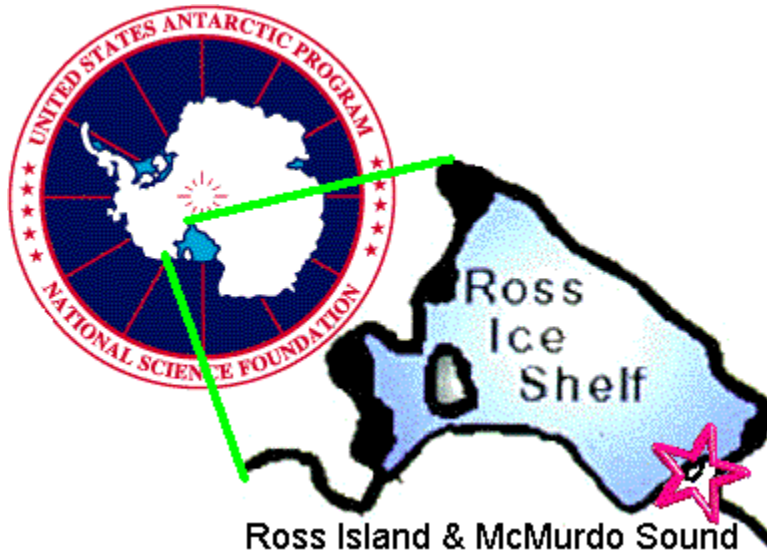


# Protoctista: foraminiferans, amoeba, algae, diatoms

## UNDERWATER FIELD GUIDE TO ROSS ISLAND & MCMURDO SOUND, ANTARCTICA

Peter Brueggeman

Photographs: Norbert Wu, Sam Bowser/S043 archives, Robert Sanders (Sam Bowser/S043 archives), & Canadian Museum of Nature (Kathleen Conlan)



The National Science Foundation's Office of Polar Programs sponsored Norbert Wu on an Artist's and Writer's Grant project, in which Peter Brueggeman participated. One outcome from Wu's endeavor is this Field Guide. This Field Guide builds upon principal photography by Norbert Wu, with photos from other photographers, who are credited on their photographs and above. This Field Guide is intended to facilitate underwater/topside field identification from visual characters. Organisms were identified from photographs with no specimen collection. Therefore these identifications are to the taxonomic level possible from photographs, and there can be some uncertainty in identifications solely from photographs.

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**giant agglutinated foraminiferan *Astrammia rara***

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**calcareous foraminiferan *Cibicides refulgens***

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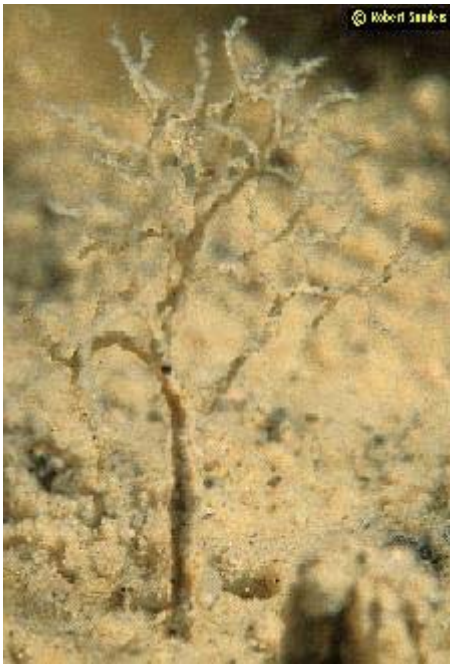
**arborescent agglutinated foraminiferan**

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**giant arborescent agglutinated foraminiferan *Notodendrodes hyalinosphaira***

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**giant agglutinated foraminiferan**  
*Astrammmina rara*

*Astrammmina rara* is usually found buried within the top centimeter of sediment, but is occasionally encountered on the surface or perched upon a worm tube [5]. Because the foram's shell is composed of locally-collected sediment grains, it is well camouflaged [5]. Here it is shown at Explorers Cove, New Harbor.

