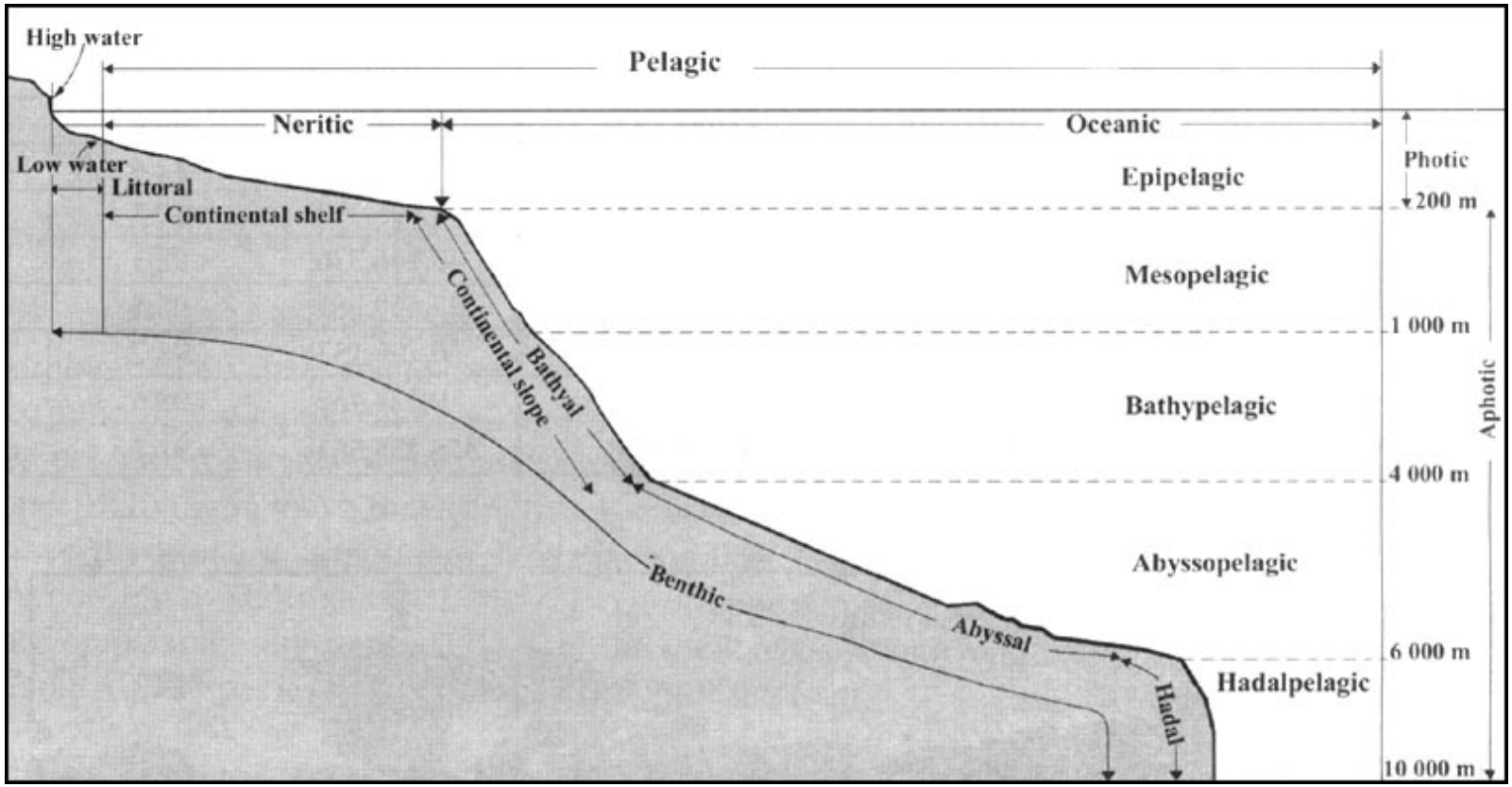
Marine Ecosystems in the Southern Ocean



Sunlight and photosynthesis

Abyssal plain

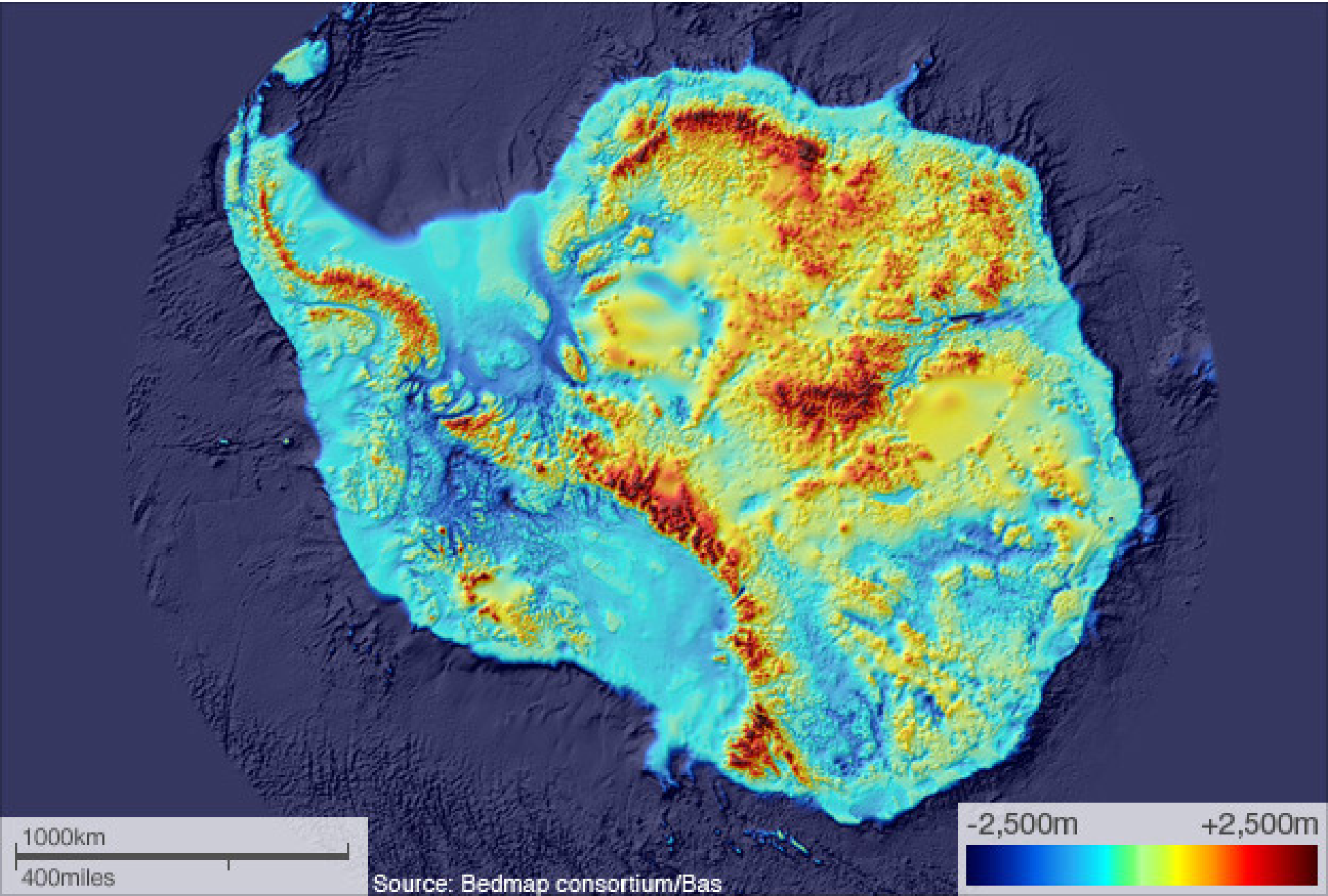
Marine life receives a gradient of light from the surface through the photic zone, much absorbed

