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Studies on Planktonic Blue-green Algae 10. Classification of Planktonic *Anabaena* with Coiled Trichomes Maintained in the National Science Museum, Tokyo

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Abstract Twenty seven strains of planktonic *Anabaena* with regularly coiled trichomes from twenty one localities in Japan were cultured under the same conditions. The form and dimensions of cells, heterocytes, akinetes and coils of all the strains were examined under a microscope. They were classified into nine species, *A. akankoensis*, *A. circinalis*, *A. crassa*, *A. mucosa*, *A. oumiana*, *A. pseudocompacta*, *A. reniformis*, *A. spiroides* and *A. ucrainica*. Of morphological characteristics, coil form is the most changeable within several years of culture, but the form and dimensions of cells, heterocytes and akinetes are stable enough to identify at the species level. Some taxonomic notes are given.

Key words: morphology, taxonomy, planktonic, *Anabaena*, strains, culture, blue-green algae, Japan.

Since Professor Okamura recorded planktonic *Anabaena*, *A. flos-aquae* and *A. spiroides* var. *crassa* from Japanese waters for the first time (Okamura 1916), eleven *Anabaena* species with coiled trichomes have been reported up to today. These are *Anabaena akankoensis* M. Watan., *A. circinalis* Rabenh. ex Born. et Flah., *A. crassa* (Lemm.) Kom.-Legn. et Cronb., *A. eucompacta* Li et M.M. Watan., *A. minispora* M. Watan., *A. mucosa* Kom.-Legn. et Elor., *A. oumiana* M. Watan., *A. pseudocompacta* M. Watan., *A. reniformis* Lemm. emend. Aptek., *A. spiroides* Kleb. and *A. ucrainica* (Schkorb.) M. Watan.

In order to examine morphological variations among *Anabaena* strains under the same controlled conditions, we have collected many plankton samples from different localities in Japan, and obtained a hundred strains from twenty water bodies. For the present study we used 27 strains from 21 different collecting sites and compared dimensions of vegetative cells, heterocytes, akinetes and trichome coils. After a long culture many strains lose the natural forms which they had when they lived in nature, but the strains keep the necessary characteristics to identify them at the species level.

Materials and Methods

The strains used in this study are shown in Table 1. They were maintained in the stock room of the Department of Botany, National Science Museum in Tsukuba, Ibaraki prefecture (TAC, Tsukuba Algal Collection). Most of the strains used in this study were isolated in 2001 and 2002 from eutrophic lakes and ponds in Japan (Fig. 1). Samples were collected with a plankton net and carried in small vials to our laboratory within a few days. Isolation was done by the pipette washing method under a binocular. Throughout this study, 10 ml of NaCB medium (Ichimura and Watanabe 1977) contained in a screw cap test tube (18 mm×150 mm) was used. The cultures were illuminated by cool-white fluorescent lamps; photon flux density was about 20 μmol/m^2/sec and the photoperiod was 12 hours light and 12 hours dark. The temperature was kept at 20°C.

Table 1. *Anabaena* strains with regularly coiled trichomes used in this study.

TAC No.	Collecting site	Date of collection	Collector	Isolator
425	Lake Toro-ko, Hokkaido Pref.	Aug. 1990	Watanabe M.	Niiyama Y.
449	Lake Sagami-ko, Kanagawa Pref.	Aug. 1991	Watanabe M.	Niiyama Y.
455	Lake Tsukui-ko, Kanagawa Pref.	—	Watanabe M.	Watanabe M.
464	Lake Inba-numa, Chiba Pref.	Aug. 1996	Watanabe M.	Watanabe M.
473	Nigo-ike pond, Hyogo Pref.	Jul. 2001	Nakagawa M.	Niiyama Y.
477	Nigo-ike pond, Hyogo Pref.	Jul. 2001	Nakagawa M.	Niiyama Y.
478	Shin-ike pond, Hyogo Pref.	Jul. 2001	Nakagawa M.	Niiyama Y.
481	Tatsugaya-ike pond, Hyogo Pref.	Jul. 2001	Nakagawa M.	Niiyama Y.
482	Lake Inba-numa, Chiba Pref.	Sept. 2001	Watanabe M.	Niiyama Y.
484	Lake Tega-numa, Chiba Pref.	Sept. 2001	Watanabe M.	Niiyama Y.
486	Lake Biwa-ko (Akanoi), Shiga Pref.	Oct. 2001	Watanabe M.	Niiyama Y.
490	Lake Yogo-ko, Shiga Pref.	Oct. 2001	Watanabe M.	Niiyama Y.
492	a pond, Niigata Pref.	Oct. 2001	M. Dai Naw	Niiyama Y.
497	Lake Shiroyama-ko, Kanagawa Pref.	Nov. 2001	Arii S.	Niiyama Y.
501	Lake Shiroyama-ko, Kanagawa Pref.	Nov. 2001	Arii S.	Niiyama Y.
504	Soe-ike-nishi pond, Hyogo Pref.	Nov. 2001	Nakagawa M.	Niiyama Y.
505	Lake Akan-ko, Hokkaido Pref.	Sept. 2002	Tuji A.	Niiyama Y.
509	Funada-ike pond, Chiba Pref.	Aug. 2002	Nakaike T.	Niiyama Y.
518	a pond in Fujiidera City, Osaka Pref.	Oct. 2002	Tuji A.	Niiyama Y.
520	Lake Suwa-ko, Nagano Pref.	Oct. 2002	Tuji A.	Niiyama Y.
522	a pond in Mannou town, Kagawa Pref.	Oct. 2002	Tuji A.	Niiyama Y.
529	Lake Biwa-ko (Otsu), Shiga Pref.	Oct. 2002	Tuji A.	Niiyama Y.
539	Lake Hachiro-gata, Akita Pref.	Jul. 2002	Sasaki S.	Niiyama Y.
541	Lake Hachiro-gata, Akita Pref.	Aug. 2002	Sasaki S.	Niiyama Y.
543	a pond in Fujiidera City, Osaka Pref.	Oct. 2002	Tuji A.	Niiyama Y.
551	Mishima-ike pond, Shiga Pref.	—	Tsujimura S.	Tsujimura S.
553	Lake Hachiro-gata, Akita Pref.	Sept. 2002	Sasaki S.	Niiyama Y.

Observations and Discussions

Morphological observations such as the forms and dimensions of vegetative cells, heterocytes, akinetes and trichomes as well as the relative location of the akinetes to the heterocytes have been performed for the twenty seven strains. All the strains were classified into the following nine species. The species are arranged approximately from small to large in vegetative cell diameter (Table 2).

1. ***Anabaena reniformis*** Lemm. emend. Aptek. Figs. 3–10

Cells spherical to slightly elongated, 3.0–6.0 μm wide, 2.5–10.0 μm long.; l/w ratios 0.67–2.50. Heterocytes spherial to slightly elongated, 4.5–7.5 μm wide, 5.5–10.0 μm long. Akinetes spherical, one to three in series, attaching usually at both sides of heterocytes, 8.0–12.5 μm wide. Trichomes regularly coiled, closely contracted, coils 20.0–50.0 μm wide, 5.0–25.0 apart.

The strains examined were TAC 478, 481, 484 and 543.

Lemmermann (1898) described *Anabaena reniformis* nov. spec. from Steinhuder Meer. The new species was characterized by kidney formed vegetative cells, though he could not observe akinetes. Aptekar reported the same alga developing akinetes richly from around Dniepro-Petrovsk in 1927. Elenkin (1938) cited Aptekar's figures in his monograph. Measuring the original figures (Fig. 2) cited by Elenkin (l.c.) l/w ratios in vegetative cells are 0.8–1.8. These measurements are comparable with those of our algae.

