

The Lesser-Known Scientific Art of Christian Gottfried Ehrenberg

L'art scientifique méconnu de Christian Gottfried Ehrenberg

John R. Dolan¹

¹ Sorbonne Université/CNRS, Laboratoire d'Océanographie de Villefranche-sur-Mer, UMR 7093, Station Zoologique, 06230 Villefranche-sur-Mer, France, john.dolan@imev-mer.fr

ABSTRACT. Christian Gottfried Ehrenberg (1795-1876) is renowned for pioneering work on microscopic organisms. His fame is based mainly on his two beautifully illustrated monographic works. The first was the 1838 monograph on living microorganisms 'Infusoria' with 64 plates, and the second in 1854, *Mikrogeologie* with 41 plates showing the remains of microorganisms in minerals and sedimentary deposits. Largely due to these two major works, Ehrenberg is recognized as a founder of protistology on one hand and micropaleontology on the other. The illustrations in Ehrenberg's two monographs are well known but they represent less than half the plates contained in his works and many of Ehrenberg's publications did not concern microorganisms, living or fossil. Here are shown the lesser-known scientific illustrations, revealing the surprisingly wide range of his scientific investigations and consequently his artwork. Following a biographical sketch of Ehrenberg's life, to place in perspective his works, a selection of these scientific illustrations are presented. The illustrations are drawn from his articles and pamphlets published from 1818 to 1859. Later publications all concerned protists, and contain illustrations thought to be likely the work of his daughter Clara who acted as his essential aide when he became physically diminished in old age.

KEYWORDS. scientific illustration, natural history, protistology, micropaleontology.

Introduction

Christian Gottfried Ehrenberg was the premier microscopist for most of the 19th century, famous in his time for drawing attention to microorganisms both living and fossil. Today he is credited as one of the founders of protozoology by authoring a "truly monumental monograph", his 1838 *Die Infusionsthierschen als vollkommene Organismen* (Corliss 1978). The monograph included an "Atlas" of 64 hand-colored plates illustrating living microorganisms. The work has been described as "the most sumptuously illustrated classic of the field" (Churchill 1989). By the late 1830's, Ehrenberg had turned his attention to studies of the remains of microorganisms in atmospheric dust, soils, minerals and sediments. He was the first to systematically investigate the remains of microorganisms, shells, skeletons, etc., and today is credited as the "Founder of Micropaleontology" (Siesser 1981). His landmark contribution, basically establishing the field of micropaleontology, was the 1854 book *Mikrogeologie*. It included 41 plates containing over 4,000 illustrations "... of a greater variety of microfossils, known or then unknown, than have ever subsequently assembled within the covers of a single work (Sarjeant 1978). Examples of Ehrenberg's illustrations from his two works of major renown are shown in Figure 1.



Figure 1. Examples of the plates from Ehrenberg's two monographs of renown. The left panel shows plate 19 from the 1838 *Infusionsthierechen* available at <https://www.biodiversitylibrary.org/bibliography/97605>. The right panel show plate 30.A. from the 1854 *Mikrogeologie* available at <https://www.biodiversitylibrary.org/bibliography/118752>

Given their fame and quality, it is perhaps understandable that tributes and reviews of Ehrenberg's works generally show only the plates from the monographs as examples of his published illustrations. This is the case, for example, for the articles in the 1998 Ehrenberg special issue of *The Linnean* (<https://www.linnean.org/our-publications/the-linnean/the-linnean-special-issues>) and the 2021 Ehrenberg issue of the *Internationale Zeitschrift für Humboldt-Studien* (<https://www.hin-online.de/index.php/hin/issue/view/43>). While the plates in his two major monographs, numbering 101, represent a very substantial corpus, Ehrenberg's other publications contain over 150 plates and have received little attention. This is likely due to two facts: the sheer variety of topics addressed in Ehrenberg's many publications and prior difficulty in accessing the publications.

With regard to the subjects of Ehrenberg's studies, while he was a typical naturalist of his time in that he worked on a variety of topics, the range of his works was unusually large. His first publications and illustrations were on mushrooms and lichens. Later, while he was working and publishing on living microorganisms, he also published on the Siberian Tiger (Ehrenberg 1831a), pollination in plants (Ehrenberg 1832a), corals of the Red Sea (Ehrenberg 1834), the apes of ancient Egypt (Ehrenberg 1835a), medusa (Ehrenberg 1837b), nervous tissue structure (Ehrenberg 1837a) and Hydra (Ehrenberg 1838b). Indeed, Ehrenberg appears in histories of biology, due to his work on corals, medusa and hydra (e.g., Winsor, 1976.)

Ehrenberg authored a very large number of publications. The catalogue of the library of the Royal Society (London) lists over 300 titles many of which are translations or re-publication in different

journals (Williams et al. 1998). Most of the works with plates were published in journals of the Royal Prussian Academy of Sciences, *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin*, *Bericht über die zur Bekanntmachung geeigneten Verhandlungen der Königlichen Preussische Akademie der Wissenschaften zu Berlin* and *Monatsberichte der Königlichen Preussische Akademie der Wissenschaften zu Berlin*. These journals in the past were described as 'not generally available' (Siesser 1981). However, they have been available online through the Biodiversity Heritage Library since 2010 and most of the plates shown here were obtained from it.

A selection of the little-known scientific illustrations of Ehrenberg from his articles and pamphlets published from 1818 to 1859 are shown here in chronological order of publication. To place his diverse studies in perspective, and explain the delineation of his works to before and after 1864, a biographical sketch of Ehrenberg is first given.

Biographical Sketch of Christian Gottfried Ehrenberg

Concerning the life events of Ehrenberg, the following account is based largely on biographies of Ehrenberg given in Rammelsberg (1876), Jahn (1998) and Mohr (2010, 2023). The account of the North Africa/Middle East Expedition of 1820-1825 is based on the detailed review of Baker (1997), and that of the Siberian Expedition of 1829 is drawn from Naumann (2007) and Wulf (2015). Figure 2 shows Ehrenberg through the years.

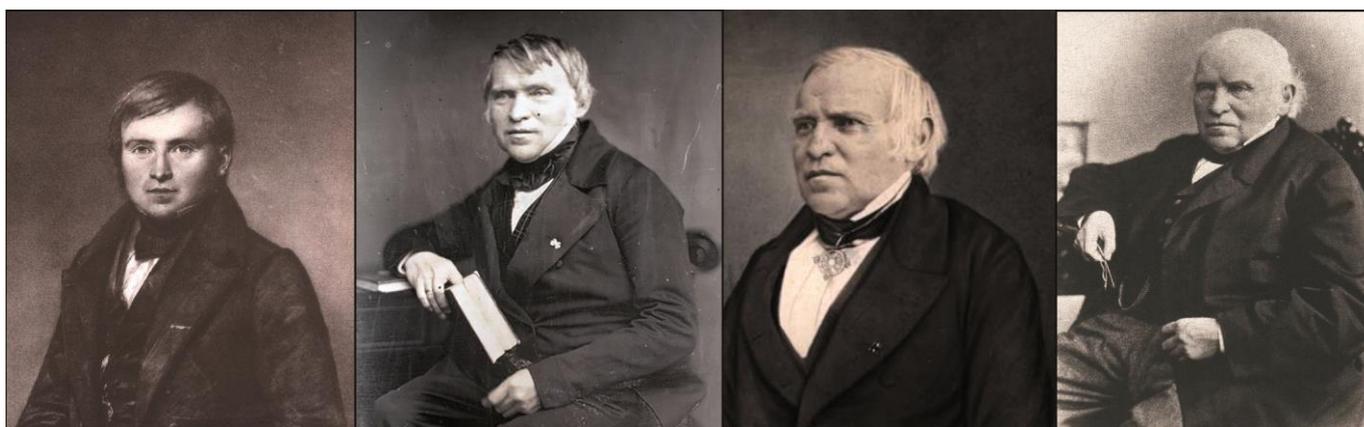


Figure 2. Christian Gottfried Ehrenberg at age ca. 25, at age 53, at age 64 and at age ca. 74.

Christian Gottfried Ehrenberg was born on the 19th of April in 1795 in Delitzsch in Saxony and there attended primary school. A gifted student, in 1810 he was granted a scholarship to attend the prestigious secondary school Pforta. After graduation in 1815, he pursued theological studies in Leipzig accordance with his father's wishes. However, his theology studies were short-lived. Reportedly, it was after his father heard him, as a first-year student, give a sermon that he allowed his son to switch his field of study from theology to medicine. Ehrenberg obtained his degree of Doctor of Medicine in November of 1818, at age 23. His inaugural dissertation (Ehrenberg 1818) was *Sylvae mycologicae Berolinenses* (Mushroom Forests of Berlin). It contained descriptions of many new species and his first published scientific illustrations.

Largely on the basis of his dissertation, Ehrenberg was elected in 1818 to the *Nationale Akademie der Wissenschaften Leopoldina*, today the oldest scientific society in continuous existence and in 1819 was named an honorary member of the elite *Gesellschaft Naturforschender Freunde zu Berlin*. He showed signs of his prodigious work capacity early on. In 1820 he published on more new mushrooms (Ehrenberg 1820a), a new lichen (Ehrenberg 1820b) and sexual reproduction in fungi (Ehrenberg 1820c). The year 1820 also marked an important turning point in Ehrenberg's life.

A Prussian General and antiquarian, Heinrich von Menu von Minutoli, organized an expedition of exploration and collection to furnish material for Prussian museums of archeology and natural history. The Academy of Sciences furnished funding for two young men, both naturalists and medical men, to join the expedition: the zoologist Wilhelm Friedrich Hemprich and the botanist Ehrenberg. They were former classmates and friends.

