Sea ice ecology

…but first, continuation of Chemical and physical setting of glaciers, snow, and permafrost…

Announcements

- Email headers (SIO121 of SIO 121)
- Quiz make up due dates
- References for annotated bibliography
  - Google Scholar
  - Harvard reference format
- Topics

1. Do sterols have a stabilizing or destabilizing effect on the lipid membrane?

Stabilizing

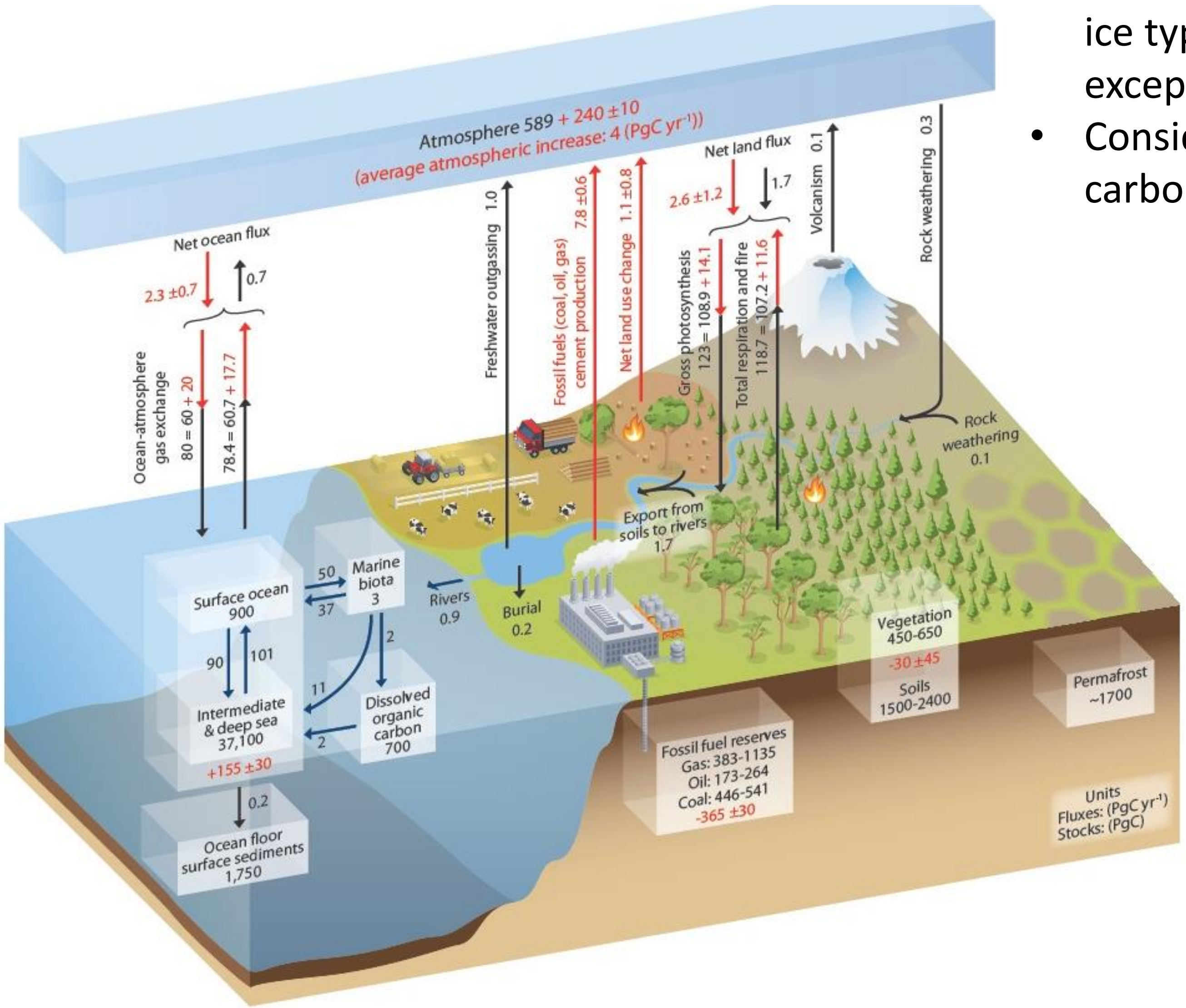
2. What is the approximate lower limit of water activity for cellular life?

0.6, accepted anything close

3. EPS is largely composed of what macromolecule?

Polysaccharides, also accepted polymers

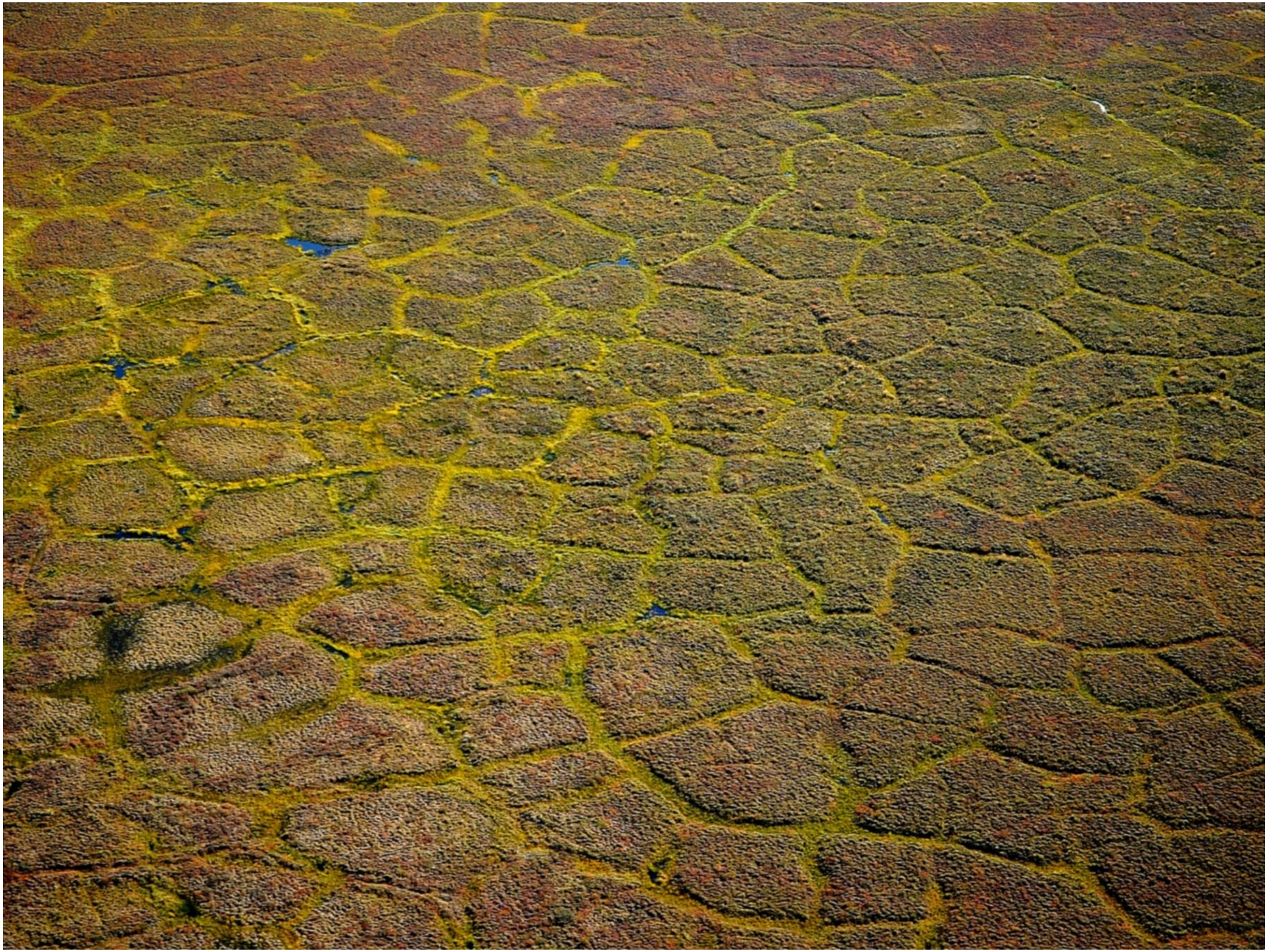
1. Do ice binding proteins lower the freezing point, raise the melting point, or both?
2. What region of a glacier is losing mass?
3. List two reasons the glacier bed is a good habitat for life.