Anabaena reniformis was recorded by Niiyama (1996) for the first time in Japan from Sikata-futago-ike pond, Hyogo prefecture and succeedingly recorded by Watanabe (1998) from Lake Koya-ike, Oosaka prefecture. According to Professor Yukio Kimura of Mukogawa Women's University, this alga caused heavy water bloom in

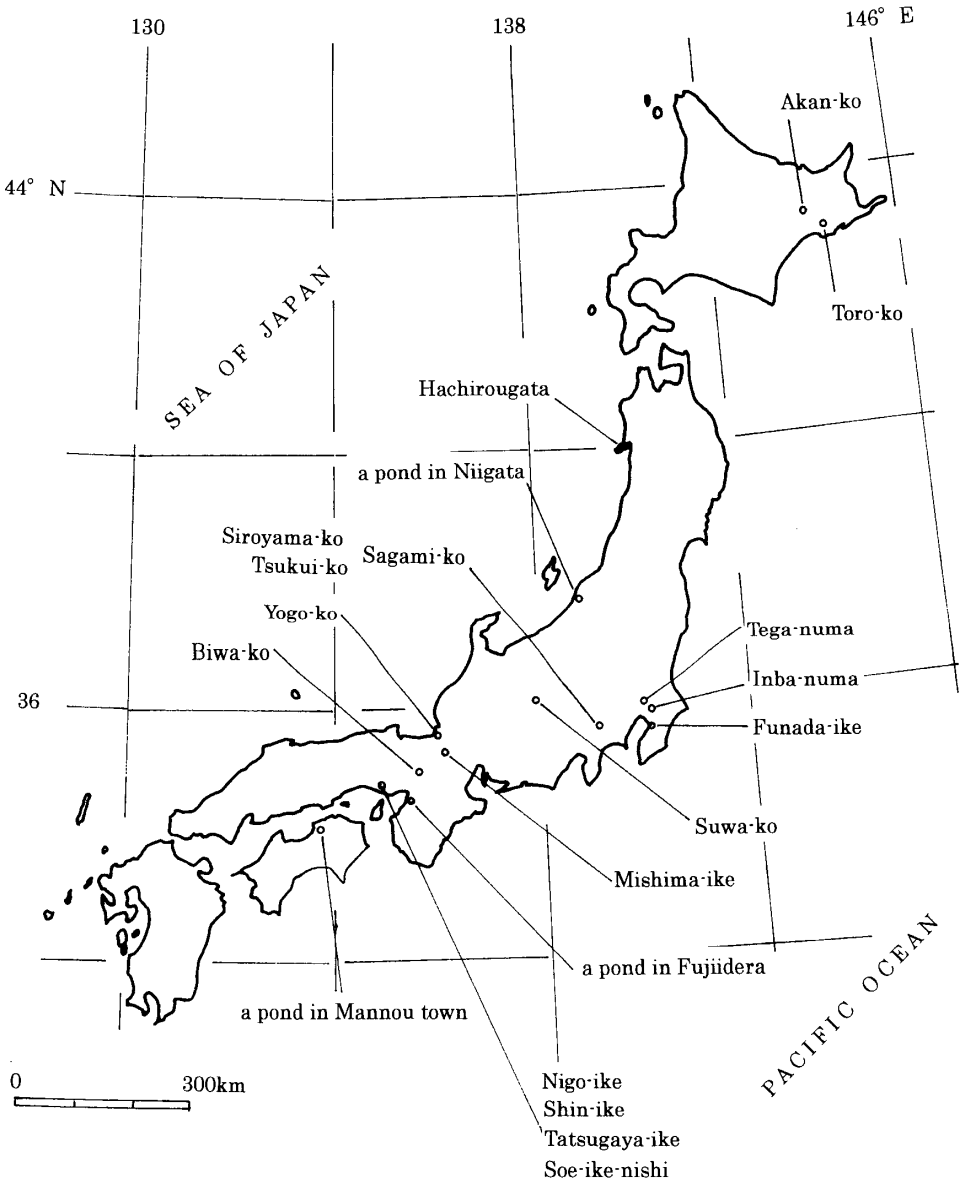


Fig. 1. Localities of strains isolated and used in this study.

Lake Koya-ike every year. In this paper, four localities, Shin-ike pond, Tatsugaya-ike pond in Hyogo prefecture, a pond in Fujiidera city, Oosaka prefecture and Lake Tega-numa, Chiba prefecture are newly added to distribution records in Japan.

Some strains lose their original form during a long culture year by year. TAC 481 isolated in July, 2001 from Tatsugaya-ike pond has now lost its regularly spiral form. The trichomes of the alga are almost straight these days. Measurements of cells, heterocytes and akinetes in strains show a more or less wider range than those in natural populations.

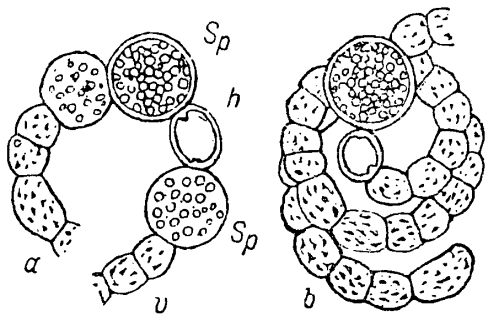


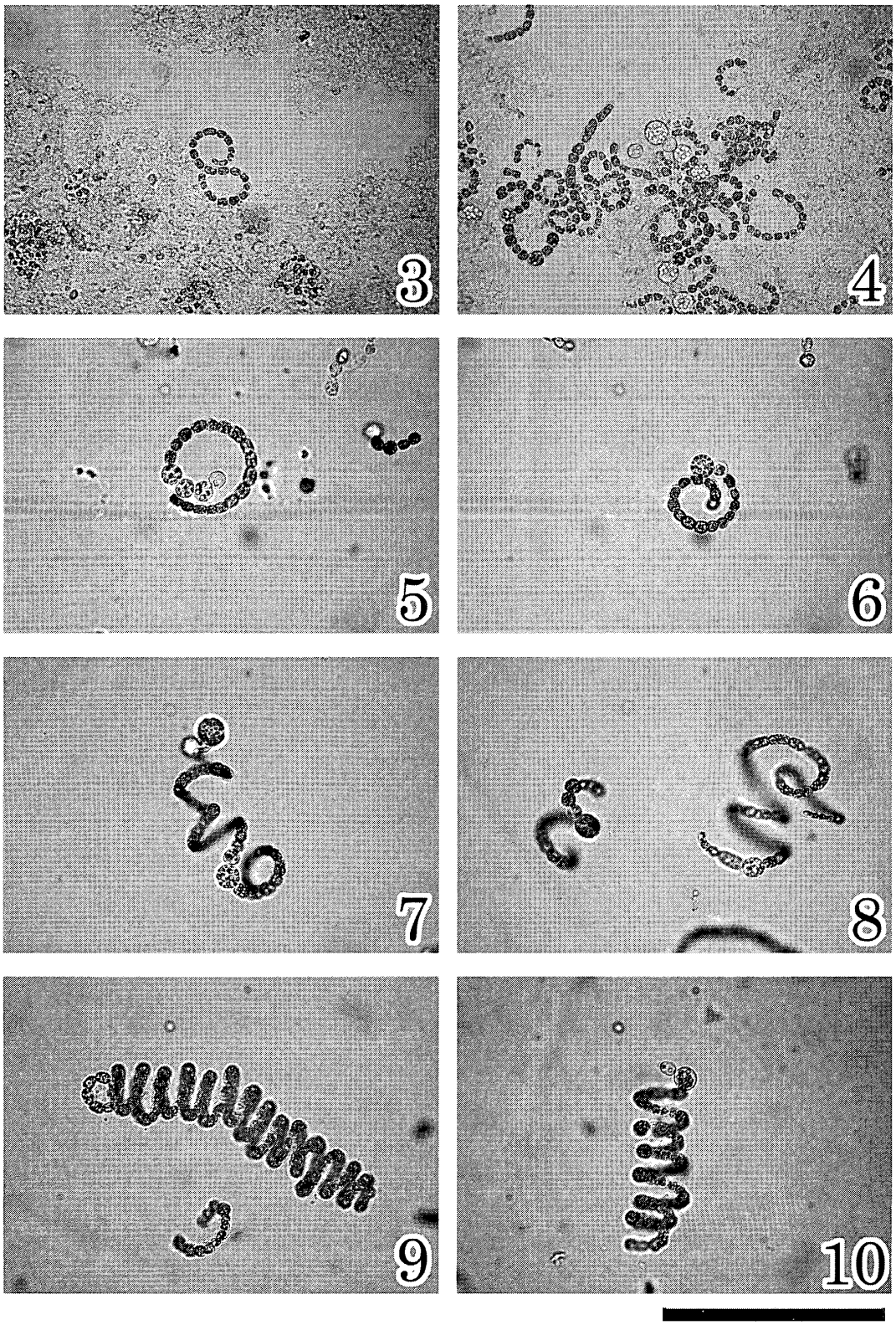
Fig. 2. *Anabaena reniformis* Lemm. emend. Aptekar after Elenkin.

