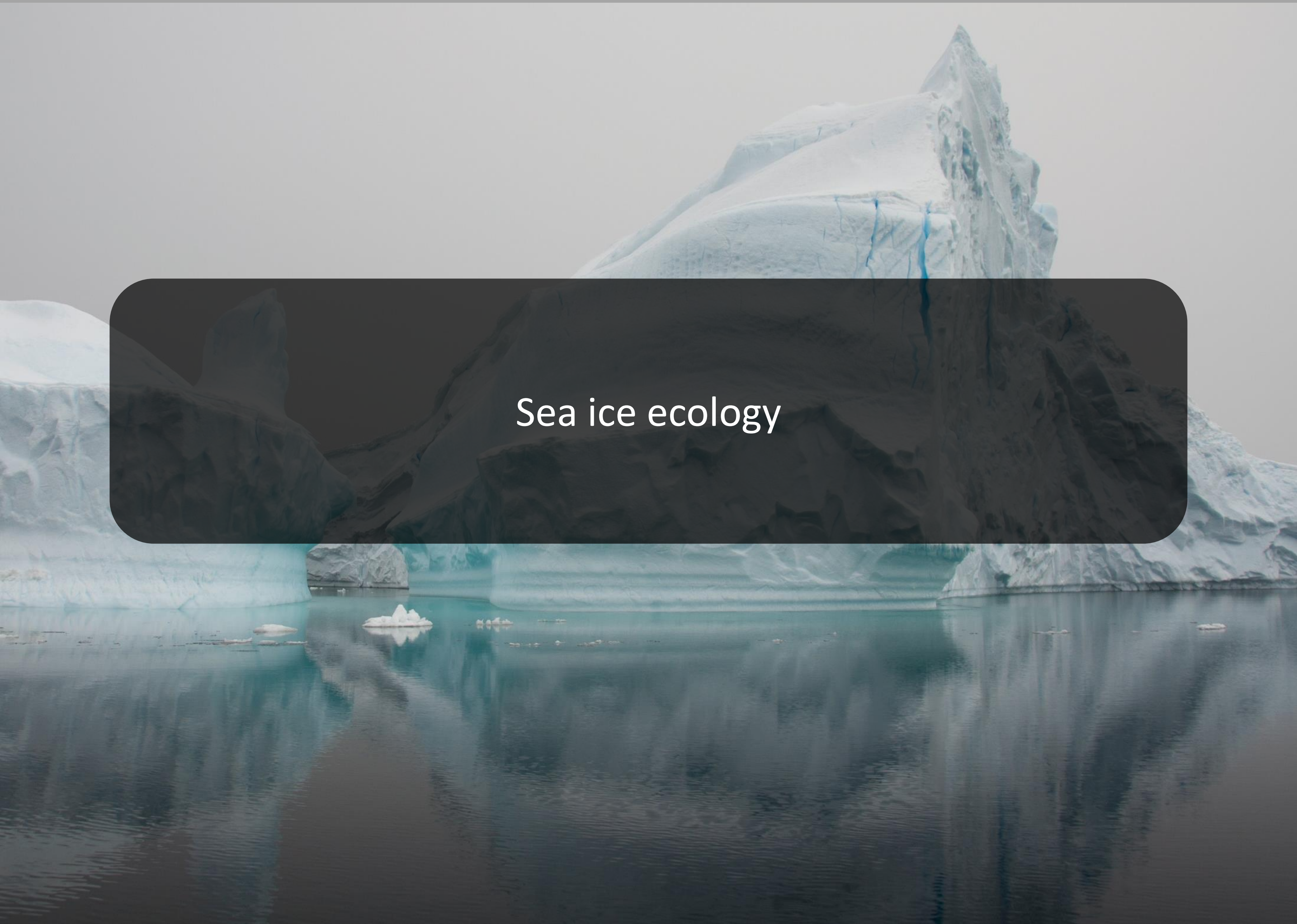
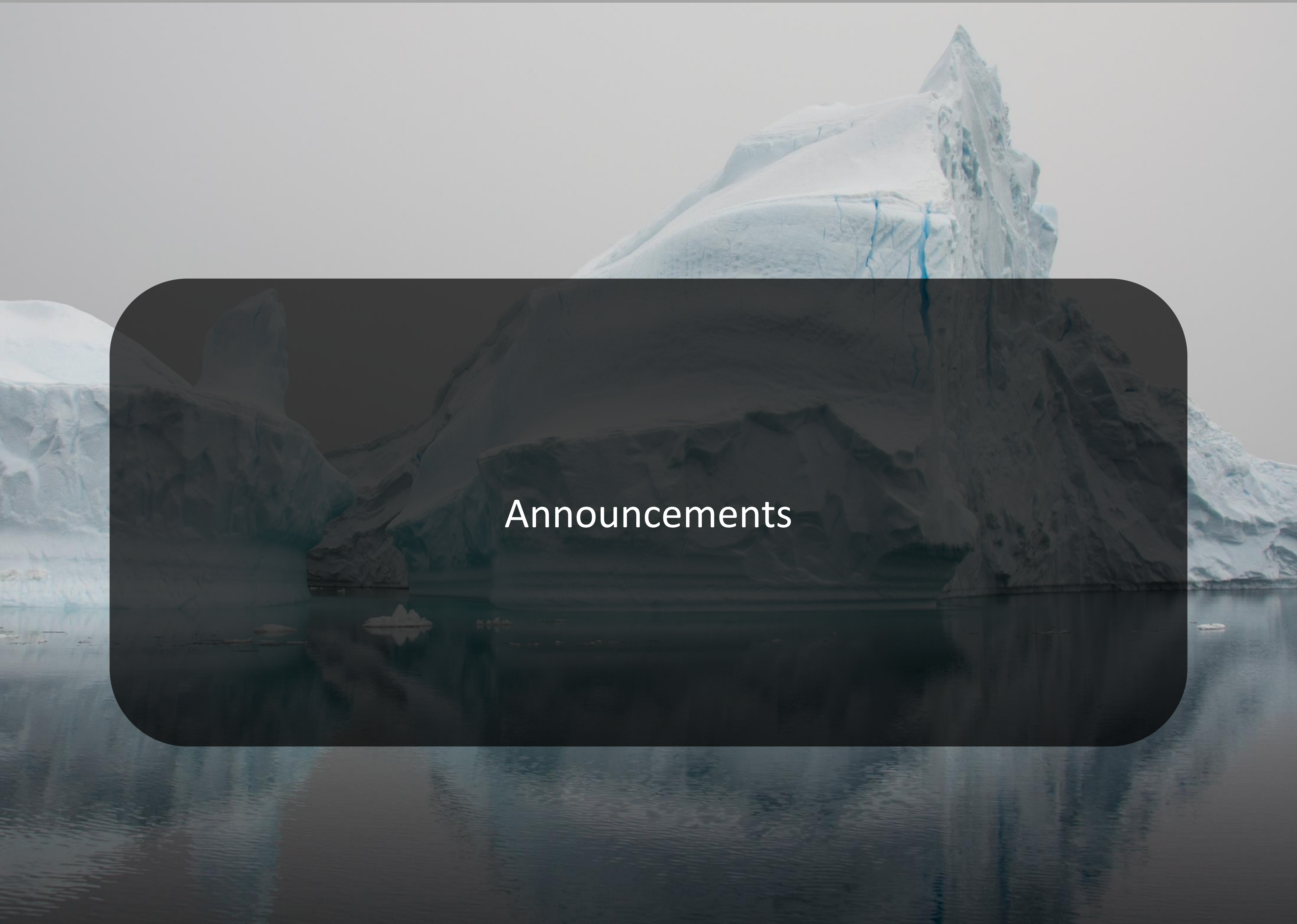


Sea ice ecology



Announcements

1. Do ice binding proteins lower the freezing point, raise the melting point, or both?

Both

2. What region of a glacier is losing mass?

Ablation zone

3. List two reasons the glacier bed is a good habitat for life.

(Relatively) warm temperature, nutrients, also accepted liquid water

1. Permafrost is a significant reservoir of…?
2. What thing(s) determine the moisture content of snowpack?
3. Diatoms have which two general morphologies?

