

Lectotypification of *Ceratoneis amphioxys* Rabenhorst (*Fragilariaceae*, *Bacillariophyta*)

Bart Van de Vijver, *Meise Botanic Garden, Research Department, Nieuwelaan 38, 1860 Meise, Belgium & University of Antwerp, Department of Biology – ECOBE, Universiteitsplein 1, B-2610 Wilrijk, Belgium* (correspondence: bart.vandevijver@plantentuinmeise.be)

Luc Ector, *Luxembourg Institute of Science and Technology (LIST), Environmental Research & Innovation (ERIN) Department, 41 rue du Brill, L-4422 Belvaux, Luxembourg*

The genus *Hannaea* R.M.Patrick (*Fragilariaceae*) was described in 1966 by Ruth Patrick (1907–2013) to accommodate a handful of taxa originally referred to the genus *Ceratoneis* Ehrenberg (Patrick & Reimer 1966). This latter genus included originally only two marine species: *C. fasciola* Ehrenberg (Ehrenberg 1839: 157) and *C. closterium* Ehrenberg (Ehrenberg 1839: 157); the second of which was designated as lectotype by Smith (1852: 9). The genus *Ceratoneis* Ehrenberg was proposed for rejection against the later name *Cylindrotheca* Rabenhorst (Rabenhorst 1859) by Medlin & Mann (2007) and this was accepted at the Melbourne International Botanical Congress.

The freshwater taxon *Navicula arcus* Ehrenberg (Ehrenberg 1836: 243) was transferred to *Ceratoneis* by (Kützing 1844: 104). After the transfer of the two original *Ceratoneis* taxa, only *C. arcus* (Ehrenberg) Kützing remained in the genus, creating a taxonomic anomaly whereby an araphid taxon was retained in an originally raphid genus. Patrick (in Patrick & Reimer 1966: 131–132), recognized this anomaly and introduced the genus name *Hannaea* R.M.Patrick typified by *Hannaea arcus* (Ehrenberg) R.M.Patrick. Species of *Hannaea* are typically asymmetrical to the apical axis and generally have arcuate valves, although there are a few exceptions such as *H. inaequidentata* (Lagerstedt) Genkal & Kharitonov (Genkal & Kharitonov 2008: 22). The central area is characterized by a small, unornamented tumid area on one side (Patrick & Reimer 1966). At present, less than 20 taxa are placed or described in this genus (Kocielek *et al.* 2020). Most of these taxa show restricted biogeographies with the majority only known from Asia (Liu *et al.* 2019 and references therein).

Patrick also transferred one *Ceratoneis arcus* variety to her new genus: *Hannaea arcus* var. *amphioxys* (Rabenhorst) R.M.Patrick (in Patrick & Reimer 1966: 133). This was described in 1853 by Rabenhorst (1853: 37, pl. 9: fig. 4) as *Ceratoneis amphioxys* Rabenhorst in the *Naviculaceae*. The original description was rather brief: “*Sie ist ziemlich constant in ihrer Grösse und wird selten über 3/100 mm lang*” [Rather constant in its size and rarely longer than 1/100 mm long.] Rabenhorst added one small drawing to his description (see Fig. 1, indicated as number 4) and further indicated that he observed the taxon on various places in Germany, however, without giving an exact locality. In 1880, Jacques-Joseph Brun (1826–1908) reported the taxon from several places in Switzerland and recombined the species as a variety of *Ceratoneis arcus* stating that the variety is shorter and stockier (“*plus courte et plus trapue*”). Brun (1880) provided a more elaborate description than Rabenhorst (translated from the French description): “Shorter and stockier. Length 35–70 µm. Valve face broad, dorsal side regularly convex. Central nodule cuneate followed by two rounded bumps. Apices narrow, constricted and recurved. Striation fine; 12–16 in 10 µm. Girdle view rectangular, long with a slight terminal constriction.”