Table 2. Dimensions of vegetative cells, heterocytes, akinetes and coils among strains used in this study.

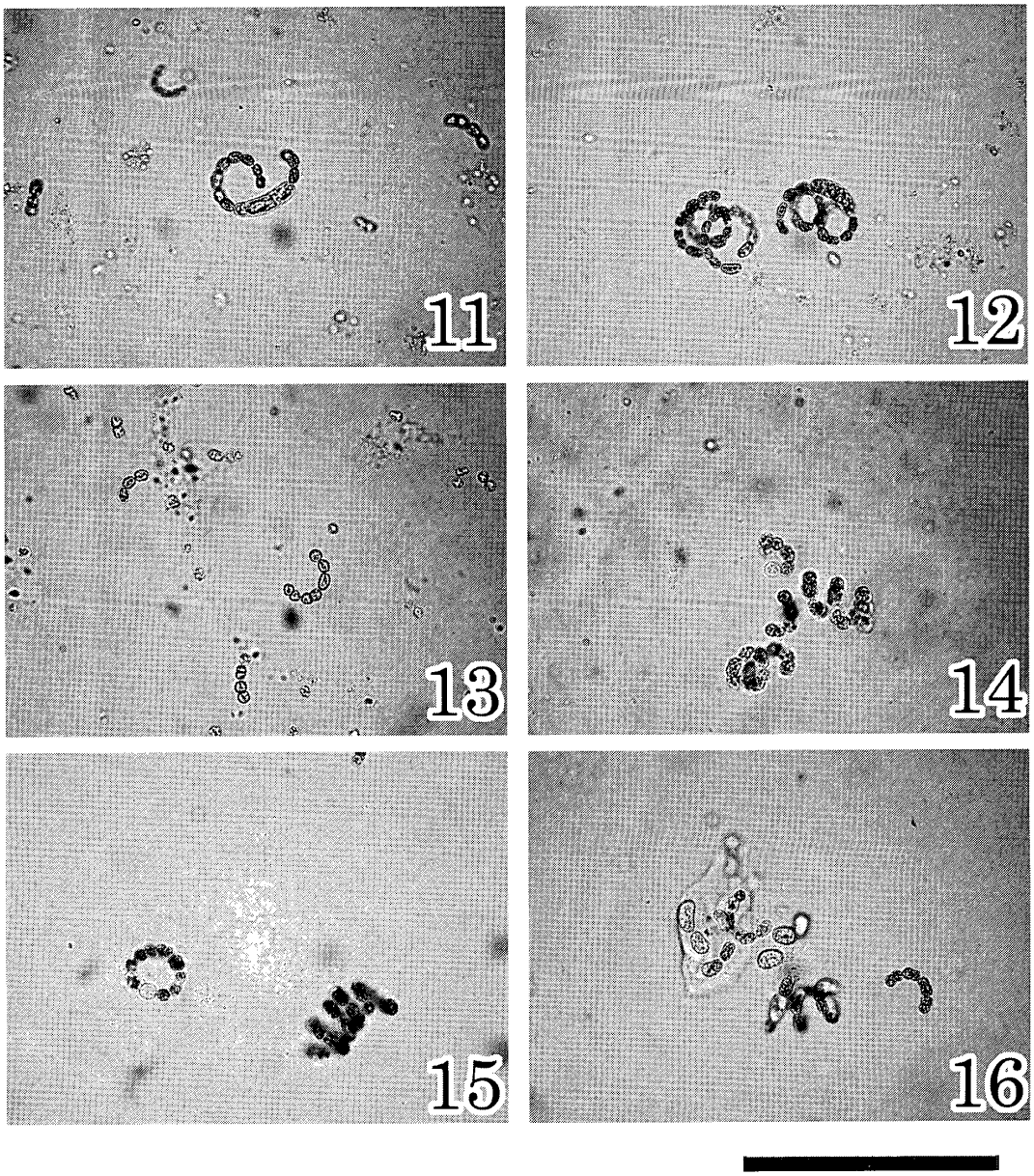
Species	TAC No.	Vegetative Cells			Heterocytes		
		Width μm	Length μm	L/W	Width μm	Length μm	L/W
A. reniformis	481	3.0–4.8 (3.87)	2.5–6.5 (4.48)	0.67–1.63 (1.16)	4.5–6.3 (5.53)	5.5–7.5 (6.48)	1.10–1.27 (1.17)
	484	3.0–5.5 (4.16)	3.0–10.0 (5.17)	1.00–2.00 (1.25)	*	*	*
	478	3.0–5.3 (4.40)	3.0–8.0 (5.16)	0.67–2.50 (1.21)	5.0–7.5 (6.33)	5.5–10.0 (7.31)	1.00–1.67 (1.18)
	543	3.8–6.0 (4.58)	3.8–7.5 (5.40)	0.84–1.40 (1.18)	5.8–6.0 (5.90)	6.5–7.5 (7.00)	1.08–1.29 (1.18)
A. pseudocompacta	539	3.0–5.0 (4.24)	3.5–7.5 (5.29)	0.73–2.50 (1.30)	5.0–7.5 (6.25)	6.3–8.0 (7.15)	1.07–1.26 (1.16)
	541	3.0–5.0 (4.43)	2.5–7.5 (4.93)	0.50–1.80 (1.13)	5.0–5.5 (5.16)	5.0–6.5 (5.52)	1.00–1.30 (1.07)
	477	4.0–6.0 (4.77)	2.5–7.5 (5.41)	0.50–1.88 (1.14)	5.0–6.3 (5.41)	5.0–7.5 (6.80)	1.00–1.42 (1.26)
A. oumiana	464	5.0–7.0 (5.96)	5.0–7.5 (6.35)	0.79–1.50 (1.09)	7.5	7.5	1.00
	509	5.5–7.5 (6.13)	3.8–6.8 (5.08)	0.53–1.13 (0.84)	7.5–8.8 (8.08)	7.5–8.8 (8.08)	1.00
A. spiroides	551	5.0–7.3 (5.90)	3.5–7.5 (5.63)	0.70–1.22 (0.95)	5.8–7.5 (6.93)	7.5–9.5 (8.17)	1.00–1.29 (1.19)
	504	7.5–9.5 (8.33)	5.5–8.0 (6.55)	0.66–1.00 (0.79)	7.5–9.5 (8.78)	7.5–9.3 (8.28)	0.86–1.06 (0.94)
A. akankoensis	505	6.3–8.8 (7.40)	5.0–11.5 (7.95)	0.64–1.53 (1.08)	7.5–10.0 (9.06)	7.5–10.0 (9.37)	1.00–1.11 (1.04)
A. crassa	518	7.0–10.0 (8.08)	5.0–8.5 (6.62)	0.50–1.00 (0.83)	7.5–9.5 (8.00)	7.3–9.5 (8.10)	0.97–1.10 (1.01)
	529	8.0–11.0 (9.93)	5.0–10.0 (6.97)	0.49–1.00 (0.70)	*	*	*
	486	9.0–11.3 (9.99)	4.5–7.5 (5.95)	0.45–0.75 (0.59)	*	*	*
	490	8.0–11.8 (10.01)	4.5–10.0 (7.41)	0.47–1.00 (0.74)	*	*	*
	473	8.5–12.5 (10.21)	4.8–10.5 (7.08)	0.48–1.00 (0.70)	*	*	*
	492	8.5–12.3 (10.31)	5.0–10.0 (7.85)	0.49–1.00 (0.77)	10.0–12.5 (10.92)	9.3–11.3 (10.28)	0.90–1.03 (0.94)
	522	9.3–13.0 (11.79)	6.3–12.5 (8.70)	0.50–0.96 (0.74)	12.5	12.5	1.00
	520	10.0–13.0 (12.03)	5.0–10.0 (7.51)	0.40–0.95 (0.63)	12.5–13.8 (13.10)	12.5–13.8 (13.10)	1.00
A. ucrainica	449	9.5–12.0 (10.43)	4.5–10.0 (7.33)	0.47–0.95 (0.70)	*	*	*
	455	10.0–12.5 (11.03)	4.5–8.0 (6.29)	0.40–0.76 (0.57)	*	*	*
A. mucosa	425	10.0–13.0 (11.94)	6.3–12.5 (9.54)	0.53–1.00 (0.79)	11.3–13.3 (12.57)	13.0–15.0 (14.02)	1.08–1.16 (1.12)
A. circinalis	482	7.5–10.5 (9.08)	5.0–12.5 (7.81)	0.53–1.33 (0.86)	8.0–10.0 (9.43)	7.5–11.3 (9.66)	0.93–1.13 (1.02)
	497	9.3–13.0 (10.72)	4.5–12.5 (7.14)	0.45–1.00 (0.65)	10.0–12.5 (11.32)	10.0–13.0 (11.06)	0.93–1.07 (0.98)
	553	10.0–12.5 (11.00)	6.3–10.0 (9.15)	0.63–1.00 (0.83)	10.0–12.5 (10.55)	10.0–12.5 (10.80)	0.97–1.14 (1.02)
	501	9.5–13.3 (11.48)	7.0–10.0 (8.49)	0.59–1.00 (0.75)	12.5–13.3 (12.80)	12.0–13.0 (12.42)	0.90–1.00 (0.97)