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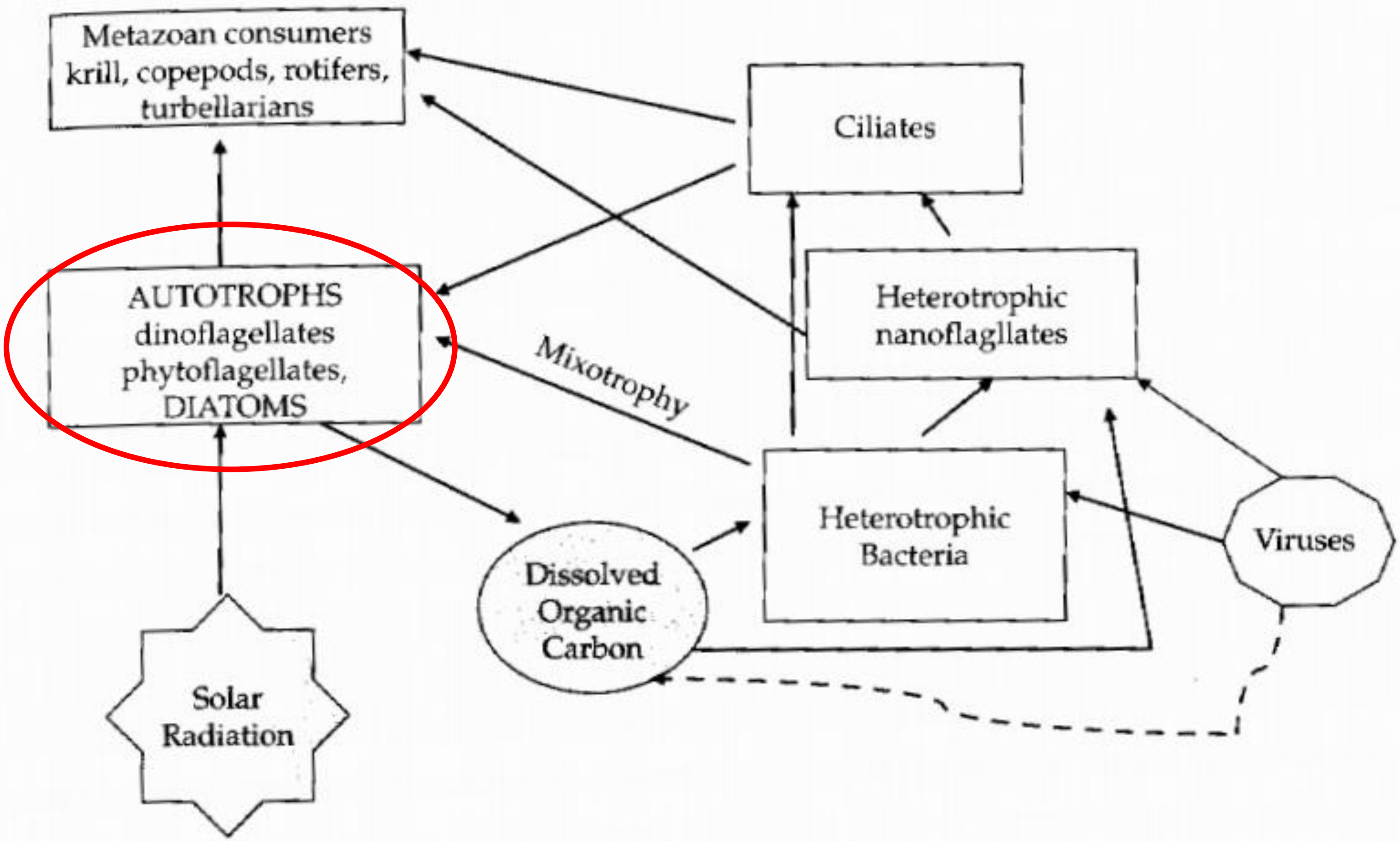
Autotrophic and heterotrophic activity in Arctic first-year sea ice: seasonal study from Malene Bight, SW Greenland

Dorte Haubjerg Søgaard[1,2,*], Morten Kristensen[1,2], Søren Rysgaard[1], Ronnie Nøhr Glud[1,4], Per Juel Hansen[2], Karen Marie Hilligsøe[3]


Metazoan consumers
krill, copepods, rotifers,
turbellarians
Ciliates
AUTOTROPHS
dinoflagellates
phytoflagellates,
DIATOMS
Mixotrophy
Heterotrophic
nanoflagllates
Heterotrophic
Bacteria
Viruses
Dissolved
Organic
Carbon
Solar
Radiation

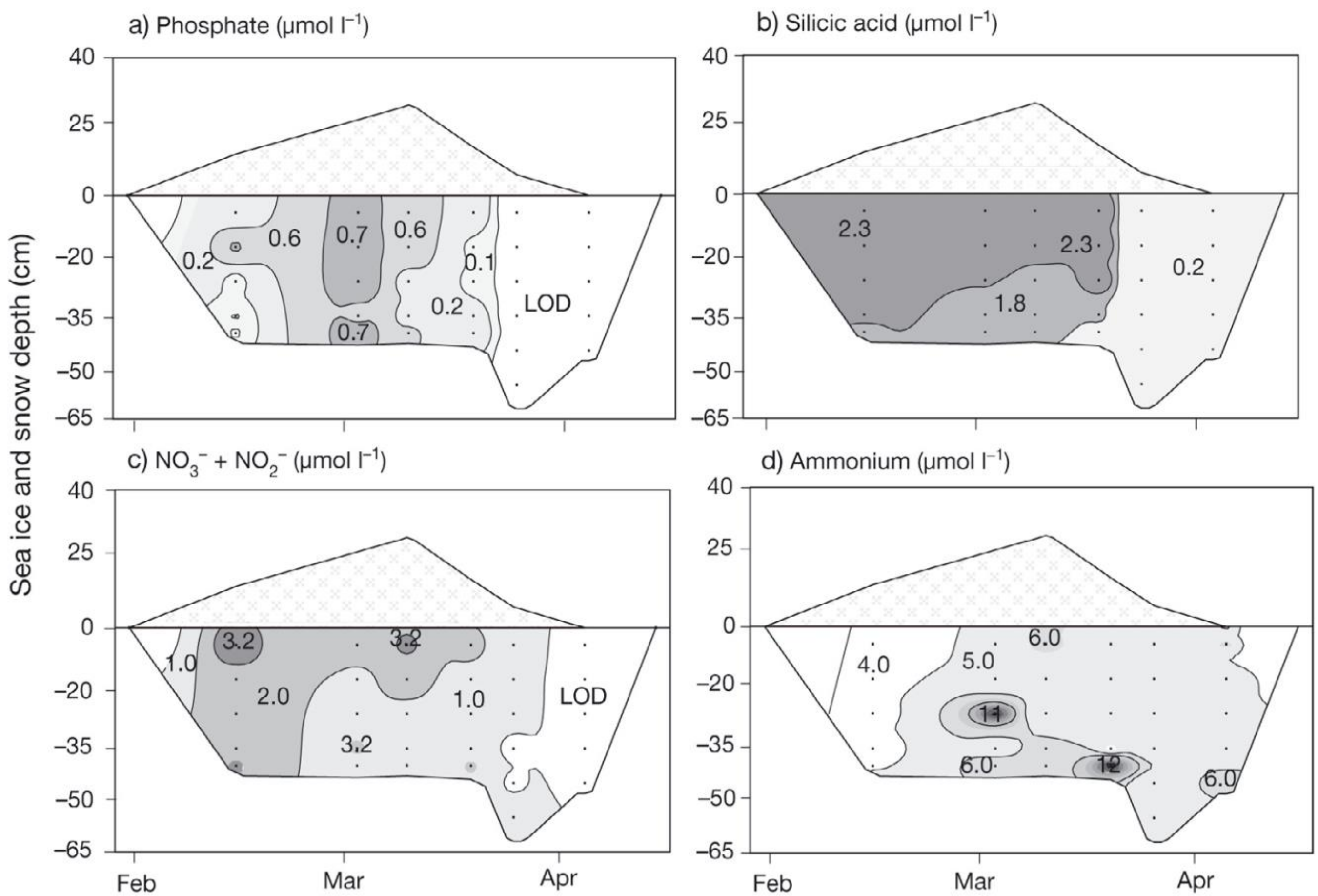


Fig. 2. Nutrient concentration (μmol l^{-1}) in bulk sea ice: (a) phosphate, (b) silicic acid, (c) NO_3^- + NO_2^-, (d) ammonium. LOD is lower limit of detection, which is calculated using the *t*-value of 2.99 corresponding to a 99% confidence interval with df = 7. The black dots represent triplicate measurements

Caron et al., 2017, in Sea Ice

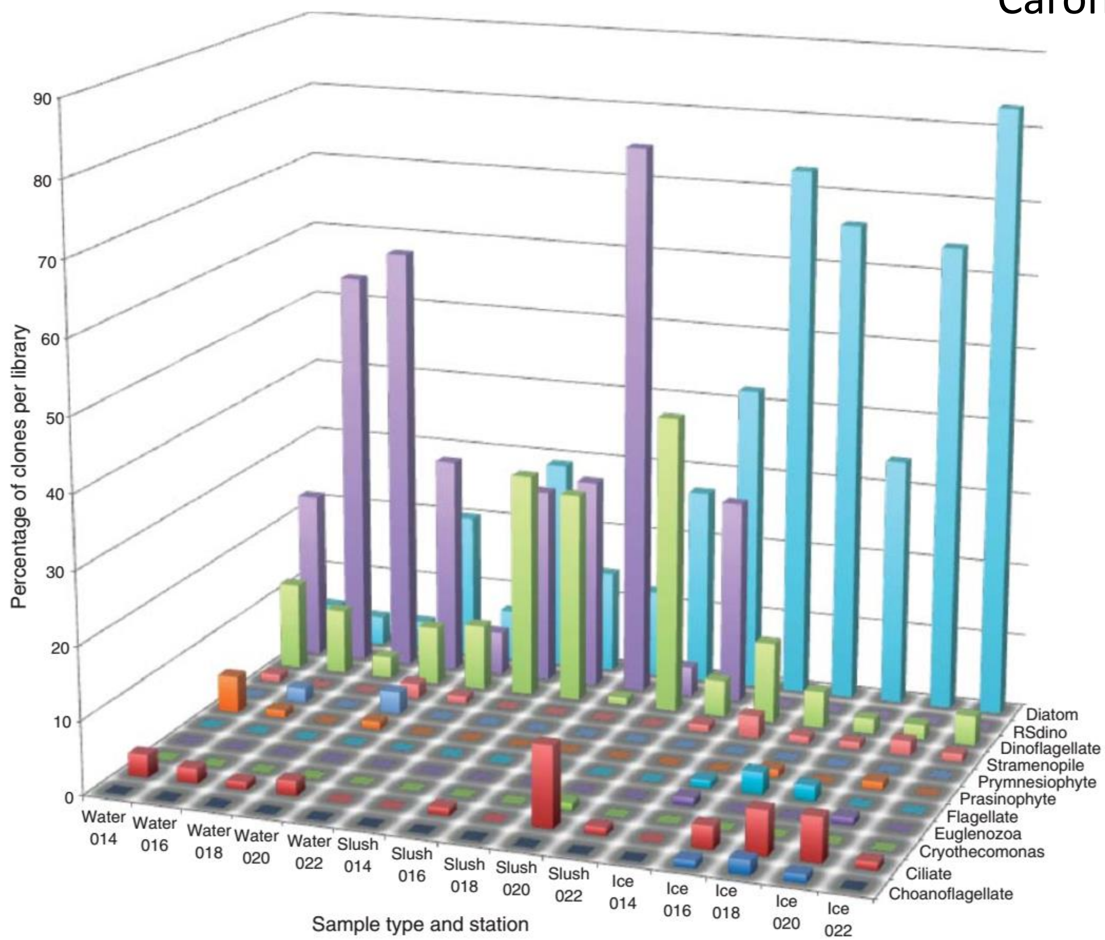
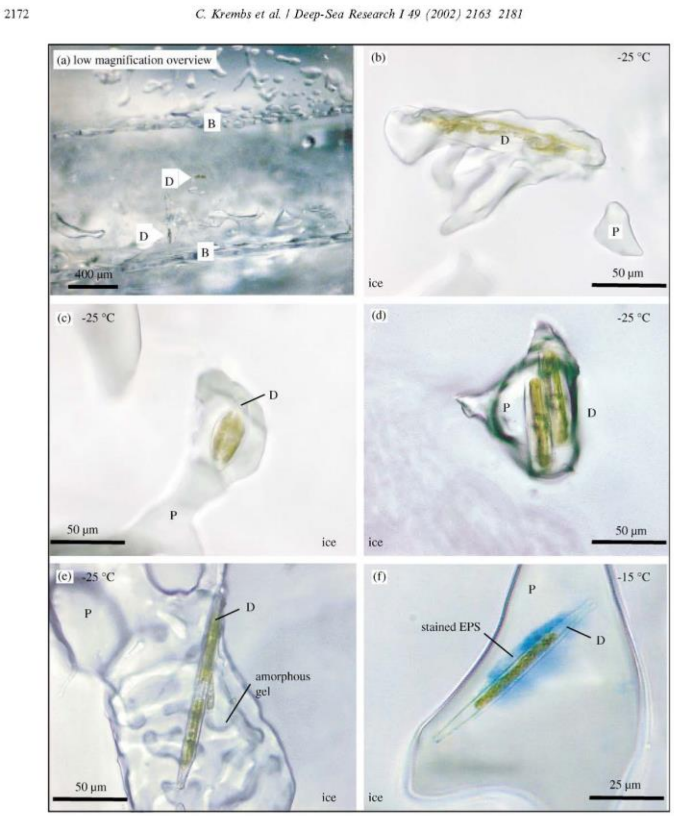


