erect plants derived from tetraspores were similar to gametophytes and that the plants formed by the germination of carpospores were also morphologically identical with tetrasporophytes. Therefore, it may be given as a conclusion that the life history of *N. nakamurae* is of the *Polysiphonia* type in which the tetrasporophyte is morphologically identical with the gametophyte.

Résumé

1. The carpospores and tetraspores of *Nemastoma nakamurae* Yendo (Nemastomataceae, Gigartinales) germinate to give rise to the respective prostrate system and then erect thalli, as seen in nature, sprout out from the system. The crustose system does not produce any reproductive organs.

2. The life history of the species is of the *Polysiphonia*-type.

The writer expresses his sincere thanks to Dr. I. A. Abbott, Hopkins Marine Station of Stanford University, for her kindness in reading the manuscript.

Literature cited

1) Dixon, P.S. (1973). Biology of the Rhodophyta, xiii+285 pp., Edinburgh.

2) Dixon, P.S., S.N. Murray, W.N. Richardson & J.L. Scott (1972). Life history studies in genera of the Cryptonemiales. Soc. Bot. Fr., Mémoires 1972: 323-332. 3) Hoek, C. van den & A.M. Cortel-Breeman (1970). Life history studies on Rhodophyceae. II. *Halymenia floresia* (Clem.) Ag. Acta Bot. Neerl. 19: 341-362. 4) Hoek, C. van den, A.M. Cortel-Breeman, H. Rietma & J.B.W. Wanders (1972). L'interprétation des données obtenues, par des cultures unialgales, sur les cycles évolutifs des algues. Quelques exemples tirés des recherches conduites au laboratoire de Gronique. Soc. Bot. Fr., Mémoires 1972: 45-66. 5) Inoh, S. (1947). Development of spores of seaweeds, 255 pp., Tokyo. 6) Kuckuck, P. (1912). Beiträge zur Kenntnis der Meeresalgen, 12. Ueber *Platoma bairdii* (Farl.) Kck. Wiss. Meeresunters., N.F., Abt. Helgoland 5: 187-208. 7) Magne, F. (1961). Sur le cytologie du *Nemalion helminthoides* (Velley) Batters. C.R. Acad. Sci., Paris 252: 157-159. 8) Magne, F. (1961). Sur la caryologie de deux Rhodophycées considerées jusqu'ici comme a cycle cytologique entièrement haplophasique. C.R. Acad. Sci., Paris 252: 4023-4024. 9) Magne, F. (1964). Les Rhodophycées a cycle haplophasique existent-elles ? Proc. Int. Seaweed Symp. 4: 112-116. 10) Martin, M.T. (1969). A review of life-histories in the Nemalionales and some allied genera. Br. Phycol. J. 4: 145-158. 11) Ramus, J. (1969). The developmental sequence of the marine red alga *Pseudogloiophloea* in culture. Univ. Calif. Publ. Bot. 52: 1-29. 12) Richardson, N. & P.S. Dixon (1970). Culture studies on *Thuretellopsis peggiana* Kylin. J. Phycol. 6: 154-159. 13) Scott, J.N. & P.S. Dixon (1971). The life history of *Pikea californica* Harv. J. Phycol. 7: 295-300. 14) Stosch, H.A. von (1965). The sporophyte of *Liagora farinosa* Lamour. Br. Phycol. Bull. 2: 486-496. 15) Umezaki, I. (1967). On a microscopic phase in the life cycle of *Nemalion pulvinatum* Grunow (Nemalionaceae Rhodophyta). Publ. Seto Mar. Biol. Lab. 15: 311-318. 16) Umezaki, I. (1972). The life histories of some Nemaliales whose tetrasporophytes were unknown. In I.A. Abbott and M. Kurogi (Ed.), Contributions to the systematics of benthic marine algae of the North Pacific, pp. 231-242.

Explanation of Plates XIV-XV

Plate XIV. Germination of carpospores, formation of discs derived from carpospores, and stages in development of erect thalli from the discs.