The expedition participants met in Alexandria and on October 6th 1820 left in a caravan of 41 camels, and 25 Bedouin guards to travel to the site of Cyrene in Libya. However, the equipment, supplies, and especially planning proved to be remarkably deficient. When the expedition neared the border, the caravan leader refused to continue without express permission of the local Libyan leader to cross the border. Messengers were sent, but Minutoli simply abandoned the expedition and left for Cairo. The expedition team, now led by Hemprich and Ehrenberg were eventually refused passage into Libya and returned to Alexandria in early December but were free to pursue exploring as they wished.

From Alexandria, Hemprich and Ehrenberg traveled to Cairo and then onto Fayum interrupted by a 3 month stay near the pyramids when Ehrenberg was ill with typhoid fever. They then traveled up the Nile. In mid-1822, Hemprich left for Alexandria with the collections made thus far to send them onto Berlin and request funding to continue their explorations and collecting. At first the demand for further funding was refused but before they could arrange return passage, they received news that the state had granted them funds to continue. They traveled to the Sinai, the Red Sea, Arabia, and Lebanon. In 1824 they traveled to Arabia and Ethiopia. In Massawa, in present day Eritrea, the entire exploration party fell ill with malaria. Hemprich died on June 30th 1825 and Ehrenberg returned to Berlin, the sole survivor of the expedition.

The expedition had been widely followed, even in British and American journals, e.g. Anon. (1821, 1824a, 1824b). Consequently, on his return to Berlin, Ehrenberg was now a well-known naturalist. He was elected to the Imperial Academy of Sciences and obtained a post as Associate Professor at the University in Berlin. Ehrenberg began an ambitious effort to publish a series of works on the animals, plants and microorganisms observed and collected during his travels with Hemprich. These were to be a series of large format (50 x 38 cm) illustrated volumes all under the general heading of *Symbolae Physicae* (Icons and descriptions), with Hemprich as first author. They were however, never completed. Ehrenberg encountered significant difficulties. The expedition collections had been seriously mismanaged by Natural History Museum. Hemprich and Ehrenberg's labels, identifying specimens and sampling locations, had been removed and many specimens had been sold, given away, or traded. Ehrenberg lacked expertise in many of the groups. Financing the publication proved difficult. The parts published in Ehrenberg's lifetime were on mammals, birds, fish, insects, invertebrates other than insects, and plants. The volumes were published in separate issues quite idiosyncratically. The complicated publication history has been examined in some detail in Braunwalder & Fet (1998) and Bauer (2000). For some of the volumes, the plates were published well in advance of the text or without the text. For example, the plates for the invertebrates other than insects volume were issued in 1828 and the text in 1832. For at least one group, the plants, the plates were issued in 1828 but the text was not published until 1900, well after the death of Ehrenberg. A likely partial explanation is that beginning in 1828, Ehrenberg became occupied with other matters.

Ehrenberg read his first study focused on microorganisms to the Academy of Sciences in January of 1828, *Die geographische Verbreitung der Infusionsthierchen in Nord-Afrika und West-Asien, beobachtet auf Hemprich und Ehrenbergs Reisen* (The geographical distribution of the infusoria animals in North Africa and West Asia, observed on Hemprich and Ehrenberg's travels). It was his first attempt to describe biographic patterns of 'infusoria' based on scattered observations made during the expedition with Hemprich. The study was not published until 1832 (Ehrenberg 1832b) by

which time he had made further voyages to investigate 'infusoria' in different localities thanks to Alexander von Humboldt.

Humboldt, the famous explorer of South America and especially the Andes, longed to visit the Himalayas to compare the distributions of flora and fauna to those he had documented for the Andes. In 1827, he received an invitation from the Russian Tsar Nikolaus to undertake an expedition across Russia. The Tsar's invitation and offer of financing, was motivated by a desire to have knowledge of the mineral deposits of Russia. For Humboldt, it would allow him to visit not the Himalayas but mountain ranges he thought likely similar, the Altys and Ural mountain ranges, north of the Tibetan Plateau. Humboldt recruited Ehrenberg to serve as zoologist and botanist and Gustav Rose to serve as geologist. From April to December 1829, they traveled and collected across the varied landscapes of Russia, from the far east to the Caspian Sea, with Ehrenberg focused on microscopic organisms. On his return to Berlin, on December 29th 1829, Ehrenberg concentrated his studies on 'infusoria', their morphologies, classifications and geographical distributions.

A mere 3 months after his return to Berlin, Ehrenberg read before the Academy of Sciences his second study dedicated to characterizing microorganisms: *Beiträge zur Kenntniss der Organisation der Infusorien und ihrer geographischen Verbreitung, besonders in Sibirien* (Contributions to the knowledge of the biology of the infusoria and their geographical distribution, especially in Siberia). The article was printed in August 1830 and distributed by Ehrenberg well before it was formally published in 1832, in the academy's proceeding for the year 1830 (Ehrenberg 1832c). Ehrenberg's 'in press article' was presented to the Academy of Sciences in Paris by Humboldt and it was received as a landmark publication. Citing the article, Ehrenberg was elected as a corresponding member of the French academy in 1831 and awarded the medal of physiology and medicine in 1832. Other honors included election as a full member of the *Gesellschaft Naturforschender Freunde zu Berlin* in 1831, and election to the Linnean Society of London. The year 1831 also marked Ehrenberg's personal life. He married Julie Rose, a cousin of Gustav Rose, his fellow scientist of the Russian Expedition. His first wife would bear 10 children, only 5 of which, a boy and 4 girls, would survive to adulthood. The eldest daughter Clara, born in 1838, would as an adult play a large role in Ehrenberg's late professional life.

As mentioned in the Introduction, Ehrenberg published on a wide variety of topics in 1830's mostly relating to his travels, for example the corals of the Red Sea, the baboons of ancient Egypt and the Siberian Tiger. He published relatively few articles on infusoria before the appearance of his massive monographic work in 1838. His articles on infusoria, showing a complexity of micro-organs in the microorganisms, which at first had brought him considerable fame, was criticized as other failed to find evidence of gonads or intestinal tracts and multiple stomachs. Beginning early on, his characterizations were disputed by the French workers Bory de Saint-Vincent (1831) and Dujardin (1835, 1838) and later by British workers whose critiques prompted an attempt at rebuttal by Ehrenberg (Ehrenberg 1839). Coincidentally or not, in the late 1830's Ehrenberg turned his attention away from studies of living microorganism to studies of the fossil remains of microorganisms. Ehrenberg read his first study on fossil microorganisms to Academy of Sciences in July of 1837 by which time it is likely that his 1838 monograph was in production. From 1839 on, Ehrenberg published nearly exclusively on micro-fossils. His major work on fossil forms *Mikrogeologie* appeared in 1854.

In 1864, Ehrenberg suffered a serious fall, resulting in a broken hip, immobilizing him for months. It was at this time that his eldest daughter Clara began working as a scientific helpmate, at first simply reading to him. Subsequently, he developed cataracts, and although surgery restored some vision, his ability to use a microscope was greatly reduced. Clara assumed the tasks of examining samples and making drawings. She illustrated Ehrenberg's publications beginning in 1866 (Fig. 2). The fact that Ehrenberg's publications were illustrated by Clara Ehrenberg was recognized at the time and her artwork was described as illustrations drawn "with the truthful skill

of her father's pencil" (Jones 1877). However, comparing figures 1 and 3, Clara Ehrenberg's plate differs from those of her father. Her plate is less crowded and more simply and clearly organized than those of her father.

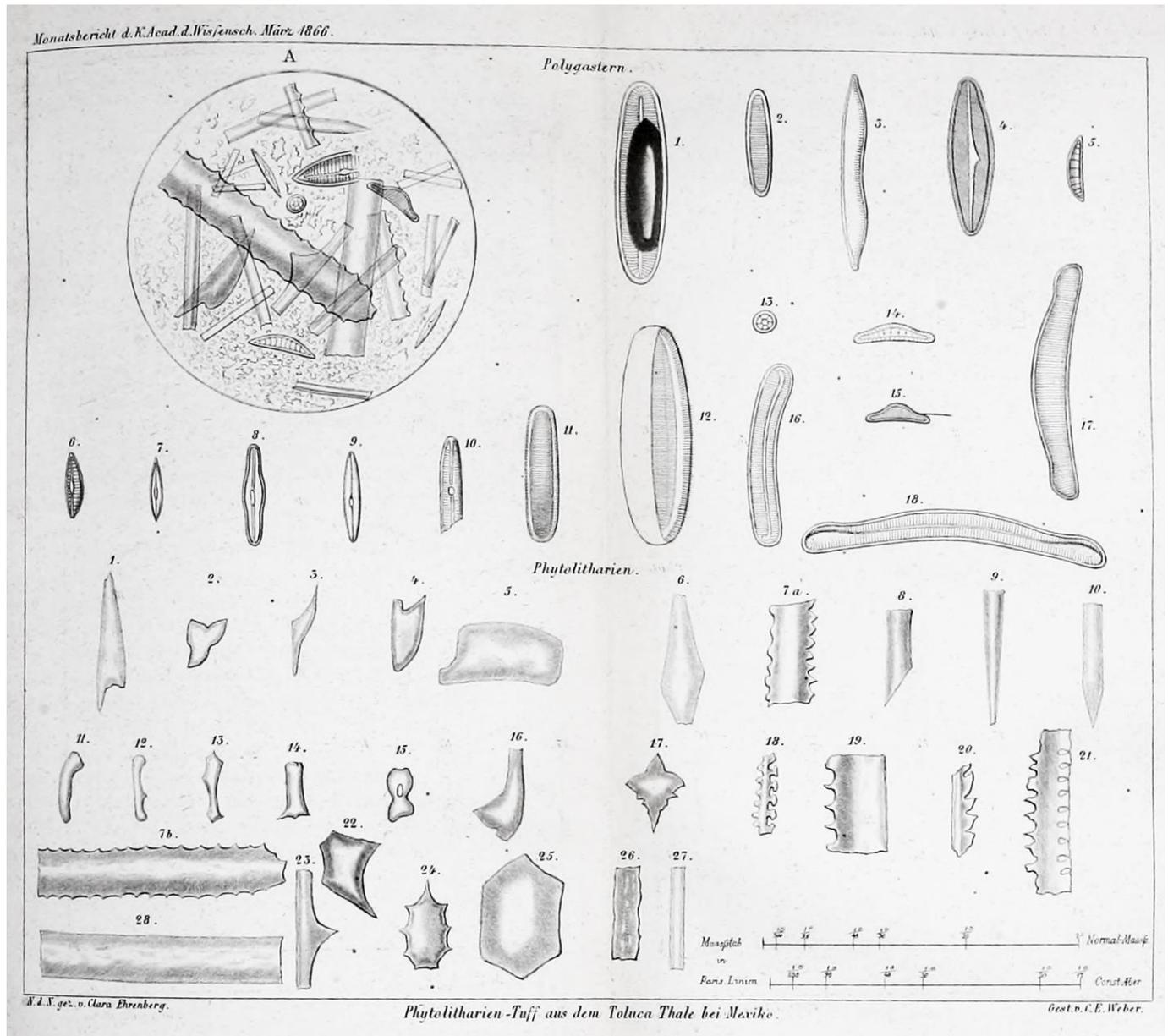


Figure 3. The plate from Ehrenberg 1867. The credit line in the lower left corner reads "N. d. N. gez. v. Clara Ehrenberg" indicating the illustrations were drawn after life, from her own observations. The engraver was C.E. Weber.