A foraminiferan is a unicellular organism, characterized by long, fine protrusions (pseudopodia) extending far away from their cytoplasmic body which is encased within a test or shell. There is always one nucleus but there may be a stage with multiple nuclei early in asexual reproduction.

Foraminifera are a class within the kingdom Protista or Protoctista (depending on author's taxonomic preference) which encompasses eukaryote organisms like algae, protozoa and flagellate fungi.

Foraminifera are almost entirely marine and are one of the most abundant marine invertebrates, playing a major role in the marine environment. Bottom-dwelling (benthic) foraminiferans occur in most marine environments, particularly in deepsea and outer continental shelf muds.

Foraminiferans as a group may eat live food (bacteria, unicellular algae, especially diatoms, other protozoa, and small crustaceans such as copepods which are snared in their pseudopodia) or dead material (dead organisms, organic-rich grains including fecal pellets, particulate organic detritus, and colloidal organic molecules). These broad food preferences make them ideally adapted to the benthic environment.

**References:** **1:** Marine Micropaleontology 26:5-88, 1995 ; **2:** Journal of Eukaryotic Microbiology 40:121-131, 1993 ; **3:** Journal of Protozoology 3:724-732, 1992; **4:** Journal of Foraminiferal Research 16:216-224, 1986; **5:** Sam Bowser, personal communication, 2000



**calcareous foraminiferan *Cibicides refulgens***

*Cibicides refulgens* is found in Antarctica from 10 to 640 meters depth [3]. *C. refulgens* prefers hard substrates (shown here attached to a small limpet and to an erratic glacial boulder, at Explorers Cove, New Harbor) [1]. *C. refulgens* is often found living on various invertebrates, including the Antarctic scallop *Adamussium colbecki* [1,2].

For those found in association with the Antarctic scallop *Adamussium colbecki*, *C. refulgens* has three feeding modes useful for survival in a food-scarce (oligotrophic) and seasonal environment: grazing algae and bacteria living on the surface of the scallop shell; suspension feeding through a pseudopodial net deployed from a

superstructure of agglutinated tubes extending from the foram's calcareous test; and, parasitism by eroding through the scallop shell, and using free amino acids from the scallop's extrapallial cavity [2].



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1: Sam Bowser, personal communication, 2000; 2: Biological Bulletin 173(1), 136-159, 1987; 3: Tethys 6(3):631-653, 1974



### arborescent agglutinated foraminiferan

Here, arborescent agglutinated foraminiferans forest the surface of a sediment core from Explorers Cove, New Harbor, where they are suspension feeders [1,2].



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**giant arborescent agglutinated foraminiferan *Notodendrodes hyalinosphaira***