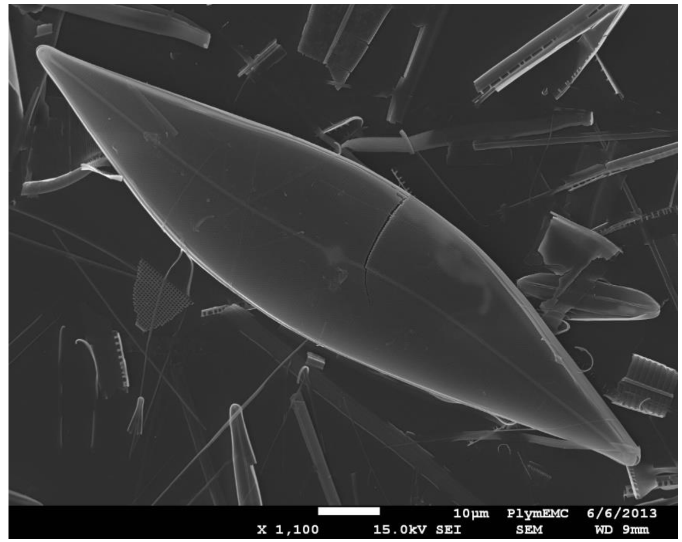
Figure 15.1 Differences in protistan community structure in sea ice, water and meltwater communities (slush) on ice floes from the Ross Sea, Antarctica, as determined from small subunit ribosomal RNA gene sequence libraries. Note the strong dominance of diatoms among the photosynthetic protists within sea ice, but also differences in the abundances of dinoflagellates (including RS dino, which is a kleptoplastidic form) and ciliates within the ice, slush and water.

Primary producers that are notably absent from the sea ice system (and polar marine waters in general) include the marine cyanobacteria: *e.g.*, prochlorococcus, synechococcus, trichodesmium

SIO 121, Lecture 6: Sea ice ecology cont'd: Primary producers

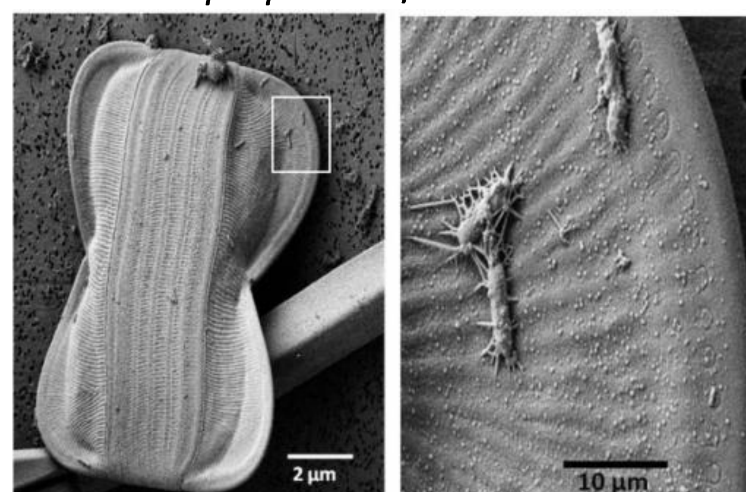


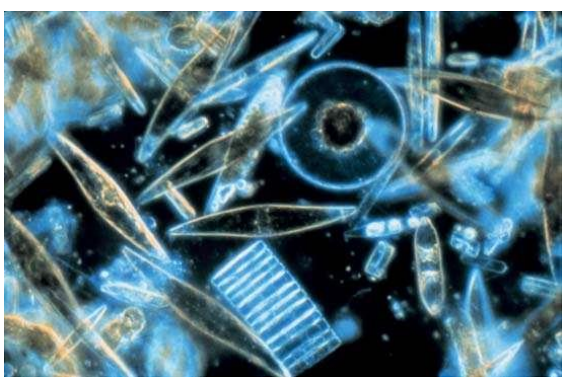
- Large pennate diatoms seem to dominate ice interior
- Colonial centric diatoms more common in mats



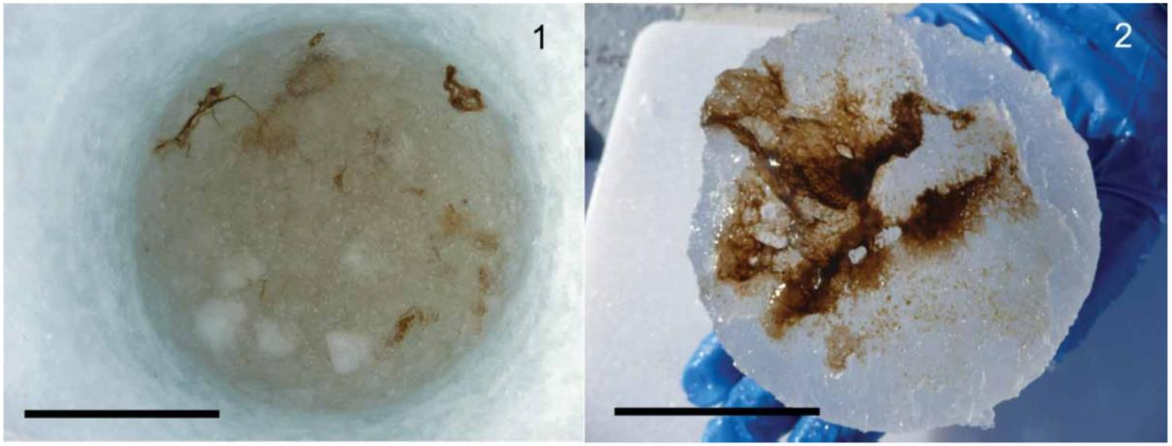
Sea ice pennate diatom, probably *Navicula*