1. Three germling spores whose protoplast is directly devided. 2. Three discs derived from indirect spore germlings. 3. One disc with one colourless hair. 4. Discs producing upright filaments which are seen separated under pressure. 5. Formation of one erect thallus at the base of which upright filaments are seen loosely separated. 6. One erect thallus from culture 4 months old.

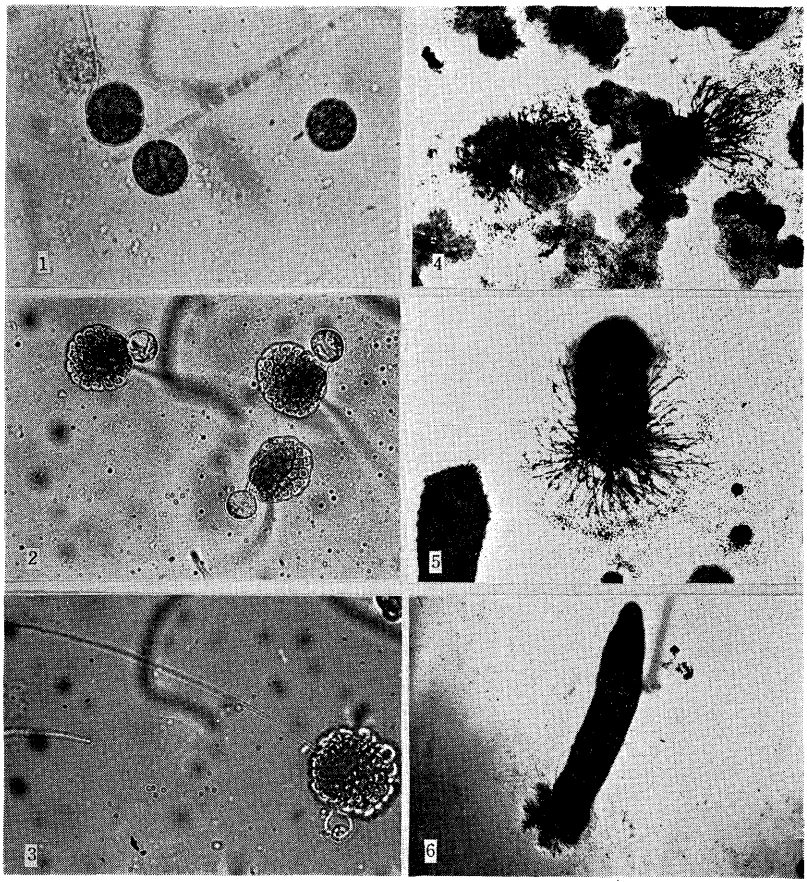
Plate XV. Successive stages in development of erect thalli. 1. Three test tubes from right to left showing one prostrate disc, one erect thallus from culture 4.5 months old and one erect thallus from culture 5 months old. 2. Two *Nemastoma* thalli from culture 6 months old.