Sea ice complicates this in winter, reduces light penetration

Cold, dense water sinks below ice but also causes nutrient rich water from below to upwell

Increases productivity around Antarctica

Continental Shelf in Blue: Narrow around most of Antarctica



Continental shelf benthos has a surprising biodiversity

Now known that ~80% of species are endemic

Some groups (e.g., sea spiders or pycnogonids) are more diverse here than anywhere else

http://www.oikonos.org/

Underwater in McMurdo Sound with an ice wall behind and many Antarctic scallops, several sea urchins, *Sterechinus neumayeri* and brittle stars, *Ophionotus victoriae*, and a white club-shaped sponge, *Homaxinella balfourensis.* **https://en.wikipedia.org/**

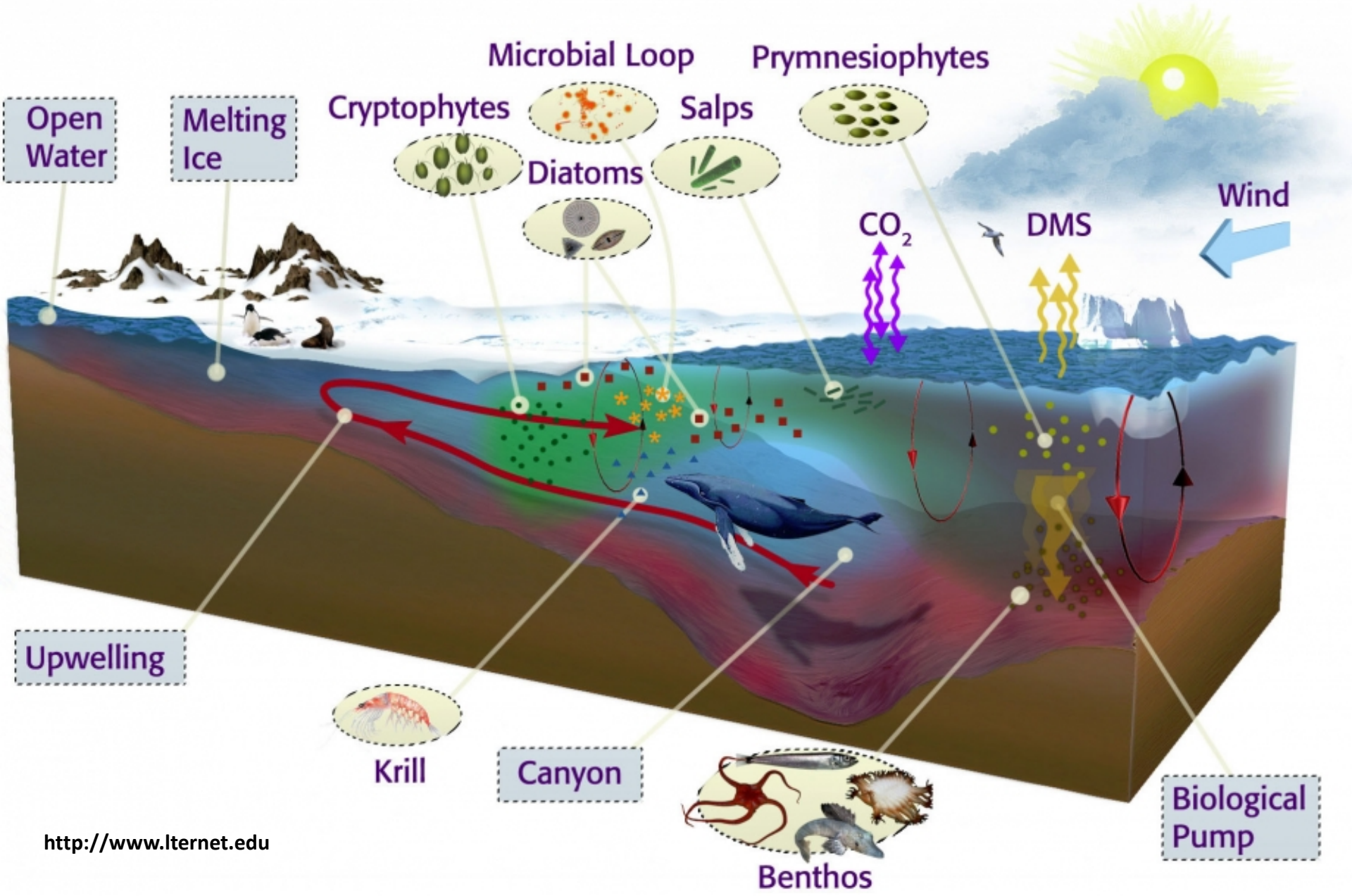
Kelp in the Antarctic Peninsula

Bull kelp can reach lengths >20m

Strongest in world to sustain heavy seas, but some still break loose

Kelp community has highest diversity of inshore marine environment, >90 spp. including worms, molluscs, mites, sea-stars, sea-cucumbers and numerous crustaceans