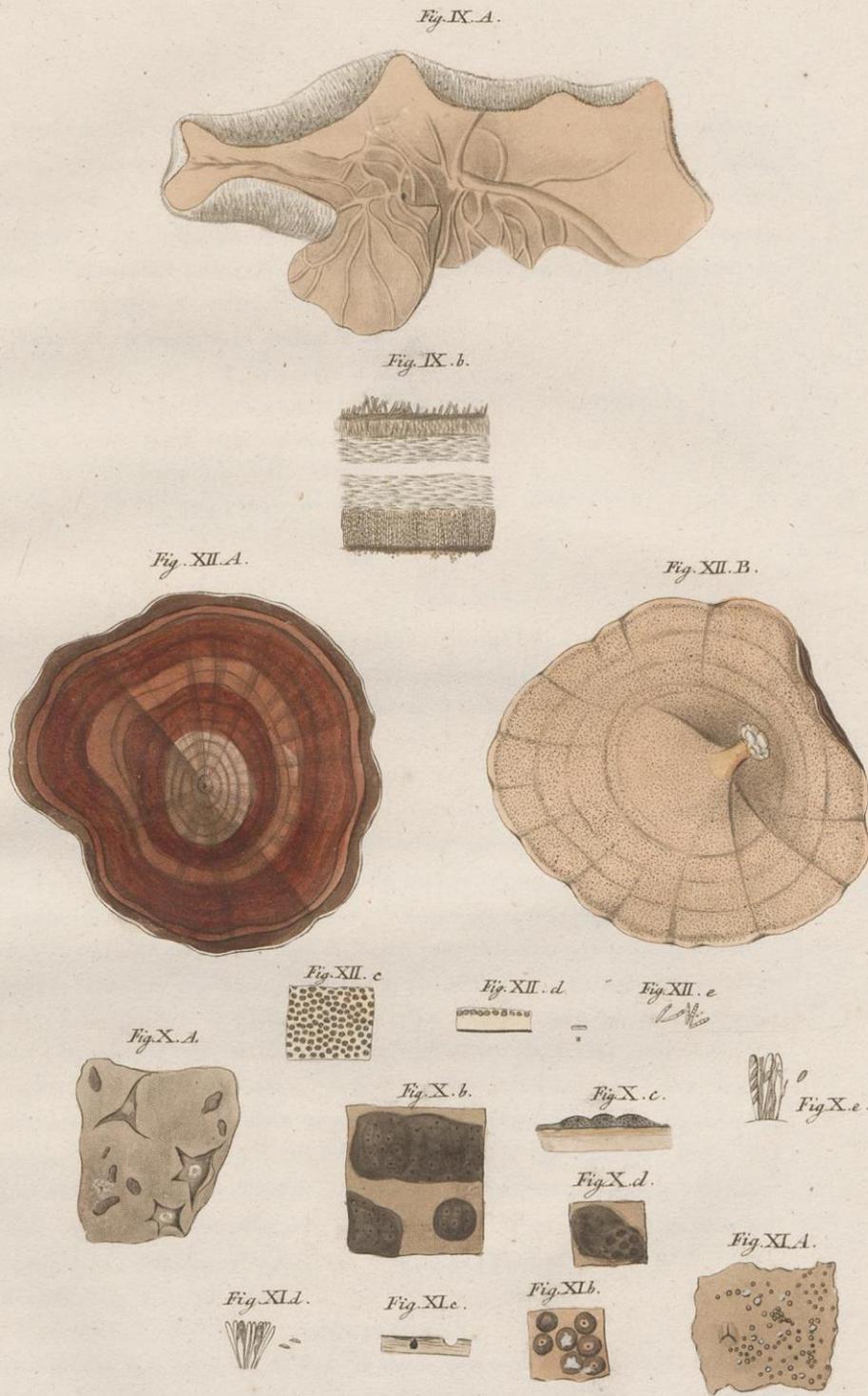
Lesser-Known Scientific Art of Christian Gottfried Ehrenberg

Below are presented a selection of plates from articles and pamphlets of Ehrenberg containing plates signed by Ehrenberg as the sole artist and not uniquely concerning microorganisms. These works contained a total of 103 'Ehrenberg plates' plates. The plates from Ehrenberg's later works, from 1864 to his death in 1876, were excluded as they are thought to be the artwork of Clara Ehrenberg, based on her own microscopic observations (Mohr 2023). Excluded from the selection pool were all plates that contained elements later reproduced in one of Ehrenberg's monographs or closely resembling the illustrations in his monographs. This yielded a pool of 48 plates from 14 works. Many of Ehrenberg's articles contained multiple plates but only a single plate was selected from each work. They were chosen specifically to provide evidence of the wide variety of subjects illustrated by Ehrenberg, other than the familiar microorganisms. Thus, the 14 plates shown below

must not be taken for a representative sampling of Ehrenberg's work. Furthermore, it is likely, if not certain, that some works have been over-looked.



Figure 4. The plate from Ehrenberg's Doctoral Thesis 1818: *Sylvae mycologicae Berolinenses* (Mycological Forests of Berlin). The engraver F. Guimpel, was an instructor at the Academy of Arts in Berlin. The actual size of the plate is 27 cm tall.



IX. *Auricularia cornea*. X. *Sphaeria profuga*.
 XI. *Sphaeria fur*. XII. *Boletus Katui*.

Dr. C.G. Ehrenberg. pinx.

Prof. F. Guimpel. sculp.

Figure 5. A plates from Ehrenberg's 1820a publication *Enumerato fungorum, a vivo clarissimo a.d. Chamisso sub auspiciis Romanzoffianis in itinere circa terrarum globum collectorum* (fungi from the most famous Chamisso collection, etc.), one of four plates. The engraver signed 'Prof. F. Guimpel'; he was by 1820 a Professor at the Academy of Arts in Berlin. The actual size of the plate is 40 cm tall.



Coenogonium Linkii.

Dr. C.G. Ehrenberg pinx.

J. Sturm sc.

Figure 6. The single plate from Ehrenberg 1820b "De coenogonio novo lichenum genere ex penu viri clarissimi chamissonis desumto" (a new genus of lichen from the most famous Chamisso collection). The engraver signed 'J. Sturm'. The actual size of the plate is 40 cm tall.