Rabenhorst distributed his *Die Algen Europa's* exsiccata sets containing more than 2500 samples, throughout the world (Rabenhorst 1861–1882). One of these exsiccatae (Rabenhorst 1875, Decas 242–243, exsiccata 2422) was collected from the Grenzbach, a small river on the borders of Germany and the Czech Republic in the village of Bärenstein near Annaberg-Buchholz (Saxony, Germany). The sample was obtained by Max Gündel. Rabenhorst mentions the presence of *Ceratoneis arcus*, *Hydrurus* sp. (*Hydruraceae*, *Chrysophyta*), and *Ceratoneis amphioxys*. It is the only sample in the entire exsiccata set with this name.

Material of exsiccata 2422 was found in the personal collection of Henri Van Heurck (1837–1909) that is now part of the Van Heurck collection housed in Meise Botanic Garden (**BR**, Belgium). Additionally, a slide prepared and identified by Brun made from a sample taken at 2600 m altitude at Salvan (near Chamonix, Canton Valais, Switzerland) containing *Ceratoneis amphioxys* and *Synedra parvula* (Kützing) Kützing was likewise found in the Van Heurck collection (**BR**, slide VII-12-C4). Given the large population of *C. amphioxys* in the slide, the latter is added as epitype linked to the designated lectotype in accordance with ICN Art. 9.8 (Turland *et al.* 2018).

Here we detail using light microscopy observations specimens from a slide prepared from exsiccata 2422 and from a slide made by Brun from Salvan (Switzerland).

Hannaea arcus var. *amphioxys* (Rabenhorst) R.M.Patrick (in Patrick & Reimer 1966: 133)

Basionym: *Ceratoneis amphioxys* Rabenhorst, *Die Süßwasser-Diatomaceen (Bacillarien.): für Freunde der Mikroskopie*, p. 37, pl. 9: fig. 4, 1853.

Synonyms: “*Euceratoneis amphioxys* Grunow”, *nom. inval.* (in Rabenhorst 1865: 7, the designation is invalid as *Euceratoneis* is a subgenus of *Ceratoneis*, not a genus), *Ceratoneis arcus* var. *amphioxys* (Rabenhorst) Brun (Brun 1880: 52), *Fragilaria arcus* var. *amphioxys* (Rabenhorst) A.Cleve (Cleve-Euler 1953: 54), *Ceratoneis arcus* f. *curta* Holmboe (Holmboe 1899: 31, pl. 1: fig. 10), *Ceratoneis arcus* f. *trigibba* C.Zimmermann (Zimmermann 1915: 36, pl. 4: fig. 10)

Lectotype (here designated): **BR**-4587, slide prepared from exsiccata 2422, Grenzbach, Bärenstein near Annaberg-Buchholz (Saxony, Germany), material present in the Van Heurck collection (**BR**). The lectotype specimen is here represented by Fig. 25.

Epitype (here designated for the above lectotype of *Ceratoneis amphioxys* Rabenhorst): slide VII-12-C4 (**BR**), Alps, 2600 m, Salvan (Canton of Valais, Switzerland), made and identified by Prof. J. Brun, Genève. The epitype is here represented by Fig. 51.

Description: Frustules in girdle view rectangular, often in pairs. Band-like colonies not observed. Valves distinctly arcuate with a strongly convex dorsal margin and a strongly to weakly concave ventral margin. Smaller valves ventrally constricted on both sides of the central area making the ventral margins between central area and apices clearly rounded. Apices shortly protracted, rostrate, occasionally slightly dorsally recurved. Valve dimensions (n=25): length 19–60 µm, width (at central area) 5.0–7.0 µm. Axial sternum slightly ventrally displaced, clearly separating dorsal from ventral striae. Sternum narrow, linear, never widening, continuing into the apices. Central area distinctly asymmetrical: dorsally absent, ventrally clearly swollen, tumid. Ghost striae occasionally present in the central area. Striae parallel ventrally and dorsally, 16–18 in 10 µm. Striae dorsally longer, near the central area often twice as long, than ventrally. Areolae not visible in LM.