Once thought simple, marine communities in Antarctica are quite diverse



http://www.lternet.edu

Inshore surface waters are actually colder than deep waters, due to katabatic winds, ice that cool the water there

The average depth over the continental shelf is ~500 m

The average temperature of the water has risen by 1° C since 1950

This cold temperature limits species—e.g., no crabs on the shelf, predators are only slow moving starfish and urchins, but…

King Crab invasion video:

https://www.youtube.com/watch?v=rcwXGfTtW3U

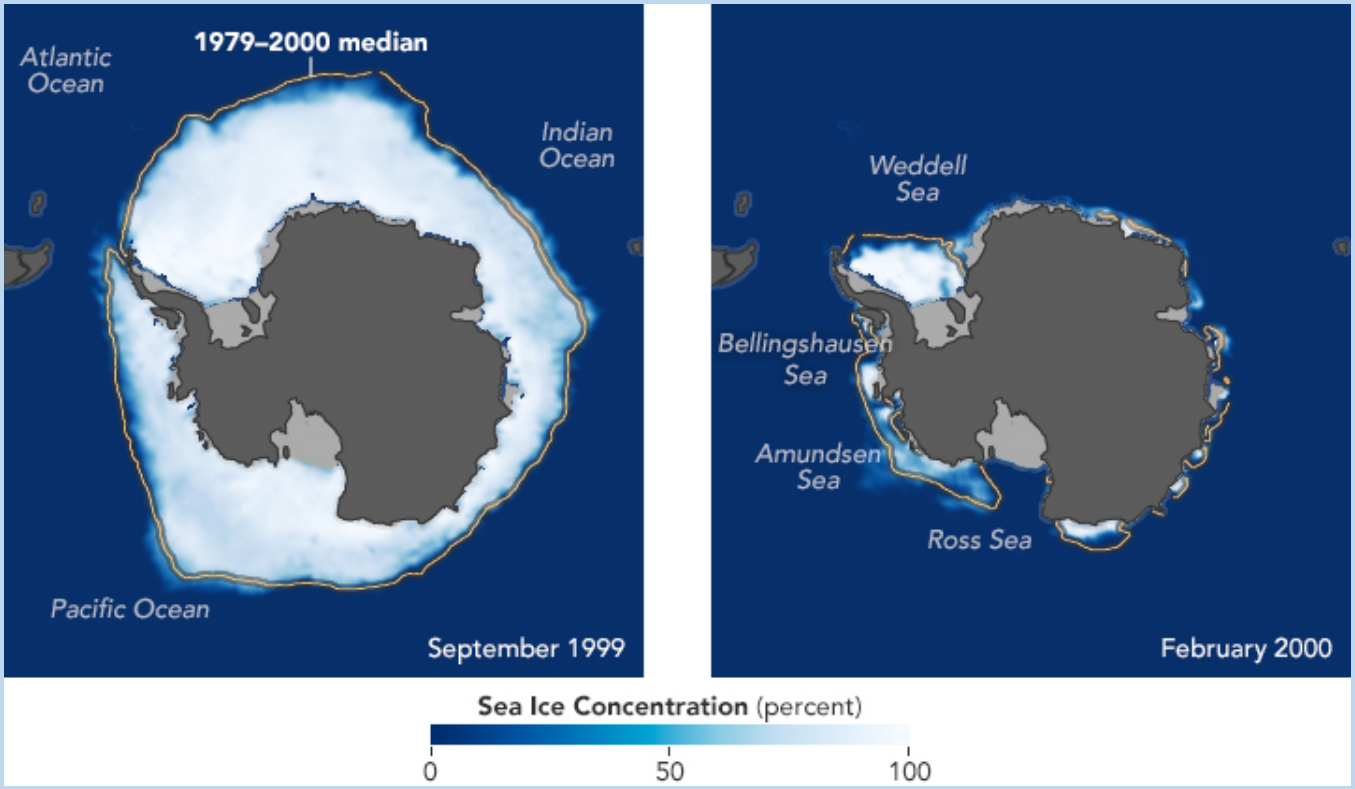
Sea Ice Drives Marine Productivity in Antarctica

--when ice begins forming in late summer, it traps marine algae in pockets in the ice