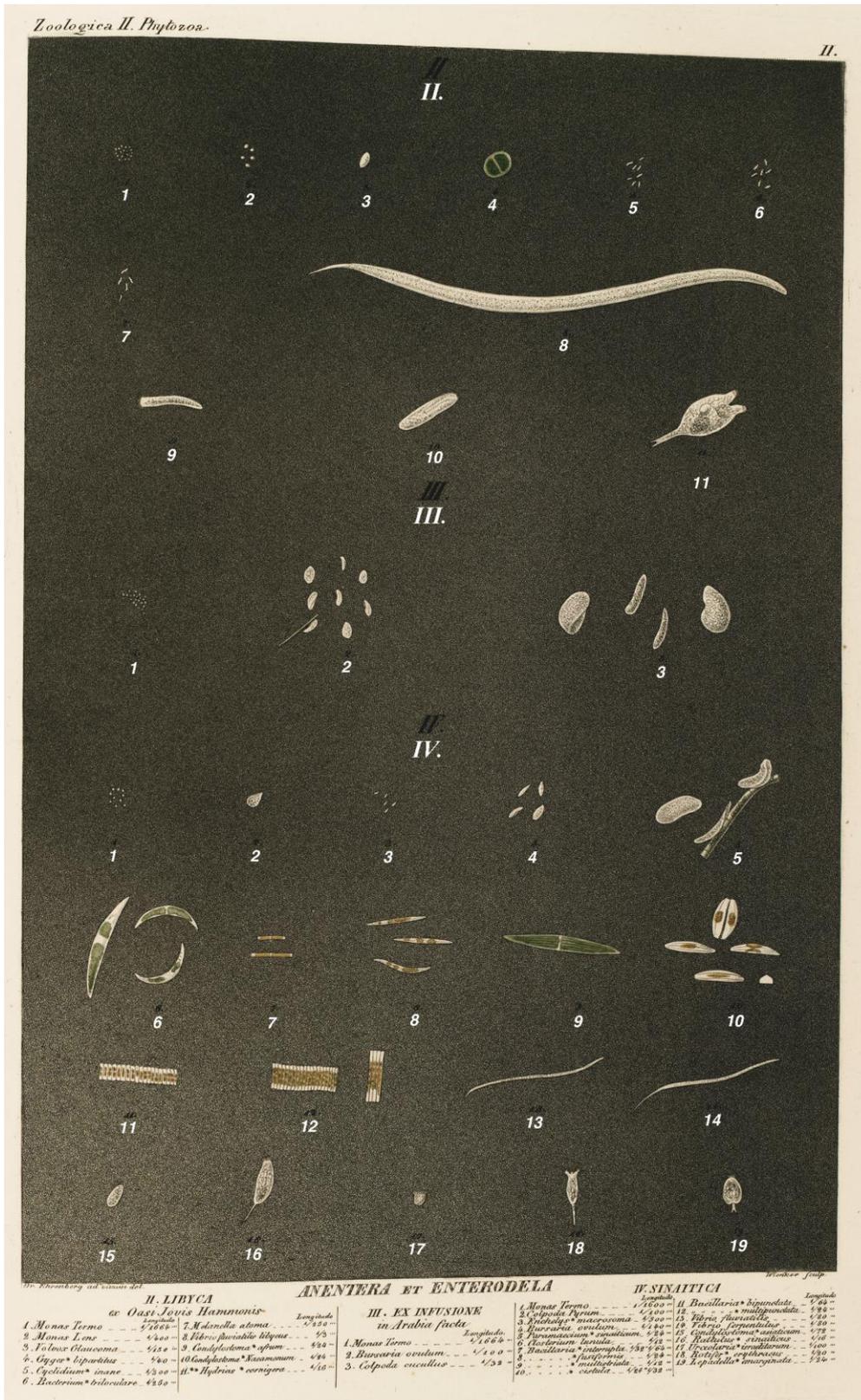


Figure 8. One of 10 plates from Hemprich & Ehrenberg's 1828-1831. *Symbolae Physicae* volume *Animalia Evertebrata Exclusis Insectis*: invertebrates excluding insects. The plate shows various aquatic microorganisms observed during Ehrenberg's 1820-1825 travels. The roman and arabic numbers in white have been added to facilitate location of the figures listed in the legend. The topmost group (II), were found in an oasis. The middle group (III) were observed in 'infusions incubated in Arabia' (III) and the bottom group IV found in 'the Sinai'. It is 1 of 3 plates constituting his earliest illustrations of microorganisms. It is included here because all 3 plates employing a black background, are very different from Ehrenberg's later illustrations of microorganisms. The plates may be the first illustrations of microorganisms on a black background. The actual size of the plate is 40 cm tall. Ehrenberg signed 8 of the 10 plates in Hemprich & Ehrenberg 1828-1831 and all were engraved by B. Wienker.

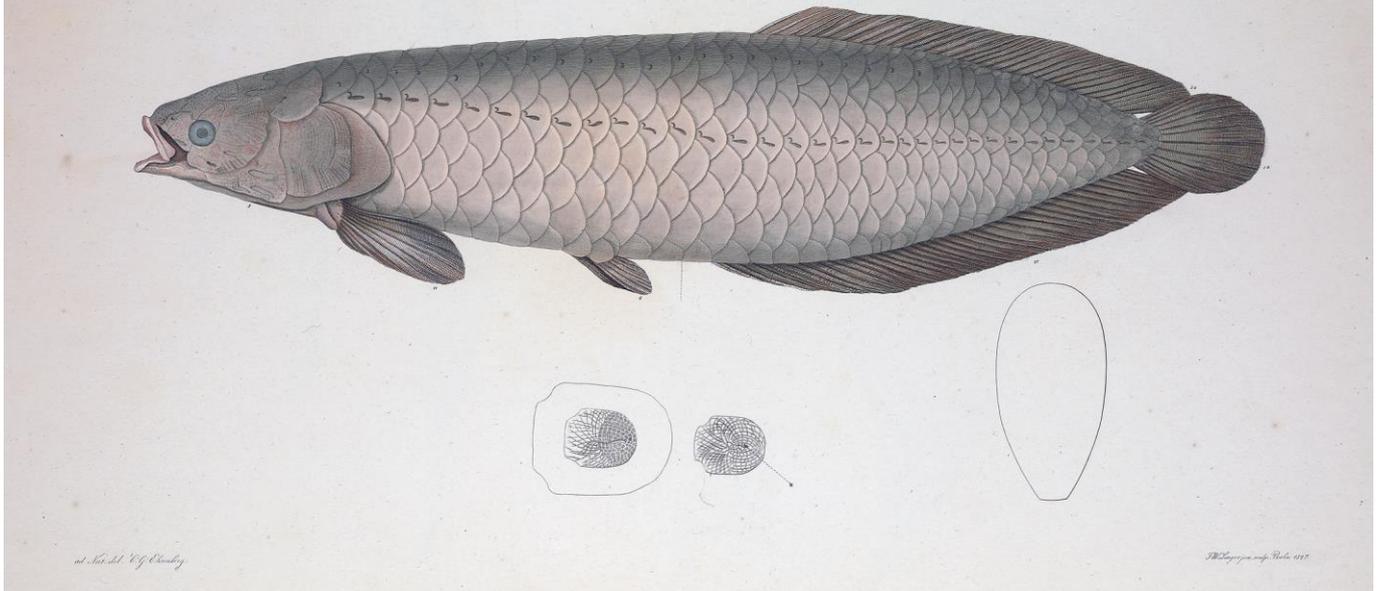
HETEROTIS nilotica H & E

Figure 9. One of the 10 plates from Hemprich & Ehrenberg's 1828a *Symbolae Physicae* volume "Pisces". (Hemprich & Ehrenberg 1828a). It depicts a new fish species *Heterotis niloticus* Hemprich & Ehrenberg from the Nile River. The engraver signed F.W. Longerjam Berlin 1827. The actual width of the plate is 50 cm. Only two of the fish plates were by signed by Ehrenberg. The other Ehrenberg fish plate was a lithograph by Pohlke.



RUBOR MARIS RUBRI

TRICHODESMIUM erythraeum.

Dr. Ehrenberg aut. nat. del.

B. Wienker sc.

21

Figure 10. One of the 24 plates from Hemprich and Ehrenberg's 1828 *Symbolae Physicae* volume "Botanica". (Hemprich & Ehrenberg 1828b). It depicts the organism that gives the Red Sea its color discovered by Ehrenberg, *Trichodesmium*. He described it in detail (without illustrations) in 1830 (Ehrenberg 1830). The figure A is 'the alga in a glass of water'. The engraver signed F.W. Longerjam Berlin 1827. The actual size of the plate is 50 cm tall. *Trichodesmium* is now commonly recognized to be a key component of the nitrogen cycle in the world ocean as it fixes nitrogen (Capone et al. 1997). The copy shown is from the 1899 re-edition. Ehrenberg signed 6 of the 24 plates in 1828 version; 2 were engraved by Röhling, 1 by B. Weber and 3 by B. Wienker.

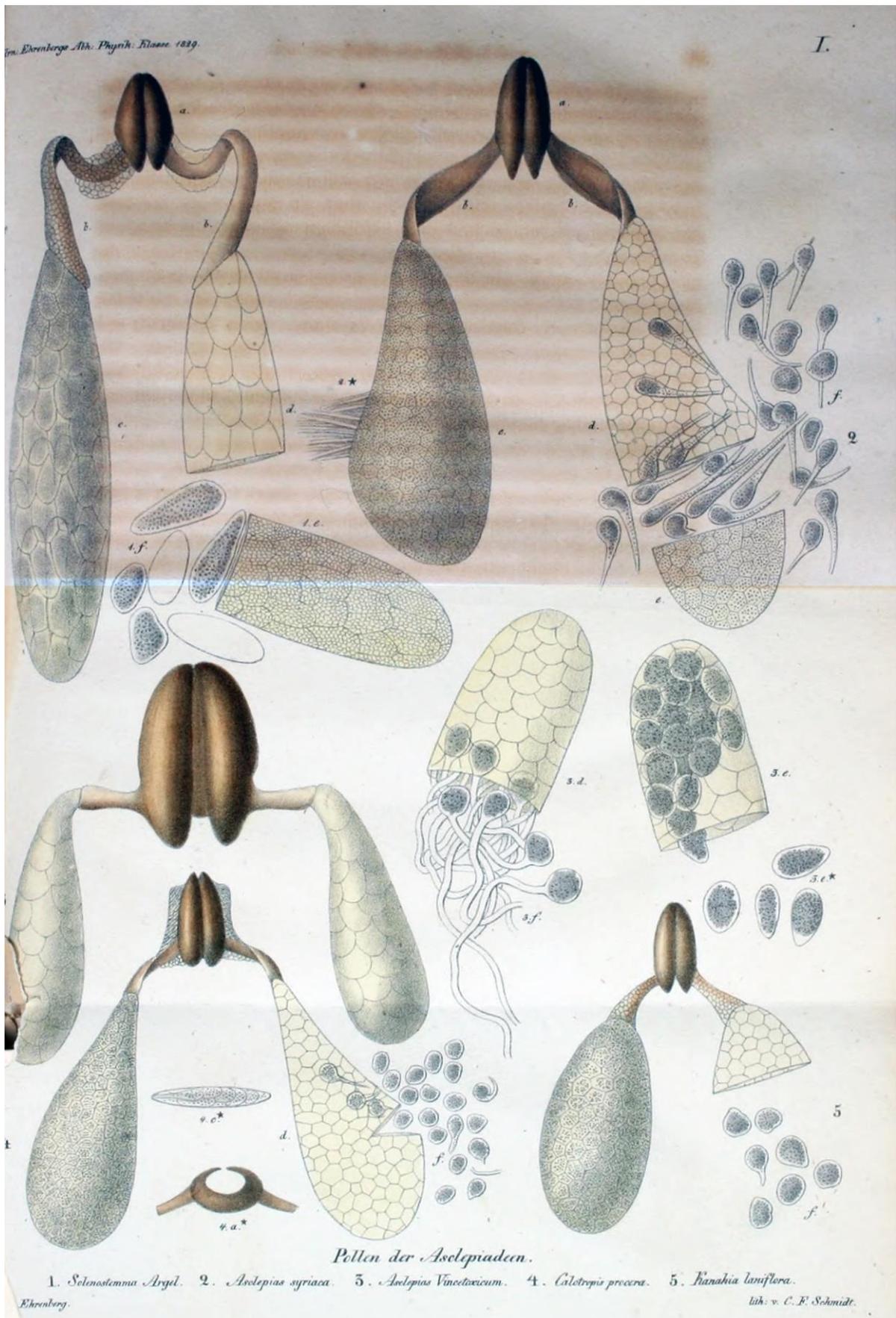


Figure 11. Plate 2 from Ehrenberg 1832a, *Über das Pollen der Asclepiadeen; ein Beitrag zur Auflösung der Anomalien in der Pflanzen-Befruchtung* (On the pollen of the Asclepiadeae; a contribution to the resolution of anomalies in plant fertilization). Ehrenberg presented the paper to the Academy of Sciences in November 1828, shortly before he left with Humboldt for the Russian Expedition but it was not printed until November 1831. Ehrenberg's study was apparently motivated by reports of plant fertilization by British workers. Unlike most of Ehrenberg's plates, which were copperplate engravings, both two plates were lithographs by Schmidt. The actual size of the plate is 36 cm tall.