- Permafrost is similar to other ice types we've discussed, except:
- Considerably more organic carbon

Features of permafrost landscapes include:

- Polygons



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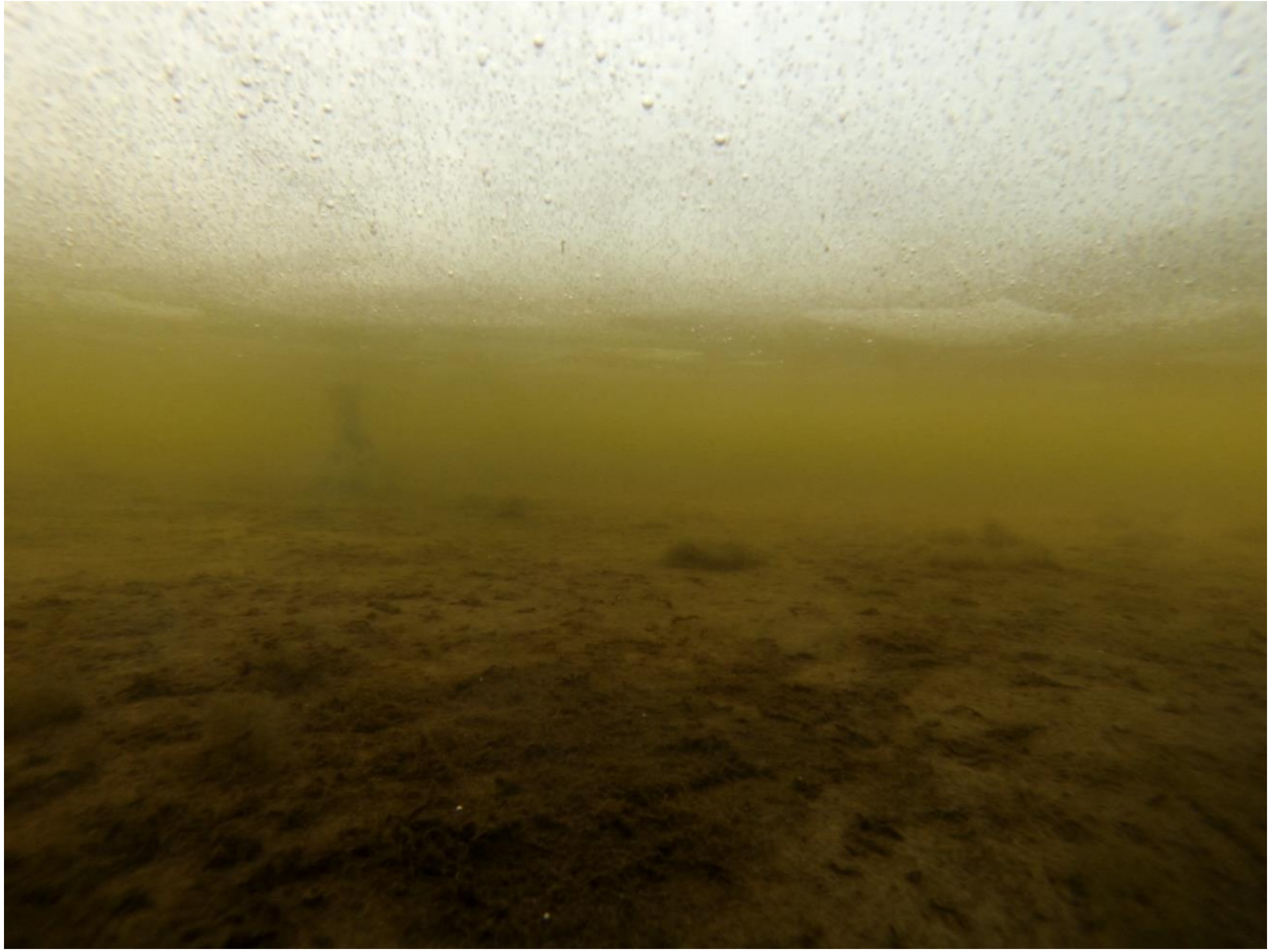
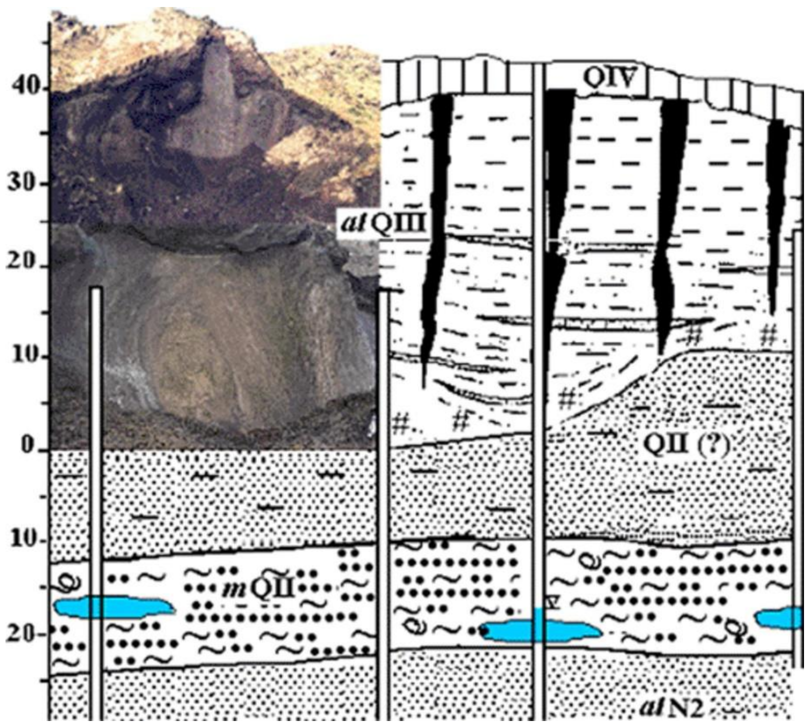
Q: What can you piece together about the ecology of these lake whitefish; what challenges and opportunities are afforded by their habitat?



Features of permafrost landscapes include:

- Polygons
- Thermokarst lakes
- Cryopegs: frozen, remnant marine sediments



Gilichinsky et al., 2005

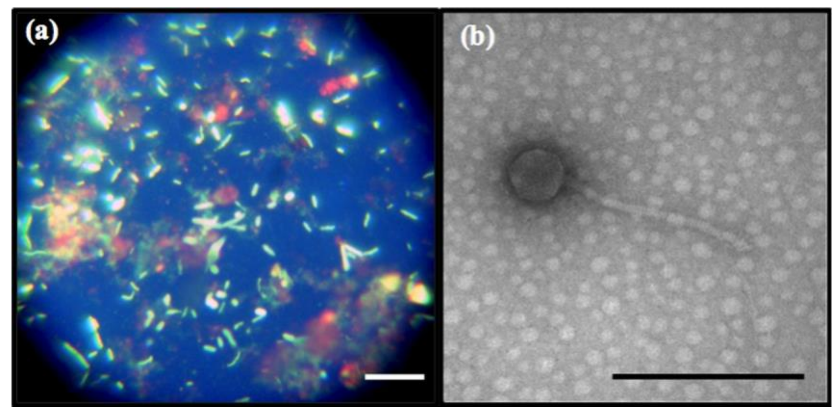


Table 1. Comparative concentration of main ions (mM) and total mineralization (g/L) in cryopegs and standard seawater

Ion, mM	Sampling Site				
	Yakutskoe Lake	Chukochii Cape	Varandei Cape	Barrow Cape	Seawater
K^+	20	10	6.2	23.5	10.2
Na^+	2000	1520	99.5	1680	469
Ca^{2+}	30	40	8.9	52.4	10.3
Mg^{2+}	310	195	28.5	357	52.8
Cl^-	2630	1940	111	1930	546
SO_4^{2-}	35	31.5	23.8	64.4	28
Mineralization (‰)	150–200	150–200	6–18	115	35