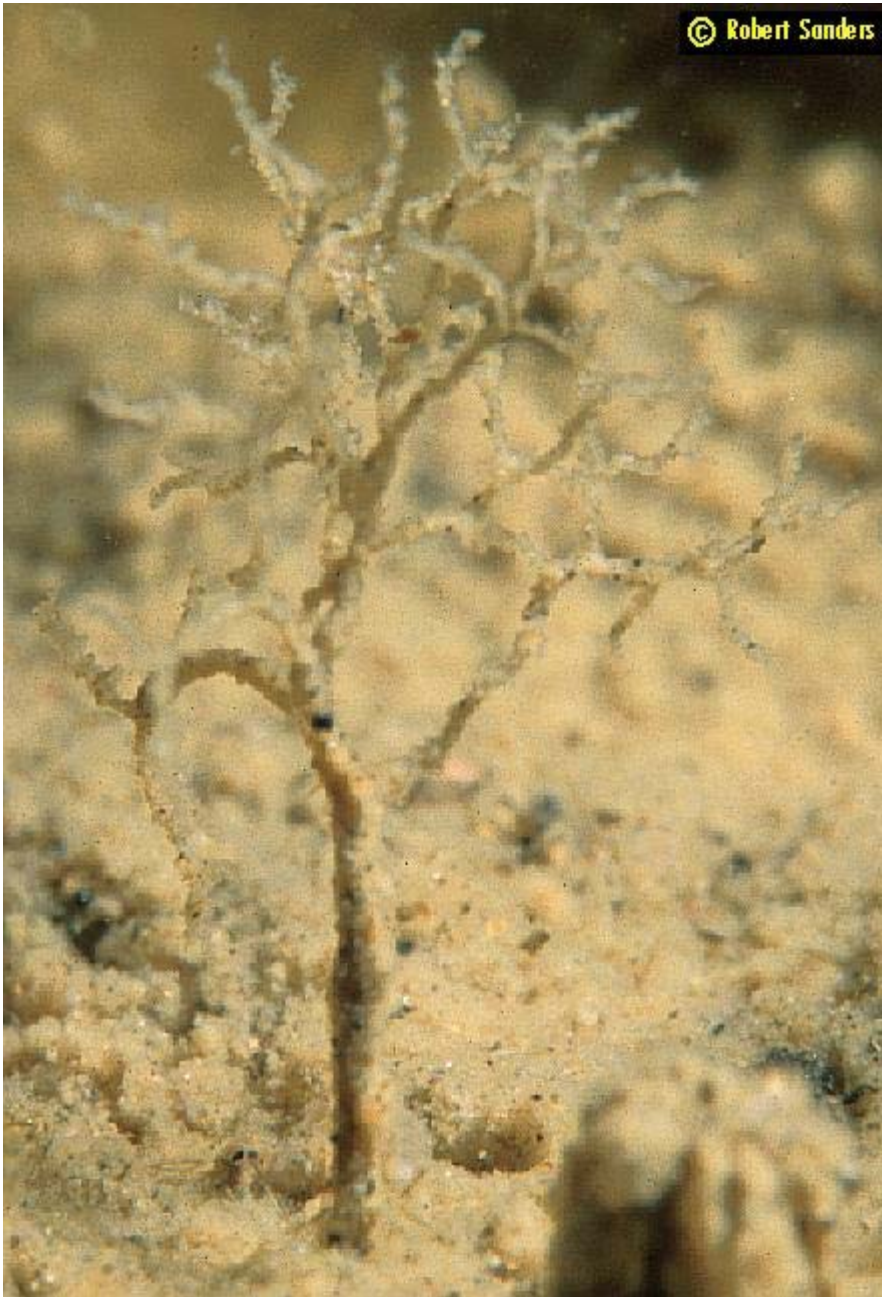
*Notodendrodes hyalinosphaira* is a giant arborescent (tree structure) agglutinated (glues sediment grains around itself) foraminiferan, with some of its cell body below the sediment surface, encased by agglutinated shells, the innermost of which is composed of clear quartz grains --- an interesting example of particle selectivity [1,3]. *N. hyalinosphaira* has been described from specimens collected at Explorer's Cove, New Harbor, at depths from 10 to 35 meters [3]. In its most complex form, the unicellular *N. hyalinosphaira* has a buried spherical cell body with surrounding agglutinated layers up to two millimeters in diameter, a dendritic 'root system' sprouting from the cell body, an umbilicus stretching from the cell body to the sediment surface, and then an arborescent structure stretching up to one centimeter above the sediment surface [3]. Well-

developed specimens of *N. hyalinosphaira* can be up to 2.7 centimeters long, encompassing the root system to the arborescent structure [3]. *N. hyalinosphaira* differs from other agglutinated aborescent foraminifers by several characters, including the flower-like shape of its aborescent structure and the quartz-rich test surrounding its buried cell body [3]. *N. hyalinosphaira* feeds several ways: absorbing nutrients from the sediment through its dendritic 'root system', capturing very small prey from the sediment, parasitism of larger organisms, and taking particulate material from the water [3].