Amphipora w/attached bacteria

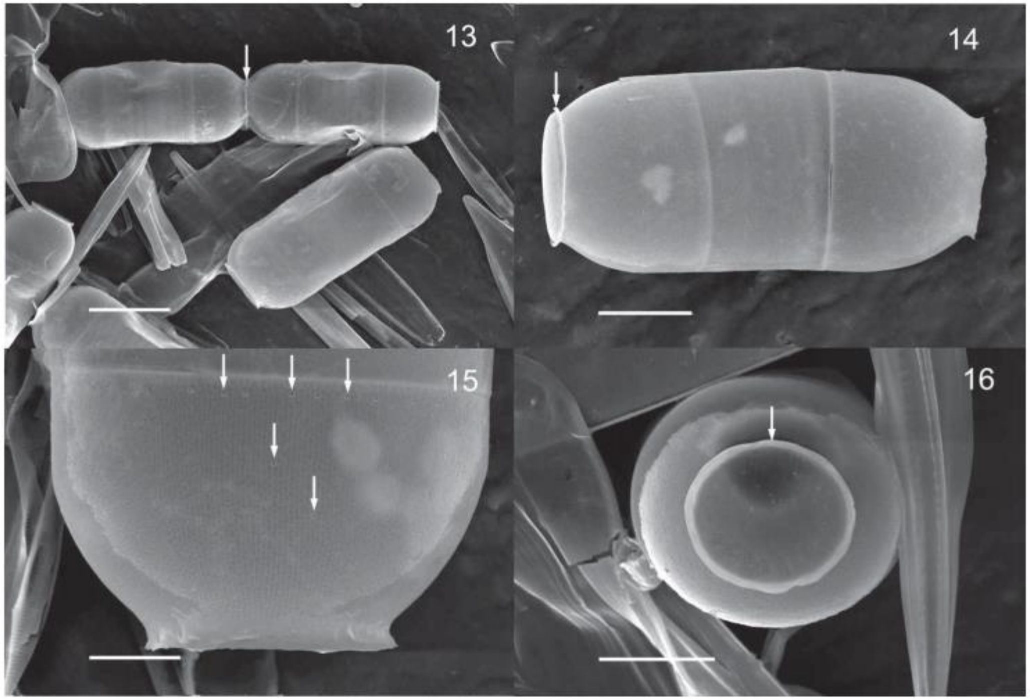




Mixed assemblage from McMurdo Sound sea ice

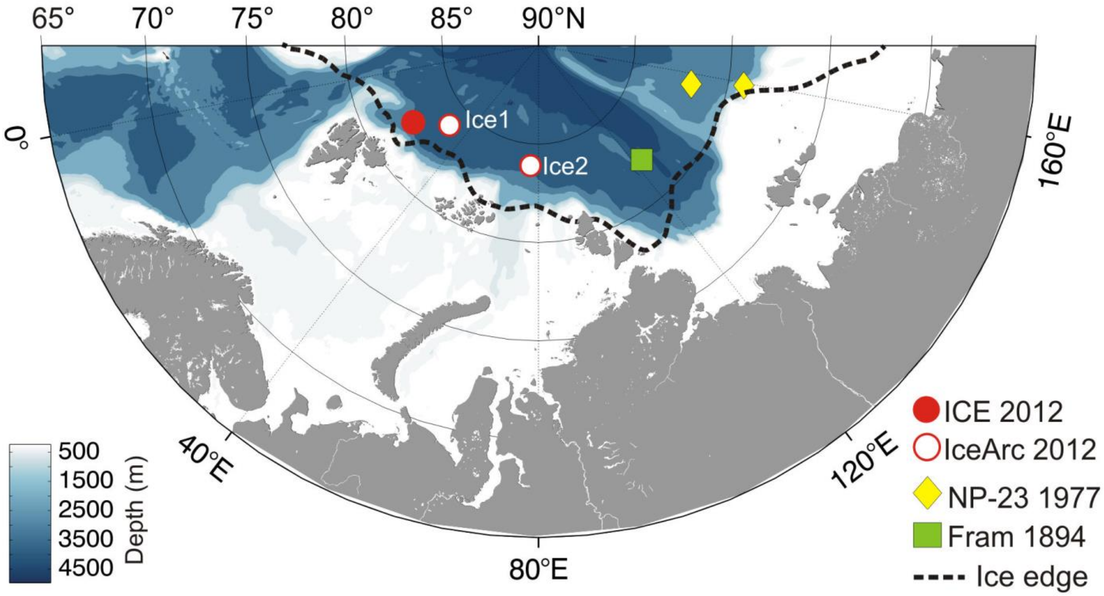


Figs 1–2. Sub-ice community off Cornwallis Island, Nunavut collected in May 2012. **Fig. 1**. Fragments of filamentous algae in the 10-cm diameter core hole. **Fig. 2.** Flattened filamentous algae on the undersurface of the 7-cm diameter bottom ice core. Scale bars = 5 cm (Fig. 1); 3.5 cm (Fig. 2).

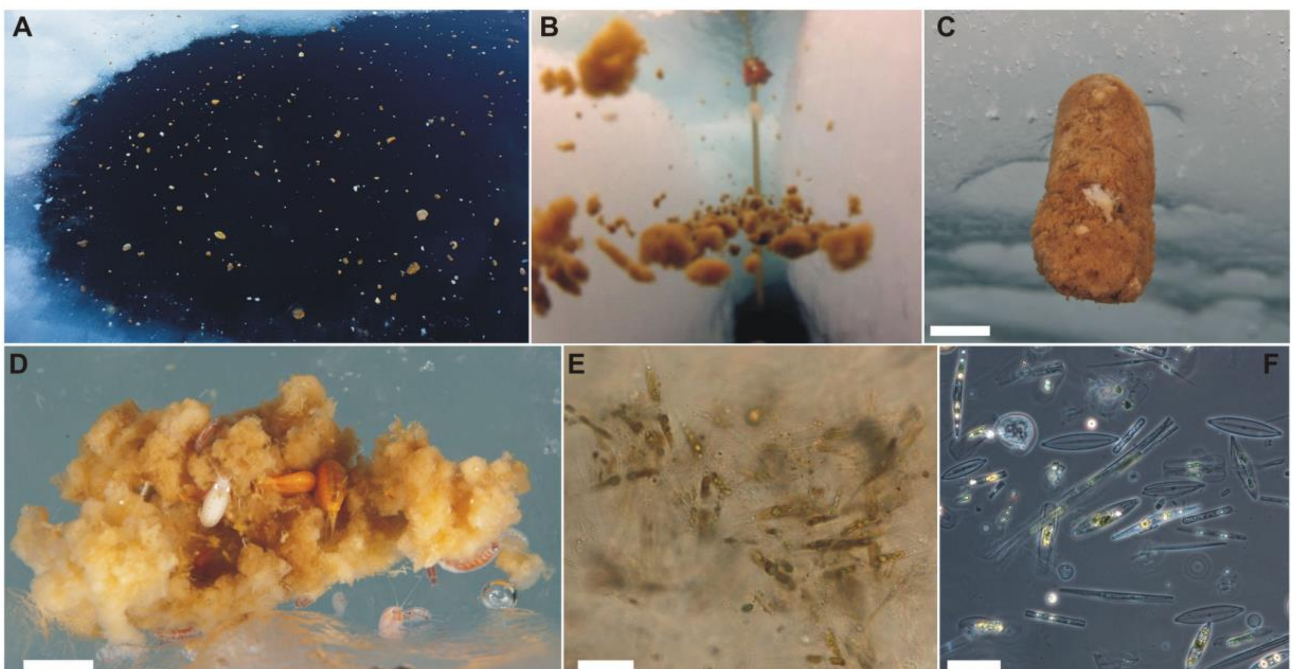


Figs 13–16. *Melosira arctica*, SEM external views. **Fig. 13**. Paired cells forming a short colony tightly connected by the carina (arrow). **Fig. 14**. Cell in girdle view showing the two valves with carinae (arrow) and girdle. **Fig. 15**. Valve in girdle view showing loculate valve face with a row of rimoportula openings near the mantle edge and scattered ones on the valve face (arrows). **Fig. 16**. Valve view showing the carina (arrow) with scattered opening of rimoportulae. Scale bars = 20 µm (Fig. 13); 10 µm (Figs 14, 16); 5 µm (Fig. 15).

Poulin et al., 2014



- Other colonial diatoms associated with sea ice, even if not attached to it
- Here, colonies of *Hantzschia* in the central Arctic



- Other dominant taxa include flagellates, ciliates, dinoflagellates
- All of these are capable of *mixotrophy*

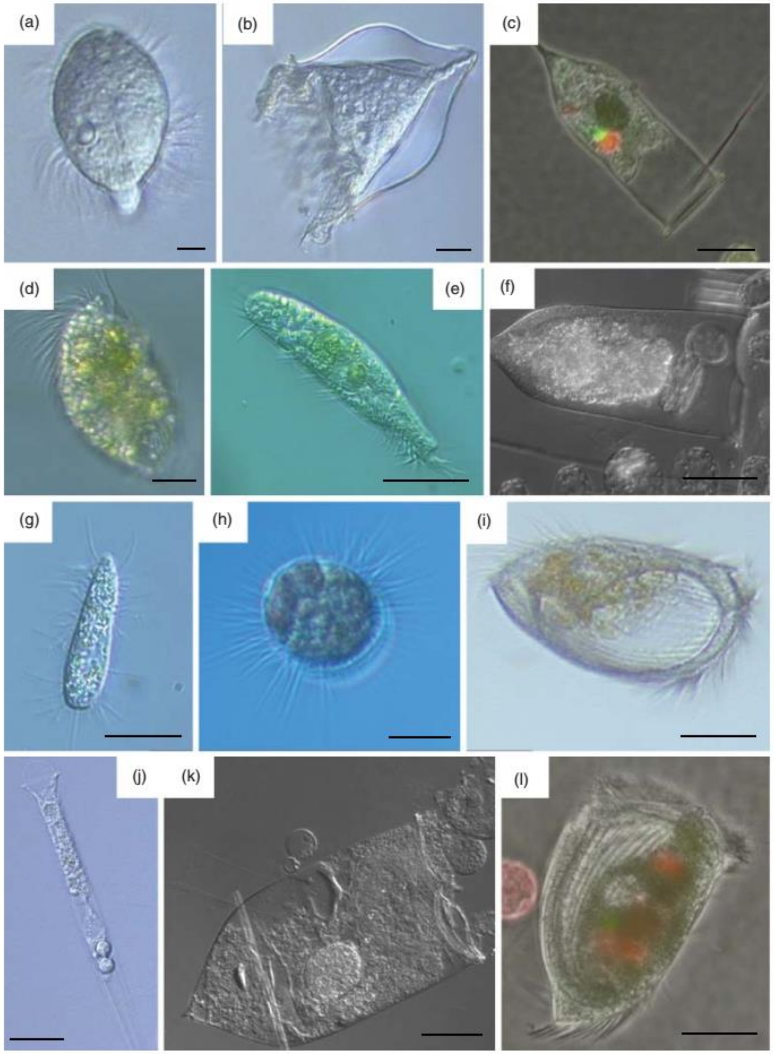


Figure 15.5 Ciliates of sea ice microhabitats in the Ross Sea, Antarctica. (a) *Didinium*, a predatory ciliate. (b, c, f, j, k) Species of tintinnids often encountered in the meltwater assemblages at the ice–snow interface of pack ice are also common in the plankton. (d) An unidentified hypotrich ciliate possessing many food vacuoles filled with algal prey. (e) A heterotrich species with elongated shape characteristic of benthic ciliates. (g) A scuticociliate that displays bacterivory in culture. (h) *Mesodinium* sp., a chloroplast-retaining ciliate. (i, l) Algal prey in food vacuoles in two large ciliates, possibly *Chlamydonella* sp., are evidence of herbivory in sea ice . The red colour in (l) is chlorophyll fluorescence from ingested algae. Scale bars are 10 (a, g), 20 (b, c, d, f, h, k) and 40 μm (e, i, j, l).