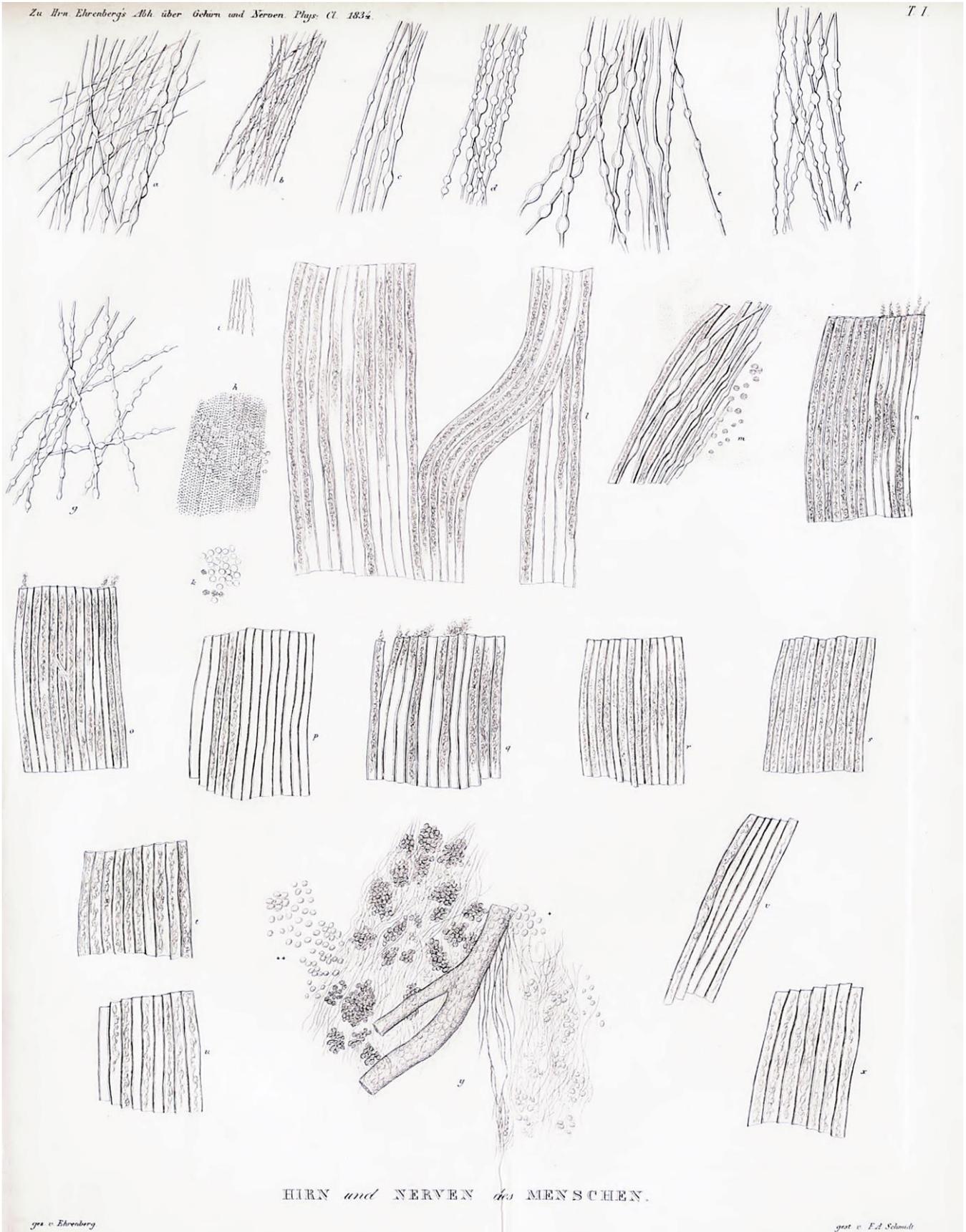


Figure 12. Plate 1 of 6 plates showing human brain and nerve tissues, from Ehrenberg's article on the structure of nervous tissue in humans and other animals, Ehrenberg 1836b, *Beobachtung einer bisher unbekanntem auffallenden Struktur des Seelenorgans bei Menschen und Thieren* (Observation of a hitherto unknown striking structure of the psychic organ in humans and animals). Ehrenberg claimed that the nodules in nerve fibers shown in the top row of figures of human nerves characterized nerve fibers but it was soon shown to be an artifact of placing tissue in water and compressing it to make a slide (Schickore 2005). The plate shown, and one other were engraved by Schmidt; the four other plates were engraved by Weber. Actual size of the plate is 26 cm tall.

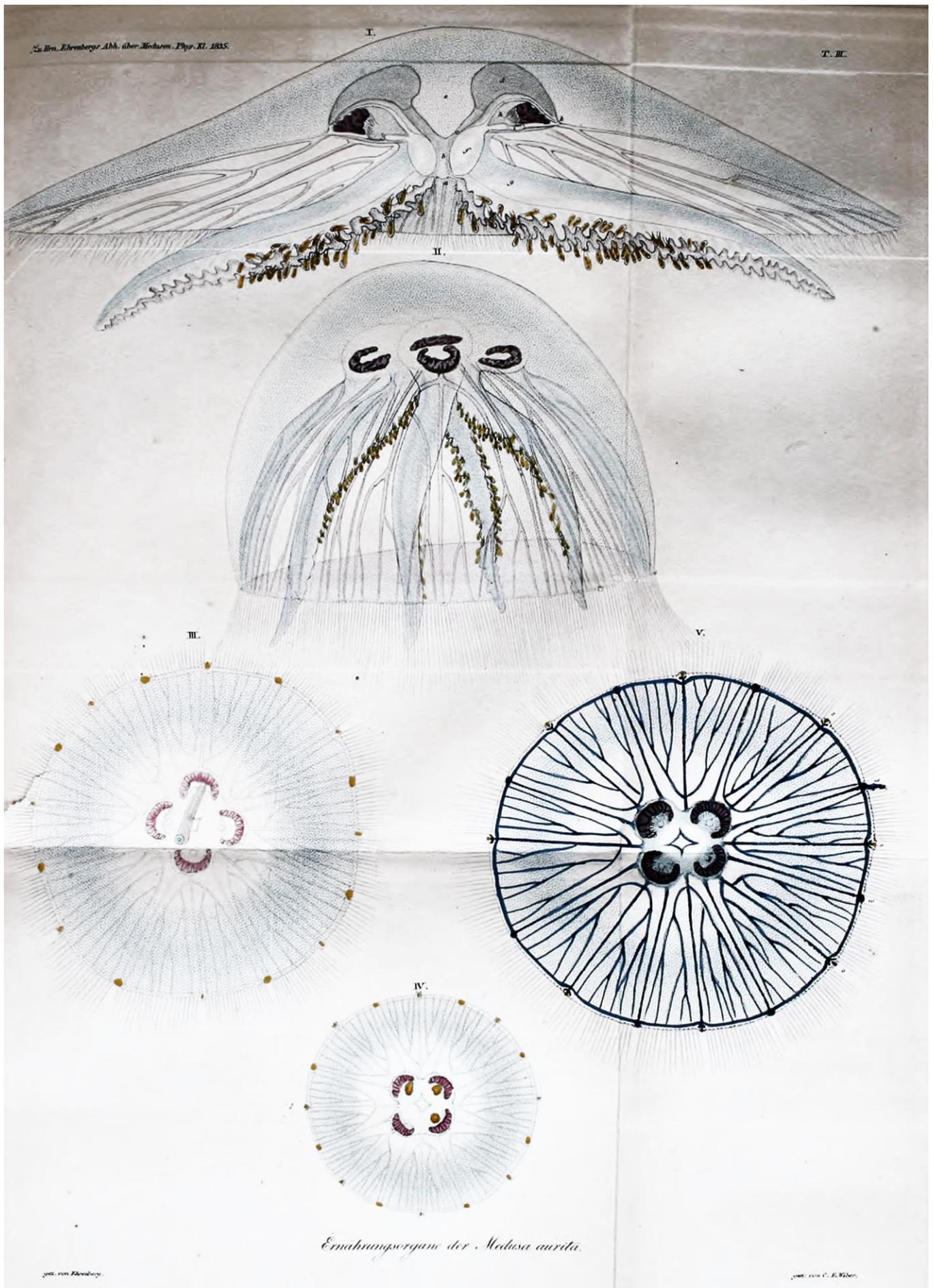


Figure 13. Plate 2 of 8 plates from Ehrenberg 1837b *Über die Akalephen des Rothen Meeres und den Organismus der Medusen der Ostsee* (On the worms of the Red Sea and the organs of the medusae of the Baltic Sea), showing the feeding organs of *Medusa aurita*. All 8 plates were engraved by Weber. The actual size of the plate is 36 cm tall.