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**Taxonomic Note:** Earlier work on this organism while it was undescribed called it the 'flower foraminifer' [3].

**References:** 1: Sam Bowser, personal communication, 2000; 2: Nature 289(5795):287-289, 1981; 3: Journal of Foraminiferal Research 32:177-187, 2002



**giant arborescent agglutinated foraminiferan *Notodendrodes antarctikos***

Shown here at Explorers Cove, New Harbor, *Notodendrodes antarctikos* stands up to 3.8 centimeters high [1,2]. *N. antarctikos* has a subcentral double-walled bulb, a dendritic root system, and a stem extending from the top of the bulb through 1-3 millimeters of sediment into the overlying seawater, where it then branches out [2,3]. *N. antarctikos* captures bottom sediments and suspended particles in cytoplasmic pseudopodia extending from the branches and stem. [1,2].

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**References:** **1:** Sam Bowser, personal communication, 2000; **2:** Zoological Journal of the Linnean Society 69(3):205-224, 1980; **3:** Marine Micropaleontology 26(1-4):75-88, 1995



### testate amoeba *Gromia oviformis*

*Gromia oviformis* has been collected in McMurdo Sound and South Georgia Island as well as western Europe, California, and New Zealand at depths from intertidal zone to 366 meters [1,2,4,5]. *G. oviformis* is seen as a brown, shiny shelled ovoid or sphere attached to the substrate by fine protoplasmic attaching pseudopodia extending from its oral region [1,2,4,5]. *G. oviformis* is multinucleated and may grow up to five millimeters in diameter [2,5].

*G. oviformis* can be found in association with seaweeds, on rock-faces and stones, or in muddy and sandy sediments [1,2,5].

*Gromia* sp. are a dominant species in the

McMurdo jetty soft-bottom macrofaunal community [7]. *G. oviformis* is a scavenger and eats diatoms and plant and animal debris [2]. *G. oviformis* has been found in gut contents of the fish *Trematomus bernacchii* [6].

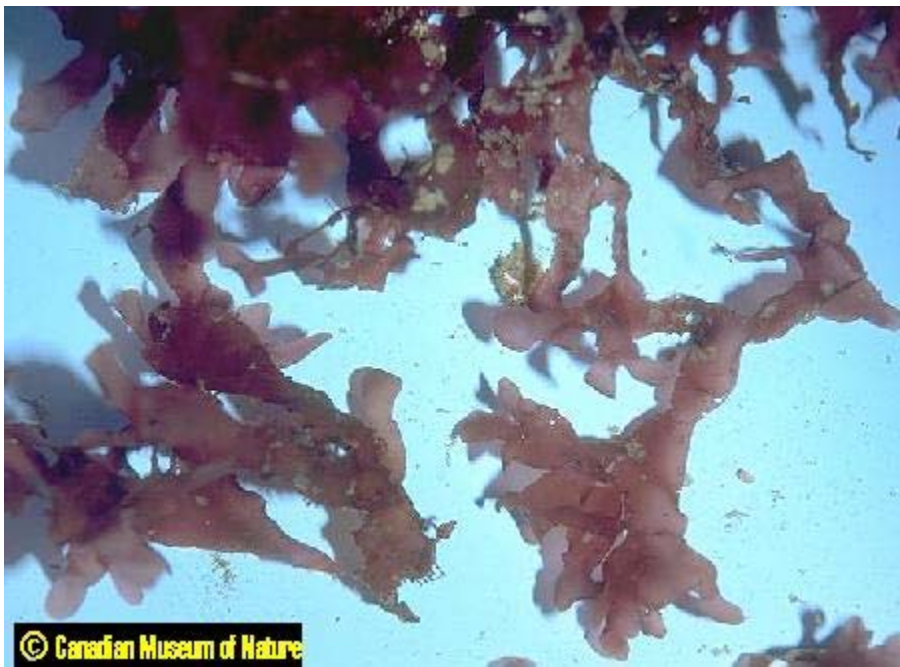
Due to its pseudopodial morphology, *G. oviformis* is regarded as a testate amoeba or sarcodine (order Filosea) [3,5].