Species	TAC No.	Akinetes			Coils	
		Width μm	Length μm	L/W	Width μm	Distance μm
A. reniformis	481	8.0–10.0 (9.41)	8.8–11.3 (9.96)	1.00–1.19 (1.06)	20.0–35.7	**
	484	8.0–12.5 (10.50)	8.0–12.5 (10.53)	0.95–1.05 (1.00)	20.0–30.0	7.5–10.0
	478	8.8–12.0 (9.91)	8.0–12.5 (10.48)	0.91–1.19 (1.06)	25.0–50.0	10.0–25.0
	543	8.8–12.5 (10.48)	8.8–12.5 (10.48)	1.00–1.00 (1.00)	20.0–30.0	5.0–10.0
A. pseudocompacta	539	7.5–7.5 (7.50)	20.5–26.3 (23.10)	2.73–3.51 (3.08)	17.5–30.0	7.5–10.0
	541	6.3–7.5 (6.90)	16.0–17.5 (16.75)	2.33–2.54 (2.43)	15.0–20.0	5.0–10.0
	477	5.0–8.0 (7.18)	10.0–15.0 (12.39)	1.33–3.00 (1.76)	17.5–30.0	5.0–10.0
A. oumiana	464	10.0–12.5 (11.28)	10.0–12.8 (11.37)	1.00–1.05 (1.01)	20.0–40.0	ca. 20.0
	509	9.5–10.5 (10.21)	9.5–10.5 (10.21)	1.00–1.00 (1.00)	30.0–37.5	10.0–30.0
A. spiroides	551	8.0–10.0 (9.62)	18.0–25.0 (20.31)	1.80–2.50 (2.11)	12.5–25.0	5.0–7.5
	504	8.0–11.3 (9.78)	19.5–28.5 (22.66)	2.00–2.64 (2.32)	30.0–35.0	ca. 30.0
A. akankoensis	505	12.0	27.5	2.29	37.7–75.0	30.0–90.0
A. crassa	518	12.5–15.8 (13.83)	15.0–20.0 (17.05)	1.14–1.37 (1.23)	32.5–40.0	30.0–40.0
	529	15.5–20.0 (18.21)	20.3–27.5 (24.48)	1.27–1.43 (1.34)	45.0–50.0	55.0–62.5
	486	15.0–18.8 (16.88)	20.0–26.3 (22.60)	1.17–1.45 (1.34)	42.5–45.0	**
	490	16.3–20.0 (17.87)	20.0–27.5 (22.43)	1.14–1.46 (1.26)	50.0–60.0	50.0–60.0
	473	15.0–18.8 (16.41)	17.0–21.3 (19.12)	1.13–1.33 (1.17)	30.0–40.0	ca. 50.0
	492	14.5–17.5 (16.08)	17.0–22.5 (19.90)	1.17–1.32 (1.24)	30.0–50.0	ca. 50.0
	522	17.5–22.5 (20.04)	22.5–27.5 (25.02)	1.13–1.57 (1.25)	50.0–62.5	67.5–82.5
	520	17.5–20.0 (18.23)	20.0–25.5 (23.71)	1.14–1.41 (1.30)	32.5–50.0	30.0–50.0
A. ucrainica	449	20.0–22.5 (20.38)	20.0–23.0 (21.19)	1.00–1.13 (1.04)	50.0–70.0	20.0–30.0
	455	17.5–22.5 (20.14)	18.0–22.5 (20.07)	0.90–1.09 (1.00)	50.0–62.5	37.5–50.0
A. mucosa	425	17.8–22.5 (19.99)	21.3–27.5 (23.39)	1.13–1.25 (1.17)	160.0–175.0	**
A. circinalis	482	12.5–16.3 (14.42)	21.3–30.0 (27.52)	1.31–2.07 (1.94)	120.0–150.0	**
	497	12.5–17.5 (15.67)	29.5–46.0 (37.05)	1.84–2.71 (2.38)	62.5–87.5	ca. 50.0
	553	13.0–20.0 (16.12)	22.5–31.5 (27.65)	1.42–2.33 (1.74)	110.0–145.0	**
	501	15.0–22.5 (17.93)	25.5–38.0 (31.97)	1.38–2.50 (1.81)	45.0–75.0	ca. 50.0

*: not developed; **: not be measured because of fragmentation; ( ): mean value.



Figs. 3–10. *Anabaena reniformis*, 3–4: TAC 481, 5–6: TAC 484, 7–8: TAC 478, 9–10: TAC 543. Scale bar=100 μm.



Figs. 11–16. *Anabaena pseudocompacta*, 11–12: TAC 539, 13–14: TAC 541, 15–16: TAC 477. Scale bar=100 μm.

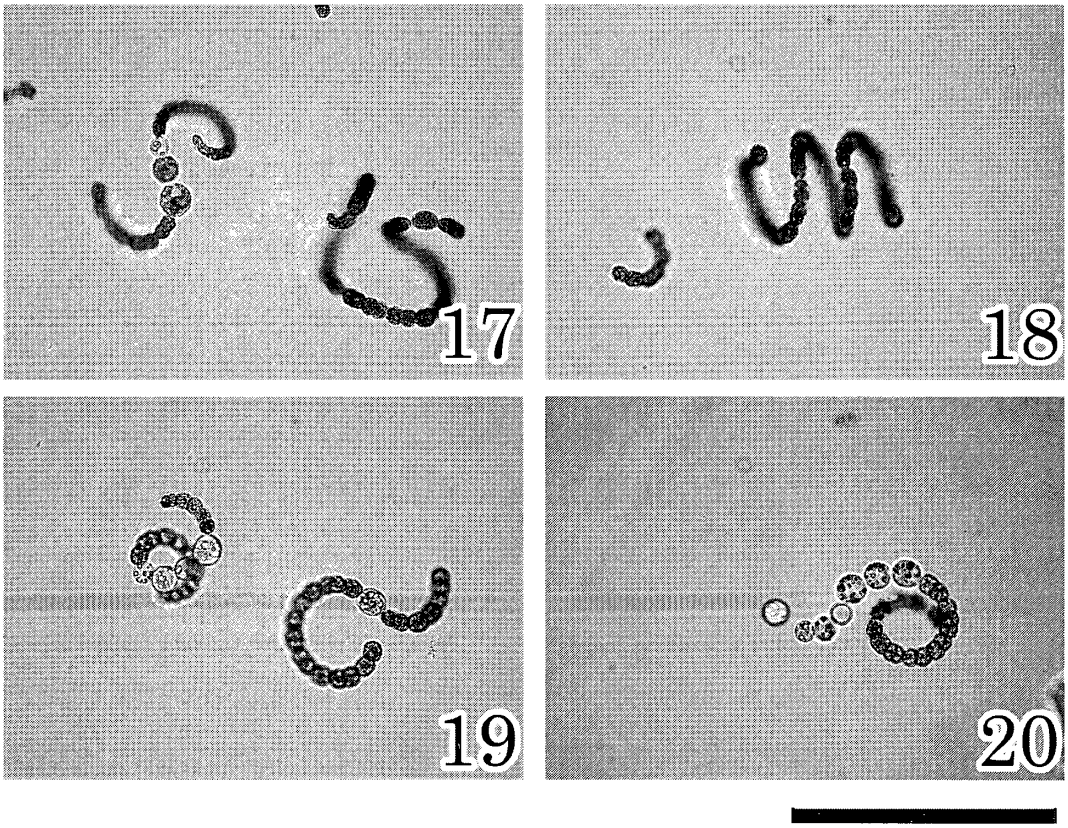
2. ***Anabaena pseudocompacta*** M. Watan.
Figs. 11–16

