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The Genera *Ankistrodesmus* Corda and *Raphidium* Kützing and their Position in the Family *Ankistrodesmaceae*

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Abstract — This paper includes the main results of a study prepared for print where the factological material and the methods used are given. During the elaboration of the taxonomical revision of the genus *Ankistrodesmus*, it appeared necessary to divide the genus into two genera. For algae with a colonial mode of life, the name *Ankistrodesmus* Corda is further used in accordance with the generic diagnosis; for algae living solitarily, the former name *Raphidium* Kützing is employed after a precisely fixed generic diagnosis. The position and the competence of the genus within the family *Ankistrodesmaceae* is discussed.

Results of taxonomical investigations of various species from a number of localities as well as from cultures show that the genus *Ankistrodesmus* s.l. (Brunnthaler 1915, Koršikov 1953, and others) should be divided into two taxonomical units.

The algae of the first group gather in colonies. The autospores form prior to liberation 4-celled fascicles inside the mother cell (in the presence of 8 to 16 autospores 2—4 fascicles being found above each other); four autospores are always liberated in the fascicle at the same time. The colonies are frequently inclosed by mucilage; their ability to form colonies, however, does not depend on the presence of a mucilaginous layer.

The species of the second group live solitarily; their autospores, lying after one another in the mother cell, are gradually liberated. The species are commonly planktonic organisms; those known and revised up to the present, have no mucilaginous sheath.

The morphological differences between these groups are of such importance that they posses the value of generic characteristics. Both types, therefore, must be considered as separate genera. The name *Ankistrodesmus* Corda 1838 belongs evidently to the first type. Its original generic diagnosis corresponds to the conception of these organisms (Alm. Carlsb. 8 : 197—198, 1838), and accordingly, the type of the genus *Ankistrodesmus* Corda 1838 must be assigned as *A. fusiformis* Corda Tab. 2/18, Alm. Carlsb. 8, 1838.

As to the group of solitarily living organisms, two possibilities may be considered. Either to use a new name and form a number of new combinations for them, or to put right the generic diagnosis and, after having chosen the type of the genus, to resume the name *Raphidium* Kützing 1848, used as a wrong synonym for the genus *Ankistrodesmus* in 1848 to 1904 (at last by Oltmanns). In a diagnosis two species are described by Kützing, one of which, namely *Raphidium fasciculatum*, is synonymous with the species *Ankistrodesmus fusiformis* Corda p. p. (corresponding to *A. falcatus* [Corda] Ralfs 1848), the second, namely *Raphidium duplex*, being solitary. The author

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describes two long, straight, fusiform cells without mucilage, joined, lying after one another. This does not concern cells gathered in colonies, since no species of the genus *Ankistrodesmus* forms such a type of a colony. A solitary species may only be considered (probably the species *Raphidium fasciculatum* A. BRAUN, i.e. two individuals randomly joined when liberated from the mother cell) or the so-called stipitate state (a temporary attachment of adult cells to the substrate), formed in all fusiform species of the genus *Raphidium*. For this reason it is possible to choose a part of the diagnosis as the type of the genus *Raphidium* KÜTZING, namely the species *Raphidium duplex* KÜTZING Phycol. germ. p. 145, 1948. The name *Raphidium* KÜTZ. may be given to a genus, containing single, free-living, fusiform or rounded cells, many times longer than broad, the autospores of which (in total 2^n) are lying after one another in the mother cell, being gradually liberated. The cells usually have no mucilage. These are generally planktonic species.

The genus *Selenastrum* REINSCH 1867, was also placed to the genus *Ankistrodesmus*, since its mode of life and multiplication wholly corresponded to the genus *Ankistrodesmus* (KORŠIKOV 1953).

Genus *Ankistrodesmus* CORDA

Ankistrodesmus CORDA, Alm. Carlsbad. 8 : 197—198, 1838.
Typus generis: Tab. 2/18 k, Ankistrodesmus fusiformis Corda p. p., Alm. Carlsbad. 8, 1838.

Synonyma:

Micrasterias AGARDH sensu CORDA, Alm. Carlsbad. 5 : 121, Tab. 2/29, 1835 p. p.;
Closterium NITZSCH sensu MENEGH., Consp. Alg. Eugan., p. 17, 1837 p. p.; non vidi, sec. RALFS 1848; MENEGH. 1840;
Binatella BRÉB., Algues Envir. Falaise, p. 53, Tab. 8, 1835 excl. typo;
Staurastrum MEYEN sensu EHRENB., Wiegm. Arch. 1936 : 185, 1936 p. p.;
Xanthidium EHRENB., Infusionsth., p. 174, Tab. 10/26, 1838 sensu auct. post. p. p.;
Raphidium KÜTZ., Phycol. germ., p. 144, 1845 p. p.
Dactylococcopsis HANSG. sensu LEMM., Bot. Centralbl. 76 : 153, 1898 p. p.;
Ankistrodesmus CORDA sensu auct. (G. S. WEST 1904, BRUNNTH. 1915, KORŠ. 1953) p. p.;
Selenastrum REINSCH, Abh. Naturh. Ges. Nürnberg 3 : 64, Tab. 4, 1867.

Cells in colonies, many times longer than broad, joined in the mid-region at least in one point; daughter cells arranged in fascicles within the mother cell-wall, always joined into groups liberating as small autocolonies.