Spirina et al., 2017

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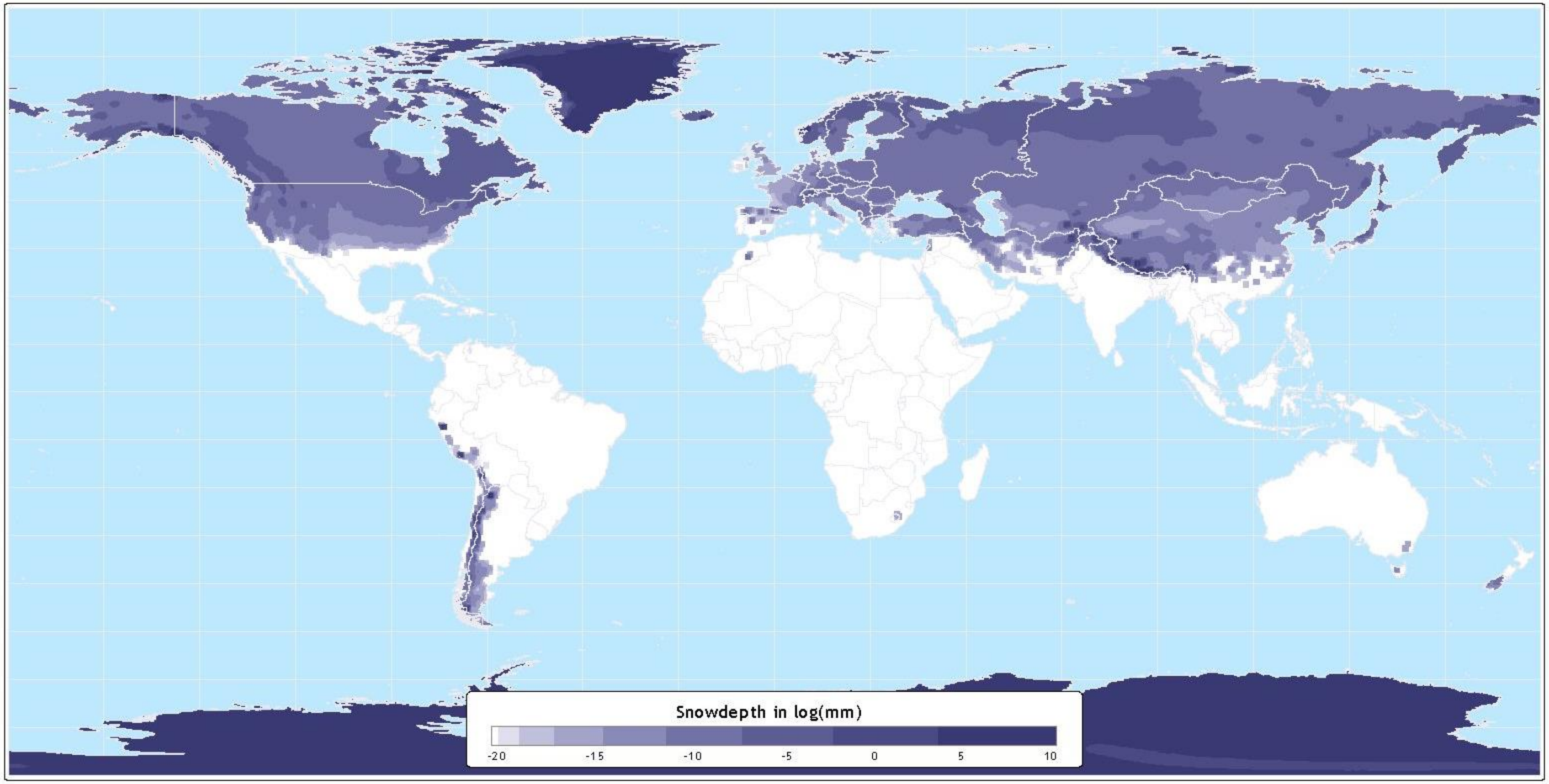
- Cryopegs: frozen, remnant marine sediments

Colangelo-Lillis et al, 2016

Winter global snowfall extent



Q: Based on our discussions so far, what aspects of the snow environment should we be most concerned about?

A: Temperature, light, moisture, nutrients

- All of these are influenced by snowpack age and crystal structure

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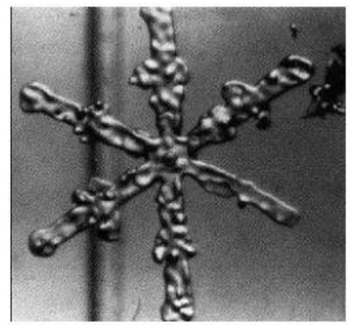
A: Temperature, light, moisture, nutrients

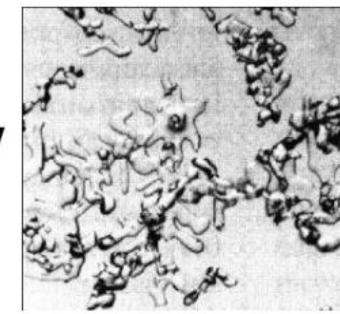
- All of these are influenced by snowpack age and crystal structure
- Snowflakes held at constant temp, metamorphosis due to migrating water molecules

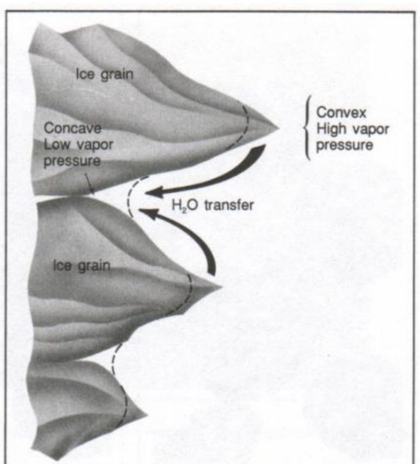
Day 1

Day 5



Day 57





From The Avalanche Handbook , McClung and Schaerer (1993)

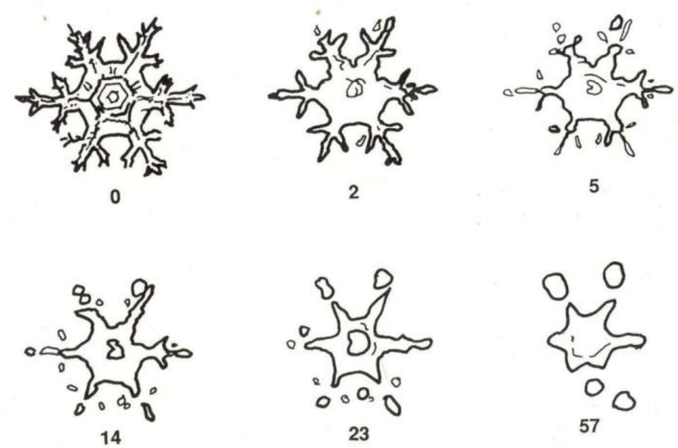
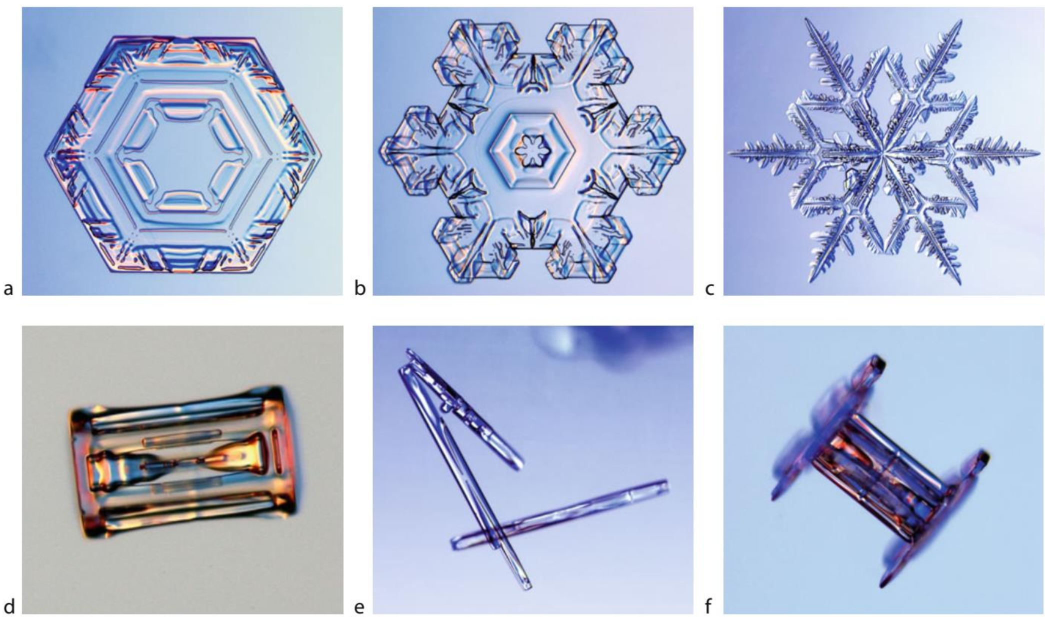
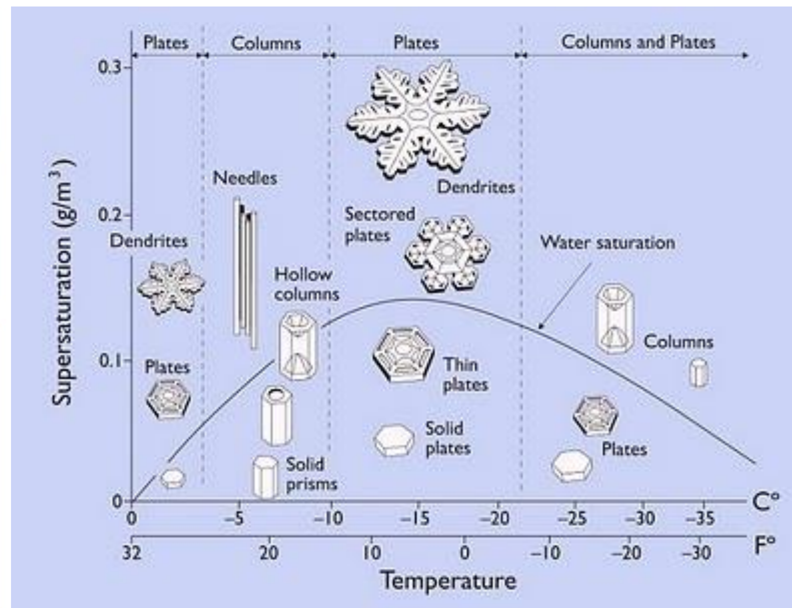


Figure 3.12. Sketch of crystal metamorphism (at constant temperature) by curvature effects. The numbers give the time in days. (After Bader, 1939)

- Snowflake morphology can serve as a rough guide to moisture content and temperature.
- Don’t confuse moisture content with snow water equivalent!
    - Moisture content: fraction of snowpack that is liquid
    - SWE: volume of water present if you melted volume of snow (partially but not wholly a function of moisture content)





Singh et al., 2011, Encyclopedia of Snow, Ice, and Glaciers

Q: What controls the moisture content?
A: Same as for sea ice brine volume fraction: temperature and bulk solute concentration!