**References:** **1:** Journal of Foraminiferal Research 16(4):285-292, 1986; **2:** New Zealand Journal of Science 5(2):121-136, 1962; **3:** Deep-Sea Newsletter 28:12-13, 1999; **4:** Antarctic Journal of the United States 31(2):122-124, 1996; **5:** Bulletin of the British Museum (Natural History) 18(2), 1969; **6:** Polar Biology 13(5):291-296, 1993; **7:** Ophelia 24(3):155-175, 1985



**red algae *Phyllophora antarctica***

*Phyllophora antarctica* is endemic to Antarctica being found throughout Antarctica and the Antarctic Peninsula, and South Orkney Islands [1,3,8,9]. *P. antarctica* is abundant at depths from 10 to 25 meters, and found down to 35 meters depth [1,7,8]. Determinants for depth ranges of algae are ice scouring, anchor ice formation, salinity changes from land runoff and melting of platelet ice under the sea ice, and photosynthetic efficiency with reduced levels of light [1]. *P. antarctica* has a short stipe and a blade up to 17 centimeters long and 1.5 centimeters wide [1,8].



McMurdo Sound has the world's southernmost populations of benthic marine algae, and three red algae are the dominant macroalgae south of 77 degrees latitude: *Iridaea cordata*, *Leptophytum coulmanicum*, and *Phyllophora antarctica* [1,9]. *P. antarctica* forms dense beds from 10-25 meters depth in Terra Nova Bay by the end of January, reaching 10,000 plants per square meter and 1.5 kilograms wet weight per square meter [6].

Antarctic seaweeds can tolerate dark periods up to one year without damage and they can grow and complete their life cycle with very low levels of light; both of these

are important for surviving long periods of winter darkness and also living under a cover of sea ice [8].



Here is *Phyllophora antarctica* attached to a *Sterechinus neumayeri* sea urchin. *S. neumayeri* attaches pieces of algae like *P. antarctica* and *Iridaea cordata* to itself as protection against the anemone *Isotealia antarctica* [4,5]. Both algae manufacture unpalatable defensive chemicals to avoid getting eaten by *S. neumayeri*, yet the urchin attaches algal pieces to itself as a detachable shield to shed when the anemone's tentacles grab onto the attached algae [4,5,9].

Serpulid polychaetes and hydroids can be found colonizing the surface of *P. antarctica*, along with the bryozoans *Beania livingstonei*, *Celleporella antarctica*, and *Harpecia spinosissima* [2,7].



At some sites where these algae occur with *S. neumayeri*, 96.5% of the urchins were using *Phyllophora antarctica* for 90% or more of their cover [5]. This is a mutually beneficial relationship between *Sterechinus neumayeri* and the algae [5]. The urchins move fertile drift algae throughout sunlit waters, thereby keeping drift algae in the reproductive area with other attached and drift algae; the urchins also extend the vertical and horizontal range of the algae and facilitate recolonization after ice scouring of the bottom or when conditions allow growth of attached plants at greater depths [5].

**References:** **1:** American Zoologist 31(1):35-48, 1991; **2:** Boletín de la Sociedad de Biología de Concepción 62:179-186, 1991; **3:** Oceanografía in Antártida, Oceanografía en Antártica. VA Gallardo, O Ferretti, HI Moyano, eds. ATTI Seminario Internazionale, ACTAS Seminario Internacional. Concepción, Chile, 7-9 March 1991. ENEA, Progetto Antartide, Italy & Centro EULA, Universidad de Concepción, Concepción, Chile, 1992. pp. 395- 408; **4:** Journal of Phycology 34(1):53-59, 1998; **5:** Marine Ecology Progress Series 183:105-114, 1999; **6:** Scientia Marina 63(Supplement 1):113- 121, 1999; **7:** Ross Sea ecology : Italian Antarctic Expeditions (1987- 1995). FM Faranda, L Guglielmo, A Ianora, eds. Berlin : Springer, 2000; **8:** Antarctic seaweeds. C Wiencke & MN Clayton. Ruggell, Lichtenstein : A.R.G. Gantner Verlag, 2002; **9:** Biology of Polar Benthic Algae. C Wiencke, ed. Berlin: Walter de Gruyter, 2011. p. 32, 85, 101-119