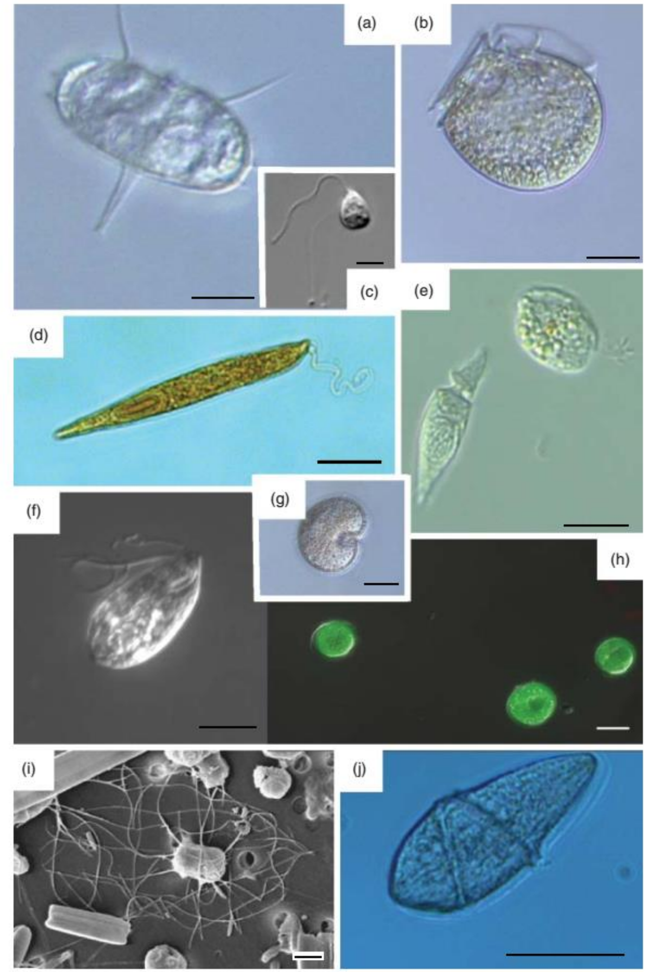
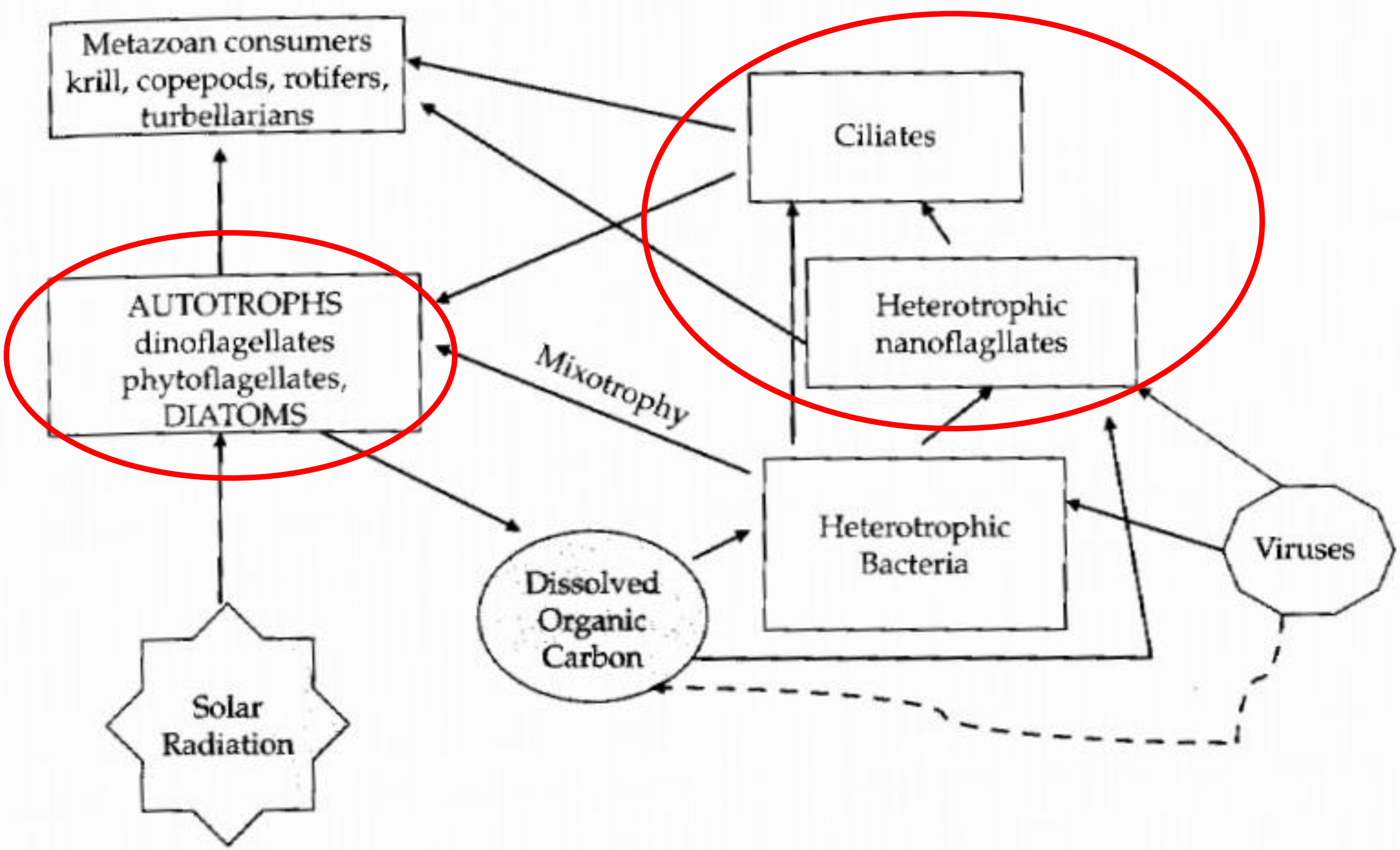


Figure 15.6 Heterotrophic flagellates are taxonomically diverse and often numerically dominant within sea ice. Heterotrophic dinoflagellates (a, b, e, g, h, j) such as *Protoperidinium* (a), *Dinophysis* (b), *Katodinium* (e, left), *Protoperidinium* (g) and *Gyrodinium* (j) may be major consumers of phytoplankton in the ice. (h) An unidentified dinoflagellate displaying a distinctive apple-green fluorescence with blue light excitation. Many heterotrophic dinoflagellates exhibit this fluorescent signal, making them very conspicuous when viewed by epifluorescence microscopy. (c) *Pseudobodo* sp., a small bacterivorous species. (d) A heterotrophic euglenoid flagellate stained with Lugol's iodine to visualize the cell and flagellum. (f) An unidentified flagellate cultured from the Ross Sea, Antarctica. (i) Scanning electron micrograph of the choanoflagellate *Diaphanoeca* sp. showing the cell and the lattice of the lorica (thin structure of bars surrounding the cell). Choanoflagellates are often extremely abundant in the plankton of high-latitude ecosystems, and are also common in sea ice microbial communities. Scale bars are 5 (c, f, i), 20 (a, b, d, e, g, h) or 50 μm (j).

Caron et al., 2017, in Sea Ice

- Other dominant taxa include flagellates, ciliates, dinoflagellates
- All of these are capable of *mixotrophy*



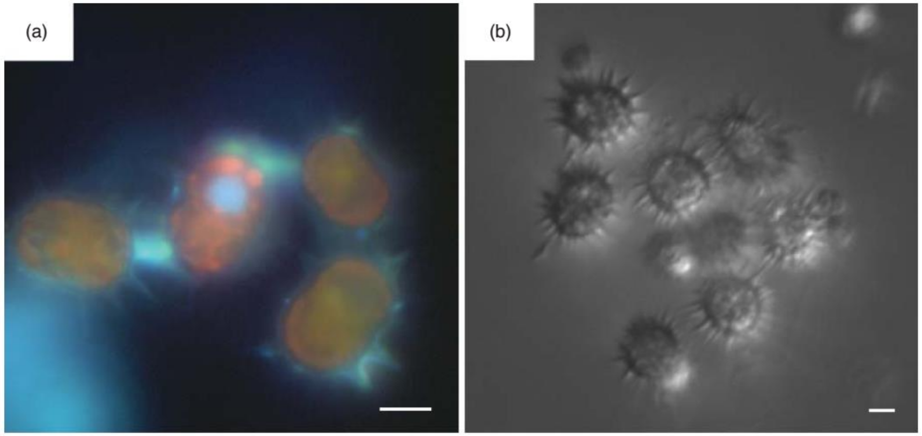


Figure 15.4 Epifluorescence micrograph (a) and transmitted light micrograph (b) of spined cysts of a phototrophic dinoflagellate (probably *Polarella glacialis*) from sea ice of the Ross Sea, Antarctica. The red colour in (a) is due to the chlorophyll fluorescence, and the whitish blue colour is from the fluorochrome DAPI. Scale bars are 10 µm.