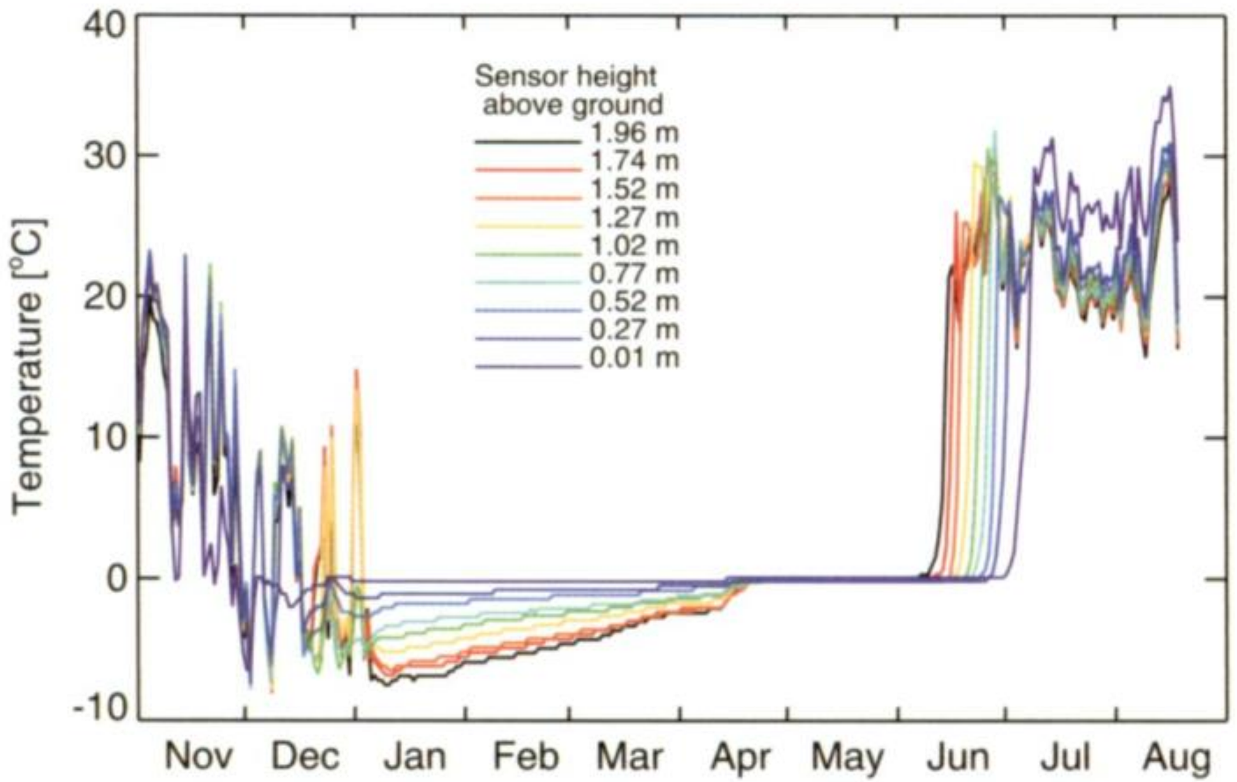
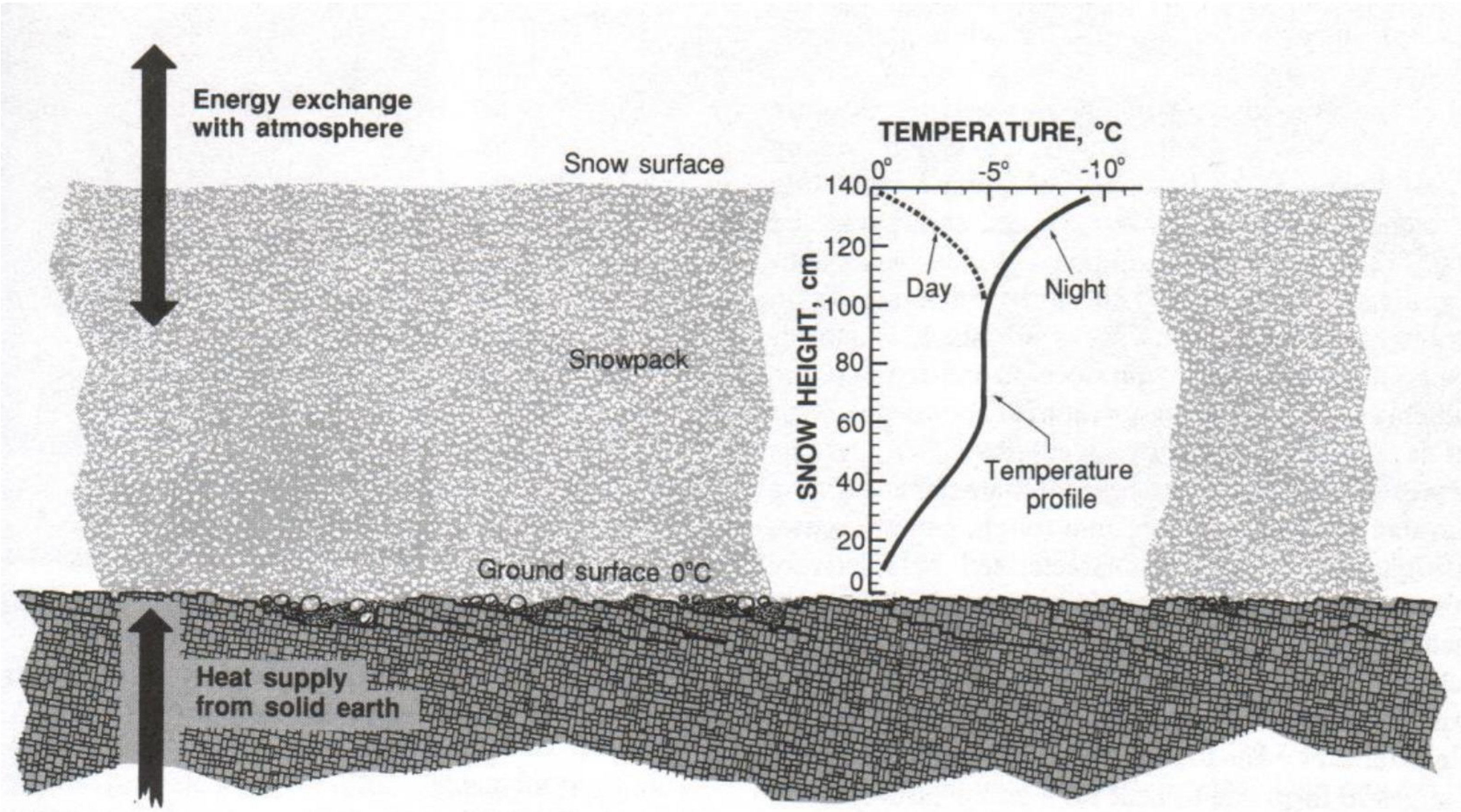


FIGURE 6. Hourly temperature data from the TidbiT temperature sensors on the tall post for the entire field season.

Q: When did the snowpack establish at this site?

A: First snowfall early December, fully established early January.

- Snowpack temperature structure is similar to a polythermal glacier



McClung and Schaerer, 1993

Snow Hydrology, Table 1 Albedo of various surfaces (From Gray and Prowse, 1993)

Surface	Typical range in albedo
New snow	0.80–0.90
Old snow	0.60–0.80
Melting snow-porous-fine grained	0.40–0.60
Forests-conifers, snow	0.25–0.35
Forests-green	0.10–0.20
Water	0.05–0.15
Snow ice	0.30–0.55
Black ice: intact → candled → granulated	0.10→0.40→0.55

- Snow has a high albedo
- Absorbs little energy, resists melting
- Considerable photochemistry at surface

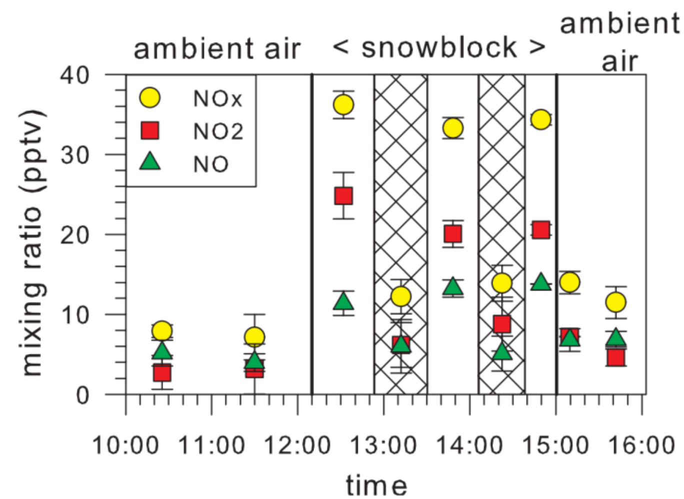


Fig. 3. Measurements of NO, NO_2 and NO_x in a snowblock shading experiment at Neumayer Station, Antarctica (Jones et al., 2000). The first and final sections are measurements made in ambient air. Middle sections are measurements made within the snowblock, alternatively fully exposed to sunlight and fully shaded to eliminate any photochemical activity. Periods of shading are indicated by cross-hatching.