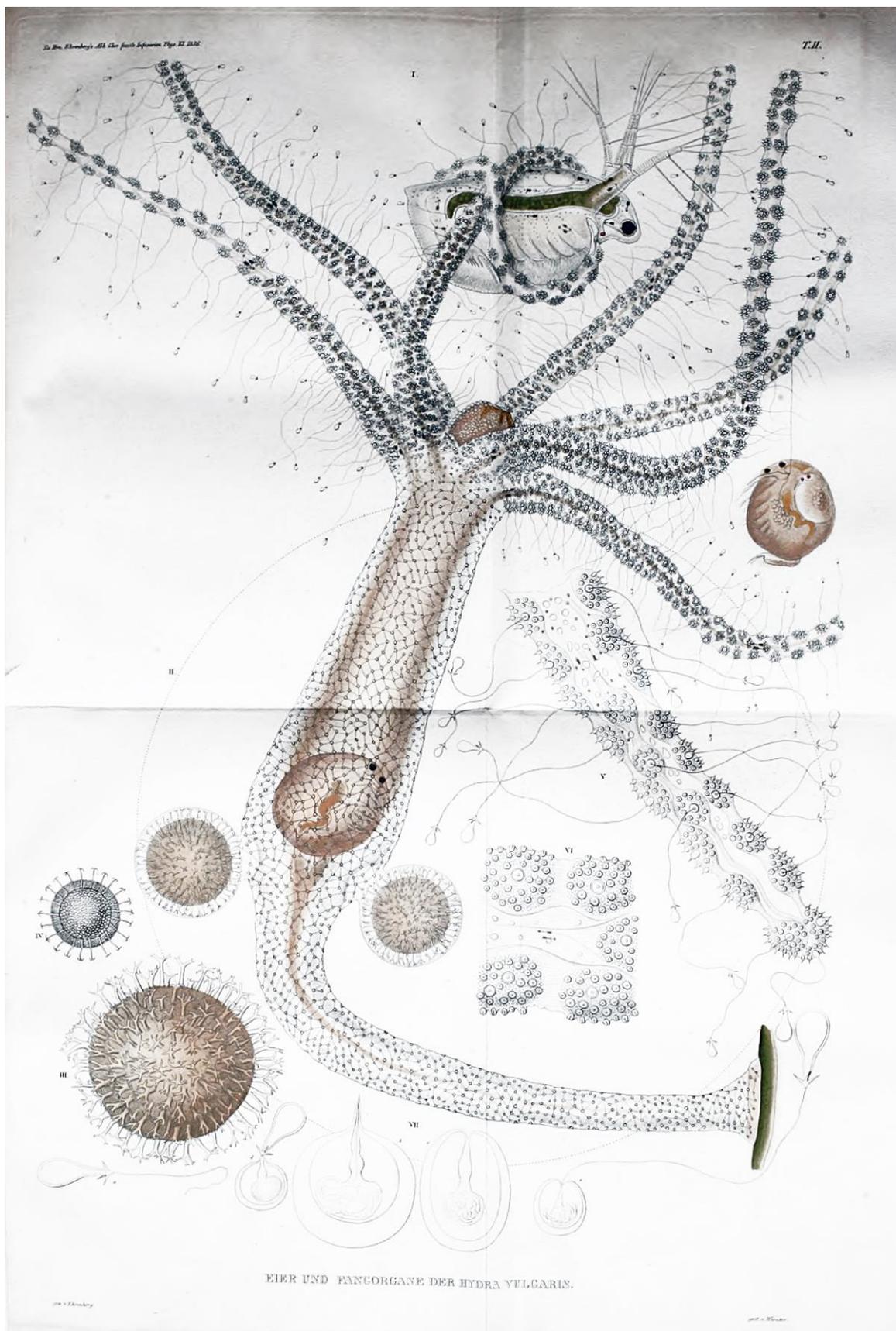


Figure 14. Plate 2 from Ehrenberg 1838b. The title of article *Über das Massenverhältniss der jetzt lebenden Kiesel-Infusorien und über ein neues Infusorien-Conglomerat als Polirschiefer von Jastraba in Ungarn* (On the mass ratio of the now living siliceous infusoria and on a new infusoria conglomerate of Polish slate from Jastraba in Hungary), gave no indication that a considerable part of the paper is devoted to the biology of Hydra. The plate, showing Hydra capturing a Daphnia, also illustrated egg formation in Hydra, previously thought to reproduce asexually. Ehrenberg's findings were said to have 'startled' naturalists (Johnson 1847). The actual size of the plate is 36 cm tall. The plate was engraved by Wienker. Plate 1, showing microfossils, was engraved by Weber.

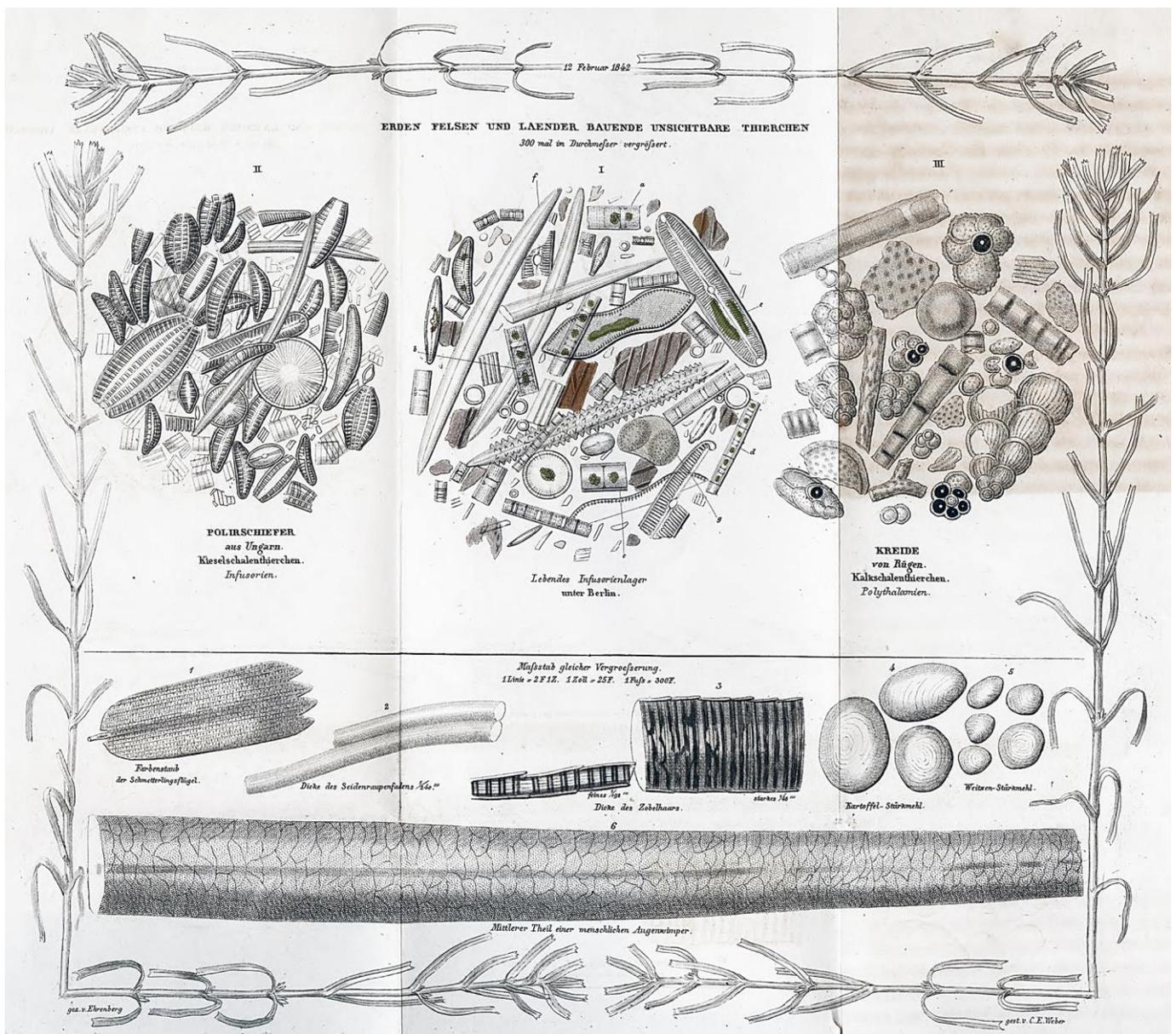


Figure 15. The plate from Ehrenberg 1842. The publication was a pamphlet based on a public lecture: *Das unsichtbar wirkende organische Leben. Eine Vorlesung im Vereine für wissenschaftliche Vorträge gehalten zu Berlin am 12 Februar 1842* (The seemingly invisible organic life). It is very unusual, because it was likely designed to appeal to, and educate, the general public. The bottom half of the plate shows illustrations of familiar items drawn to the same scale as the remains of microorganisms found in minerals. In the bottom half, at the top from left to right, are a scale from a butterfly wing, silk thread, sable, and grains of potato starch, all above a human eyelash. The engraver was Weber. The actual size of the plate is 21 cm tall.