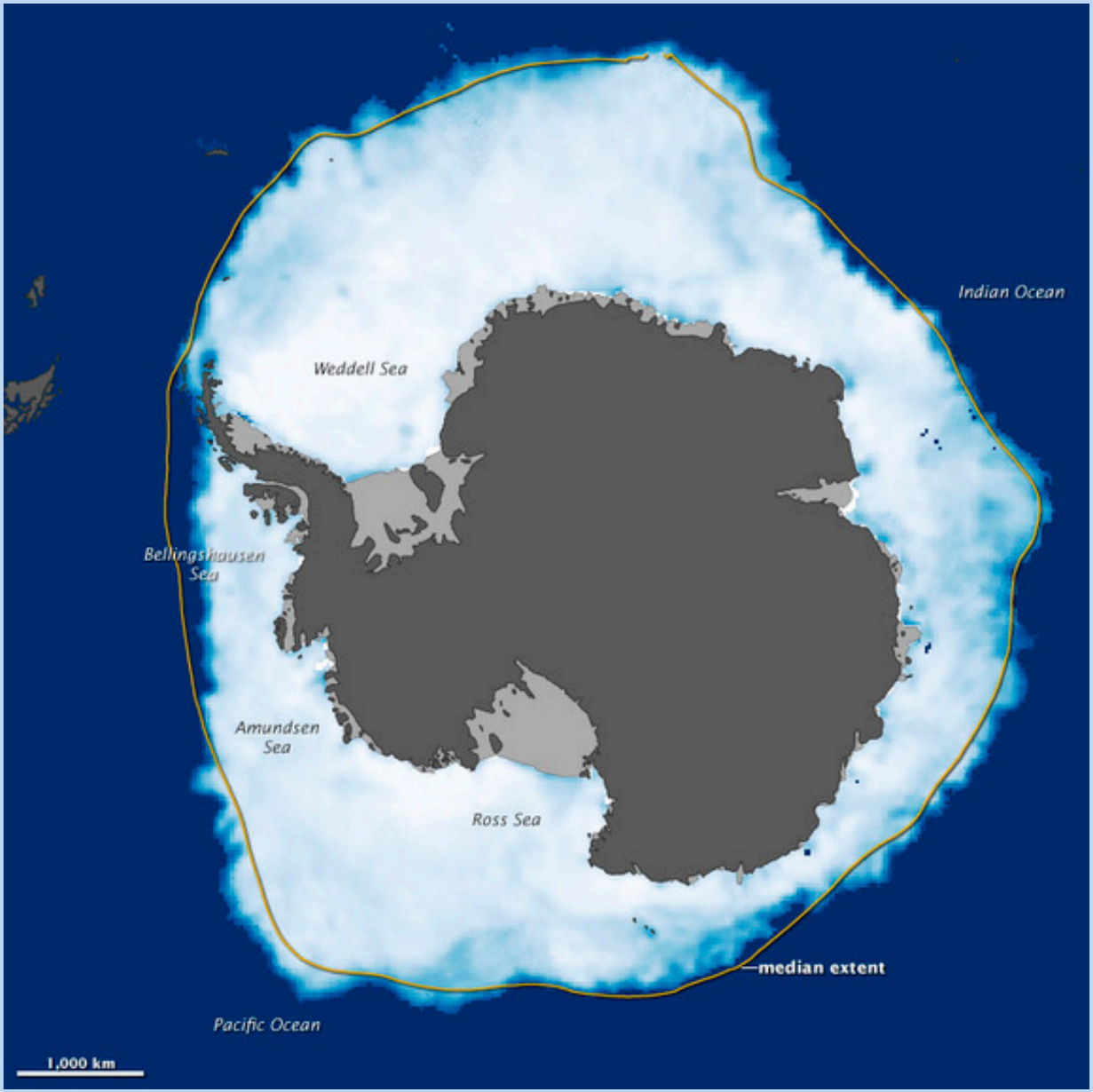
--the algae remains dormant during the long winter, but with spring sunlight, can grow in the ice

--when ice melts, it releases all this algae into the marine food web

Heavy ice years = high productivity, and vice versa



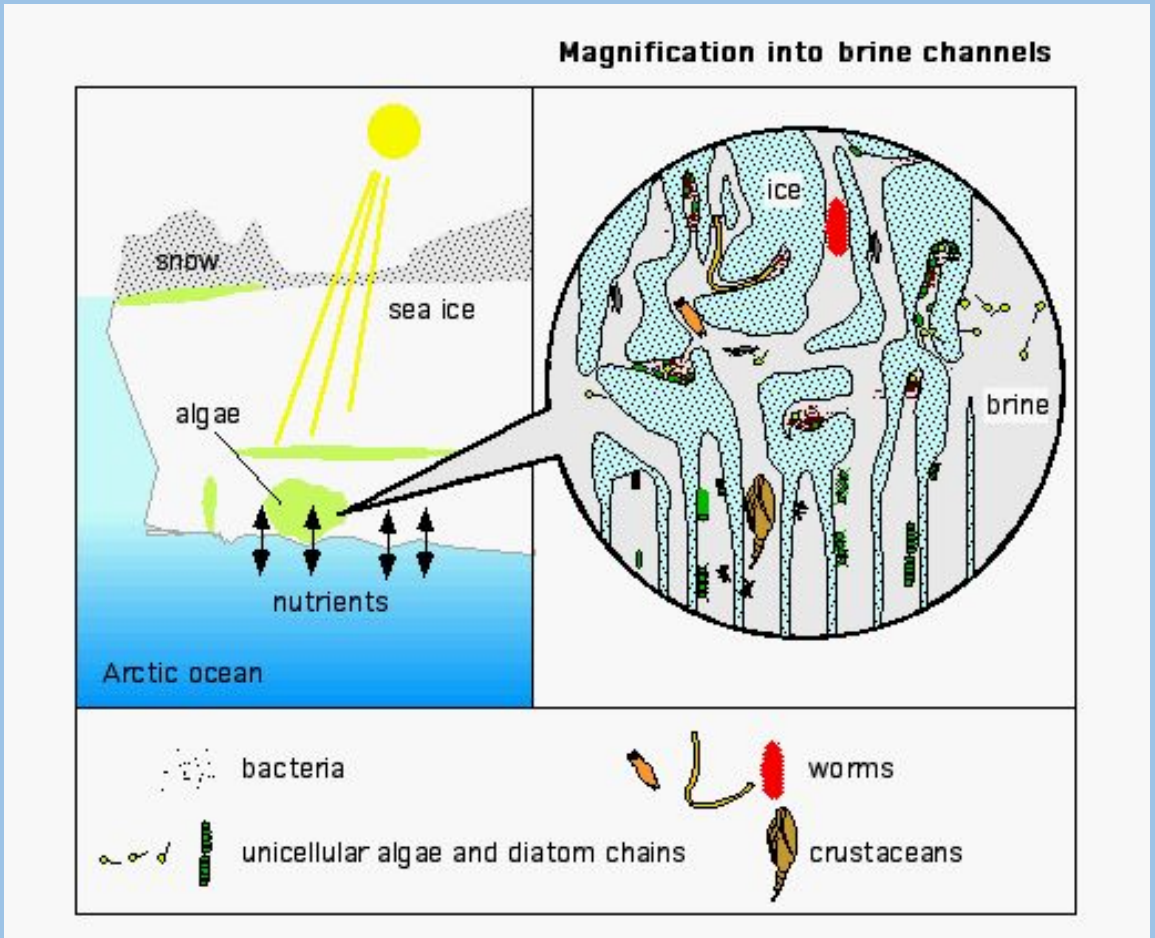
Record sea ice extent, 2012, caused by warmer temperature over Antarctica and stronger katabatic winds producing more ice