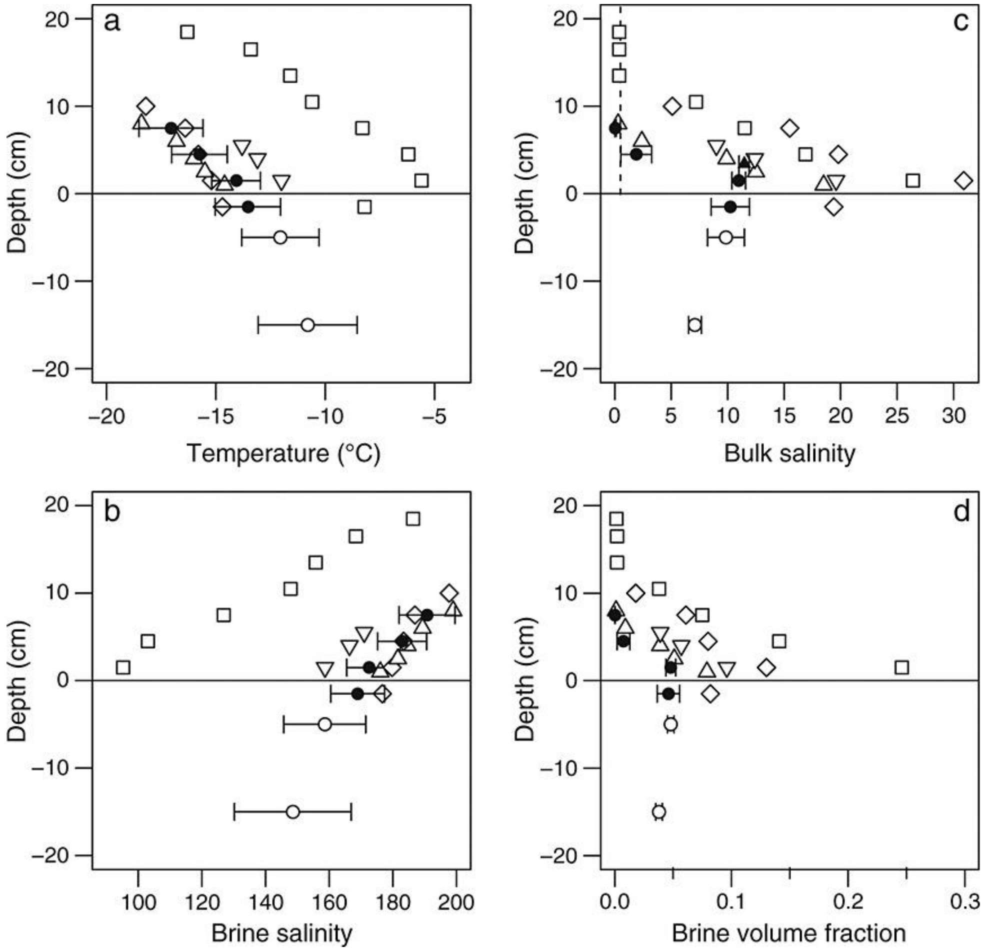
$$NO_3^- + h\nu \rightarrow NO_2 + O^-$$

$$NO_3^- + h\nu \rightarrow NO_2^- + O(^3P)$$

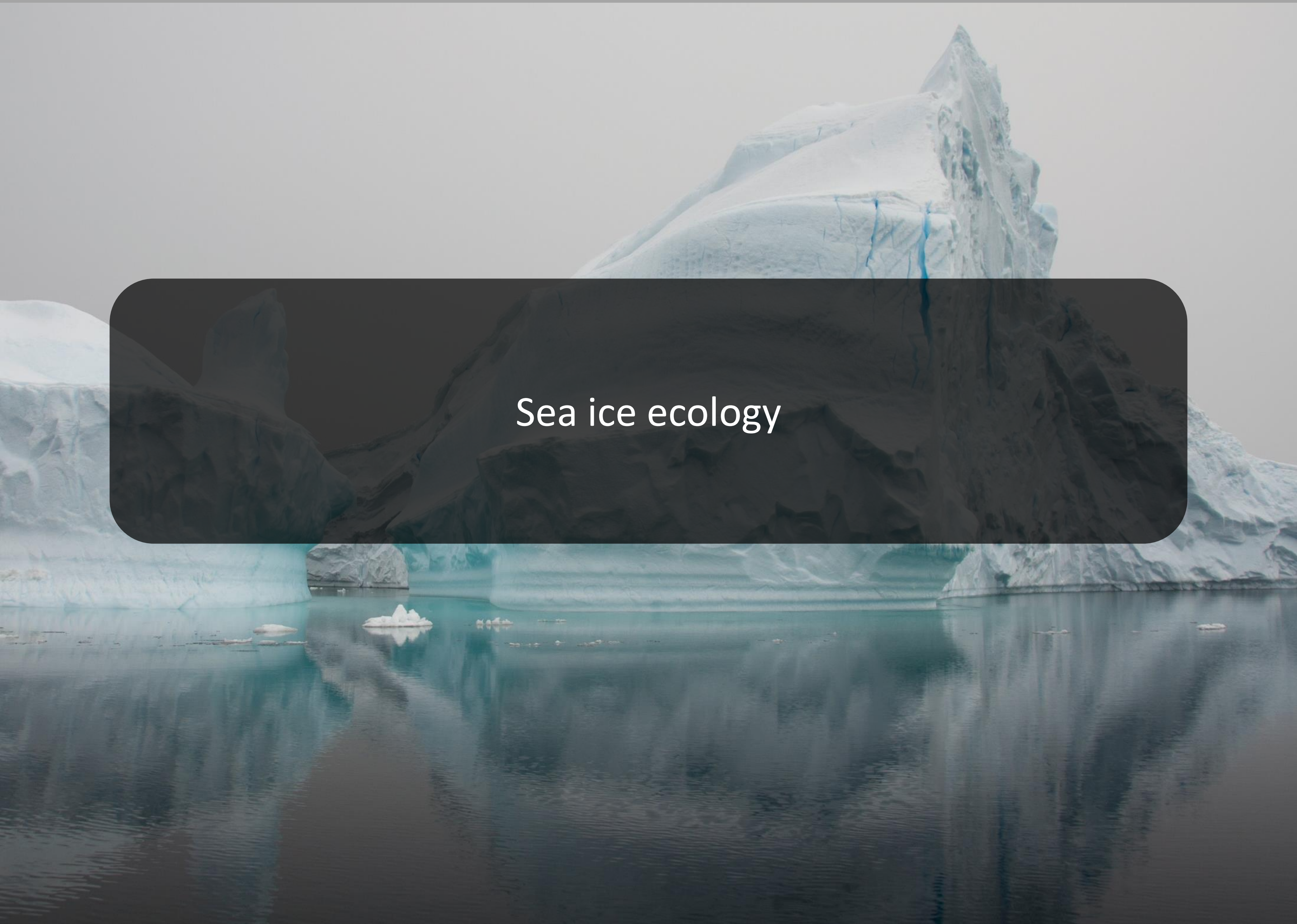
Extremely reactive!