**coralline algae, probably *Leptophytum coulmanicum***

Here is the rocky bottom at nine meters depth at Couloir Cliffs at Granite Harbor with coralline algae covering the rocks and boulders [2]. In very shallow water, the bottom is regularly disturbed by ice, with rocks and boulders being scraped, moved, or completely overturned [1]. Coralline algae may dominate upward-facing rock in shallow water [4]. Coralline algal growth on the upper surfaces of

rocks is a surrogate measure of the relative change in turnover or disturbance with surface area and depth [1].



Coralline algae is also called encrusting or crustose algae.

The taxonomic status of most Antarctic coralline species is uncertain, requiring intensive investigation [3]. A 2011 book lists three red algae occurring regularly in McMurdo Sound: *Leptophytum coulmanicum*; *Iridaea cordata*, and *Phyllophora antarctica* [6]. A 2002 book on Antarctic seaweeds lists four species of coralline algae with distributions in the environs of McMurdo Sound: *Clathromorphum obtectulum*; *Leptophytum coulmanicum*; *Phymatolithon foecundum*; and *Phymatolithon lenormandii* [3]. At Terra Nova Bay, the rose-colored *Clathromorphum lemoineanum* is particularly abundant from the shoreline down to 70 meters depth [3,5,6].



Sea spider walking on coralline algae.

**Taxonomic Note:** The name *Leptophytum coulmanicum* is in dispute [6].

**References:** **1:** Journal of Experimental Marine Biology and Ecology 196(1,2):251-265, 1996; **2:** Kathleen Conlan, personal communication, 1999; **3:** Antarctic seaweeds. C Wiencke & MN Clayton. Ruggell, Lichtenstein : A.R.G. Gantner Verlag, 2002; **4:** Marine Biology 121(3):565-572, 1995; **5:** Oceanografia in Antartide, Oceanografia en Antartica. VA Gallardo, O Ferretti, HI Moyano, eds. ATTI Seminario Internazionale, ACTAS Seminario Internacional. Concepcion, Chile, 7-9 March 1991. ENEA, Progetto Antartide, Italy & Centro EULA, Universidad de Concepcion, Concepcion, Chile, 1992. pp. 395-408; **6:** Biology of Polar Benthic Algae. C Wiencke, ed. Berlin: Walter de Gruyter, 2011. p. 32, 58-59

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### under-ice filamentous algae