The LM analysis of both the slide made from Rabenhorst exsiccata 2422 and the slide made by Brun shows that a continuum is present from longer valves showing the typical valve morphology of *Hannaea arcus* to shorter valves with the indentations that are typical for *Hannaea arcus* var. *amphioxys*. This lack of a clear morphological separation in valve outline was also observed in a contemporary population of *H. arcus* from Sweden (Van de Vijver, unpubl.). *Hannaea arcus* var. *amphioxys* valves have been reported from a large number of localities worldwide in Asia, Europe, South and North America. Records with illustrations were reported from Belgium (Fabri & Leclercq 1979: pl. 6: fig. 5, Leclercq & Fabri 1982: 61, pl. 4: figs 1b, 1c [SEM], Fabri & Leclercq 1984: 177–178, pl. 16: figs 437–439), Canada (Poulin *et al.* 1984: 361, fig. 76, Antoniadis *et al.* 2008: 154, pl. 3: fig. 21), Chili (Rivera 1973: 33, pl. 5: fig. 41, Rivera *et al.* 1973: 19, pl. 2: fig. 5), China (Li & Qi 1986: pl. 4: fig. 2 [SEM]), Europe (Hustedt 1930: 135, fig. 123, Hustedt 1932: 179–180, fig. 684d), Finland (Mölder & Tynni 1970: 135, pl. 2: fig. 38), France (Brun 1880: 52, pl. 2: fig. 28, Germain 1981: 58, pl. 17: fig. 8), Germany (Rabenhorst 1853: 37, pl. 9: fig. 4), Great

