Collecting microfossils – Diatoms as Science and Art

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What is a diatom?

- **One-celled photosynthetic eukaryotic organisms** (chlorophyll a/c and fucoxanthin)
- **Derived by secondary endosymbiosis** (a non-photosynthetic eukaryote engulfed a photosynthetic eukaryote (probably a red alga))
- **Autotrophs** (exceptions - *Nitzschia* spp. - heterotrophs in dystrophic conditions)
- **Motile** (polysaccharide mucilage) or dependent on floating ability (storage of fatty acids; colonial forms)
- Genomically, **part animal and part plant**
- **200,000 to 1,000,000 species worldwide**
- **Size range:** ~3 μm to 2 mm; usually ~10 μm to 100 μm
- **25-50% contribution to global primary production**
- **Drivers of aquatic food webs and global carbon and silica cycles**
- **Indicators** of environmental, climate, and sea level changes
- **85%** of diatoms living during the Cretaceous are extant
The Bodélé Depression—the source of diatomite. “The dustiest place on Earth.”

A diatomite dust cloud traveling across the Atlantic Ocean from Africa.


‘On the 16th of January (1833), when the Beagle was ten miles off the N. W. end of St. Jago (Cape Verde Islands), some very fine dust was found adhering to the under side of the horizontal wind-vane at the mast-head; it appeared to have been filtered by the gauze from the air as the ship lay inclined to the wind. The wind had been for twenty-four hours previously E. N. E., and hence, from the position of the ship, the dust probably came from the coast of Africa’.
Darwin collected and sent some of the dust to C. G. Ehrenberg (1844)—
The dust was found to be composed of diatoms.
In freshwater periphyton: epiphytic and epizoic

In geyser pools in Iceland

In acidic peat bogs

In oceanic subduction zones

In aerial habitats

In East African soda lakes

In sea ice

(PHOTOS: E. F. Stoermer)
Diatoms hitching a ride...

Yellowish coating on killer whale skin is diatoms.

The grooves or cracks in sloth hair carry diatoms.

Common murre with diatoms on feathers.

worldlandtrust.org

Croll and Holmes 1982

1000birds.com
Diatoms – utilized in products and industry
- **U. S. is the largest producer of diatomite** — 813,000 metric tons produced in 2011
- **2,060,000 metric tons produced worldwide in 2011**
- In 2009, 790,000 metric tons of diatomite had a value of $179 million
Klamath Lake, Oregon
freshwater fossil
diatomite deposits

Lompoec, California
marine fossil
diatomite deposits
DIATOMS and technology

Nanoscience and nanotechnology

Biofuels

- Sunlight
- Diatom Bioreactor
- CO₂
- Sea water + Silicic acid
- Diatom biomass extraction
- Protein-rich biomass
- Lipids
- Biodiesel
- Animal feedstock or combustion
- Carbohydrates → Ethanol
Diatoms in pottery, bricks and other archaeological finds

Stone Age pottery sherds from Kotka, Finland made of Ancylus clays with *Melosira arenaria*. (Battarbee 1988)

Pottery clays with freshwater diatoms are thought to be from inland, then transported to coastal marine areas.
Diatoms

Diatoms and Forensics

Application of a simple enzymatic digestion method for diatom detection in the diagnosis of drowning in putrefied corpses by diatom analysis

Extraction of high quality DNA from bloodstains using diatoms

Scanning and transmission electron microscopical evidence of the capacity of diatoms to penetrate the alveolo-capillary barrier in drowning

Diatoms penetrating alveolar lung tissue
Diatoms as Inspiration
DIATOM INSPIRATION...