1. *Ankistrodesmus falcatus* (CORDA 1835) RALFS, Brit. Desmid., p. 180, Tab. 34/3 a, b, c, var *falcatus*; dimensions: 29—62 × 1.2—4.5 μ.
2. *Ankistrodesmus falcatus* (CORDA) RALFS var. *stipitatus* (CHODAT 1902) LEMM., Arch. Hydrob. Planktonk. 4 : 176, 1908; dimensions 43—100 × 1.4—6 μ.
3. *Ankistrodesmus bibraianus* (REINSCH 1867) KORŠ., Vizn. prisnov. Vodor. 5 : 302, Fig. 263, 1953; dimensions: 21—57 × 1—4.8 μ.
4. *Ankistrodesmus fusiformis* CORDA 1838 sensu KORŠ., Vizn. prisnov. Vodor. 5 : 300—301, Fig. 263, 1953; dimensions: 21—57 × 1—4.8 μ.
5. *Ankistrodesmus gracilis* (REINSCH 1867) KORŠ., Vizn. prisnov. Vodor. 5 : 305, non Fig. 267, 1953; dimensions: 14—40 × 1.4—4.3 μ.
6. *Ankistrodesmus spiralis* (TURNER 1893) LEMM., Arch. Hydrob. Planktonk. 4 : 176, 1908; dimensions: 37—67 × 1.4—4.5 μ.

Key to the species

1a. Cells sickle-shaped to nearly straight, fusiform, sometimes cylindric, pointed, joined together with their convex lateral margins, arranged in cross form in the middle section
2a. The cells form secondary many-celled colonies inclosed by dense mucilage . . . . . *A. falcatus* var. *falcatus* (Tab. 1/1)
2b. Cells long, narrow, slightly curved to straight, in 2—4—8 celled colonies, without mucilage . . . . . *A. falcatus* var. *stipitatus* (Tab. 1/2)
2c. Cells markedly sickle-shaped, thick, forming 4, often 8 celled colonies with 4 cells above each other . . . . . *A. bibraianus* (Tab. 2/1)
1b. Cells sickle-shaped or straight, with pointed ends, gathered in free, decomposing colonies, joined solely in one point in the centre
3a. Cells straight, forming fine star and cross like colonies, planctonic species . . . . . *A. fusiformis* (Tab. 3/2)
3b. Cells sickle-shaped, fine, forming star-shaped, colonies to irregular clusters, without mucilage or in a thin diffused mucilaginous layer . . . . . *A. gracilis* (Tab. 3/1)
1c. Cells cylindric, irregularly curved, colonies twisted about one another, forming secondary colonies . . . . . *A. spiralis* (Tab. 2/2)

Genus Raphidium Kützing, emend. Legnerová

Raphidium Kützing, Phycol. germ. p. 144, 1845;
Typus generis: p. 145, *Raphidium duplex* Kützing, Phycol. germ., 1845.

Synonyma:

Closterium Nitzsch sensu Berkeley, Ann. Nat. Hist. 13 : 256, Tab. 14/2, 1854 p. p.; sensu Brébisson, Mém. Soc. imper. Sci. nat., Cherbourg 4 : 156, Tab. 2/48, 1956;
Dactylococcopsis Hansg., Notarisia 3 : 590, 1888 p. p.;
Ankistrodesmus Corda sensu lato (Brunnth. 1915, Korš. 1953 etc.) p. p.

Cells solitary, several times longer than broad, daughter cells arranged after one another within the mother cell-wall, liberating gradually.

A nomenclatoric revision showed that it was necessary to establish a new combination for *Ankistrodesmus contortus* Thuret in Bréb. (Mém. Soc. imper. Sci. nat. Cherbourg 4 : 158, Tab. 2/31, 1856), named *A. angustus* Bernard up to the present time. Apart from this, Bernard's combination of transferring it from the genus *Raphidium* to *Ankistrodesmus* cannot be found in the literature (probably ascribed to Bernard by Brunnthaler 1915). The names *A. angustus* and *R. angustum* were also wrongly used, for priority was given to Thuret's epithet from 1856. The description of the species and the picture brought additionally are very clear. Nevertheless, the combination of the genus *Raphidium* was not established.

1. *Raphidium aciculare* A. Braun, Flora 13 : 491, 1855; dimensions: 15—120 × 1.5—7.2 μ.

2. *Raphidium braunii* Nageli in Kützing, Spec. Algarum p. 891, 1849; dimensions: 13—52 × 1.4—8 μ.

3. *Raphidium contortum* (Thuret in Bréb. 1856) Legnerová combinatio nova; dimensions: 17—60 × 1—4.3 μ.

4. *Raphidium convolutum* (Corda 1838) Rabenh., Fl. eur. Algarum p. 46, 1868; dimensions: 5.5—17.5 × 1.4—6 μ.