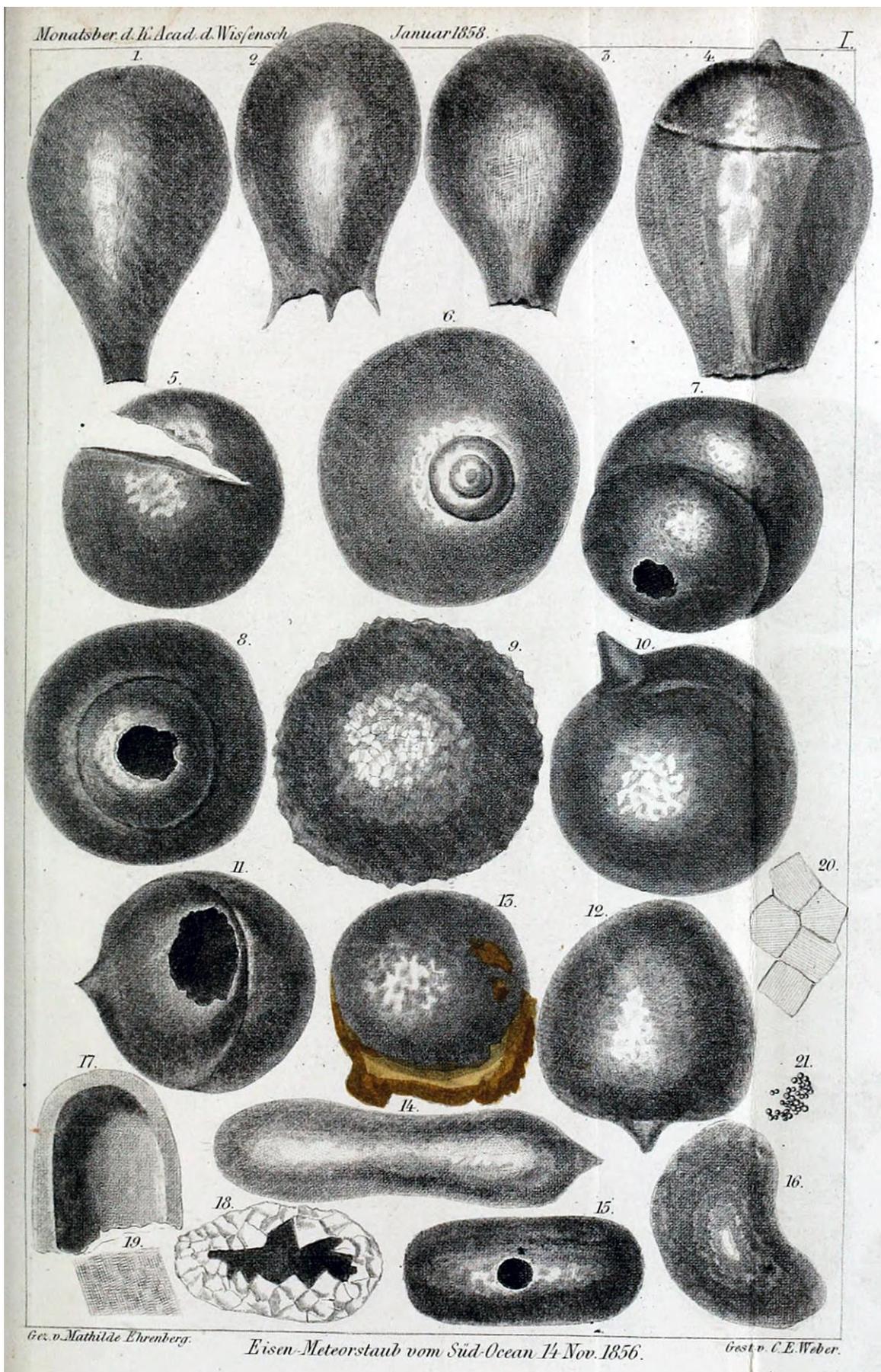


Figure 16. The single plate from Ehrenberg 1859a. *Über einen Niederfall von schwarzem, polirten und hohlen Vogelschrot-Körnern ähnlichen atmosphärischen Eisenstaub im hohen Süd-Ocean* (On a rain of black, polished, and hollow birdshot-like atmospheric iron dust in the high South Ocean). It is unusual as the particles shown are examples of iron particles formed during a volcanic eruption which resemble the remains of microorganisms. The actual size of the plate is 24 cm tall. The engraver signed C.B. Weber

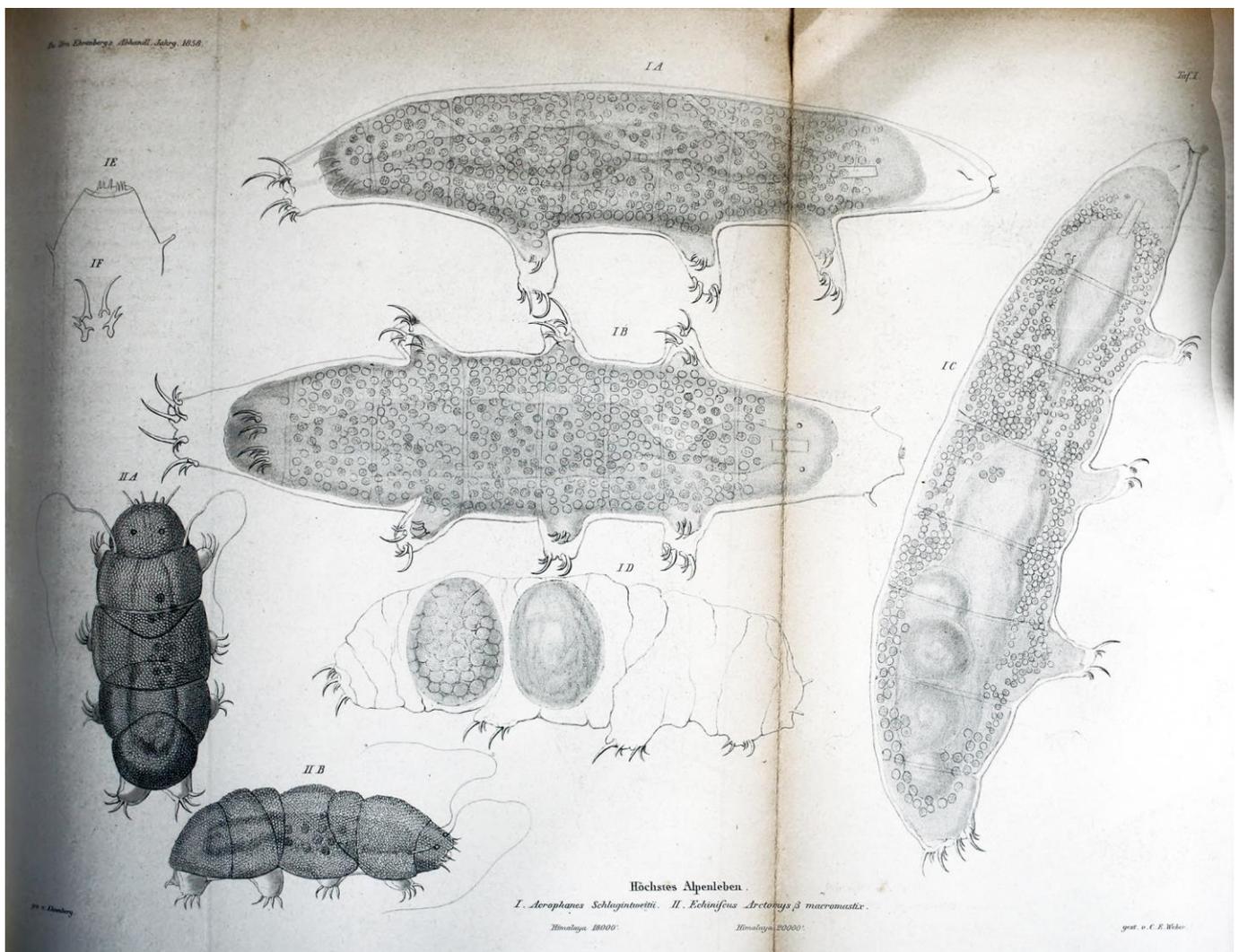


Figure 17. Plate 1 of the 3 plates from Ehrenberg 1859b: *Beitrag zur Bestimmung des stationären mikroskopischen Lebens in bis 20000 Fuss Alpenhöhe* (Contribution to the determination of microscopic life in up to 20,000 feet altitude). The plates showed tardigrades, popularly known as 'water bears' found in soil samples from Himalayas sent to Ehrenberg. The plates, all engraved by Weber, are the only illustrations of tardigrades by Ehrenberg.

Conclusion

Hopefully shown here is that Christian Gottfried Ehrenberg's scientific artwork ranged well beyond his renowned illustrations of protists, rotifers and micro-fossils. The interest in shining a light on Ehrenberg's lesser-known works is two-fold. The first is to demonstrate the surprising breadth of Ehrenberg's studies as he is often categorized as either a microbiologist or micro-paleontologist. The second is to show the quality of his illustrations 'the truthful skill of his pencil' whether drawing a mushroom, a fish, or a particle of iron.

Acknowledgements

Barbara Mohr kindly provided me with advance copy of her 2023 article on Clara Ehrenberg. Vivien Bauer, at the Bibliothek of the Museum für Naturkunde at the Leibniz Institute for Evolution and Biodiversity Science, kindly provided me with a high-resolution copy of Ehrenberg's 1820 article in the *Verhandlungen der Gesellschaft Naturforschender Freunde zu Berlin*, and information on the dimensions of the journal.