Cells spherical to slightly elongated, 3.0–6.0 μm wide, 2.5–7.5 μm long; l/w ratios 0.50–2.50. Heterocytes spherial to slightly elongated, 5.0–7.5 μm wide, 5.0-8.0 μm long. Akinetes long ellipsoidal, remote from heterocytes, 6.3–8.0 μm wide, 10.0–26.3 μm long; l/w ratios 1.33–3.51. Trichomes regularly coiled, coils 15.0–30.0 μm wide, 5.0–10.0 μm apart.

Strains examined were TAC 477, 539 and 541.

This alga from Lake Kasumigaura was first reported as *Anabaena spiroides* (Watanabe and Chihara 1980) and afterwards it was described as a new species based on natural samples from Lake Tega-numa and Lake Inba-numa, Chiba prefecture (Watanabe 1996a). In this paper two localities, Nigo-ike pond, Hyogo prefecture and Lake Hachirougata, Akita prefecture are newly added to distribution records in Japan. This alga resembles *A. reniformis* in sterile conditions, but clearly differs in akinete form and in relative location of akinetes to heterocytes.

Measurements of cells in the strains used in



Figs. 17–20. *Anabaena oumiana*, 17–18: TAC 464, 19–20: TAC 509. Scale bar=100 μm.

this study are slightly smaller than those in a natural population from Lake Teganuma (Watanabe 1996a).

3. ***Anabaena oumiana*** M. Watan.

Figs. 17–20

Cells spherical, 5.0–7.5 μm wide, 3.8–7.5 μm long: l/w ratios 0.53–1.50. Heterocytes spherical, 7.5–8.8 μm wide. Akinetes spherical, attaching at both sides of heterocytes, 9.5–12.5 μm wide. Coils slightly irregular, 20.0–40.0 μm wide, 10.0–30.0 μm apart.

The strains examined were TAC 464 and 509.

This alga was originally described by Watanabe (1996) studying natural samples from Lake Biwa-ko, Shiga prefecture. In this paper, two localities, Lake Inba-numa and Funada-ike pond in Chiba prefecture, are newly added to distribution records in Japan. Measurements of cells in strains examined in this study show a slightly wider range than those in the natural population (Watanabe l.c.).

This alga seems to be most identifiable with *A. spiroides sensu auct.* (Klebahn 1895), because both algae have spherical akinetes attaching at one or both sides of heterocytes, and they also show similar forms and dimensions in cells, heterocytes, akinetes and coils. The concept of *Anabaena spiroides*, especially on akinetes, was changed after original publication. Lemmermann (1910) defined akinete form as "Akinetes at first spherical, later slightly curved, almost hexagonal in optical longitudinal section". Lemmermann (l.c.) did not mention the relative location of akinetes to heterocytes, but Geitler (1932) added a new concept "next to heterocysts or remote from heterocysts". Thus the current concept of *Anabaena spiroides* has been established.

According to Klebahn (l.c.) *A. spiroides* has cells 6.5–8 μm in diam. and a young akinete 14 μm in diam. When this akinete develops into elliptic form, the akinete also attains a wider diameter than 14 μm. Few planktonic species of *Anabaena* have an akinete in which width gains

more than two times more than vegetative cells. A rare case can be seen in *Anabaeba macrospora* Kleb. (Kleb. 1895, akinete w./cell w. ratio is more than 2.6; Watanabe, Kiyosawa and Hayashi 1985, Watanabe 1992, akinete w./cell w. latio is 2.4).

To his shame Watanabe (1996) passed at least the following three papers unmarked. Frémy (1930) recorded *Anabaena spiroides* from Victoria-Nyanza, Africa with a figure of spherical akinetes attaching to both side of herocytes. Tiffany and Britton (1952) recorded the same alga with a figure after Frémy (l.c.) from Illinois, USA. Baker (1991) also recorded the same alga from several water bodies in Australia. After Klebahn published the original description we can not fined very many records on *Anabaena spiroides* in an original sense in Europe or in the USA, regrettably.

4. ***Anabaena spiroides*** Kleb. Figs. 21–26

Cells spherical, 5.0–9.5 μm wide, 3.5–8.0 μm long; l/w ratios 0.66–1.22. Heterocytes spherical, 5.8–9.5 μm wide, 7.5–9.5 μm long. Akinetes long ellipsoidal, remote from heterocytes, 8.0–11.3 μm wide, 18.0–28.5 μm long; l/w ratios 1.80–2.64. Coils slightly irregular, 12.5–35.0 μm wide, ca 5.0–30.0 μm apart.

The strains examined were TAC 504 and 551.

As seen in Finland (Kom.-Legn. and Elor. 1992) *Anabaena spiroides* does not distribute so widely in Japanese waters as *A. crassa*. and *A. circinalis* do. Most records of *A. spiroides* lacking akinete information were possibly of *A. oumiana*, *A. crassa* or *A. circinalis*. The forms and dimensions of akinetes in this species are the same as those in *A. pseudocompacta*, but the cells in the former are larger and relatively shorter than those of the latter.

Measurements of cells and akinetes in strains examined in this study show a slightly wider range than those in a natural population at Lake Koyama-ike (Watanabe 1998).

5. ***Anabaena akankoensis*** M. Watan. Figs. 27–28

Cells almost spherical, sometimes somewhat protruding at both ends, 6.3–8.8 μm wide, 5.0–11.5 μm long: l/w ratios 0.64–1.53. Heterocytes spherical, 7.5–10.0 μm wide, 7.5–10.0 μm long.

The strain examined was TAC 505.

Only one immature akinete was observed during the present study. The akinete is elongated, 12.0 μm wide and 27.5 μm long. This alga was reported from Lake Akan-ko by the first author of this paper for the first time as *Anabaena circinalis* (Watanabe 1971) and described as a new species after examinations on enough natural samples with mature akinetes by the same author (Watanabe 2003). Akinetes of *A. akankoensis* develop at both sides of and one or two cells remote from heterocytes. The strain TAC 505 was isolated from the same natural sample with a preserved specimen, no. 54054 (TNS).

Measurements of cells in this study show a wider range than those in a natural population from Lake Akan-ko, sample no. 54054 in TNS (Watanabe l.c.).