Grannas et al. 2007

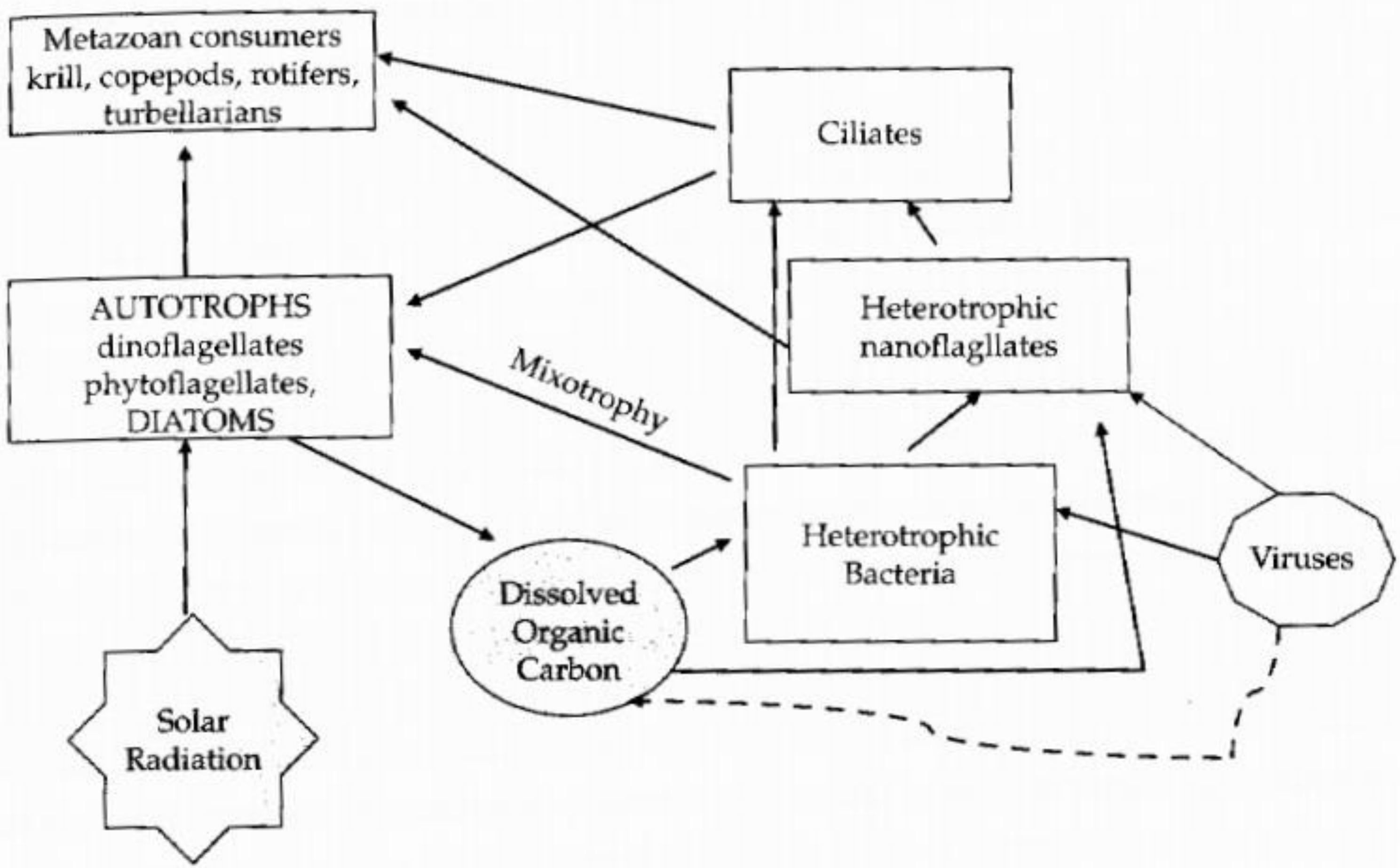
Saline snow on sea ice



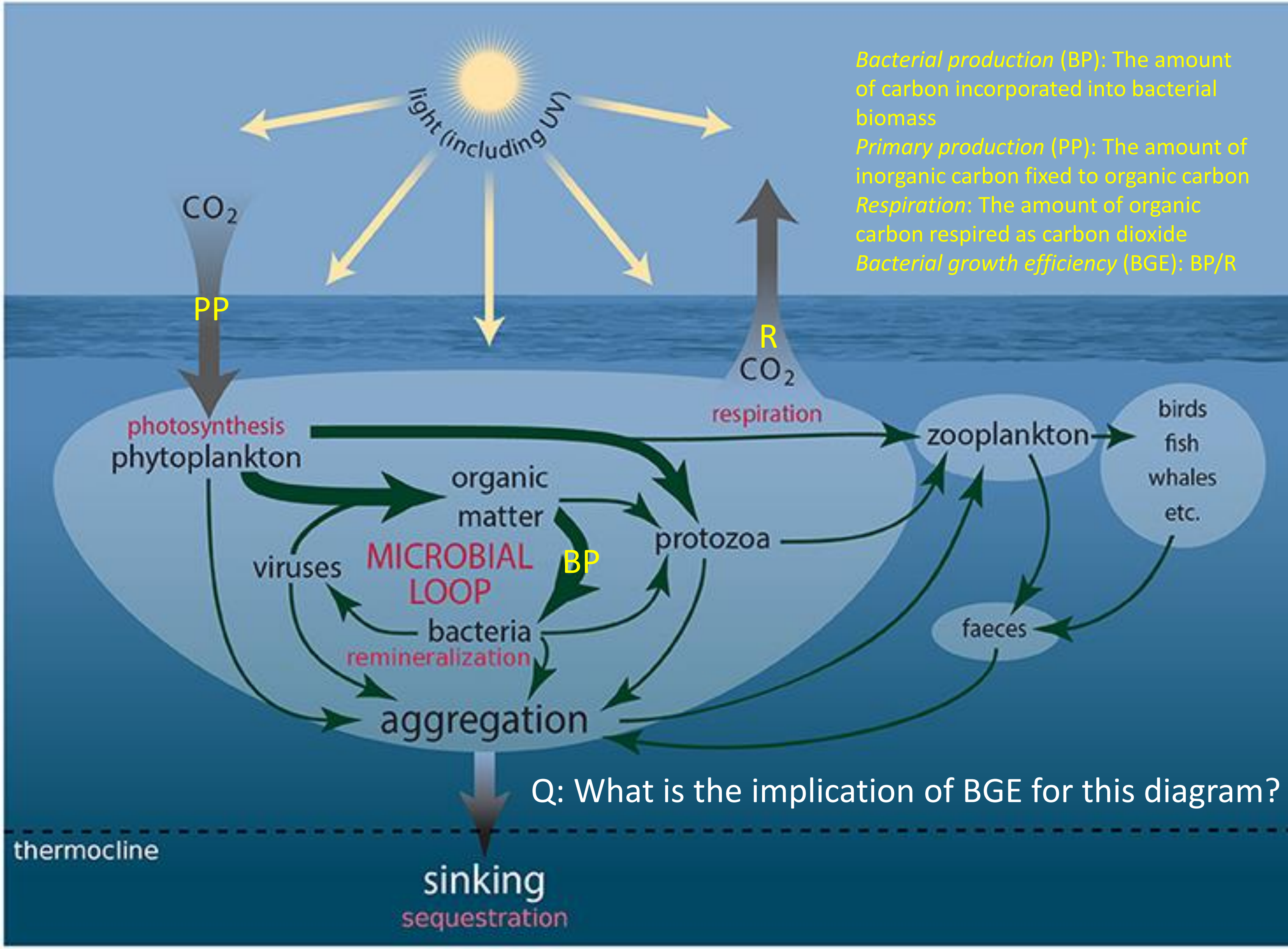
Ewert et al., 2014



Sea ice ecology


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

SIO 121, Lecture 5: Sea ice ecology



Bacterial production (BP): The amount of carbon incorporated into bacterial biomass

Primary production (PP): The amount of inorganic carbon fixed to organic carbon

Respiration: The amount of organic carbon respired as carbon dioxide

Bacterial growth efficiency (BGE): BP/R

Q: What is the implication of BGE for this diagram?

We will start at the base of the food web with the *primary producers*

Q: What determines the level of primary production in sea ice?

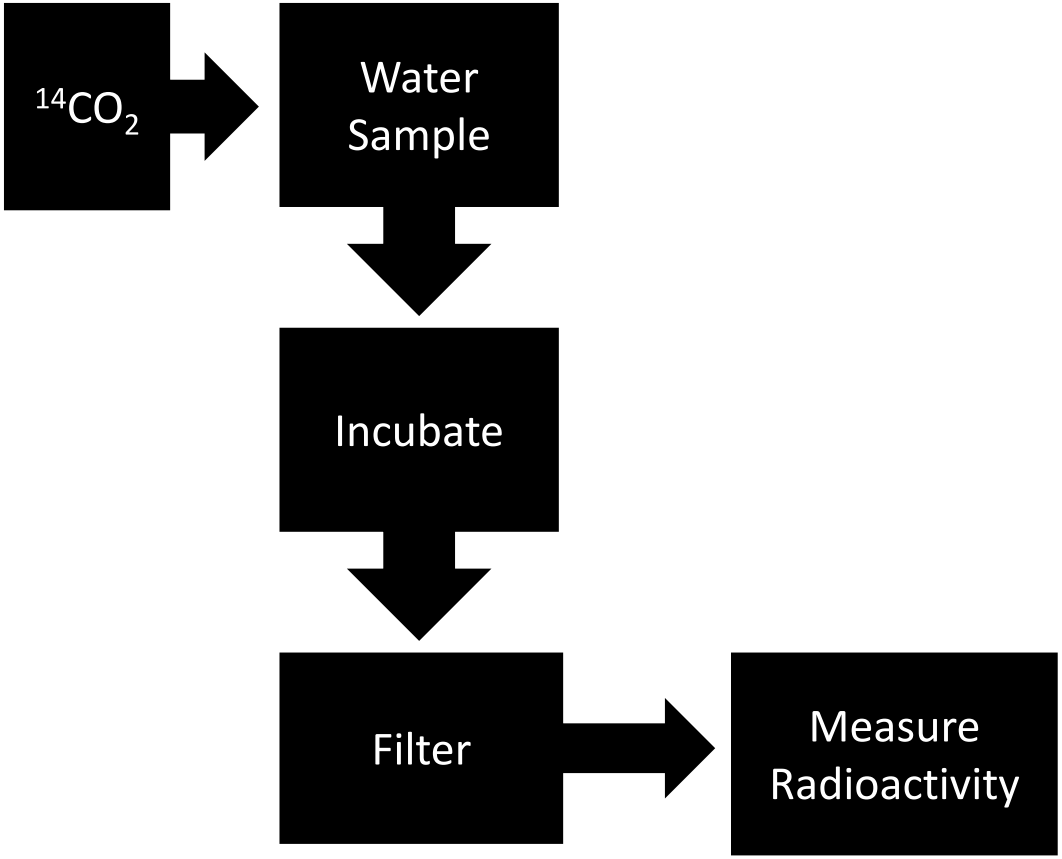
A: Light and nutrients!