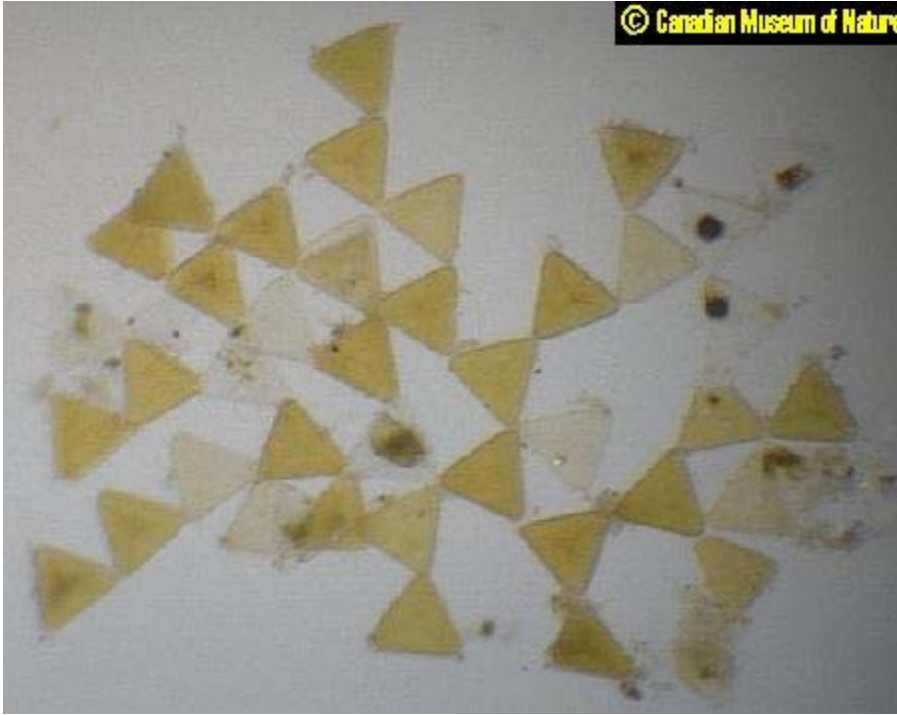
McMurdo Sound is continuously dark for four months in the winter and continually light for four months in the summer; these are separated by two-month transition periods in which the light increases or decreases by twenty minutes per day [1]. To the human eye, lighting can be dim under the sea ice. The sea ice reduces light as does its overlying snow cover and the organisms living on its underside. At noon during McMurdo Sound summer, the sea ice undersurface receives less than 1% of the sun's irradiance [2]. This isn't much light for algae and diatoms to use for their photosynthesis yet they have adapted. Called cryophiles for their ice lifestyle, they live in low light intensity and make a significant contribution to primary productivity under the ice [2].

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The fish *Pagothenia borchgrevinki* is perched on a grounded iceberg just south of Cape Evans on Ross Island. The surface of the ice is covered with a sea ice microbial community comprised of **algae**, diatoms, bacteria and protozoans; the brown coloration is due to photosynthetic pigments. Crustaceans and molluscan pteropods graze on the microalgae and fish prey on the crustaceans.

**References:** 1: Science 238:1285-1288, 1987; 2: Polar Biology 2:171-177, 1983



## diatoms

These are benthic diatoms collected at the McMurdo Station jetty [3]. Benthic diatoms under the annual sea ice are among the most shade-adapted microalgae and play a role in supplying fixed carbon and energy to the McMurdo Sound benthic fauna [6]. Benthic diatom distribution is affected by grazing, substrate, turbulence, ice, and availability of sunlight [5]. Many benthic diatoms live within the sponge spicule mat on the seafloor; the sponge spicules create a dimensional matrix in the sediment in which the diatoms live, as well as act as natural optical fibers channeling light a short distance (five centimeters) into the mat, thus enhancing benthic diatom

photosynthesis [12,13].

Benthic diatoms collected in the sponge spicule mat at Cape Armitage at twenty meters depth are dominated by the pennate diatom *Trachyneis aspera* [6]. Benthic diatoms collected at Explorers Cove at New Harbor at twenty meters depth are dominated by *Amphora antarctica* with these diatoms in lower abundance: *Trachyneis aspera*, *Amphiprora kufferathii*, *Fragilariopsis* sp. and *Nitzschia* sp. [4].



The fish *Pagothenia borchgrevinki* is perched on a grounded iceberg just south of Cape Evans on Ross Island. The surface of the ice is covered with a sea ice microbial community comprised primarily of **diatoms** and also other microalgae, bacteria and protozoans; the brown coloration is due to photosynthetic pigments [2,8]. Crustaceans and molluscan pteropods graze on the microalgae and fish prey on the crustaceans. McMurdo Sound is continuously dark for four months in the winter and continually light for four months in the summer; these are separated by two-month transition periods in which the light

increases or decreases by twenty minutes per day [1]. To the human eye, lighting can be dim under the sea ice. The sea ice reduces light as does its overlying snow cover and the organisms living on its underside. At noon during McMurdo Sound summer, the sea ice underside receives less than 1% of the sun's irradiance [2]. This isn't much light for diatoms and algae to use for their photosynthesis yet they have adapted. Called cryophiles for their ice lifestyle but more properly named epicryotic, they live in low light intensity and make a significant contribution to primary productivity under the ice [2,7,8].