Marine Algae: Sea Ice versus Open Ocean

Sea ice dominated by small pennate diatoms: *Fragilariopsis cylindrus* and *Fragilariopsis curta; and* prymnesiophyte *Phaeocystis antarctica*

Some grazers from the water can gain access to algae in ice via the brine channels, even in winter



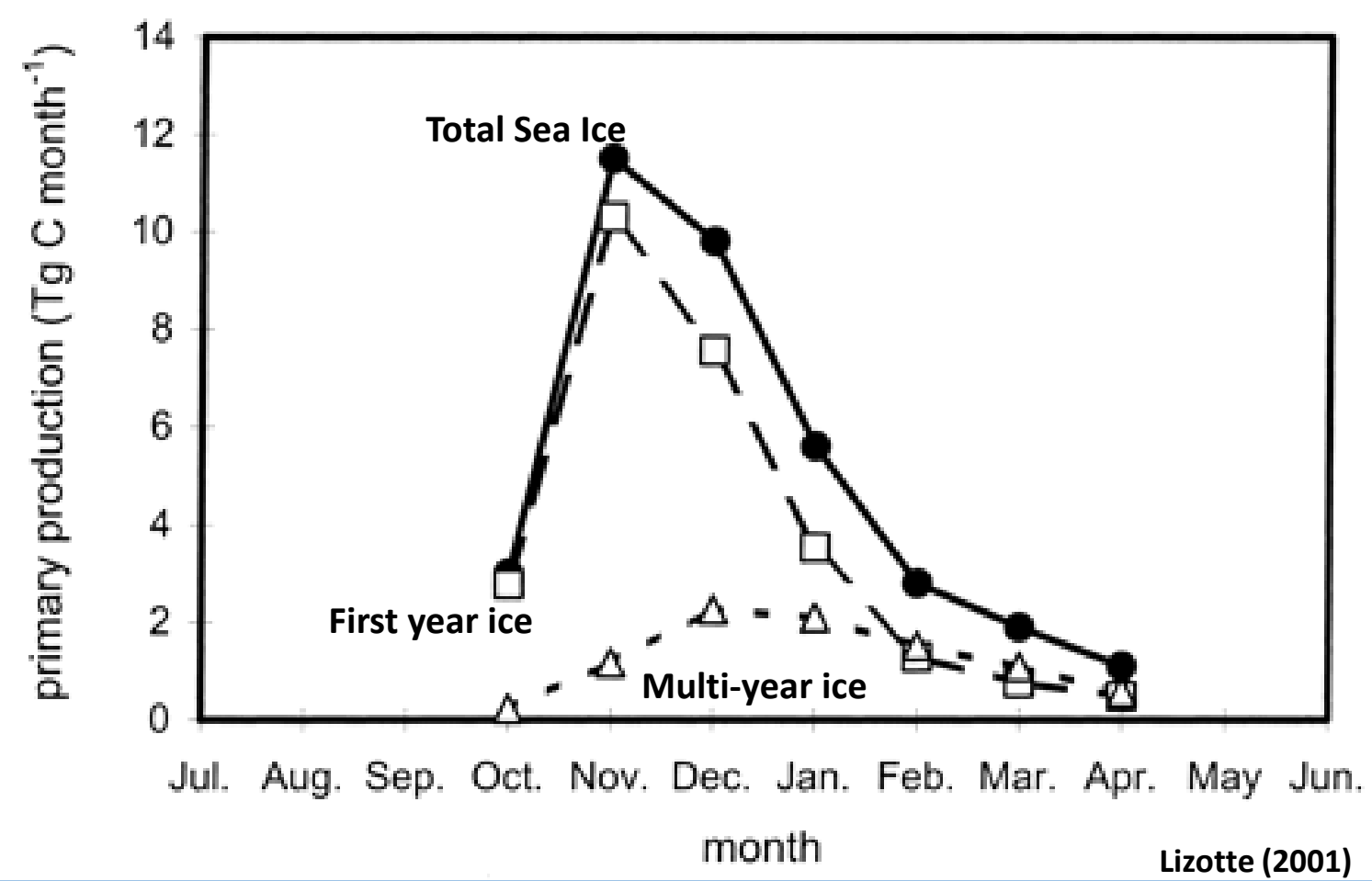
https://web.duke.edu

Although offshore plankton production in the open ocean exceeds that of sea ice algae, the blooms of sea ice algae differ in timing and distribution near the continent

Sea Ice is an important driver of productivity near the continent where water column productivity is negligible, providing food resources for higher tropic species

Primary production in sea ice surface communities by month

These data show that most production is in the annual sea ice, which is mostly farther south near the continent



Lizotte (2001)