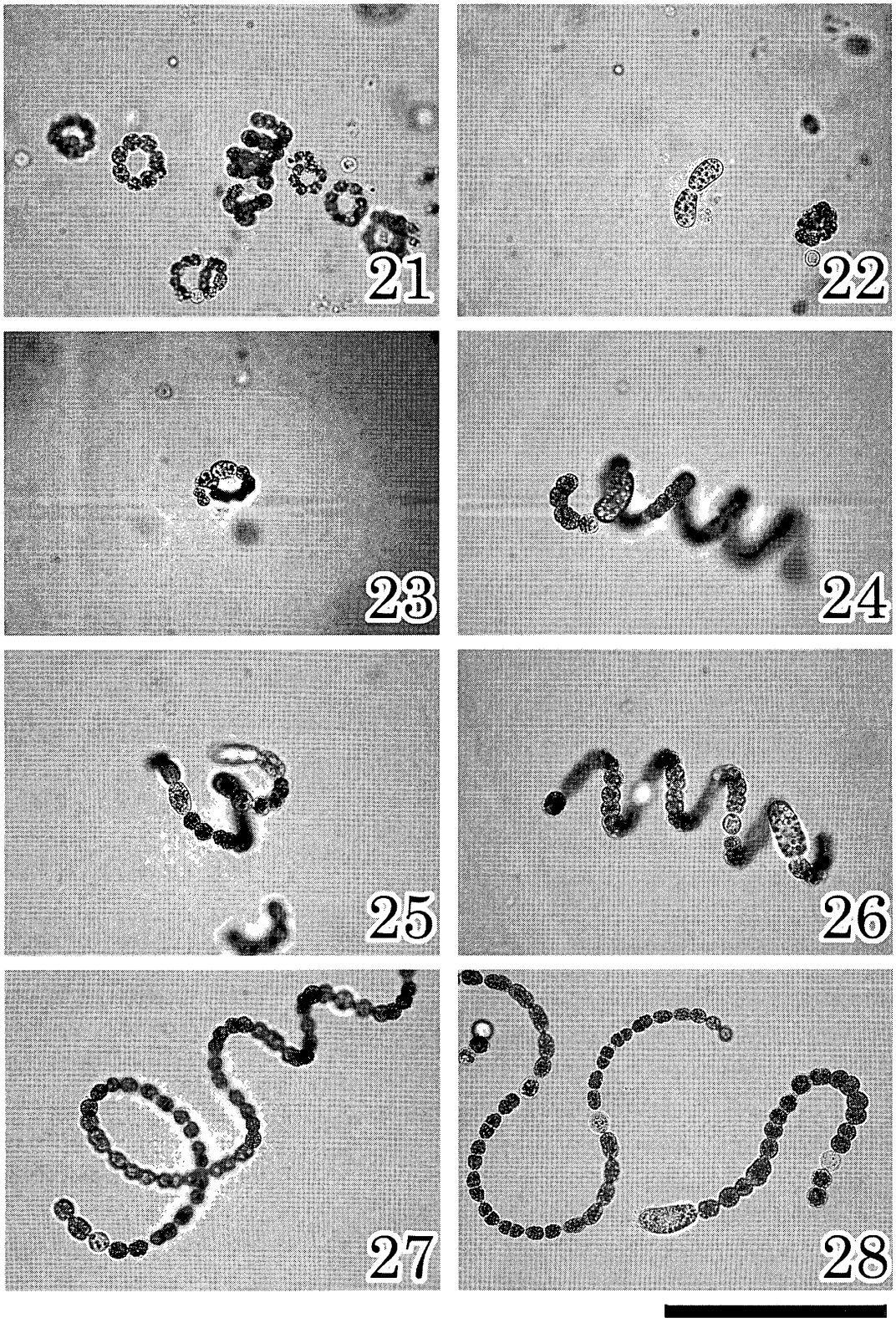
This species resembles *A. fusuca* Hill (1976) described from a Minnesota lake in the forms of cells, heterocytes and akinetes, but clearly differs in dimensions (Watanabe l.c.).

6. ***Anabaena crassa*** (Lemm.) Kom.-Legn. and Cronb. Figs. 29–42

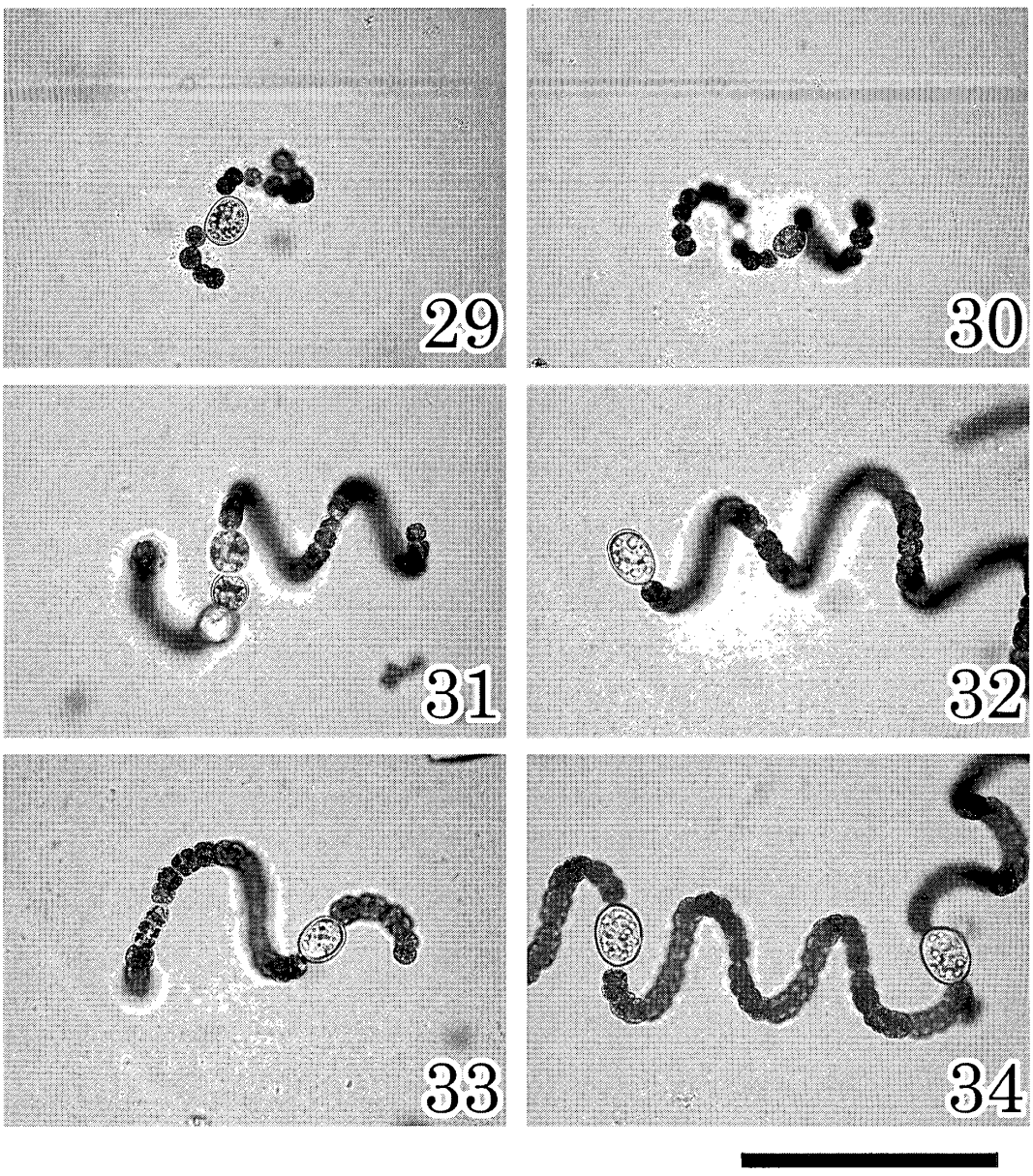
Cells spherical, 7.0–13.0 μm wide, 4.5–12.5 μm long; l/w ratios 0.40–1.00. Heterocytes spherical, 7.5–13.8 μm wide, 7.3–13.8 μm long. Akinetes ellipsoidal, remote from heterocytes, 12.5–22.5 μm wide, 15.0–27.5 μm long; l/w ratios 1.13–1.57. Coils regular, 30.0–62.5 μm wide, 30.0–82.5 μm apart.

The strains examined were TAC 473, 486, 490, 492, 518, 520, 522 and 529.

This alga shows the widest distribution throughout Japan and inter strainal variations are also wide. Four strains did not form heterocytes under the present culture condition. Measurments of cells, heterocytes, akinetes and coils of the strains used in this study show a wider range than those in natural populations (Watanabe 1998).



Figs. 21–26. *Anabaena spiroides*, 21–23: TAC 551, 24–26: TAC 504.
Figs. 27–28. *Anabaena akankoensis*, TAC 505. Scale bar=100 μm.



Figs. 29–34. *Anabaena crassa*, 29–30: TAC 518, 31–33: TAC 529, 34: TAC 486. Scale bar=100 μm.