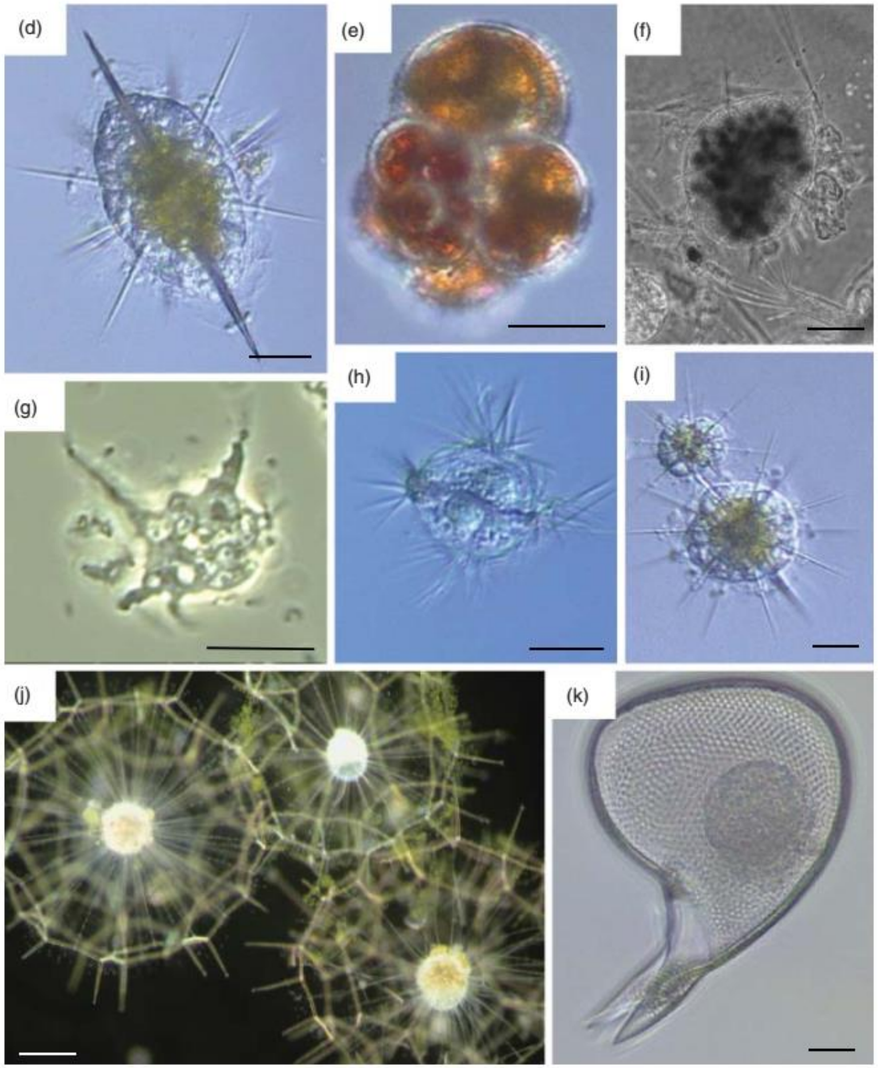


Figure 15.8 Amoeboid protozoa of the plankton and sea ice of the Ross Sea, Antarctica. Gymnamoebae (a, b, g) are inconspicuous, particle-associated protozoa. Acantharia (c, d, f, i) occur in the water column but are also observed in slush microhabitats in apparently good physiological condition. Red-fluorescing structures in a specimen observed by epifluorescence microscopy (c) indicate the presence of endocellular symbiotic algae in the same specimen examined by transmitted light microscopy (f). Endosymbionts are also present as yellowish-brown areas in the light micrographs of specimens in (d) and (i). (e) The 'planktonic' foraminifer *Neogloboquadrina pachyderma* is often present in sea ice. (h, j, k) Heliozoa and radiolaria. The unusual heliozoan *Sticholonche* sp. (h) and phaeodarian radiolaria (j, k) are occasionally observed in sea ice, but are more commonly found at the pack ice edge. (k) *Protocystis* sp. Scale bars are 10 (a, b, g, i), 20 (d, h, k), 50 (c, f, j) and 100 µm (e).

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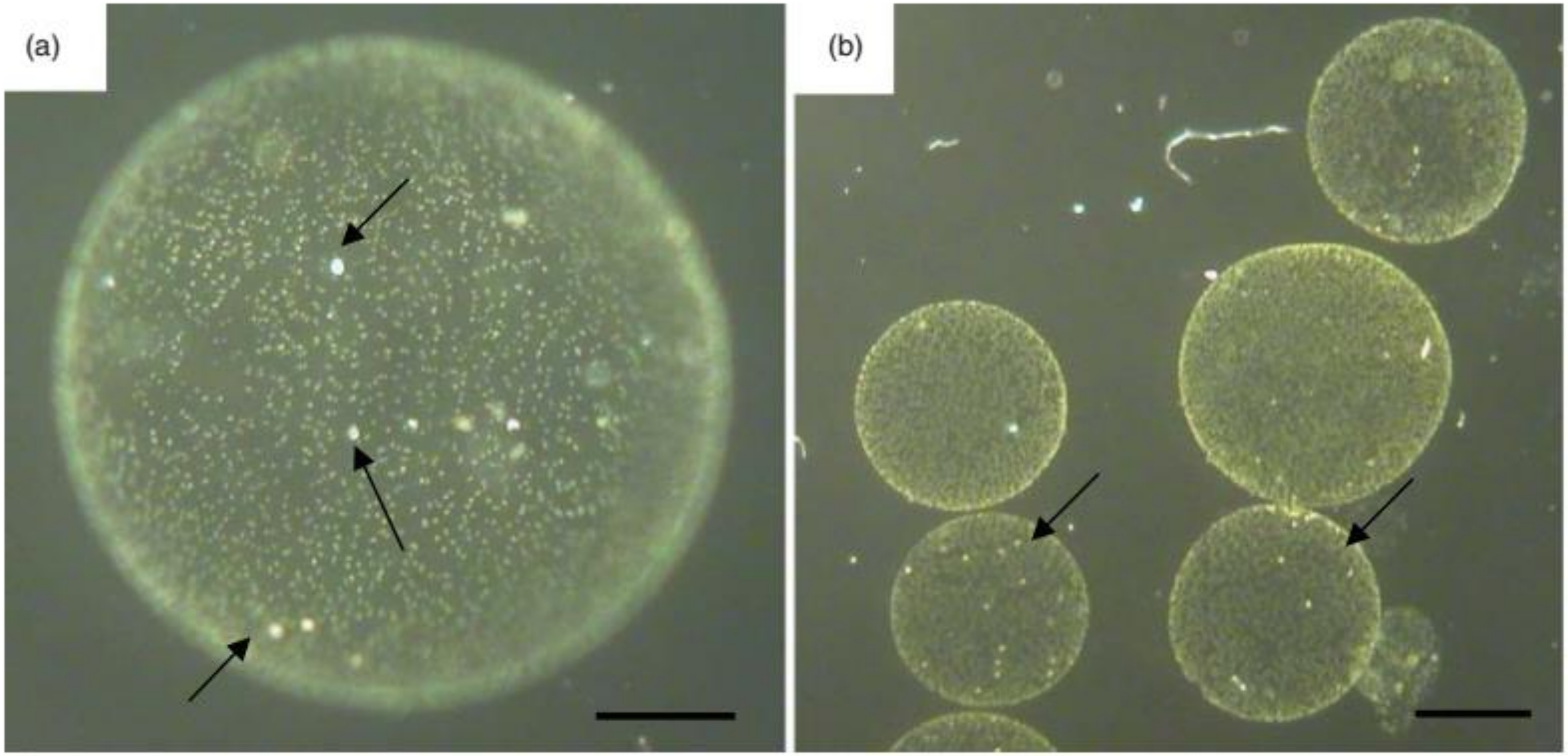
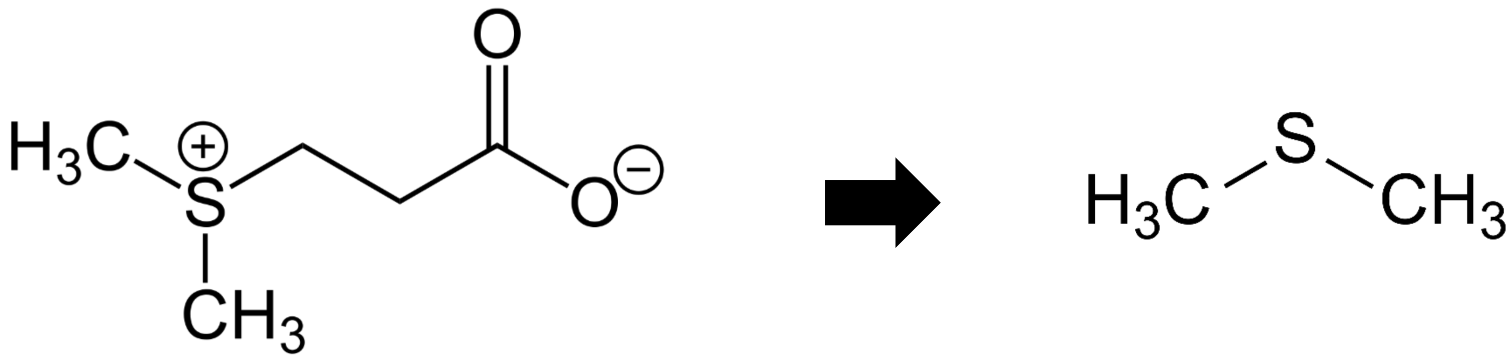
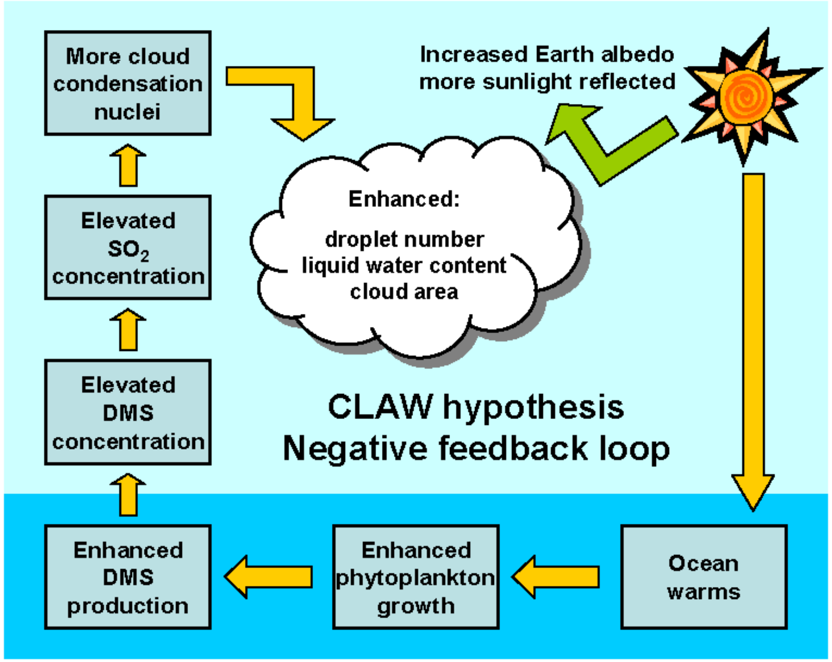


Figure 15.7 Colonization of *Phaeocystis antarctica* colonies by protozoa in the Ross Sea, Antarctica. Individual algal cells are visible in a single colony (a) as minute green dots. Arrows point to several heterotrophic protists associated with the colony. (b) Several colonies from a water sample. The interior of two of the colonies (arrows) are colonized with several heterotrophic protists each (white dots). Scale bars are 200 (a) and 500 (b) µm.