Krill: A Keystone Species in the Southern Ocean

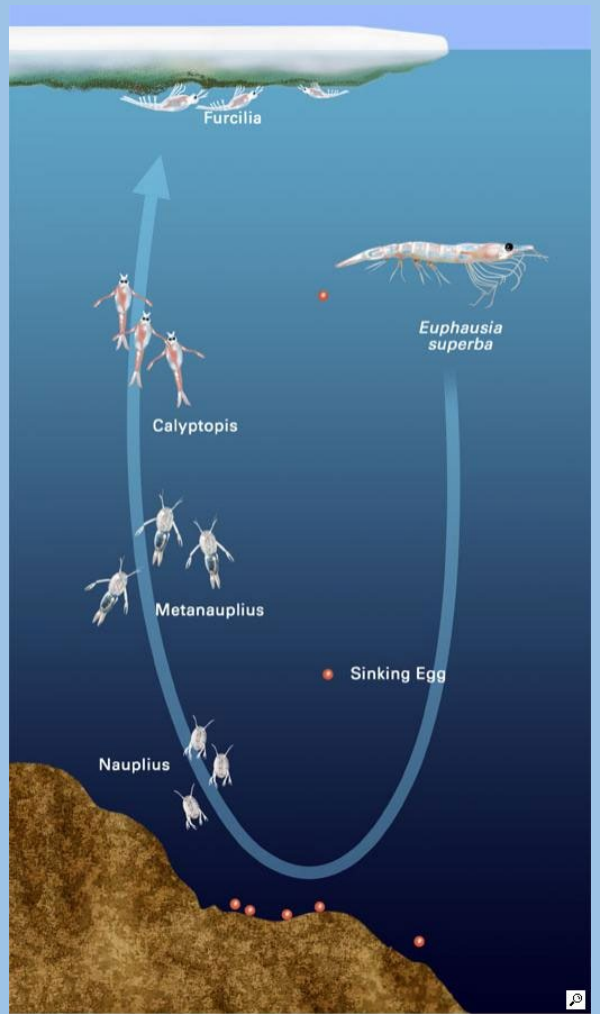
Euphausia superba

Basic Biology

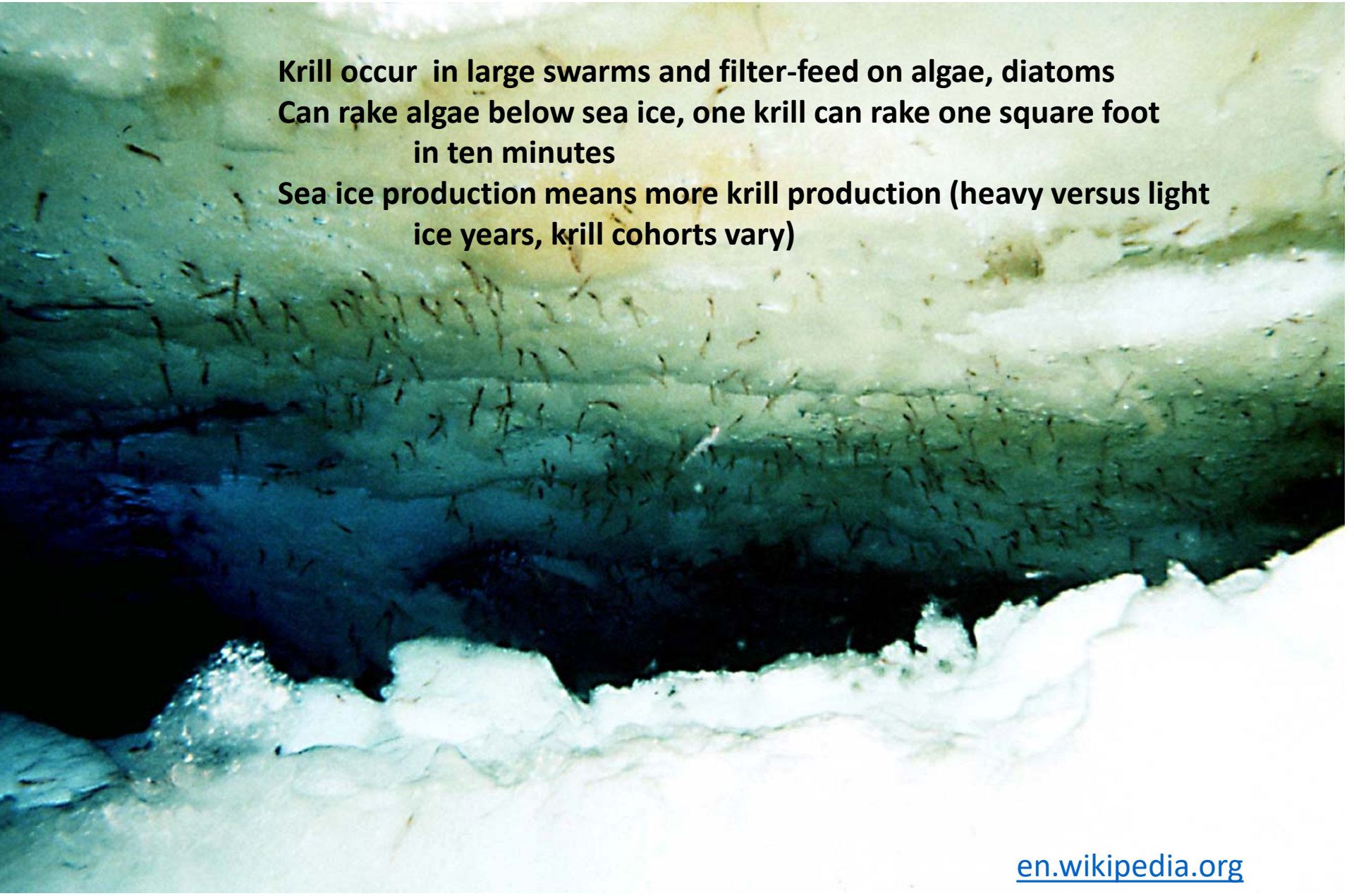
- **Large black eyes**
- **Cold-blooded**
  - **Metabolism controlled by temperature**
- **Translucent bodies**
  - **Chitinous exoskeletons, reddish orange**
  - **Digestive system is visible**
  - **Highly visible gills**

Krill have a complex life cycle

--spawn in January to March
--eggs laid in water at surface, sink to over 2000 m depth
and hatch after 10 days
--larval krill grow and live up to seven years