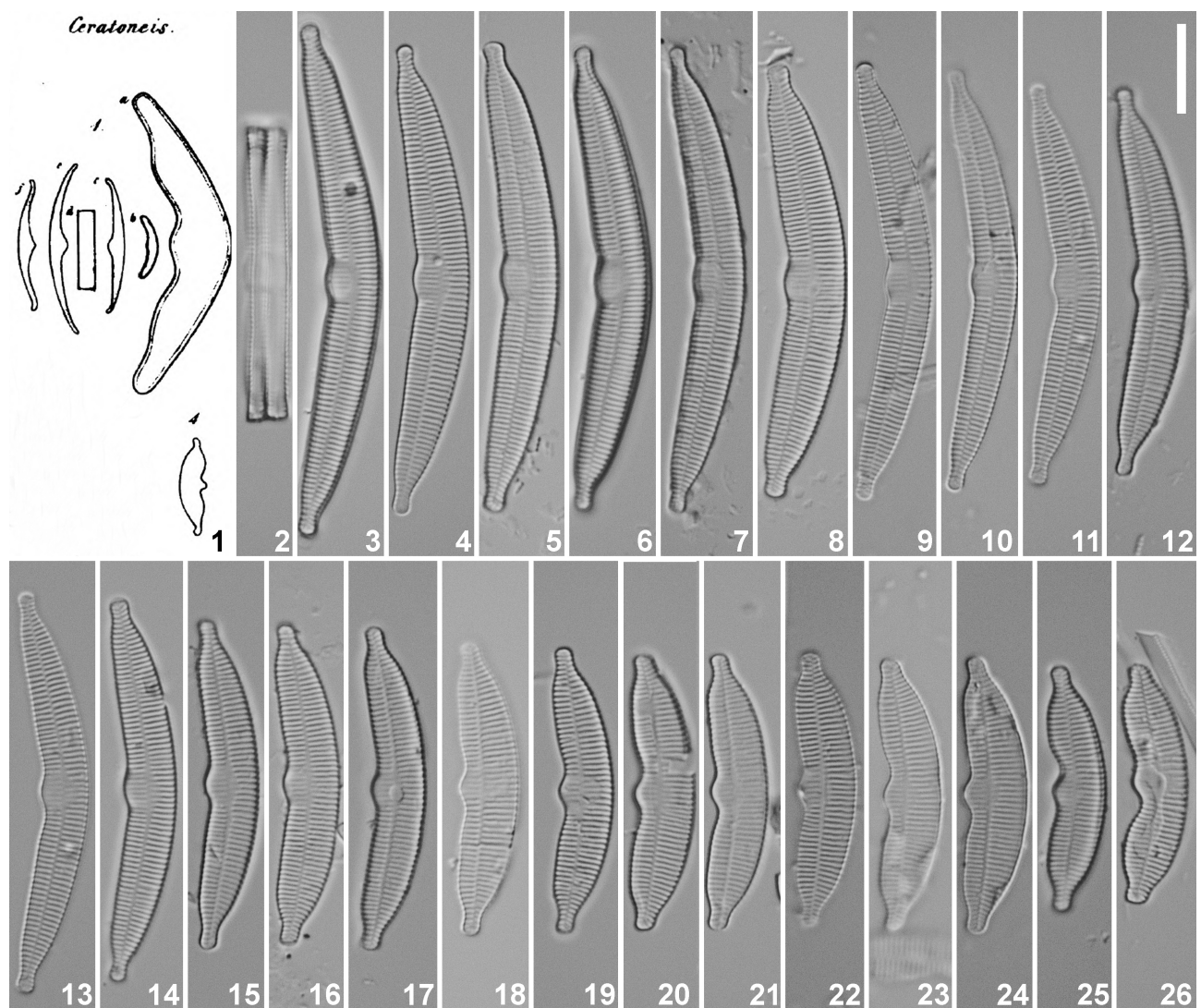
Britain (Sims 1996: pl. 115: fig. 9), Greenland (Foged 1973: 29, pl. 2: fig. 6), Iceland (Foged 1974: 34, pl. 3: fig. 19), Ireland (Foged 1977: 33–34, pl. 7: figs 18–19), Poland (Schumann 1867: 65, pl. 2: fig. 33), Sweden (Cleve-Euler 1953: 54, fig. 373f–g), Switzerland (Brun 1880: 52, pl. 2: fig. 28, Meister 1912: 91, 241, pl. 11: fig. 18, Wuthrich 1975: 301, pl. 3: figs 12–14), Turkey (Şahin 1998: 184, fig. 9a), United States of America (Tennessee: Patrick & Reimer 1966: 133, pl. 4: fig. 1, Idaho: Clark & Rushforth 1977: 38, pl. 7: fig. 7, Utah: Lawson & Rushforth 1975: 13, 143, pl. 4: fig. 9, Johansen & Rushforth 1981: 342, pl. 2: fig. 3, Alaska: Foged 1981: 61, pl. 5: fig. 18). In Portugal, one valve showing all features of the var. *amphioxys* was reported under the name *Ceratoneis arcus* f. *trigibba* by Zimmermann (1915: 36, pl. 4: fig. 10) whereas Holmboe (1899: 31, pl. 1: fig. 10) published one illustration from Norway as *Ceratoneis arcus* f. *curta* Holmboe. Both depicted valves show however a clear similarity with *Hannaea arcus* var. *amphioxys* and should therefore be considered conspecific.