Interior dome of the Hagia Sophia, Istanbul, Turkey

A knitted shawl

Arachnoidiscus

Filip Knežić

Science Photo Library

offthehookastronomy.blogspot.com
DIATOM INSPIRED FIBER, GLASS
WOOD AND CERAMIC ARTS
Diatom inspired sculptures

Entomoneis
Artist: Alan Ross

Stephanodiscus
Natural History Museum, NY

Campylodiscus
Artist: Alan Ross

Portland, Oregon

Artist: Fernanda D’agostino
Science, Diatoms, and Diatomists
How to make a van Leeuwenhoek microscope:


Antoine van Leeuwenhoek (1632-1723)

In 1702, van Leeuwenhoek probably saw diatoms with his microscope and determined their size by his unit of measure—a sand grain. His measurements are equivalent to 20 – 120 μm.

- van Leeuwenhoek’s drawings of sand grains as viewed through the microscope
- his description and illustration of organisms thought to be diatoms are equivocal and unverifiable
In 1703, diatoms were first discovered and illustrated in a published account in the Philosophical Transactions of the Royal Society of London, but the author’s name was not recorded.

His drawing resembles the freshwater taxon *Tabellaria*.
Christian Gottfried Ehrenberg (1795 – 1876) - zoologist

He was the premier diatom expert in the 1800s

Some slides from his collections at University of Berlin

Some of his diatom drawings at University of Berlin
Reverend William Smith (1808-1857) – amateur turned professional - academic and diatomist

He collected and mounted diatoms and had a lucrative business selling prepared slides and making mounts for people.
Pharmacist, school teacher, turned diatomist

- In 1833, he determined that diatom shells were composed of silica

- By 1835, his discovery that diatoms were composed of two parts to their shells was published and noted by Ehrenberg

Kützing’s drawing of *Frustulia splendens* (1833)

His original description and drawing of *Cymbella pediculus*
Johann Diedrich Möller (1844 - 1907) – originated the art of diatom mounting

- In 1891, 4000 different diatoms were mounted on a 5 by 6 mm coverslip

**Coverslip mount of 121 diatoms (1880)**

**80 diatom species (1880)**
Henri-Ferdinand Van Heurck (1839 – 1909) - botanist

He proposed that the resin from *Styrax*, a deciduous bush, could be used as a stable diatom mountant with a high refractive index in slide preparations.
Henri-Ferdinand Van Heurck (1839 – 1909) - botanist

Watson & Sons 1923 Catalog – Van Heurck originally designed this microscope in 1891.

This Microscope was first made by us to the specification and order of the late Dr. Henri Van Heurck, the celebrated Microscopist, of the Botanical Gardens, Antwerp, for conducting the researches for which he gained such distinction, and for his high-power Photographic work.

Photo-Micrography, especially with high powers of large aperture, demands a working excellence and accuracy of the highest grade in every part—it is, in fact, the severest test to which a microscope can be put. In the construction of this instrument the usual causes of failure have been eliminated. It will at once be recognised that the precision which is requisite for high-power photography and which is provided in this instrument, is of immense value to the ordinary visual worker, for it enables him to secure the fullest and most effective means of conducting his researches. Especially does this apply to Laboratory work, in which reliance has to be placed on the results obtained; and to those who are doing original and accurate work, this microscope will be found to embody every convenience for rendering such work more easy and exact.

The Van Heurck is, in fact, the last word in modern microscope construction.
Astrid Cleve-Euler (1875 – 1968)

- In 1898 – First Ph.D awarded to a female scientist at Uppsala University, Sweden
- Botanist, chemist, geologist, diatomist
- Published many monographs on diatoms, papers in chemistry, and a text on biochemistry

Although 1,540 slide preparations and some raw material are housed in Sweden, most of her collections, including slides, were lost.

~ 1948
Friedrich Hustedt (1886 – 1968)

- A school teacher for 32 years, becoming head teacher in 1924 at Hauffstraße in Bremen, Germany
- Gained increasing stature and standing in the scientific community and was encouraged and funded to study diatoms full time in 1939 when he decided to leave his teaching position
- Described over 2000 taxa
- Amassed the largest private diatom collection which was donated to the Alfred Wegener Institute, Bremerhaven, Germany with the stipulation that it be used for scientific research
The popularity of diatoms
THE NATURAL HISTORY OF DIATOMS.