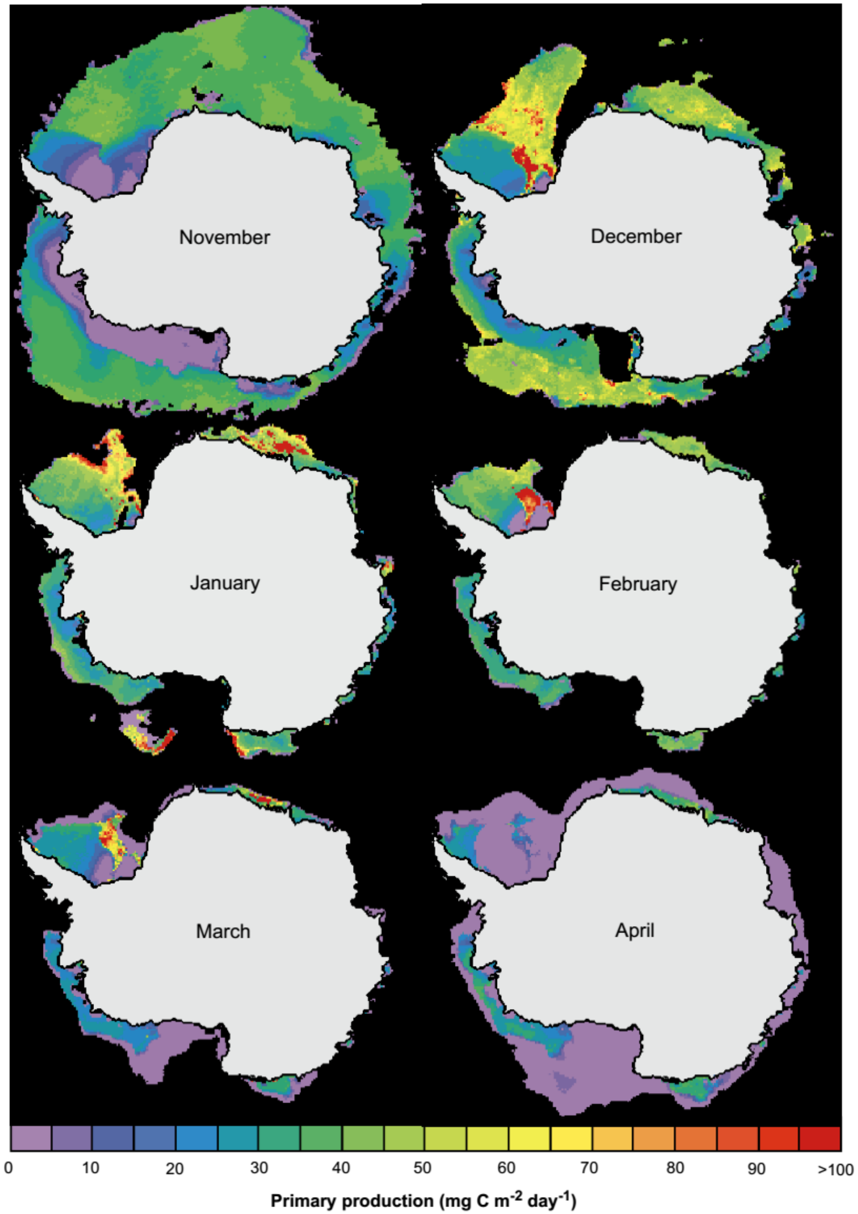
Q: What additional factor controls the level of algal biomass?

A: Grazers

- Sea ice is a highly *productive* ecosystem
- Primary production in sea ice can reach ~ 40 % of the depth-integrated water column primary production (but usually much less)
- Most concentrated zone of biomass anywhere in the water column

Ecologists are generally more interested in rates than biomass – why? Imagine a situation where considerable amounts of biomass are being generated but consumed. There will be a low *standing stock*. Measuring the standing stock gives an unrealistic view of what the ecosystem is doing.





Arrigo et al., 1997

TABLE 1. *Percent of total primary production in the Antarctic Seasonal Ice Zone contributed by sea ice algae, based on model estimates for sea ice (Arrigo et al., 1998b) and phytoplankton (Arrigo et al. 1998c).*

Month	Weddell	Indian	W. Pacific	Ross	B–A*	Total
October	6.1	35.0	6.4	21.7	8.8	10.3
November	11.9	12.0	2.4	8.6	6.5	8.8
December	4.6	2.6	1.4	3.8	2.6	3.4
January	2.1	1.6	1.1	1.2	1.5	1.6
February	1.2	0.8	0.7	0.5	1.4	1.0
March	1.7	0.6	1.2	1.3	1.4	1.3
April	1.0	1.3	2.1	2.0	2.4	1.5

* Bellingshausen-Amundsen.

Lizotte, 2001

- Model estimates of sea ice primary production around Antarctica
- Highest primary production associated with dynamic, first year ice zones with high snowfall
- BUT… models like this are based on very little data!

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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]

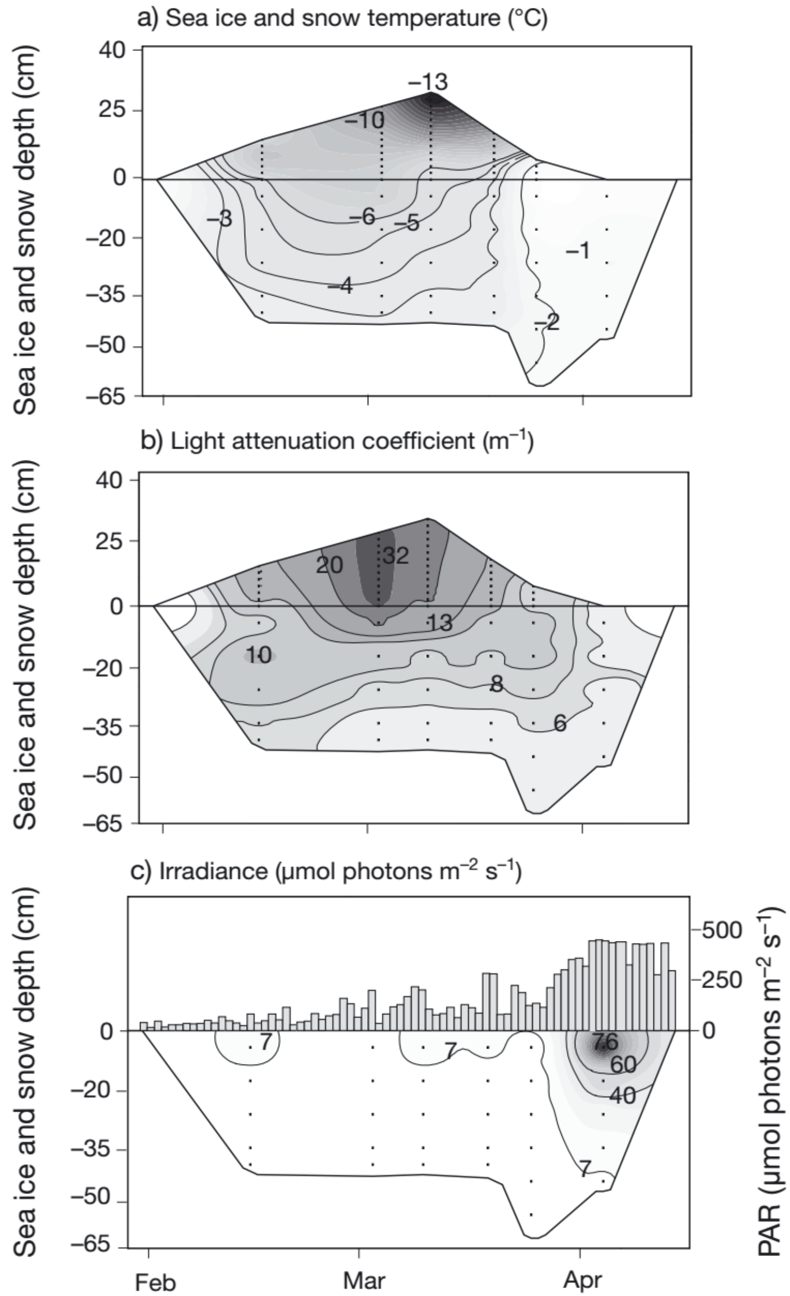

Fig. 1. Sea ice development in Malene Bight, NW Greenland, during the 2008 season: (a) sea ice and snow temperature (°C), (b) light attenuation coefficient (m^{-1}), (c) average daily photon irradiance in sea ice and at surface (PAR, µmol photons m^{-2} s^{-1}), (d) bulk salinity, (e) relative brine volume fraction (%). The sea ice in late March from 0 to 16 cm is a layer of granular snow–ice. The black dots represent triplicate measurements