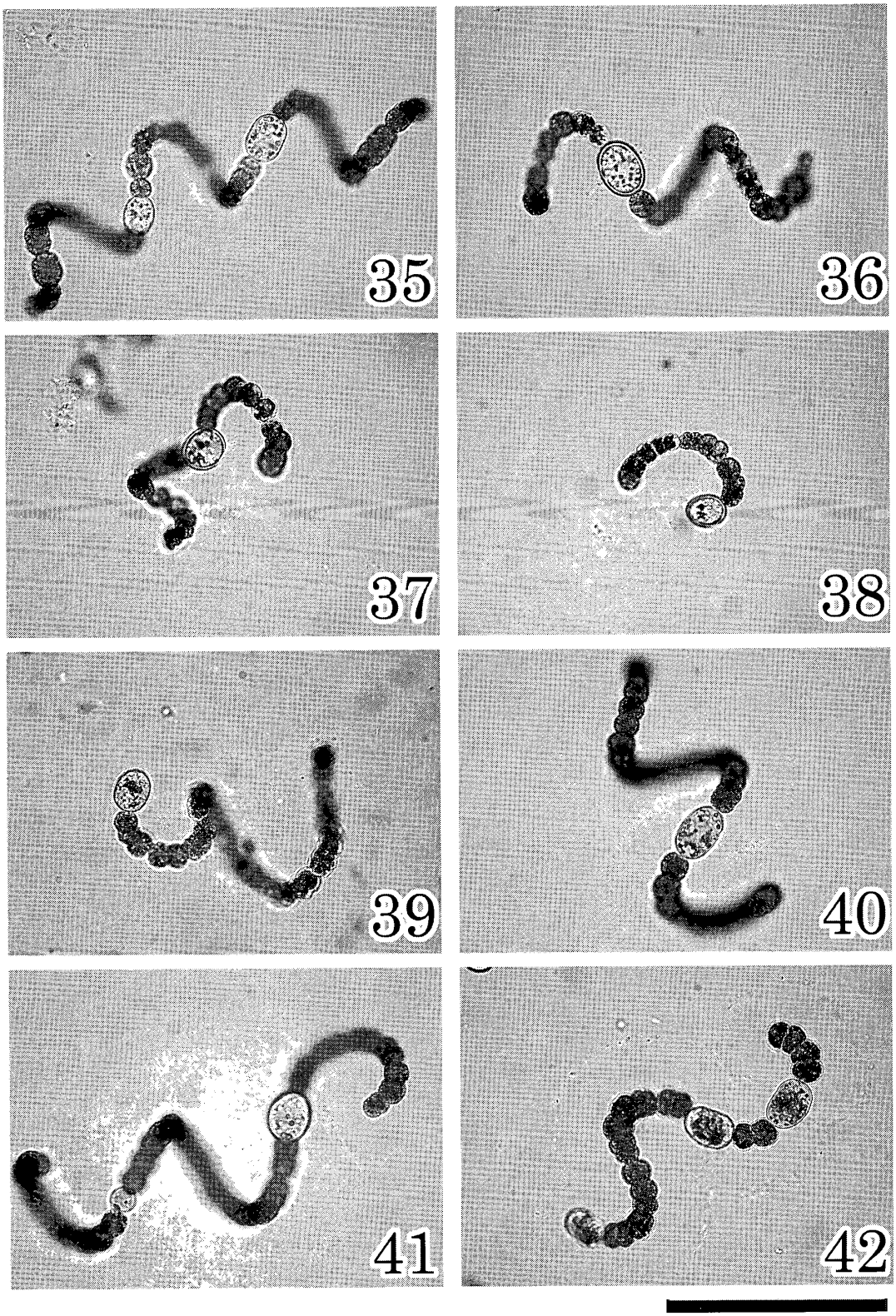
7. ***Anabaena ucrainica*** (Schkorb.) M. Watan. Figs. 43–46

Cells spherical, 9.5–12.5 μm wide, 4.5–10.0 μm long; l/w ratios 0.40–0.95. Heterocytes not observed. Akinetes spherical, 17.5–22.5 μm wide, 18.0–23.0 μm long; l/w ratios 1.00–1.04. Coils regular, 50.0–70.0 μm wide, 20.0–50.0 μm apart.

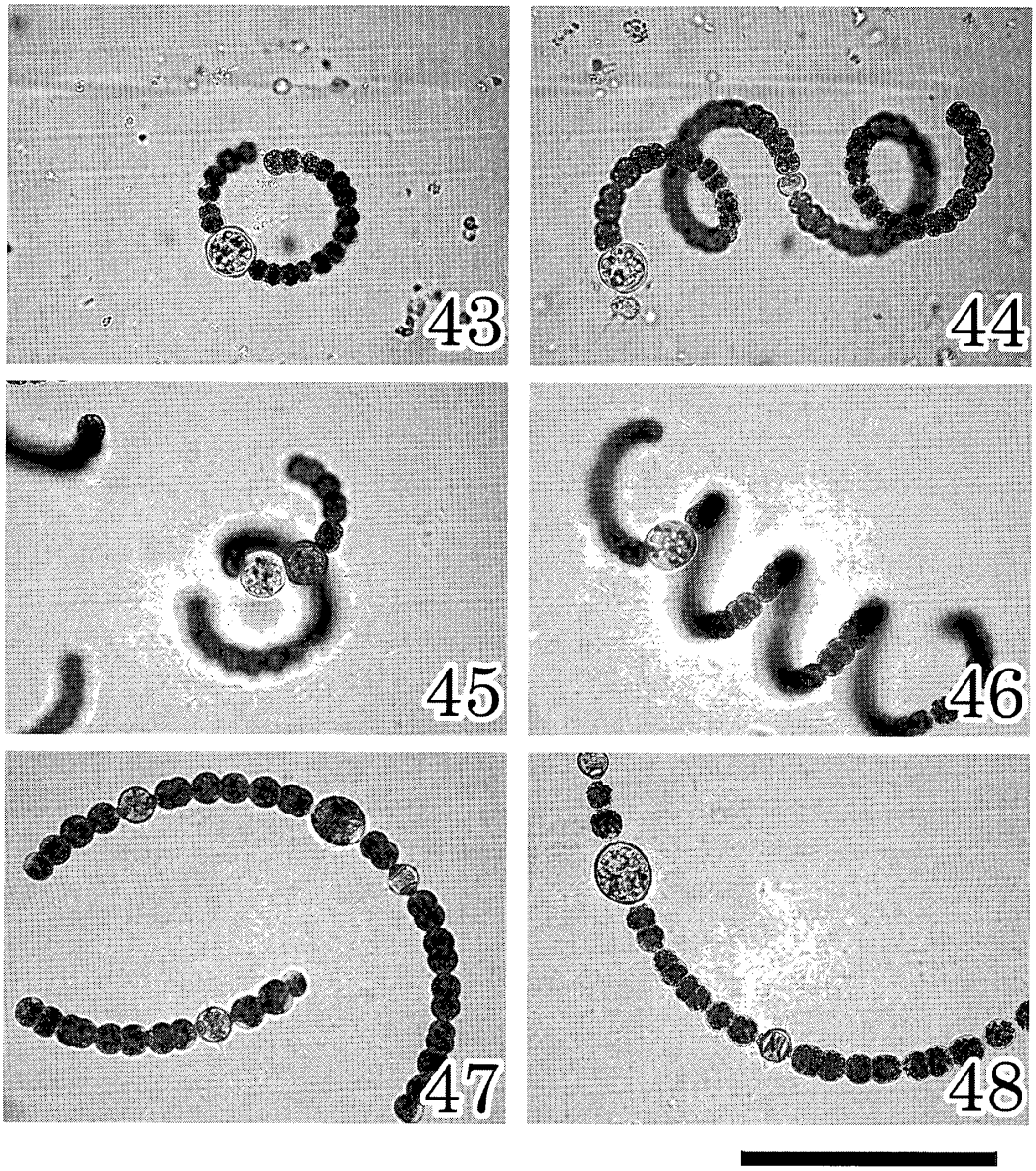
The strains examined were TAC 449 and 455.

This alga was recorded from Lake Sagami-ko by the present author for the first time in Japan (Watanabe 1994, as *A. spiroides* var. *ucrainica* Schkorb.), and was second recorded from Lake Biwa-ko (Watanabe 1996). Measurements of cells and akinetes in the strains used in this study show a slightly wider range than those in natural populations from Lake Sagami-ko and Lake Biwa-ko (Watanabe 1998).