Their invisible germs are so light (I do not call them spores) that they remain suspended in the air, thus passing from one region to another. Amongst the Algae, these germs are able to remain months without parting, on the dry rocks exposed to the sun, or on the glaciers exposed to the luster cold; and when a ray of sun comes, and some drops of water, we see them appear by millions!

Their dissemination on the surface of the globe is by the joint action of the air and water that diatoms are disseminated, and it is the winds and the rains which render their distribution constant. Once dried, their extensive tenacity permits the slightest eddy to sweep them up and spread them abroad over immense tracts of country, and even from one continent to another. When the air becomes calm they gradually settle down. The rains stir this organic dust everywhere on the surface of the soil, and even as far as the highest summits of the Alps, carrying it into the brooks, the mountains, the past-hogs, and the lakes, and there, in every season, the diatomaceous dust soon commences to live. This diffusion distributes every species of fresh-water Diatomaceae all over the surface of the globe.

Diatoms are indeed amongst the most singular objects of the vegetable kingdom. The more one studies them, the more one is astonished to see with what abundance they are distributed in nature; we meet with them nearly everywhere where water is to be found, whether stagnant as in running, limpid or troubled, just or very cold, even among the melting snow of the lofty Alps. Everywhere in the deposits of these waters, the eye, aided by the microscope, discovers diatoms, and nearly always in immense numbers.

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Their Silicious Frustules.—I do not believe that there ever has been in nature a more marvellous organic incrustation than the silicious envelope of the Diatoms, whether used by mankind or not. These envelopes are formed of an extremely hard, but still transparent, silicious material, which is incrustation immobile, and gives a considerable magnitude (sufficient 400 to 1000) that we are enabled to resolve the finest strata of certain species. But for the determination of species a linear power of +300 or 400 is nearly always sufficient, and especially in employing oblique light. However, all works treating on the microscope give the necessary instructions. This silicious envelope preserves the petroform for an indefinite time, and remains intact at the bottom of the water as each of the diatoms die, forming in this way in many countries considerable deposits (Kieselguhr), and which require less time to be found. The water is thin, and also take from the water a portion of the mineral substances, which it contains in a dissolved state; as iron, alum, lime, and, above all, much silica, which constitutes its hard and transparent glassy frustules.

If in a phial containing drinking-water and many living diatoms we inject a very slow current of carbonic acid gas, and the gas which escapes collected under the influence of light, experience proves that the latter gas is richer in oxygen than the atmospheric air.

Clastic Deposits due to Diatoms.—Nearly all waters contain lime (calcite carbonate). Lime, it is true, is completely insoluble in water chemically pure; but when the water contains carbonic acid, the gas renders them slightly soluble. In proportion as the diatoms decompose this gas, the dissolved lime is separated, and then it is either precipitated or else it incrusts the mucilaginous envelope of the minute silicious species. It is especially the gelatinous spheres where the Epithema and some Synedra grow which afford the microscope the prettiest groups of calcareous crystals. Where the water is quiet, the lime that is set free settles to the bottom, and partially forms the mud of stagnant waters; but if the water is running, the calcareous particles are immediately swept on with the current. We must not forget in proportion as the carbonic acid gas off the water is decomposed, the same water dissolves a new amount of gas that it borrows from the atmosphere, which gas serves in its turn to dissolve the carbonic acid gas. It contains a trace of iron, which is found in the form of a porodic when living diatoms are calcined. It resists pretreatment for a long time. The species which I collected in the Sahara, in 1837, and preserved in the water in which I took them, had still, four years after, their endochronic in good condition. It remained translucent and yellow, but its primitive form had changed and become contracted. I have seen fossil diatoms, from a considerable deposit in Holland, and which, for a long time, had been buried for ages, show here and there examples whose endochronic was still yellow and transparent, although it had become thicker and more radiating; but the Diatoms which I studied in the "Kieselguhr" of Hannover, noticed the same fact. I am convinced that this only took place in those species which had arrived at perfect maturity, and whose two valves were still hemispherically closed.