Here's a closer look at a diatom mat on the underside of sea ice in McMurdo Sound. A study of the diatoms under the sea ice at Cape Armitage found 32 species of which eleven were numerically dominant: *Amphiprora kjellmanii*, *Amphiprora oestrupii*, *Biddulphia weissflogii*, *Coscinodiscus subtilis*, *Eucampia balaustium*, *Fragilaria linearis*, *Nitzschia martiana*, *Nitzschia seriata*, *Pleurosigma antarcticum*, *Rhizosolenia alata*, and *Rhizosolenia rostrata* [8]. Another study noted the Cape Armitage ice diatom community encompassed *Amphiprora* spp., *Berkeleya* spp., *Nitzschia* spp., and *Pleurosigma* spp. [6]. These epicryotic

diatoms living in association with the underside of the sea ice are a community distinct from plankton diatoms, though with the deterioration of the annual sea ice during summer, the epicryotic diatoms join the plankton [8].



This is the triangular diatom *Triceratium* sp. [3].

Antarctic planktonic diatoms are grazed by phagotrophic protists (loricate and naked ciliates, radiolaria, foraminifera, flagellates, choanoflagellates) and large zooplankton (salps, copepods, krill) [9]. Antarctic benthic diatoms have been found in the gut contents of a wide variety of Antarctic organisms [11].



These are centric diatoms, possibly *Podosira* sp. or *Hyalodiscus* sp. [3].

Diatoms are hosted by several Antarctic sponges within the food-capturing cells lining the passages through which the sponge circulates water; these endobiont diatoms live by consuming carbohydrates produced by the sponge and also by photosynthesis [10,14,15]. Diatoms produce large amounts of polysaccharids, thus giving the sponge an alternative food source during food-scarce periods [14,15]. This symbiotic adaptation by the diatoms enhances their survival in the low light levels found down deep under the ice (as well as the dark months of winter) [10]. Diatoms that have been observed in this association are usually the pennate diatoms *Fragilariopsis curta*, *Fragilariopsis* sp., and *Pseudogomphonema* sp. and

less commonly, centric diatoms belonging to the genera *Porosira*, *Coscinodiscus*, and *Rhizosolenia* [10,14,15].

**References:** **1:** Science 238:1285-1288, 1987; **2:** Polar Biology 2:171-177, 1983; **3:** Kathleen Conlan, personal communication, 1999; **4:** Marine Ecology Progress Series 64(1-2):129-136, 1990; **5:** Antarctic Journal of the United States 8(5):307-309, 1973; **6:** Journal of Phycology 21(4):664-667, 1985; **7:** Oceanography and Marine Biology, an Annual Review 9:83-139, 1971; **8:** Nature 199(4900):1254-1255, 1963; **9:** Polar Marine Diatoms. LK Medlin and J Priddle, eds. Cambridge: British Antarctic Survey, Natural Environment Research Council, 1990; **10:** Biological Bulletin 198:29-33, 2000; **11:** Citations too numerous to list; diatoms as a food item are noted throughout this Field Guide for relevant organisms; **12:** Scientia Marina 63(Supplement 1):113- 121, 1999; **13:** Nature 383(6599):397-398, 1996; **14:** Ross Sea Ecology : Italiantartide Expeditions (1987-1995). FM Faranda, L Guglielmo, A Ianora, eds. Berlin : Springer, 2000. pp. 551-561; **15:** Polar Biology 14:55-58, 1994