Key to the species

1a. Cells straight to nearly straight
2a. Cells markedly long, spindle-shaped, pointed to narrowly drawn out . . . . . *R. aciculare* (Tab. 4/1)

2b. Cells shorter, thick, ends rounded, chromatophor with one marked pyrenoid . . . . . *R. braunii* (Tab. 4/2)

1b. Cells arcuate, sigmoid or irregularly sigmoid

3a. Organisms sickle-shaped, sigmoid or double sigmoid, narrow, sharply pointed . . . . . *R. contortum* (Tab. 5/1)

3b. Cells sigmoid, small, thick, with the ends sharp to blunt . . . . *R. convolutum* (Tab. 5/1)

At the time of the revision of the genus *Ankistrodesmus* and the emandation of the genus *Raphidium*, the position of them and of the related genera in the family *Ankistrodesmaceae* were also studied together with their systematics. CORDA (1838) placed the genus *Ankistrodesmus* near the genus *Scenedesmus* MEYEN for its formation of colonies and the presence of a "small pouch" inside the cells of both genera. The latter was considered as a notch in the chromatophor in the g. *Ankistrodesmus*, as a pyrenoid, in the g. *Scenedesmus*. CORDA's view and description, however, were soon forgotten and the genus *Raphidium* KÜTZING 1845, described later and used for a long time as a valid synonym for the genus *Ankistrodesmus*, was placed by KÜTZING (1845, 1848) to the group *Desmideae*. RABENHORST (1863, 1868) rules out the green one-celled algae from this group and establishes the family *Palmellaceae* on the basis of the following characteristics: Presence of mucilage and multiplication by means of zoospores. Since the family contained very different algae, HANSGIRG (1886) gives attention to the inner system of the family. He concentrates in the group *Raphidieae* (subfamily *Eremobieae*) one-celled free-swimming algae, living in colonies or solitarily, i.e. *Ophiocytium* (at the present time belonging to *Xanthophyceae*), *Raphidium* KÜTZING, *Selenastrum* REINSCH, *Actinastrum* LAGERH., *Tetraedron* KÜTZ., and *Eremosphaera* DE BARY. The author places for the first time the genus *Raphidium* very near to those algae which multiply by autospores. CHODAT included HANSGIRG's *Raphidieae* in the family *Protococcaceae* as asexually reproducing algae, and after having studied reproduction, he added the genus *Kirchneriella* SCHMIDLE to this group. G. S. WEST (1904) excluded from the family *Protococcaceae* all genera reproducing otherwise than by autospores or by autocolonies. He separated the families *Palmellaceae* and *Pleurococcaceae*, since these had a different mode of reproduction. He distinguished four subfamilies according to the shape of the coenobia and cell morphology, i.e. *Coelastraceae*, *Crucigenieae*, *Selenastreae*, and *Oocystideae*. He characterized the subfamily *Selenastraceae* by elongated curved cells, united in unstable or stable colonies. The characteristics pointed out by WEST for the family, and subfamily respectively, were also acknowledged by other authors (Tab. 1). Further studies excluded genera with a different mode of reproduction (*Elakotothrix* WILLE, *Schroederia* LEMM.) and those forming coenobia (*Scenedesmus* MEYEN). The conception of the family becomes more and more narrow. SMITH (1933) and PRESCOTT (1951) place the genus *Ankistrodesmus* to *the family Oocystaceae*, which however includes all autosporic algae. This makes the family very extensive and hence not easily surveyable.

The family *Ankistrodesmaceae* may be outlined by the following attributes: (1) Reproduction only by autospores. (2) Cells distinctly longer than broad. (3) Cells single or in colonies, not forming coenobia. (4) Division by transverse or slightly obliqueplanes (KORŠIKOV 1953). (5) The mother membrane bursts and either becomes gelatinized, without forming a mucilaginous envelope, or persists for a time as small rests (FOTT 1959).

Table I

Brunnthaler, J. Pascher's Süsswasserfl. 5/2 : 179—193, 1915	fam. *Scenedesmaceae* group *Selenastreae* (without tax. value)	*Ankistrodesmus*, *Selenastrum*, *Kirchneriella*, *Dictyosphaerium*, *Dimorphococcus*	Colonies arranged spacially
Smith, G. M. Phytopl. Inl. Lakes Wisconsin 1920	fam. *Autosporaceae* subfam. *Selenastreae*	*Schroederia*, *Closteriopsis*, *Ankistrodesmus*, *Selenastrum*, *Kirchneriella*, *Quadrigula*, *Elakatothrix*	Elongated colonial or solitary cells.
West, G. et Fritsch, F. E. Brit. Freshw. Algae p. 127—134 1927	series *Autosporineae* (without tax. design.) subfam. *Selenastraceae*	*Dactylococcus* (= *Keratococcus*) *Ankistrodesmus*, *Quadrigula*, *Closteriopsis*, *Selenastrum*, *Kirchneriella*, *Actinastrum*	Elongated cells in free colonies or adhering stipitately to each other.
Koršikov, O. A. Vizn. prisnov. Vodor. 5 : 282—321, 1953	order *Protococcales* fam. *Ankistrodesmaceae*	*Pseudococcomyxa*, *Chlorolobion*, *Fusola*, *Ankistrodesmus*, *Hyaloraphidium*, *Gloxidium*, *Nephrochlamys*, *Kirchneriella*	Elongated cells: division occurs by transverse or oblique walls: mother membrane gelatinizes or it persists
Fott, B. Algenkunde 257—259 1959	fam. *Oocystaceae* subfam. *Selenastroideae*	*Selenastrum*, *Ankistrodesmus*, *Hyaloraphidium*, *Gloxidium*	Elongated cells; mother membrane either gelatinizes or persists

Table II

Differentiation of the genera of the family *Ankistrodesmus* based on intergeneric features