Exposition.—Diatoms, like all the Algae, require, by means of the carbonic acid gas which all waters exposed to the atmosphere contain in a dissolved state (gaseous nutrition). No carbonic acid, no diatoms. Besides, the diatoms require of the living gas, but the oxygen is set free and escapes, little by little, under the form of minute bubbles. The carbon is used in the formation and development of all the soft parts of the vegetable called the Thallus. After the termination of their life, they also take from the water a portion of the mineral substances, which it contains in a dissolved state; as iron, alumina, lime, and, above all, much silica, which constitutes its hard and transparent glassy frustules.
### Advertisements

#### 1879

**Small packet of diatomaceous earth** (Stoneyford, Ireland) sent upon receipt of stamped envelope; any object of interest will be thankfully accepted. I have some very fine selected slides of diatoms, some arranged in pattern, that I will exchange for fragments of *Hyalonema mirabilis*, or other good spicula bearing sponges. — W. White, 18 Convent Street, Nottingham.

**Very fine slides of anchors, and plates of Synapta Gallienica,** selected and arranged in various symmetrical patterns, likewise a few diatom slides arranged in different designs, in exchange for really good unmounted microscopic material. Would like to correspond with some microscopist in the locality of Torquay, with a view to mutual exchanges. — W. White, 18 Convent Street, Nottingham.

#### 1881

**Mounted slides of anchors and anchor plates of Synapta Gallienica,** arranged in patterns—beautiful object for the polariscopes or spot lens, in exchange for good unmounted material. Wanted good forms of spicula, &c. — W. White, 7 Warden Place, York Street, Nottingham.

**Anatomical microscopic objects** well finished, for good unmounted microscopic material. Fragments of sponge, gorgonias named *Holothuria chirodota,* and synapta most wanted. — W. White, 7 Marden Place, York Street, Nottingham.

**To Microscopists.** Educational Series of Plant Structure, 80 varieties, embracing all the most beautiful forms of Plant-hairs, Scales, &c., prepared ready for mounting, 1s. per dozen: postage extra. — W. White, Warden Place, Nottingham.

#### 1882

**Diatoms Wanted.** Mounted or unmounted microscopic objects for good gatherings of *Camopylopus castellus,* *Meridian cyanus,* *Achnanthes longipes,* &c. Liberal exchange given. — W. White, 7 Warden-place, York-street, Nottingham.

#### 1883

**Microscopic Objects.** 12 botanical sections, stained ready for mounting, 1s. 6d. — W. White, Warden-place, Nottingham.

**Microscopic Objects.** Twelve anatomical preparations in tube, with directions for mounting, 1s. 7d. — W. White, Warden-place, Nottingham.

#### 1886

**Good mounts of whole insects or selected and arranged Diatomaceae offered in exchange for male cockchafers** (*Melolontha vulgaris*), field crickets, etc., also wings of *Urania rhyphasis* (Madagascar), insects fresh caught, not dried cabinet specimens. — W. White, 17 York Street, Nottingham.

#### 1890

**Microscopic Objects, mounted in saline, thousands to select from at 6d. per dozen.** — W. White, 17 York-street, Nottingham.

#### 1898

**Slides.** — W. White, 2 Rick street, Nottingham, England, offers cabinet of 72 slides for 21 shillings.
John Thomas Redmayne (1846 – 1880) – surgeon, physician, and amateur diatomist

Advertisement to exchange a self-published book of diatom micrographs for a microscope objective or slides

1874

Guon Slides of Eunotia sibirica and Coscinodiscus radiatus for other diatoms.—Address, J. Redmayne, Astley Bank, Bolton.

1875

Perse gatherings prepared of Fragilaria capucina and Thallassiothrix elongatum, for other good Diatomaceous Material or Slides.—John Redmayne, Surgeon, Bolton, Lancashire.

1878

An Album of eighty Micro-photographs of nearly 300 of the Diatomaceae, magnified 250 to 4000 diameters, in exchange for first-class 1½ inch Objective, or first-class Micro Slides (approval).—Address, Dr. Redmayne, Bolton, Lancashire.