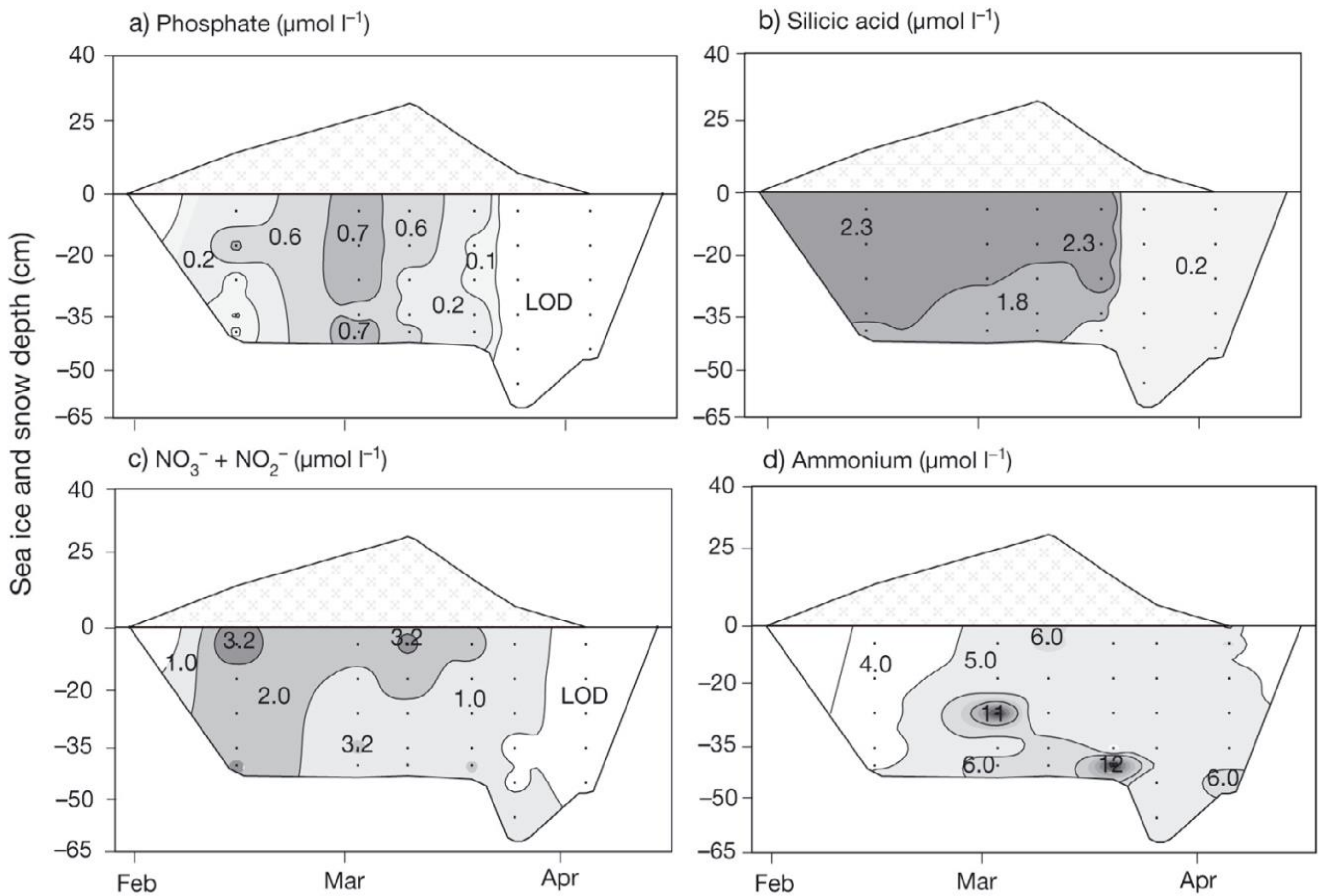

Fig. 2. Nutrient concentration (μmol l^{-1}) in bulk sea ice: (a) phosphate, (b) silicic acid, (c) $NO_3^- + NO_2^-$, (d) ammonium. LOD is lower limit of detection, which is calculated using the *t*-value of 2.99 corresponding to a 99 % confidence interval with df = 7. The black dots represent triplicate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

Q: Nutrient drawdown suggests that which phytoplankton taxa are dominant in this sea ice bloom?

A: Drawdown of silicic acid suggests that diatoms are particularly important.

- Other dominant taxa include flagellates, ciliates, dinoflagellates

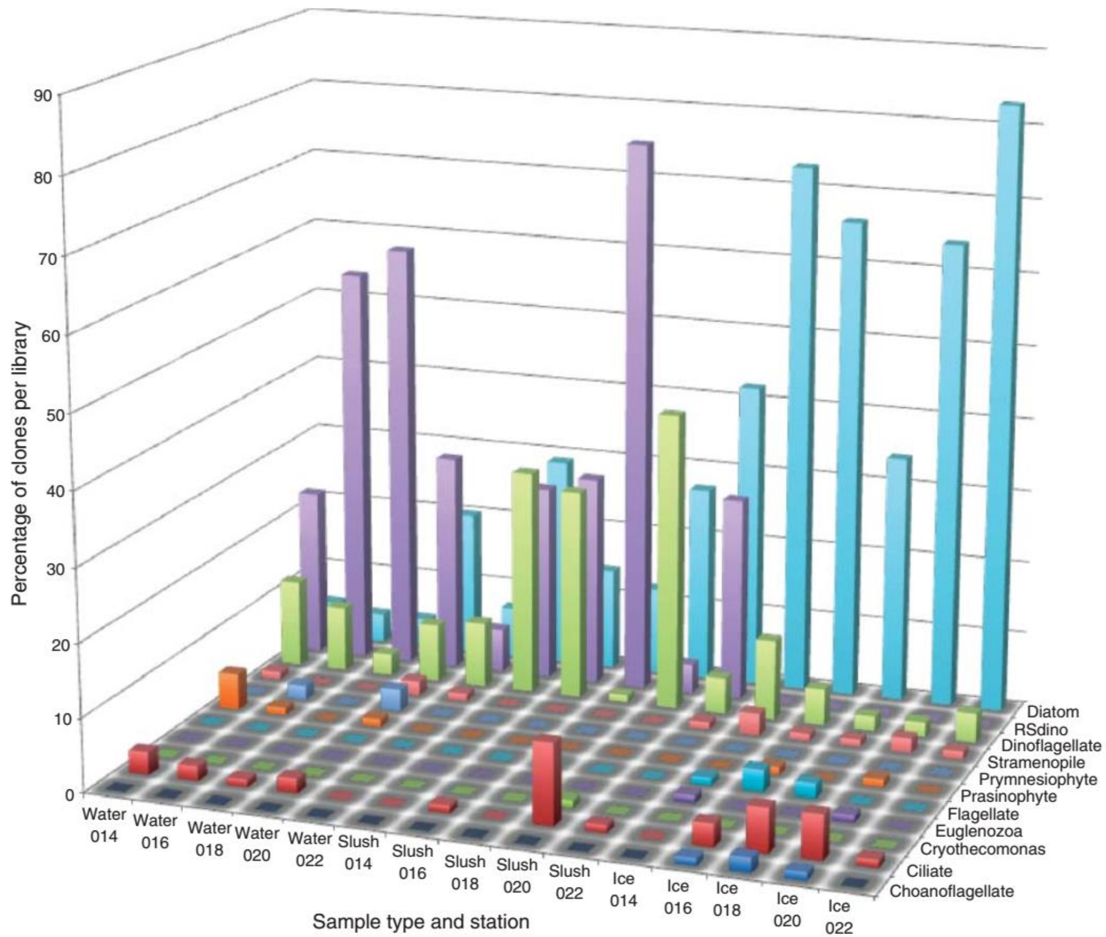

Figure 15.1 Differences in protistan community structure in sea ice, water and meltwater communities (slush) on ice floes from the Ross Sea, Antarctica, as determined from small subunit ribosomal RNA gene sequence libraries. Note the strong dominance of diatoms among the photosynthetic protists within 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.

Caron et al., 2017, in Sea Ice

- Diatoms are tremendously morphologically diverse, cell size covers two orders of magnitude from ~ 2 microns to 200 microns
- Two basic body forms – pennate and centric
- Both form have single cell and colonial varieties
- Characterized by silicate frustule and absolute adherence to phototrophic lifestyle
- No flagellum, but can move via gliding motion and by controlling buoyancy
- See Table 4.2 in book for list