	Pseudococ.	*Keratoc.*	*Chlorolob.*	*Raphid.*	*Fusola*	*Coccom.*	*Kirchn.*	*Quadr.*	*Ankistr.*
Pseudococcomyxa	—	C	BC	C	ABC	A	ACF	ACD	ACD
Keratococcus	C	—	BC	C	ABC	AC	ACF	ACD	ACD
Chlorolobion	BC	BC	—	B	AF	ABC	ABCF	ABD	ABCD
Raphidium	C	C	B	—	AB	AC	ACF	AD	AD
Fusola	ABCF	ABCF	AF	AB	—	BC	BC	BD	BDE
Coccomyxa	A	AC	ABC	AC	BC	—	C	D	CDE
Kirchneriella	ACF	ACF	ABCF	AF	BC	C	—	CDF	CDEF
Quadrigula	ACD	ACD	ABC	AD	BD	D	CDF	—	E
Ankistrodesmus	ACD	ACD	ABCD	AD	BDE	CDE	CDEF	E	—

A — Formation of colonies. B — Presence of the proper pyrenoid. C — Shape of cells. D —Parallel position of autospores in the mother membrane. E — Distant position of cells in the colonies of colonial genera. F — Mother membrane partially or entirely gelatinizing, taking part in the formation of the mucous layer.

Accordingly, the family *Ankistrodesmaceae* comprises the following genera:

Pseudococcomyxa KORŠ., Vizn. prisnov. Vodor. 5 : 282, 1959.
Type: *P. adhaerens* KORŠ., Vizn. prisnov. Vodor. 5 : 283, Fig. 244, 1959.
Chlorolobion KORŠ., Vizn. prisnov. Vodor. 5 : 283, 1959.
Type: *Ch. obtusum* KORŠ., Vizn. prisnov. Vodor. 5 : 284, Fig. 254, 1959.
Keratococcus PASCHER sensu HINDÁK, Thesis, Bot. Dept., Charles Univ., 1959.
Type: *K. bicaudatus* (A. BRAUN) BOYE PET., Bot. Icel. 4 : 430, 1928.
Raphidium KÜTZ. em. LEGNEROVÁ, Phycol. germ., p. 145, 1945.
Type: *R. duplex* KÜTZ., Phycol. germ., p. 145, 1945.
Ankistrodesmus CORDA, Alm. carlsbad. 8 : 195.
Type: *A. fusiformis* CORDA 8 : 197, Tab. 2/18 d, 1838.
Fusola Snow, U. S. Fish. Comm. Bull. 1902 : 378—379, 1902.
Type: *F. viridis*, U. S. Fish. Comm. Bull. 1902 : 379, Tab. 4/1—4, 1902.
Coccomyxa SCHMIDLE, Ber. deutsch. bot. Ges.: 19—20, 1901.
Type: Not determined.
Kirchneriella SCHMIDLE, Ber. Naturf. Ges. Freiburg 7 : 15, 1893.
Type: *K. lunaris* (KIRCHN.) Schmidle Ber. Naturf. Ges. Freiburg 7 : 15—16, Tab. 2/1—2, 1893.
Quadrigula PRINTZ, Det. Kgl. Norske Vidensk. selsk. Skr. 1915 : 49, 1915.
Type: *Q. closterioides* (BOHL.) PRINTZ, Det. Kgl. Norske Vidensk. selsk. Skr. 1915 : 49, Tab. 4/110, 1915.

The genera *Hyaloraphidium* PASCHER et KORŠ. and *Gloxidium* KORŠ. may be also considered as colourless homologues of green algae. The other genera in Table 1 belong to other families, e.g. *Dictyosphaericeae* (*Dictyospaerium* NAG., *Dimorphococcus* A. BRAUN), *Scenedesmaceae* (*Actinastrum* LAGERH., *Didymogenes* SCHMIDLE), *Oocystaceae* (*Nephrochlamys* KORŠ.), or they are unclear organisms (*Closteriopsis* LEMM.).

All the families may be differentiated on the basis of several decisive features (Tab. 2), which were studied on natural and cultivated material, if possible always on several species. The not yet re-observed genus *Chlorolobion* and the rare genus *Fusola* were only studied from the literature.

Table 2 presents the differences between the genera of the family *Ankistrodemaceae*, which are characterized according to the possession or lack of the decisive attributes. The table gives clearly the reasons for the separation of the genus *Raphidium* KÜTZ. from the genus *Ankistrodesmus* CORDA; both genera differ from each other, showing that they have a remote position among the other genera of the family.

Key to the genera in the family *Ankistrodesmaceae*

1a. Cells solitary, without a gelatinous envelope
  2a. containing one pyrenoid with a starch sheath . . . . . g. *Chlorolobion*
  2b. Pyrenoid naked, without starch or absent
    3a. Cells ovoid to oblong, always with rounded ends, without a pyrenoid . . . . . g. *Pseudococcomyxa*
    3b. Cells spindle-shaped, ends generally pointed, rarely rounded, without a pyrenoid or with one without a starch layer
      4a. Cells extending at the poles into 1—2 spines . . . . . g. *Keratococcus*
      4b. Cells many times longer than broad, not extending into spines . . g. *Raphidium*
1b. Cells colonial, mostly embedded in a mucilaginous envelope
  5a. Cells irregularly inclosed in mucilage
    6a. Cells spindle-shaped, containing 1—2 pyrenoids with a starch layer . . g. *Fusola*
    6b. Cells not spindle-formed, without a pyrenoid
      7a. Cells strongly curved or spirally twisted, planktonic species within a thin gelatinous envelope . . . . . g. *Kirchneriellc*
      7b. Cells oval, embedded in an extensive mucilaginous envelope, mostly aerial species . . . . . g. *Coccomyxa*
  5b. Cells inclosed by a gelatinous sheath, grouped in regular colonies
    8a. Cells unattached, but arranged in a quadrangle . . . . . g. *Quadrigula*
    8b. Cells forming clustered colonies joined at least in one point . . . . g. *Ankistrodesmus*