Diatom collecting device described in Hardwicke’s - 1875
John Albert Long (1863-1945) – amateur diatom mounter

Map and species list

Darkfield

Brightfield

microscopy-uk.org.uk
William Gatrell (1864 – 1902) – dentist; amateur turned commercial specimen mounter
DIATOM ARRANGEMENTS:
From Victorian times to the present
Modern Amateur Diatomists
Klaus D. Kemp (Microlife Services)

◊ Specialist in diatom microslides and diatom arrangements

◊ Inspired by the mounts of J. D. Möller and R. I. Firth

◊ Provides identification strewn mounts and mounts to test microscope objectives

http://www.diatoms.co.uk/
Klaus D. Kemp (Microlife Services)
Stephen S. Nagy, M.D. – Psychiatrist and amateur diatomist (Montana Diatoms)

http://montanadiatoms.tripod.com/

It is our mission to see, to image, to display, and to conserve diatoms from worldwide locations. To that end we work cooperatively and with integrity with individuals, organizations, and Museums to help achieve maximal beauty of diatoms, from whatever source, whether fossil or recent origin.

- make high refractive-index diatom mountants available to diatomists worldwide
- provide tools that are otherwise unavailable, such as the Klaus Kemp Micromanipulator
- exchange samples with other diatomists from obscure or hard-to-reach locations
- work cooperatively with Museums to assist them in exhibiting their collections to maximum benefit
- provide very limited numbers of arranged microscope slides of diatoms to assist in the display of collections, increase the individual enjoyment of microscopists, and to provide scientific artwork to publications and to businesses
- increase interest in, appreciation of, and knowledge of diatoms and their inherent beauty for every visitor to our website
Starting in 1999, he learned how to mount diatoms with instructions from Klaus Kemp via e-mail and telephone!
COLLECTING, CLEANING, MOUNTING, AND PHOTOGRAPHING DIATOMS

STEPHEN S. NAGY
Montana Diatoms, P.O. Box 5714, Helena, MT 59604-5714, USA

Figure 1. An ornate square of arranged diatoms by the author, which includes freshwater and marine diatoms. Didymosphenia forms the main spokes of the arrangement and has a shape similar to a classic bottle of Coca-Cola (Photo copyright retained by author).

Figure 5. Light-colored guide rings on the rear of the slide and dark India ink ring on the mounting glass to help locate the diatom arrangement. The guide rings are removed when the slide is finished (Photo copyright retained by author).

4. Collecting Fossil Diatoms

There are sites around the world where diatoms fell as sediment out of marine or freshwater bodies of water over time, and formed deep concretions on the bottom. Over time, the organic material decomposed and the diatom frustules were pressed together, resulting in diatomaceous earth, or diatomite. Perhaps, the most famous location to diatomists are the deposits at Oamaru, New Zealand, a marine deposit with extinct and exotically unique forms unlike those found anywhere else in the world. Additional sites of some notoriety include: the freshwater deposits at Terrebonne, Oregon, on the eastern slope of the Cascade Mountains north of Bend, Oregon on the banks of the Deschutes River. These deposits are quite loosely packed, appear as white layers in road cuts near the Deschutes River, and appear to be composed of about 97% unbroken frustules. There are freshwater fossil deposits in Klamath Falls, Oregon, well known to Victorian diatomists as the source of varied freshwater species which form brilliant white, hard chalky deposits throughout the Klamath basin, the site of an ancient lake which preceded the formation of the Cascade Mountains. This diatomite or diatomaceous earth is much more densely compressed and is actually used as chalk by children growing up there to draw hopscotch courts on the pavement of driveways.
What do you need to become an amateur diatomist and diatom mounter?