Based on the results of the morphological analysis using light microscopy, we propose to treat *Hannaea arcus* var. *amphioxys* (Rabenhorst) R.M.Patrick as a heterotypic synonym of *Hannaea arcus* (Ehrenberg) R.M.Patrick. A similar suggestion was already made by Krammer & Lange-Bertalot (1991: 134) stating that the var. *amphioxys* was merely a shape variant ('*Umrissvariation*') and Genkal & Kharitonov (2008: 17, pl.1: fig. 8) indicated a similar opinion without clearly stating why.

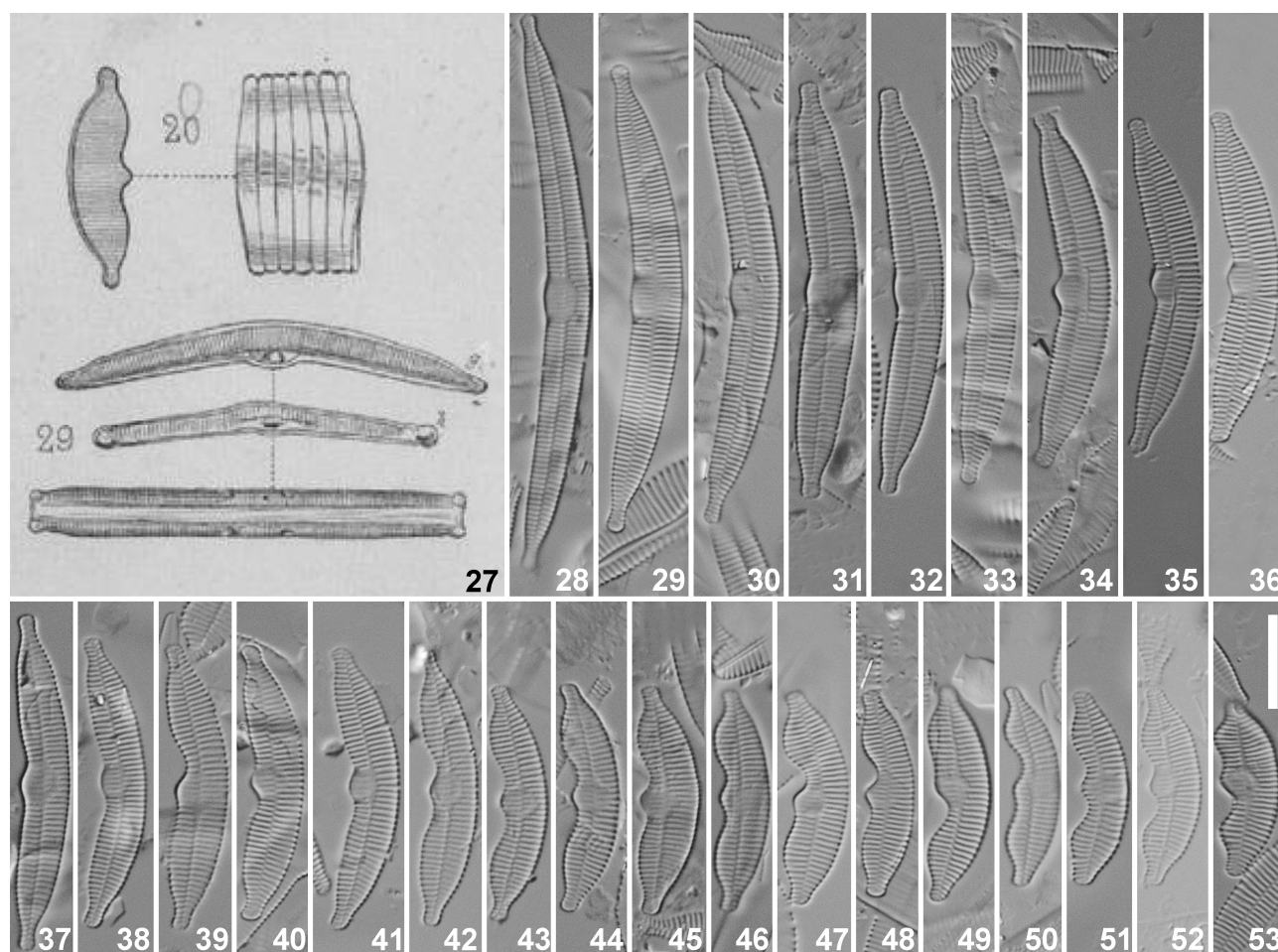
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Figs 1–26. Fig. 1. *Ceratoneis amphioxys* Rabenhorst. Original drawings from Rabenhorst (1853: 37, pl. 9: fig. 4; fig 1 (a–f) represents *Ceratoneis arcus*). **Figs 2–26.** Cell cycle of *Hannaea arcus* taken from the lectotype material (BR-4586, Grenzbach, Bärenstein) gradually changing from typical *H. arcus* valves into *Hannaea arcus* var. *amphioxys*. Fig. 25 represents the lectotype specimen. The smallest valves (Figs 25, 26) clearly show the typical morphology as depicted by Rabenhorst (1853). Scale bar represents 10 µm.



Figs 27–53. **Fig. 27.** *Ceratoneis arcus* var. *amphioxys* (Rabenhorst) Brun. Original drawings from Brun (1880: 52, pl. 2: fig. 28). Drawing 29 represents *Ceratoneis arcus*. **Figs 28–53** Light microscopy observations of the epitype population (Salvan, Canton of Valais, Switzerland, slide made and identified by J. Brun), Fig. 51 representing the epitype. Cell cycle of *Hannaea arcus* gradually changing from typical *H. arcus* valves into *Hannaea arcus* var. *amphioxys*. The smallest valves (Figs 43–45) clearly show the typical morphology as described by Brun (1880). Scale bar represents 10 μm .