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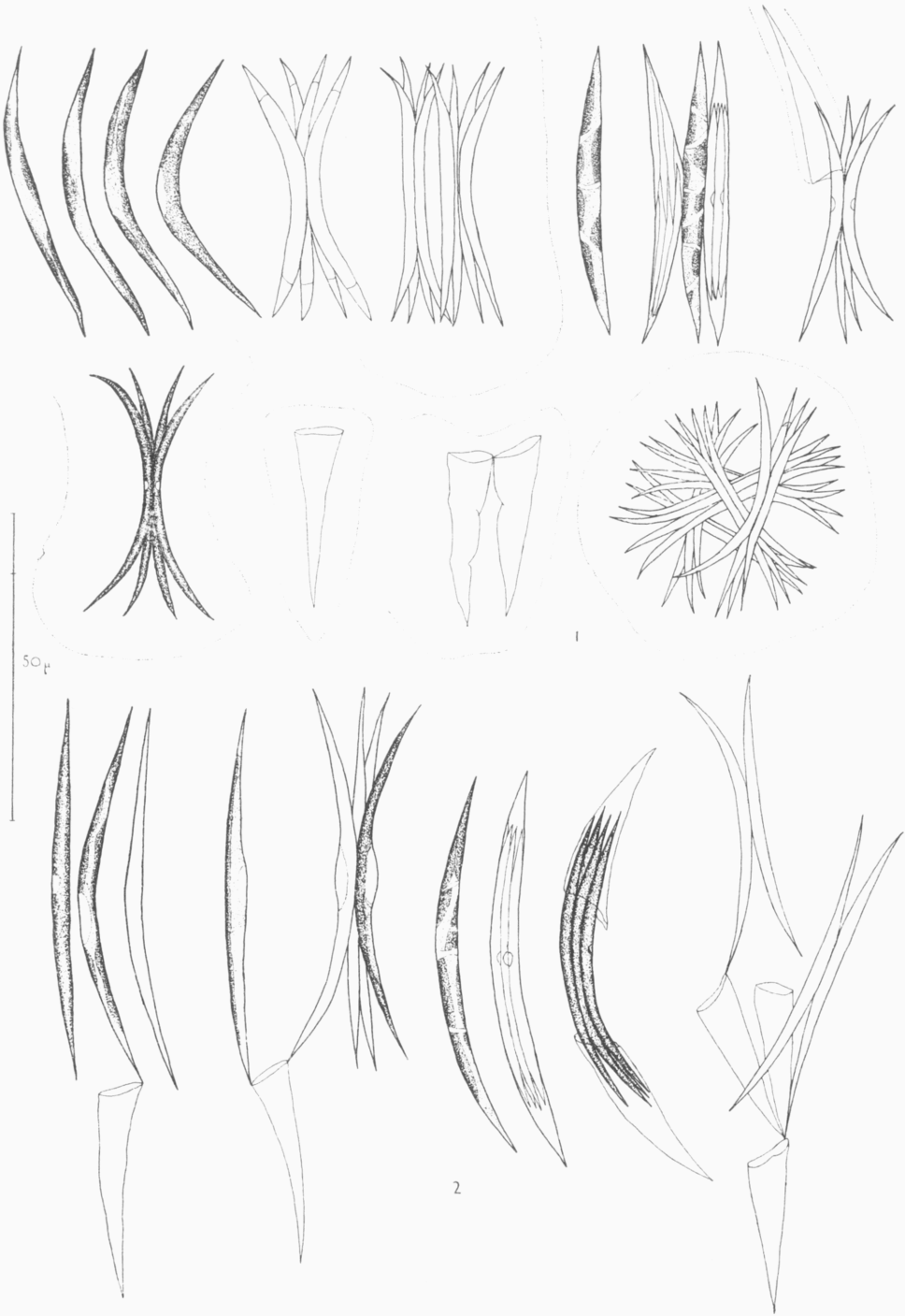
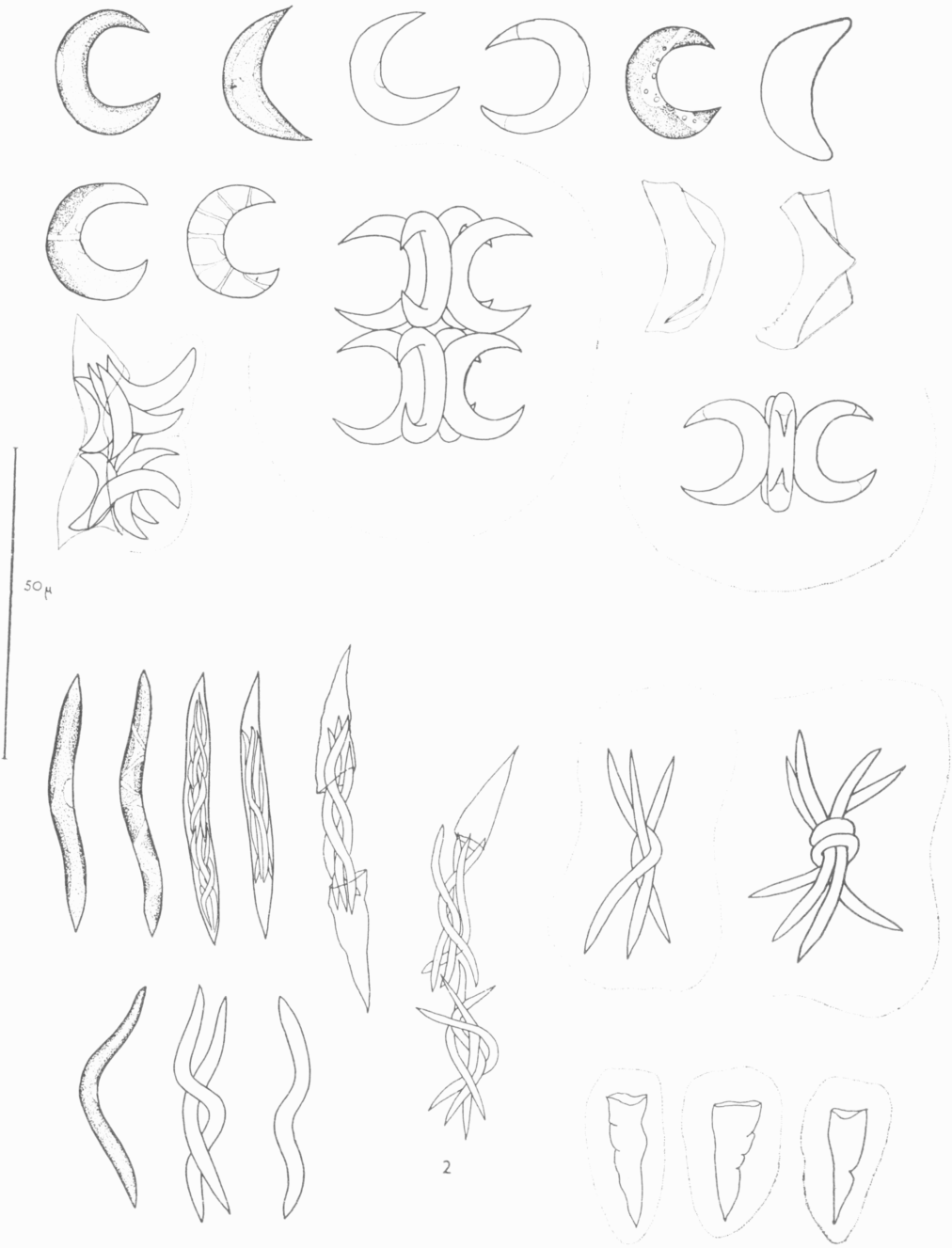
Explanations of the plates:

Tab. I — 1. *Ankistrodesmus falcatus* (Corda) Ralfs var. *falcatus*; 2. *Ankistrodesmus falcatus* var. *stipitatus* (Chodat) Lemmerm.
Tab. II — 1. *Ankistrodesmus bibraianus* (Reinsch) Koršikov; 2. *Ankistrodesmus spiralis* (Turn.) Lemmerm.
Tab. III — 1. *Ankistrodesmus gracilis* (Reinsch) Koršikov; 2. *Ankistrodesmus fusiformis* Corda sensu Koršikov.
Tab. IV. — 1. *Raphidium aciculare* A. Braun; 2. *Raphidium braunii* Nageli in Kütz.
Tab. V. — 1. *Raphidium contortum* (Thuret in Bréb.) Legn. c. n.; 2. *Raphidium convolutum* (Corda) Rabenh.



J. Legnerová: The Genera *Ankistrodesmus* CORDA and *Raphidium* KÜTZING and their Position in the Family *Ankistrodesmaceae*



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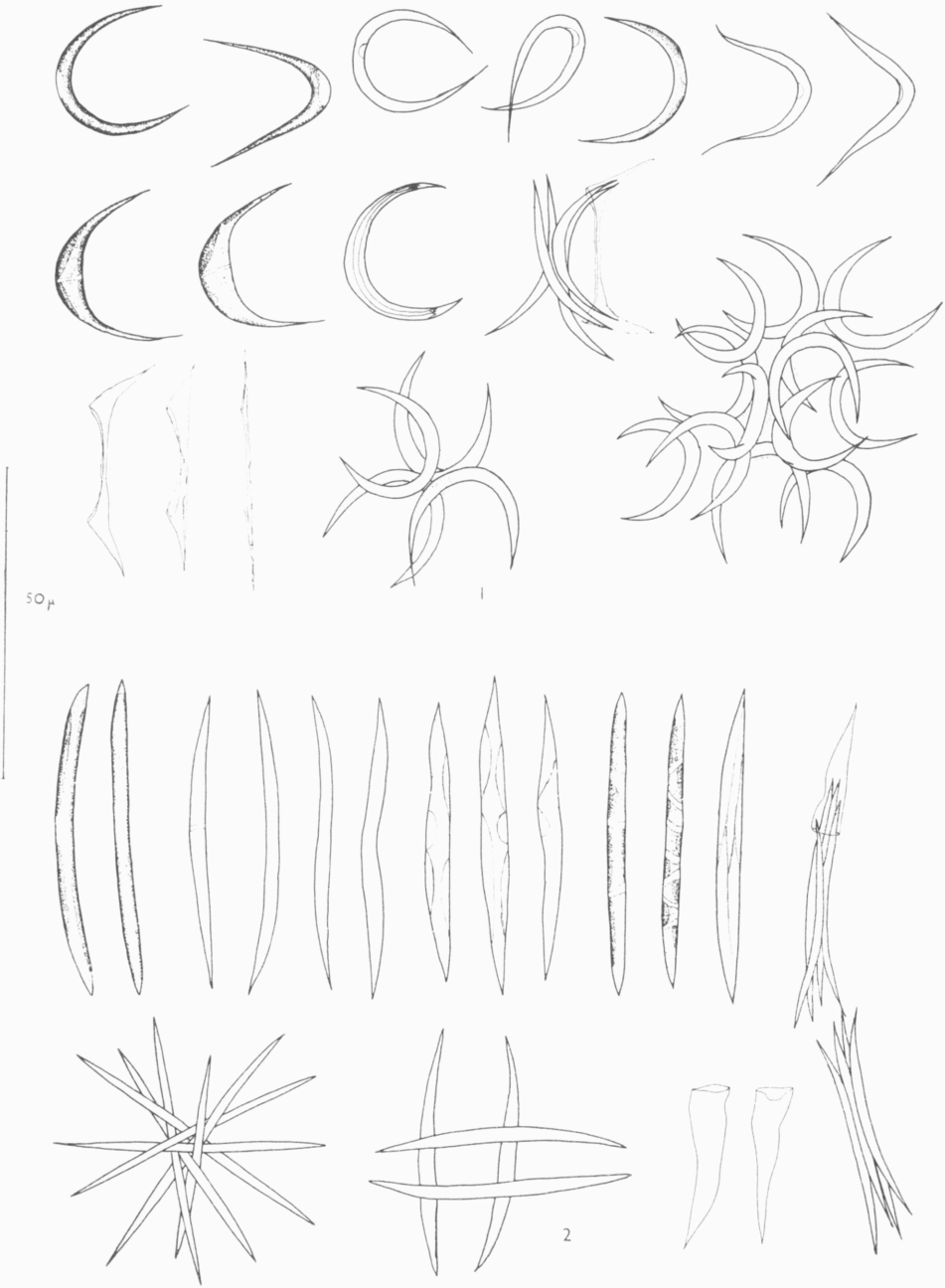

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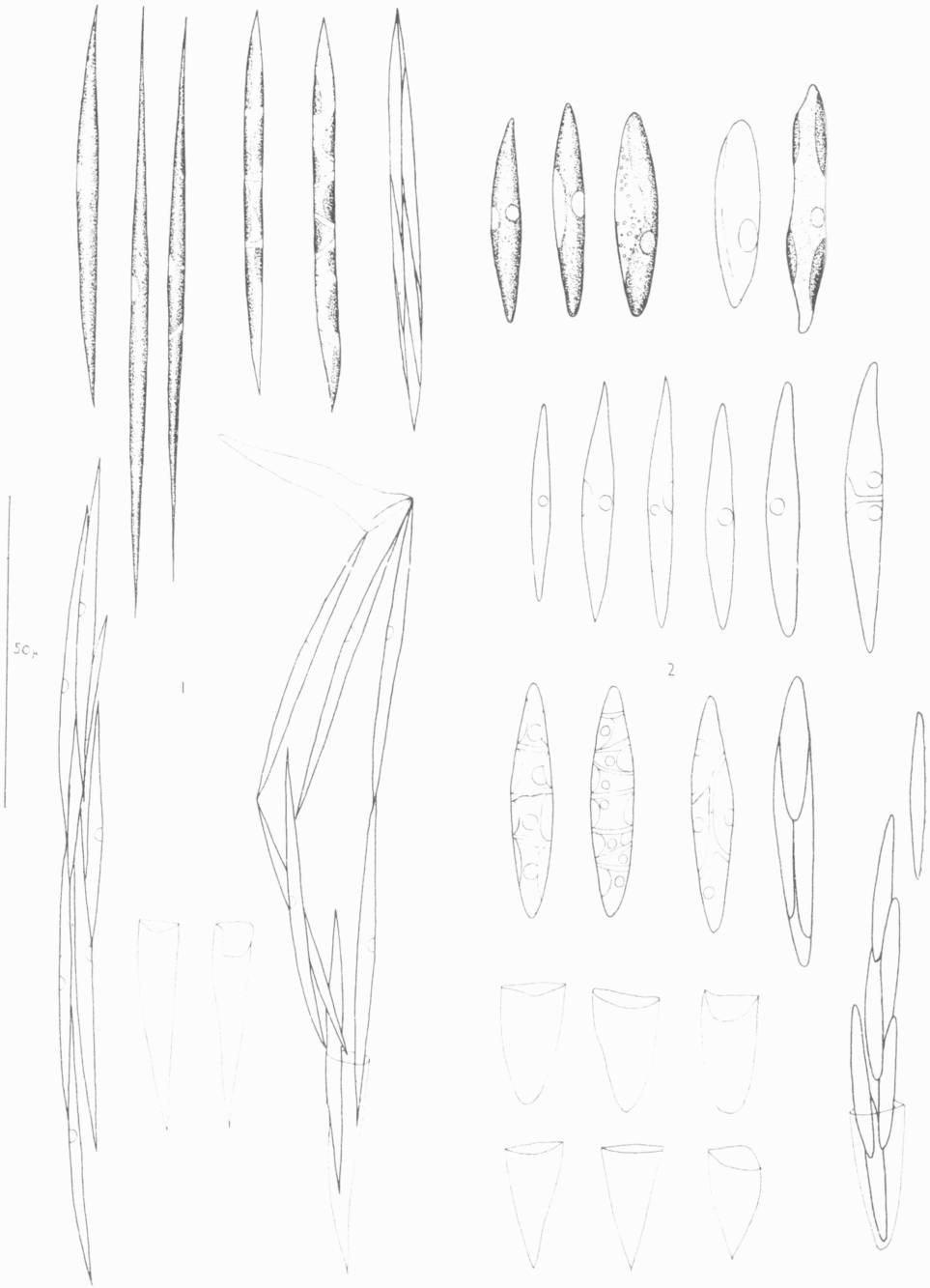