Caron et al., 2017, in Sea Ice



- Dimethylsulfoniopropionate (DMSP)
- A common compatible solute and cryoprotectant
- A highly preferred growth substrate for marine bacteria
- One enzymatic pathway for the degradation of DMSP produces dimethylsulfide (DMS)



Returning to Malene Bight…

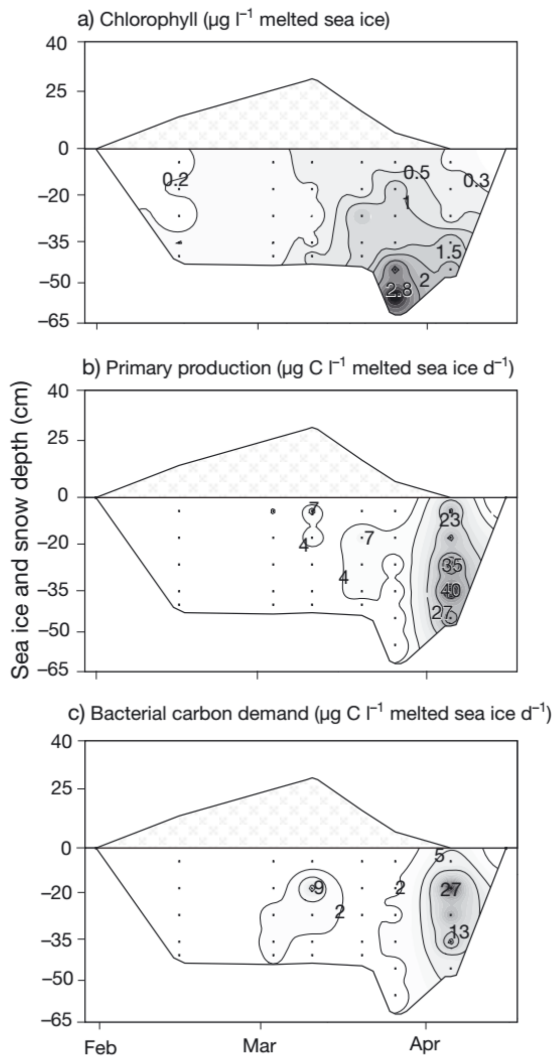


Fig. 4. (a) Chl *a* concentrations (μg chl *a* l^{-1}) in bulk sea ice. (b) Primary production (μg C l^{-1} melted sea ice d^{-1}). (c) Bacterial carbon demand (μg C l^{-1} melted sea ice d^{-1}) calculated according to Rivkin & Legendre (2001). The black dots represent triplicate measurements

Q: What prevents the bloom from initiating earlier?

A: Light! Specifically, seasonality and snow…

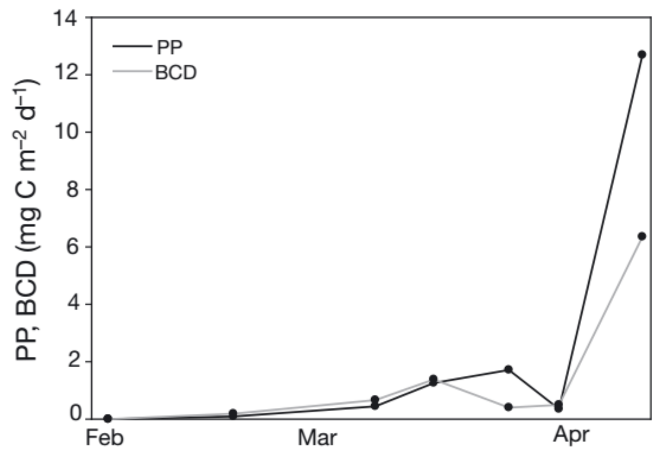
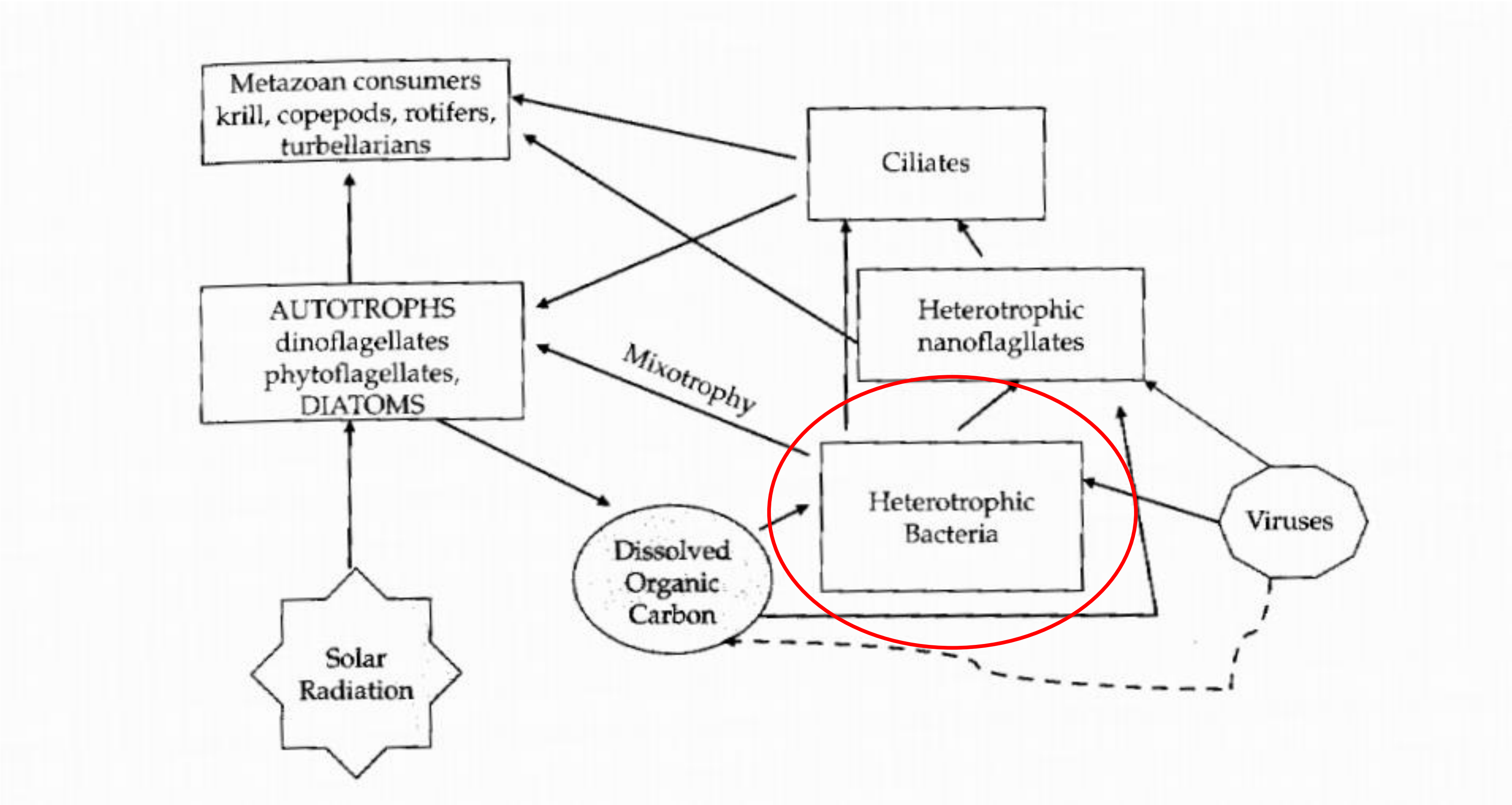
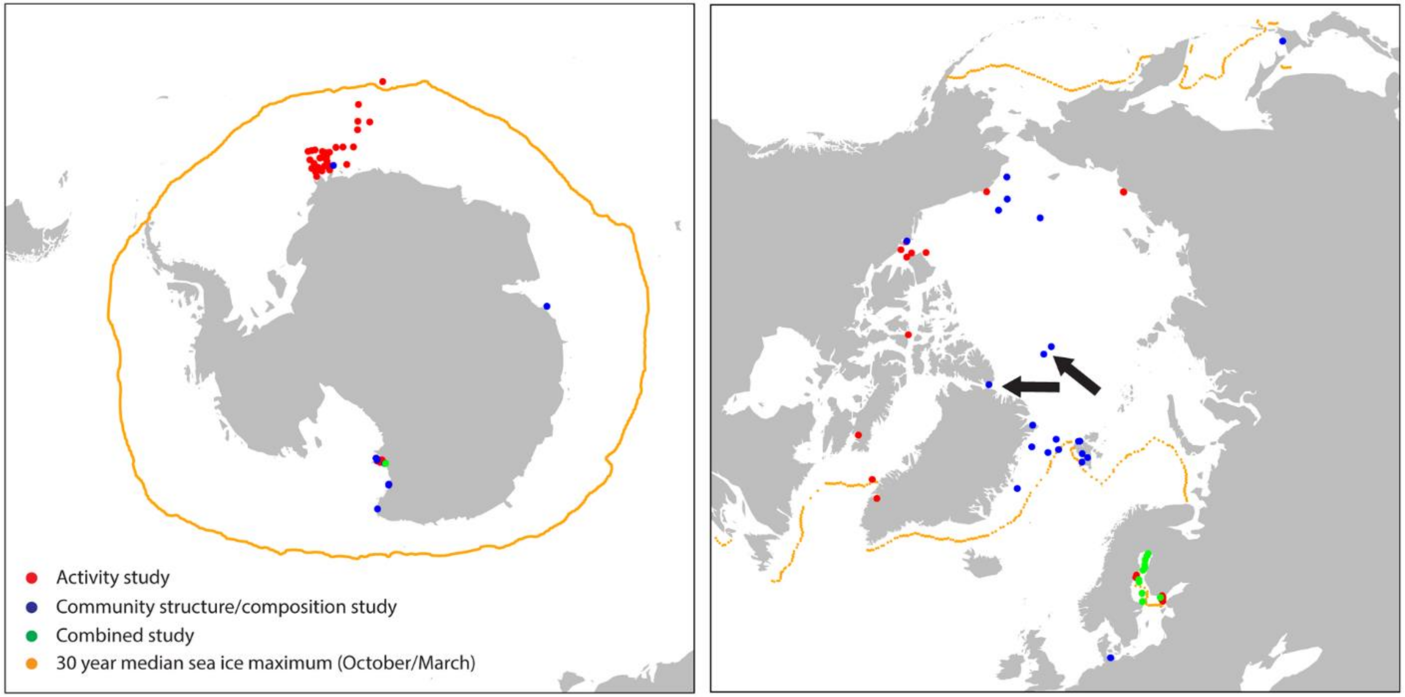