Morphological characters except the akinete form of this species almost resemble those of *A. crassa*. The length width ratios of akinetes deviate from each other. Li et al (2000) measured one of the strains (TAC 449) used in this study and presented the dimensions of the heterocytes as 10.8–15.4 μm in diameter, and of the akinetes as 16.5–31.0 μm in diameter.



Figs. 35–42. *Anabaena crassa*, 35–36: TAC 490, 37–38: TAC 473, 39: TAC 492, 40–41: TAC 522, 42: TAC 520. Scale bar=100 μm.



Figs. 43–46. *Anabaena ucrainica*, 43–44: TAC 449, 45–46: TAC 455.
Figs. 47–48. *Anabaena mucosa*, TAC 425. Scale bar=100 μm.

8. ***Anabaena mucosa*** Kom.-Legn. and Elor. Figs. 47–48

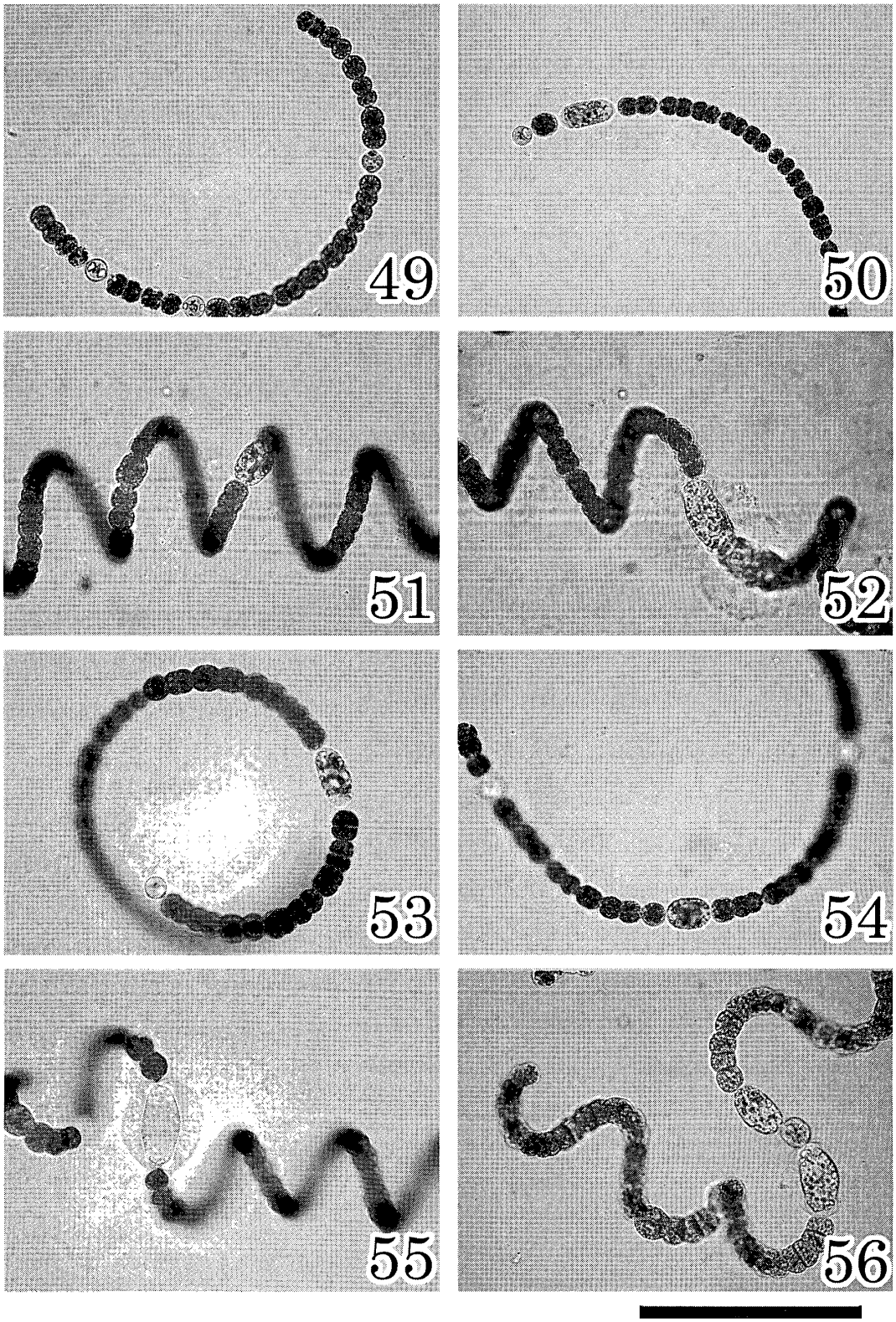
Cells spherical, 10.0–13.0 μm wide, 6.3–12.5 μm long; l/w ratios 0.53–1.00. Heterocytes spherical or slightly elongated, 11.3–13.3 μm wide, 13.0–15.0 μm long. Akinetes slightly longer than wide, remote from heterocytes, 17.8–22.5 μm wide, 21.3–27.5 μm long; l/w ratios 1.16–1.25.

The strain examined was TAC 425.

Morphological characters except the akinete form of this species almost resemble those of *A. circinalis*, but the length width ratios of akinetes markedly deviate from each other. This species was recorded from Lake Hime-numa and Lake Toro-ko in Hokkaido, Lake Higurashi-ike in Aomori prefecture and Lake Sagami-ko in Kanagawa prefecture (Watanabe 1998).

9. ***Anabaena circinalis*** Rabenh. ex Born. and Flah. Figs. 49–56

Cells spherical, 7.5–13.3 μm wide, 4.5–12.5 μm long; l/w ratios 0.45–1.33. heterocytes spherical, 8.0–13.3 μm wide, 7.5–13.0 μm long.



Figs. 49–56. *Anabaena circinalis*, 49–50: TAC 482, 51–52: TAC 497, 53–54: TAC 553, 55–56: TAC 501. Scale bar = 100 μm.

Akinetes elongated or cylindrial, remote from heterocytes, 12.5–22.5 μm wide, 21.3–46.0 μm long; l/w ratios 1.31–2.71. Coils more or less regular, 45–150 μm wide, about 50 μm apart.

The strains examined were TAC 482, 497, 501 and 553.

Those four strains show comparatively wide variations in dimensions of vegetative cells, hetercytes and coils but the form and dimensions of the akinetes are largely overlapped, thus all of the strains are identified with *A. circinalis*. Dimensions of vegetative cells among strains belonging to *A. crassa*, *A. ucrainica* and *A. circinalis* are continuously overlapped, but length/width ratios of akinetes among three species clearly deviate from each other. They are 1.2–1.3, 1.0 and 1.7–2.4 respectively.

Key to the species of planktonic *Anabaena* with regularly coiled trichomes recorded in Japan. Two species affixed with an asterisk were not treated in this study.

1. Akinetes spherical 2
   2. Akinetes attaching at both side of heterocytes 3
      3. Mean value of cell width about 4 μm . . . . . *A. reniformis*
      3. Mean value of cell width about 5–6 μm . . . . . *A. oumiana*
   2. Akinetes remote from heterocytes 4
      4. Mean value of cell width about 11 μm . . . . . *A. ucrainica*
      4. Mean value of cell width about 7 μm . . . . . *A. minispora**
1. Akinetes longer than wide 5
   5. Akinetes attaching at both side of heterocytes . . . . . *A. eucompacta**
   5. Akinetes remote from heterocytes 6
      6. Akinetes one or two cells remote from heterocytes . . . . . *A. akankoensis*
      6. Akinetes more than three cells remote from hetercytes 7
         7. Mean value of cell width about 4–5 μm . . . . . *A. pseudocompacta*
         7. Mean value of cell width about 8–12 μm 8
            8. Mean value of l/w ratios of akinetes 1.7–2.4 . . . . *A. circinalis*
            8. Mean value of l/w ratios of akinetes 1.2–1.3 9
               9. Coil width 30–60 μm. . . . . *A. crassa*
               9. Coil width 160–175 μm. . . . . *A. mucosa*

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