References

- Anon., 1821. New details relative to the discoveries in Egypt extracted from the correspondence of Gen. Minu de Minutoli. *Monthly Magazine or British Register of Politics, Literature and the Belles Lettres*, 52:336-339.
- Anon., 1824a. Prussia. *Monthly Magazine or British Register of Politics, Literature and the Belles Lettres*, 57:541.
- Anon., 1824b. Prussian travelers. *American Journal of Science and Arts*, 1824: 195.
- Baker, D.B. 1997. C.G. Ehrenberg and W.F. Hemprich's travels, 1820-1825 and the Insecta of the Symbolae Physicae. *Deutsche Entomologische Zeitschrift*, 2:165-202.
- Bory de Saint-Vincent, J.-B. 1831. Règne Animal. Microscopiques (introduction). *Dictionnaire Classique d'Histoire Naturelle* 17:50–53.
- Bauer, A.M. 2000. The Symbolae Physicae and the herpetology of Hemprich and Ehrenberg's expedition to Egypt and the Middle East. *Newsletter and Bulletin of the International Society for the History and Bibliography of Herpetology*, 2:8-16.
- Braunwalder, M.E., Fet, V. 1998. On publications about scorpions (Arachnida, Scorpiones by Hemprich and Ehrenberg (1828-1832). *Bulletin British Arachnology Society*, 11:29-35.
- Capone, D.G., Zehr, J.P., Paerl, H.W., Bergman, B., Carpenter, E.J. 1997. *Trichodesmium*, a globally significant cyanobacterium. *Science*, 276:1221-1229.
- Churchill, F.B. 1989. The guts of the matter: infusoria from Ehrenberg to Bütschli: 1838-1876. *Journal of the History of Biology*, 22:189-213.
- Corliss, J.O. 1978. A salut to fifty-four great microscopists of the past: a pictorial footnote to the history of protozoology. part 1. *Transactions of the American Microscopical Society*, 97:419-458.
- Dujardin, F. 1835. Recherches sur les organismes inférieurs. *Annales des Sciences Naturelles*, ser 2, Zool., 4:343–377.
- Dujardin, F. 1838. Mémoire sur l'organisation des Infusoires. *Annales des Sciences Naturelles*, ser 2, Zool. 10:230–315.
- Ehrenberg, C.G. 1818. *Sylvae Mycologicae Berolinensis*. Berlin: Theophili Brusckke, 32 pp + 1 plate.
- Ehrenberg, C.G. 1820a. Enumerato fungorum, a vivo clarissimo a.d. Chamisso sub auspiciis Romanzoffianis in itinere circa terrarum globum collectorum. in Nees ab Esenbeck, C.G. (ed) *Horae Physicae Berolinenses Collectae ex Symbolis Virorum Doctorum*, Bonnae: Adoplhi Marcus., pp. 77-104 + 4 plates.
- Ehrenberg 1820b. De coenogonio novo lichenum genere ex penu viri clarissimi Chamissonis desumto. in Nees ab Esenbeck, C.G. (ed) *Horae Physicae Berolinenses Collectae ex Symbolis Virorum Doctorum*, Bonnae: Adoplhi Marcus., pp. 119-123 + 1 plate.
- Ehrenberg, C. G. 1820c. Syzygites, eine neue Schimmelgattung, nebst Beobachtungen über sichtbare Bewegung in Schimmeln. *Verhandlungen der Gesellschaft Naturforschender Freunde zu Berlin I*: 98–109 + 2 plates.
- Hemprich, F.G., Ehrenber, C.G. 1828a. *Symbolae Physicae seu Icones et Descriptiones Piscium*. 10 plates without text. Berlin: Ex Officina Academica, venditur a Mittlerlo.
- Hemprich, F.G., Ehrenberg, C.G. 1828b. *Symbolae Physicae seu Icones et Descriptiones plantarum cotyledonearum quae ex intere per Africam borealem et Asiam Occidentalem*. 24 plates without text. Berlin: Ex Officina Academica, venditur a Mittlerlo.
- Hemprich, F.G., Ehrenberg, C.G. 1828-1831. *Symbolae Physicae. Animalia Evertebrata Exlusis Insectus*. Berlin: Ex Officina Academica, venditur a Mittlerlo. 10 Plates published in 1828, text in 1831.
- Ehrenberg, C.G. (1830), Neue Beobachtungen über blutartige Erscheinungen in Aegypten, Arabien und Sibirien, nebst einer Uebersicht und Kritik der früher bekannten. *Annalen der Physik und Chemie*, 94: 477-514.
- Ehrenberg, C.G. 1831a. Observations et données nouvelles sur le tigre du nord et la panthère du nord, recueillies dans le voyage de Sibérie fait par M. A. de Humboldt, en l'année 1829. *Annales des Sciences Naturelles*, 21: 387-412.
- Ehrenberg, C.G. 1832a. Über das Pollen der Asclepiadeen; ein Beitrag zur Auflösung der Anomalien in der Pflanzen-Befruchtung. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin*, Year 1829: 21-39 + 2 plates. (Noted as read in November 1828, printed with corrections in November 1831).
- Ehrenberg, C.G. 1832b. Die geographische Verbreitung der Infusionsthierchen in Nord-Afrika und West-Asien, beobachtet auf Hemprich und Ehrenbergs Reisen. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin*, Year 1829: 1-20. (Noted as read 10th Jan. 1828).

- Ehrenberg, C.G. 1832c. Beiträge zur Kenntniss der Organisation der Infusorien und ihrer geographischen Verbreitung, besonders in Sibirien. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin*, Year 1830: 1-88 +8 plates. (Noted as read in March 1830, printed with corrections August 13 1830).
- Ehrenberg, C.G. 1834. Beiträge zur physiologischen Kenntniss der Corallenthiere im allgemeinen, und besonders des rothen Meeres, nebst einem Versuche zur physiologischen Systematik derselben. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin*, Year 1832: 225-380.
- Ehrenberg, C.G. 1835a. Über den Cynocephalus der Ägyptier nebst einigen Betrachtungen über die ägyptische Mythe des Thot und Sphinx vom naturhistorischen Standpunkte. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin*, Year 1833: 337-368 + 4 plates (plates not signed).
- Ehrenberg, C.G. 1836b. Beobachtung einer bisher unbekanntem auffallenden Struktur des Seelenorgans bei Menschen und Thieren. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin*, Year 1834: 665-721 + 6 plates. (Noted as read 24 oct. 1833, printed in Feb. 1836).
- Ehrenberg, C.G. 1837b. Über die Akalephen des rothen Meeres und den Organismus der Medusen der Ostsee. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin*, Year 1835: 181-260 + 8 plates. (Noted as June 18, 1835).
- Ehrenberg, C.G. 1838a. *Die Infusionsthierchen als Vollkommene Organismen. Ein Blick in das tiefere organische Leben der Natur*. Leipzig: L. Voss, text 547pp, atlas 64 plates.
- Ehrenberg, C.G. 1838b. Über das Massenverhältniss der jetzt lebenden Kiesel-Infusorien und über ein neues Infusorien-Conglomerat als Polirschiefer von Jastraba in Ungarn. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin*, Year 1836:109-135 + 2 plates. (Noted as read July 20 and August 3, printed with corrections in December).
- Ehrenberg, C.G. 1839. Communication respecting fossil and recent infusoria made to the British Association at Newcastle. *Annals of Natural History*, 2:121–124.
- Ehrenberg, C.G. 1842. *Das unsichtbar wirkende organische Leben. Eine Vorlesung im Vereine für wissenschaftliche Vorträge gehalten zu Berlin am 12 Februar 1842*. Leipzig: Leopold Bok, 53 pp. + 1 plate.
- Ehrenberg, C.G. 1854. *Mikrogeologie: das Erden und Felsen schaffende Wirken des unsichtbar kleinen selbständigen Lebens auf der Erde Mikrogeol.* Leipzig: L. Voss, text 374 pp, atlas 40 plates.
- Ehrenberg, C.G. 1859a. Über einen Niederfall von schwarzem, polirten und hohlen Vogelschrot-Körnern ähnlichen atmosphärischen Eisenstaub im hohen Süd-Ocean. *Monatsberichte der Königlichen Preussische Akademie der Wissenschaften zu Berlin*, 1858: 1-41 + 1 plate. (Read Jan 1858).
- Ehrenberg, C.G. 1859b Beitrag zur Bestimmung des stationären mikroskopischen Lebens in bis 20,000 Fuss Alpenhöhe. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin*, Year 1858:429-456 + 3 plates. (Noted as read 29 April 1858).
- Ehrenberg, C.G. 1867. Über einen Phytolitharien-Tuff als Gebirgsart im Toluca-Thale von Mexiko. *Monatsberichte der Königlichen Preussische Akademie der Wissenschaften zu Berlin*, 1866:158-168 + 1 plate.
- Jahn, R. 1998. C.G. Ehrenberg: the man and his contribution to botanical science. In: Williams, D.M., Huxley; R. (eds) *Christian Gottfried Ehrenberg (1795–1876): The Man and His legacy*. London: The Linnean Society, pp 15-28.
- Jones, T.R. 1877. The late Professor Ch. G. Ehrenberg's researches on the recent and fossil foraminifera. *Monthly Microscopical Journal*, 18: 49-
- Johnston, G. 1847. *A history of the British Zoophytes*, 2nd Ed., Vol.1, London: John Van Voorst, 488 p.
- Mohr, B. A. R. 2010. Wives and daughters of early Berlin geoscientists and their work behind the scenes. *Earth Sciences History*, 29:291–310.
- Mohr, B.A.R. 2023. Clara Ehrenberg (1838-1915), an early woman micropaleontologist: her contribution to science with an outlook on international environmental and climate research. *Earth Sciences History*, 42:1-22.
- Naumann, F. 2007. Alexander von Humboldt in Russia: the 1829 expedition. In: Wyse Jackson, P.N. (ed.), *Four Centuries of Geological Travel: The Search for Knowledge on Foot, Bicycle, Sledge and Camel*. Geological Society, London, Special Publications, 287:161–175.
- Rammelsberg, C. 1876. Christian Gottfried Ehrenberg. *Annals Magazine Natural History*, 19:113-116.
- Sarjeant, W.A.S. 1978. Hundredth year memorium: Christian Gottfried Ehrenberg 1775-1876. *Palynology*, 2:209-211.

- Schickore, J. 2005. 'Through thousands of errors we reach the truth' - but how? On the epistemic roles of error in scientific practice. *Studies in History and Philosophy of Science*, 36:539-556.
- Siesser, W.G. 1981. Christian Gottfried Ehrenberg: founder of micropaleontology. *Centaurus*, 25:166-188.
- Winsor, M.P. 1976. *Starfish, Jellyfish, and the Order of Life*. New Haven: Yale University Press, 228 pp.
- Wulf, A. 2013. *The Invention of Nature: The Adventures of Alexander von Humboldt, The lost Hero of Science*. London: John Murray, 473 pp.