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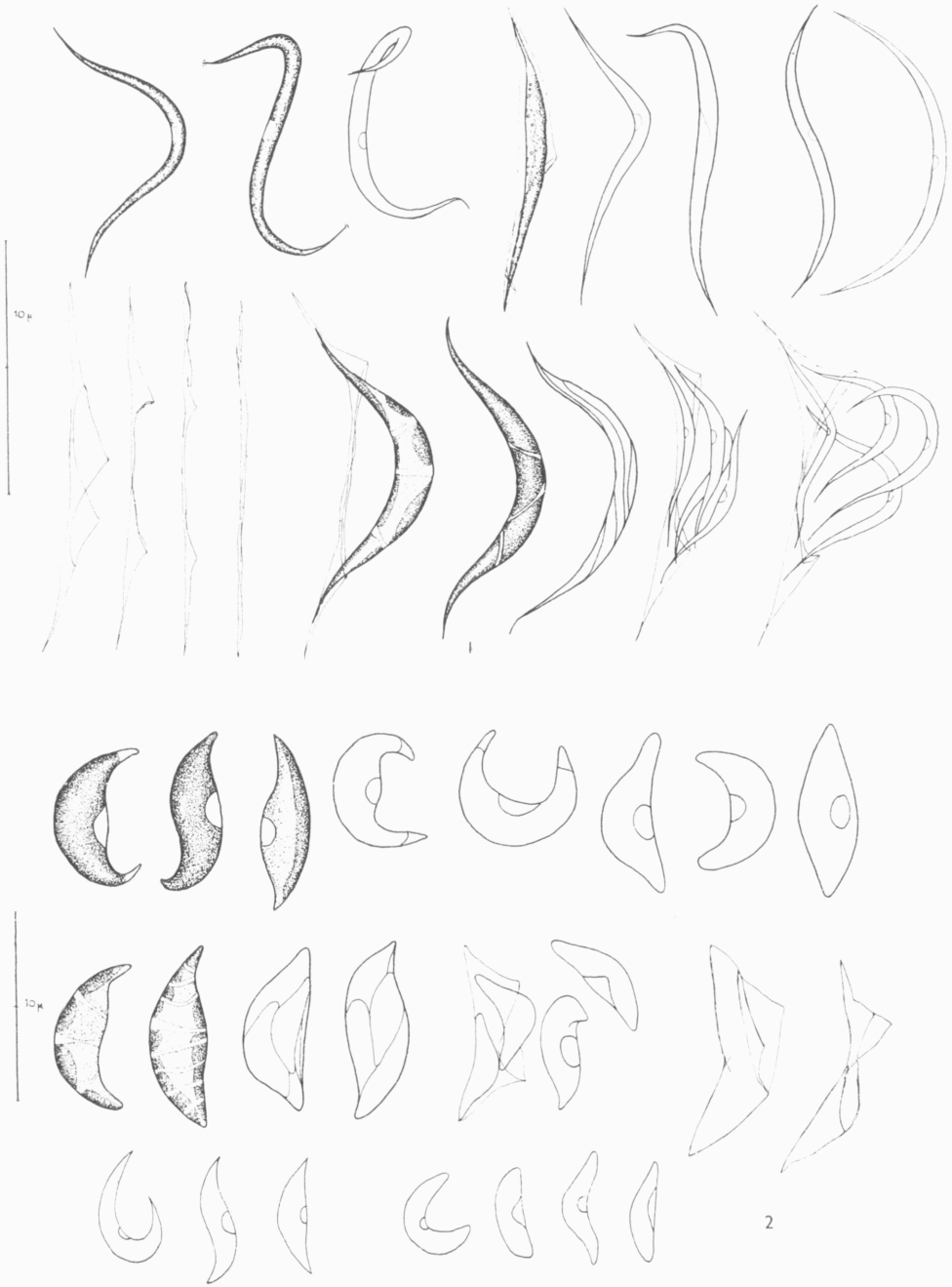

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