Krill feeding on algae under the sea ice



Krill occur in large swarms and filter-feed on algae, diatoms

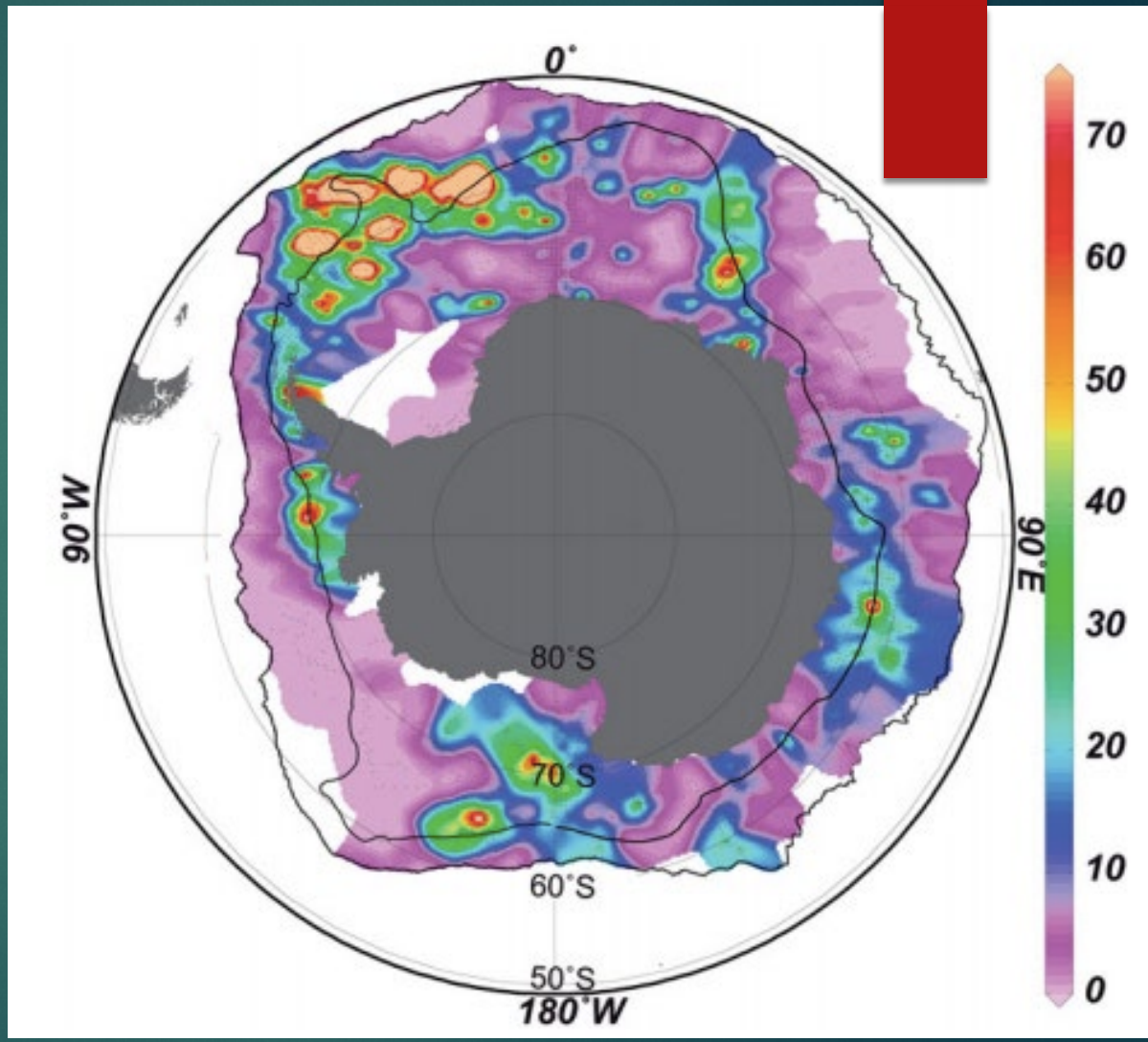
Can rake algae below sea ice, one krill can rake one square foot in ten minutes

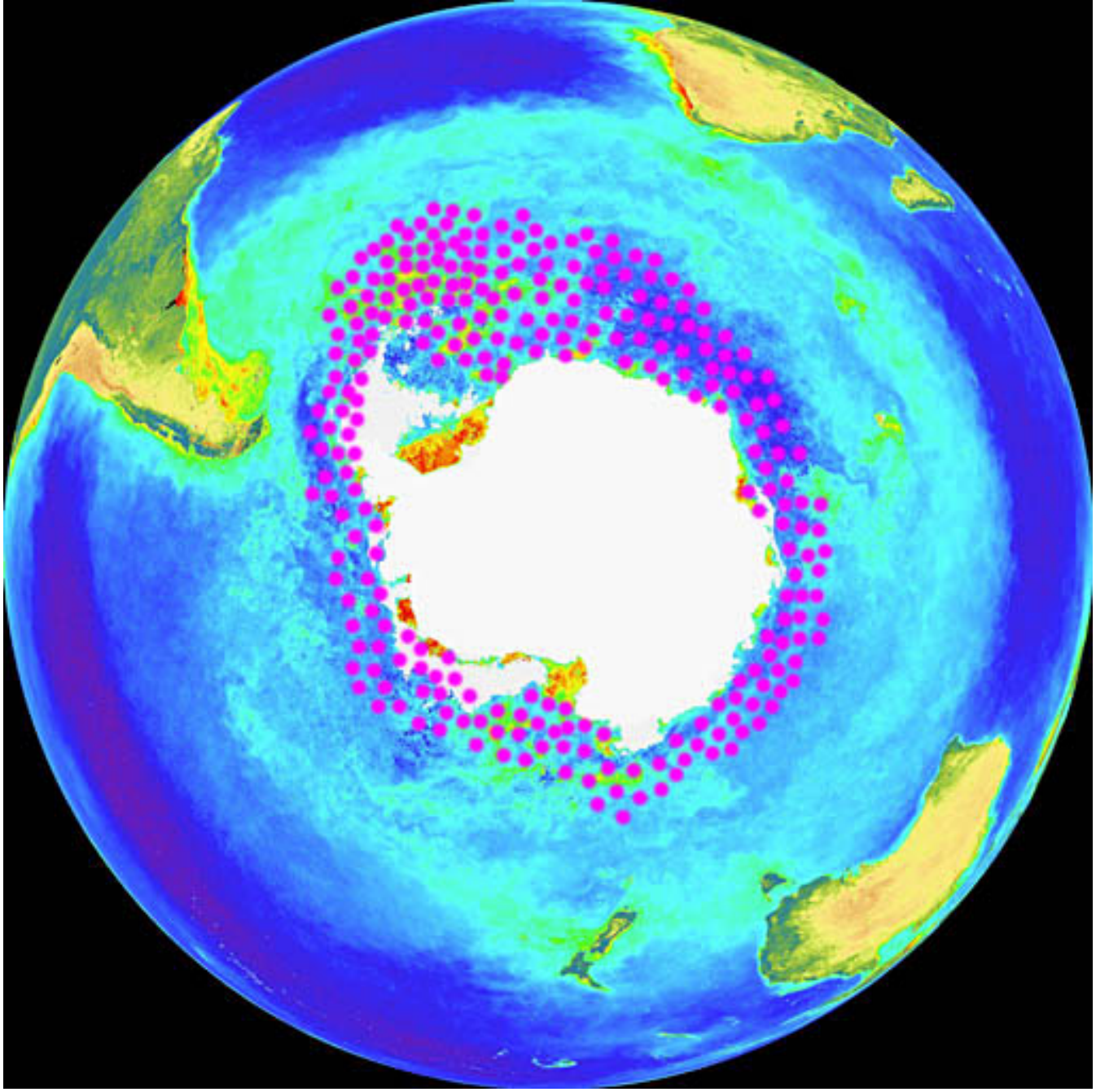
Sea ice production means more krill production (heavy versus light ice years, krill cohorts vary)