1) A compound light microscope with appropriate optics
2) High quality immersion oil
3) Glass microscope slides and coverslips
4) Pasteur pipettes, fine insect pins mounted to handles, fine forceps
5) Mounting media with a high refractive index
6) Information about diatoms from books, the Internet, experts
7) A Kemp micromanipulator (optional)
8) Digital imaging capability (optional)
**Compound light microscope**

**Brands:** Olympus, Nikon, Leica, Zeiss

**Older brands:** Bauch & Lomb, American Optical

**Cost:** Used/refurbished – $500 - $2000 +
Compound light microscope: parts

**Objectives:** $50 - $1000 +

- short barrel objectives greatest working distance to transfer diatoms to slides
- numerical aperture of 1.25 – 1.4
- oil immersion – 100X to 140X
- plan apochromatic

Can use a 3X or 4X objective to isolate diatoms initially

**Condenser:**

- numerical aperture equal to objective
- Köhler illumination
**Supplies:**

- Immersion oil: Types A, B, and others - Different viscosities
- Increases resolution at high magnification

**To select individual diatoms:**

- Kemp Micromanipulator

- Glass pasteur pipettes – using a forceps, draw out the tips by heating

- Insect needle (size 000) mounted to a thin wooden handle
**Supplies:**

Mounting media: e.g., Styrax, Zrax, Naphrax, Pleurax, Canada Balsam, Taft’s medium

Ringing the coverslip: Asphaltlack

Brunel Microscopes, UK: sells ringing tables

OR

Seal coverslips with clear nail polish

[Links: modernmicroscopy.com, microscopy-uk.org.uk, microscopy-uk.org.uk, microscopy-uk.org.uk]
An amateur diatomist’s set up – R. H. Hummelink, The Netherlands

http://hummelrh.home.xs4all.nl/index.html

Fossil diatoms from Denmark

Diatom mounts – specimens from New Zealand and The Netherlands
Photomicroscopy, digital imaging, and digital mounting

- **Darkfield – Rheinberg illumination** – colored filters are used to change the light rays entering the condenser.

- **Phase contrast (Zernike)** – phase shifts in light are used to affect brightness variation.

- **Differential interference contrast (Nomarski)** – polarized light is used to create shadows.

- **Holographic microscopy**
  
  (requires a laser source and beam-splitter)
Photomicroscopy, digital imaging, and digital mounting

Steve Gschmeissner – scanning electron microscopy
http://www.theworldcloseup.com
**Books** – for instance...

**Websites** – for instance...

- **Zeiss**: [http://zeiss-campus.magnet.fsu.edu/articles/basics/resolution.html](http://zeiss-campus.magnet.fsu.edu/articles/basics/resolution.html)

- **Small Worlds: the art of the invisible**: [https://www.mhs.ox.ac.uk/smallworlds/exhibition/](https://www.mhs.ox.ac.uk/smallworlds/exhibition/)


**Amateur Diatomists and Microscopists**

- John Thomas Quekett (1815 – 1861)
  - Histologist and surgeon
  - Founder of the Royal Microscopical Society in 1839

- **Microscopy for amateurs**: [http://www.microscopy-uk.org.uk/index.html](http://www.microscopy-uk.org.uk/index.html)
Diatom mounts
- Diatomite/diatomaceous earth
- Microscopes, slides, coverslips, drawers and storage boxes
- Glass Pasteur pipettes, fine forceps, size 000 insect pins
- Immersion oil

(Some listings I found in February and March, 2014)
If you just want to view diatoms...the Prakash folding microscope:

A video about an economical, foldable microscope - Manu Prakash: A 50-cent microscope that folds like origami

http://www.youtube.com/watch?v=12Mub6htz3w

http://www.wired.com/2014/03/paper-microscope/

http://www.technologyreview.com/view/525471/the-1-origami-microscope/

http://arxiv.org/abs/1403.1211
Special thanks to...

Extant:

Dr. Daniel J. Miller – microscopist, 3D visualization/statistical surface analysis and invertebrate fossils expert – especially mollusks that eat diatoms

Friends of the Museum of Paleontology

Diatoms

Extirpated:

Some of the diatoms mentioned in this presentation (perhaps)

Extinct:

Some of the diatoms mentioned in this presentation (definitely)
The End