Fig. 5. Primary production (PP, mg C m^{-2} d^{-1}) and bacterial carbon demand (BCD, mg C m^{-2} d^{-1}) in bulk sea ice

- Bacteria respond quickly to primary production
- But never use all of the available carbon

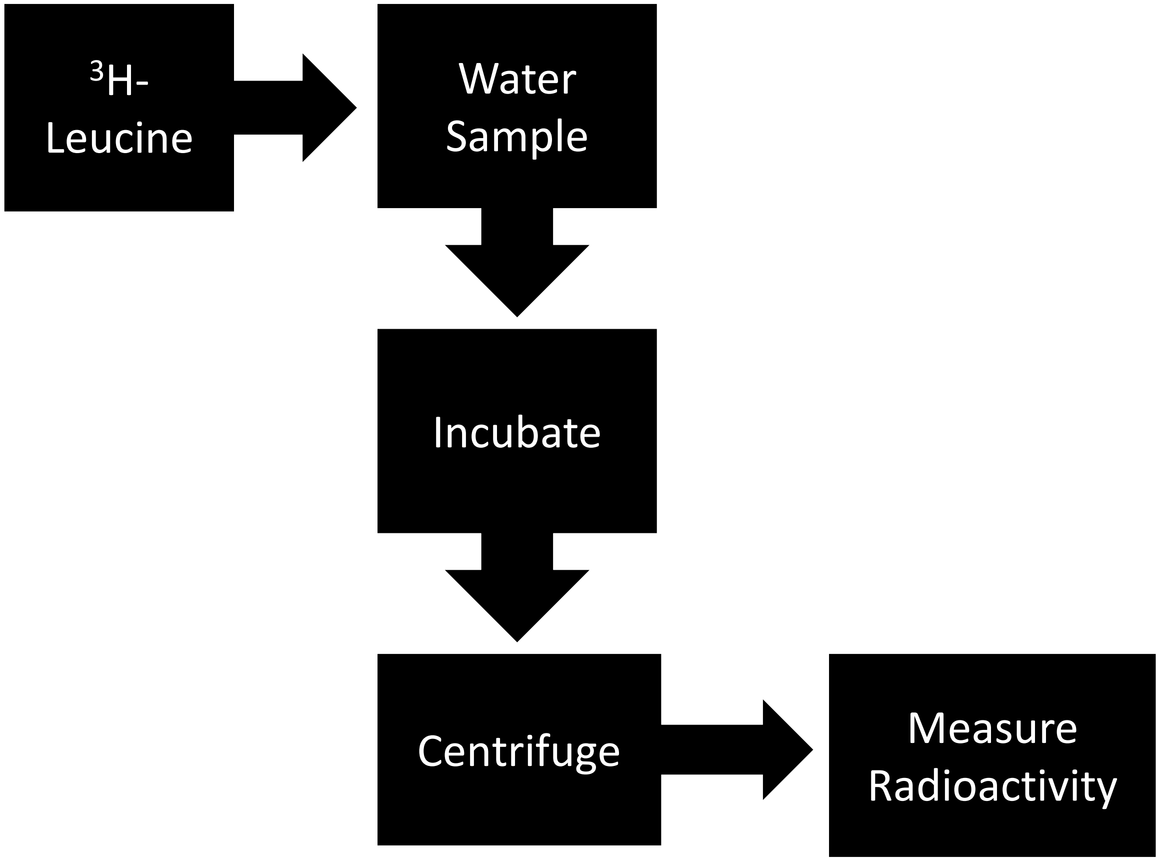

Metazoan consumers
krill, copepods, rotifers, turbellarians
Ciliates
AUTOTROPHS
dinoflagellates
phytoflagellates,
DIATOMS
Mixotrophy
Heterotrophic nanoflaglates
Heterotrophic Bacteria
Viruses
Dissolved Organic Carbon
Solar Radiation

- Very few studies of sea ice bacteria, particularly using modern "molecular" techniques in combination with BP assays

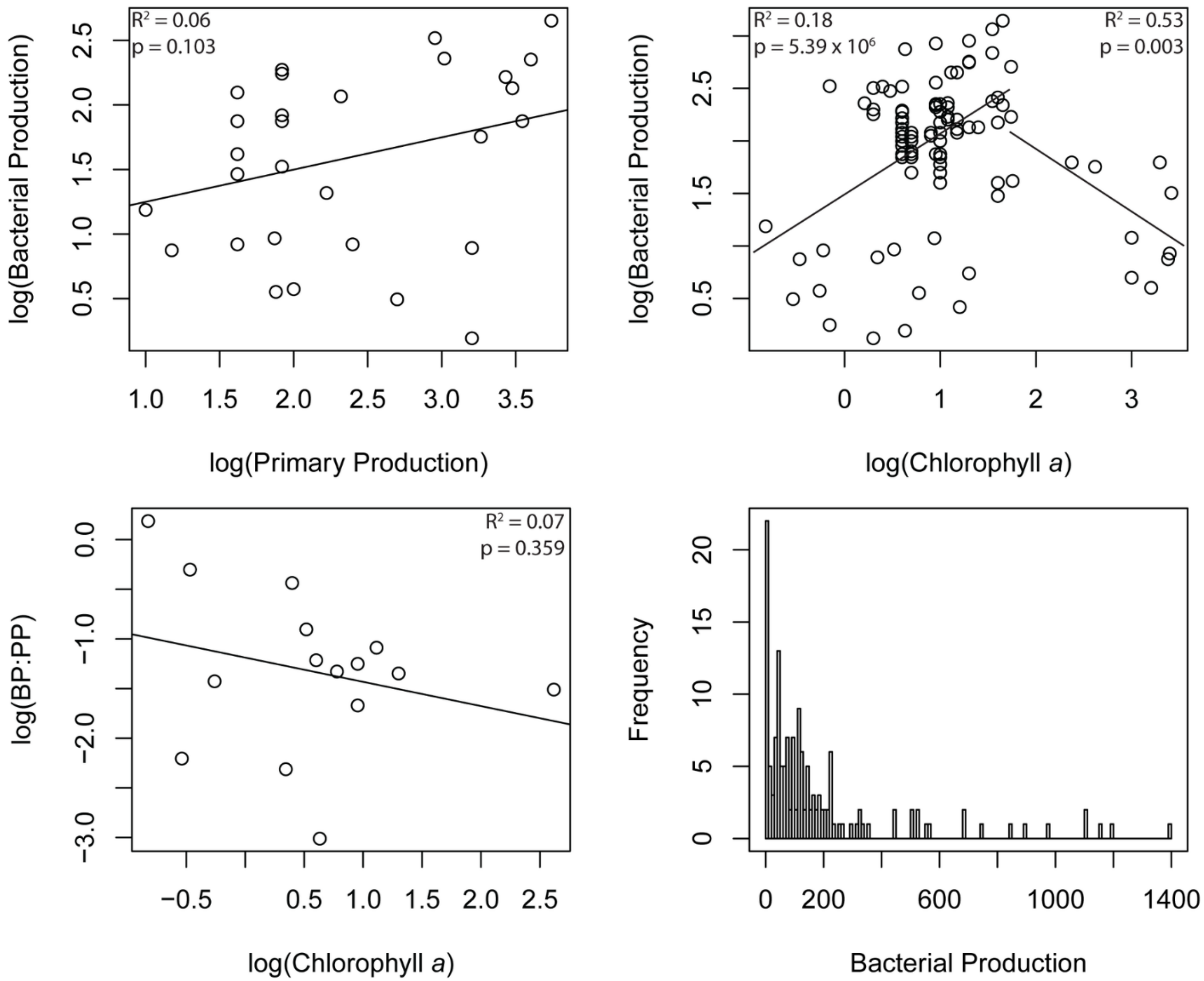


Bowman, 2015

- Very few studies of sea ice bacteria, particularly using modern "molecular" techniques in combination with BP assays
- BP is measured very similar to PP, except that the amino acid leucine is used as a tracer in place of HCO_3^-



- As in many environments, BP is poorly explained by PP (here only 10 % of variance explained)
- Chlorophyll concentration is a better predictor, but very high chlorophyll concentrations seem to *inhibit* bacterial growth



Bowman, 2015