* * * *

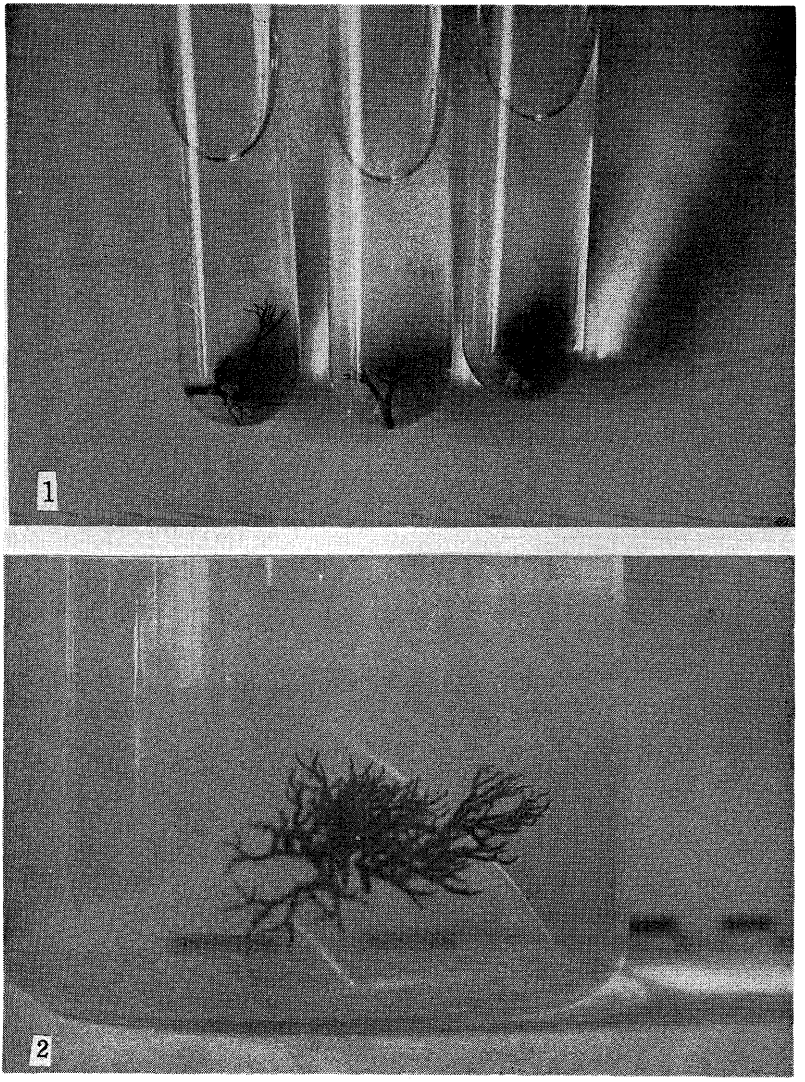
紅藻植物門真正紅藻綱スギノリ目ヒカゲノイト科のヒカゲノイト (*Nemastoma nakamurae* Yendo) の果胞子と四分胞子の発芽体を単種培養によつてその生活史を研究した。両胞子ともに発芽して盤状体を形成した。3ヶ月後には，その盤状体上に直立体が発出した。その後，この四分胞子直立体も果胞子直立体も同じ形態の植物体に生長し，海にみられるものと同じ形状のものになった。それらの体上に生殖器官が形成されなかったが，本種の生活史はイトグサ型であると考えられた。なお，胞子が発芽してできる盤状体は次の世代までの中間期を過すためのステージであるとともに，その盤状体自体が枝を出して，その数や大きさを増大せしめることから，栄養生殖をするステージでもあると考えられた。

□原 寛・佐藤邦雄・黒沢幸子： **軽井沢の植物** A5, 原色図 124, 挿図 32, 分布図, 本文 310 頁, 1974 年 7 月, 価 ¥6,500。東京文京区, 本郷 6 丁目, 井上書店発行。主な内容は軽井沢の植物の特色, 軽井沢の四季の変化, 注目に価する植物, 軽井沢植物の検索表, 有用および有毒植物, 高等植物目録, 文献, 和名索引, 地図等。著者と軽井沢という地名とは, ともに余りにも知られているので, 今更ことあたらしく吹聴するまでもないが, 原氏は過去 50 年の間にわたり軽井沢の植物に親み, 植研 9 巻 (1933) から 13 巻にわたり「軽井沢のフローラ」を連続記録されたことは周知の通りであるが, その後, 共著者等と共同検討の結果と, 時の経過で若干の追加が必要となったのと, 一般の同好者の便をはかり, 軽井沢の植物をまとめたものと考えられる。

(久内清孝)



I. UMEZAKI: Life history of *Nemastoma nakamurae*



I. UMEZAKI: Life history of *Nemastoma nakamurae*