en.wikipedia.org

Distribution

- Of the 32 million km^2 area of the entire Southern Ocean, krill only inhabit 19 million km^2, or 59%
- Northern limit of Antarctic krill is south of the Polar Front
- Main krill concentrations confined to the Weddell-Scotia Sea
- Poor krill habitat on NE and SW sides of the continent





Distribution of krill NASA SeaWIFS image

Ice or Crystal Krill

Euphausia crystallorophias

--smaller than *E. superba*
--found farther south, 74° latitude and higher
--eggs do not sink, larva and adults in same shallow water associated with sea ice

Krill Swarm

--krill are keystone as they are extremely abundant
--fed upon by fish, seabirds including penguins, seals, and whales
--500 million tons of biomass in Southern Ocean each year

Antarctic Krill
Euphausia superba

https://www.youtube.com/watch?v=RFqhocQqbgM

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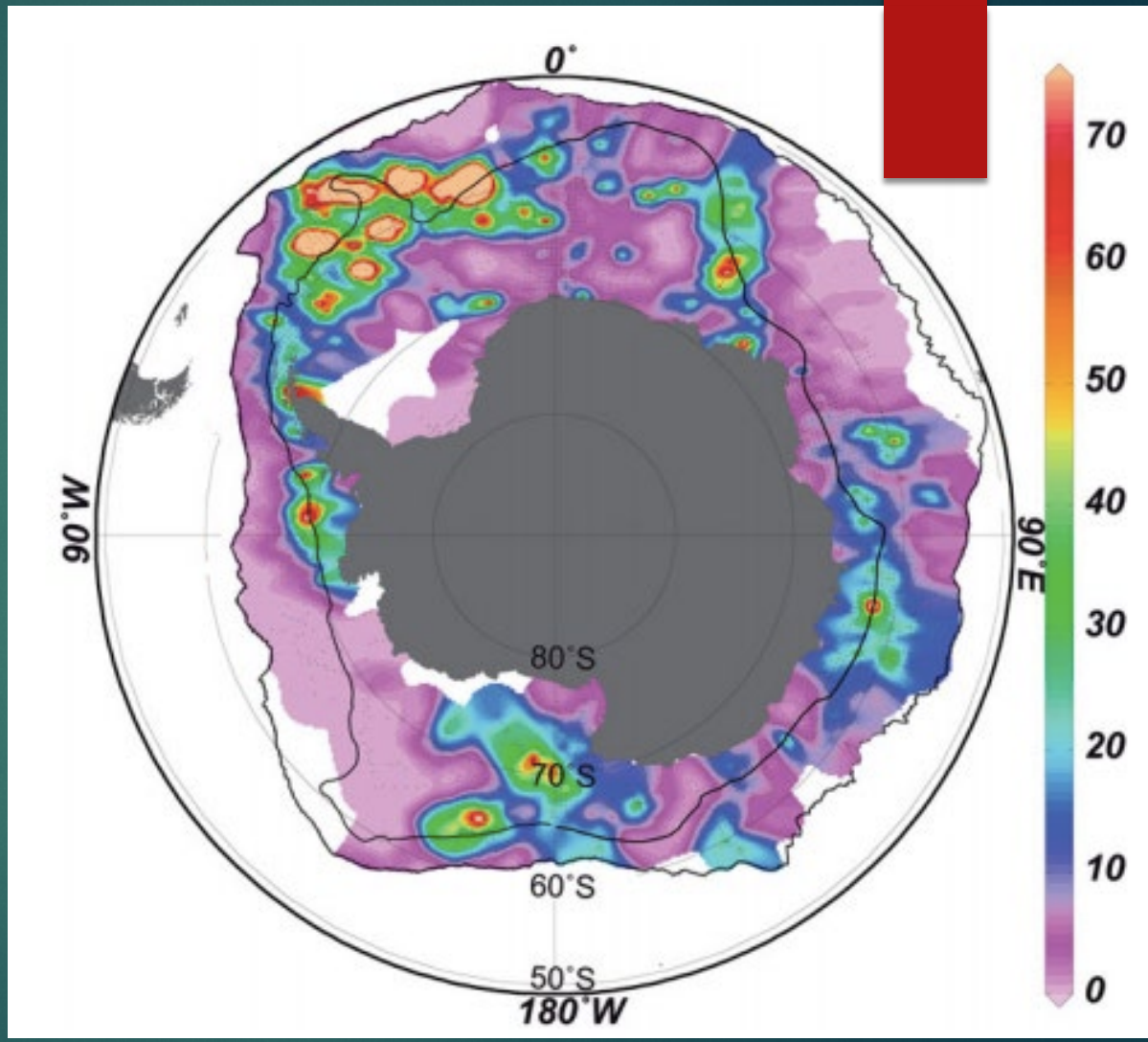


Quiz

1. What is bull kelp and describe the community associated with it.

2. What marine species contribute to the ‘biological pump’?

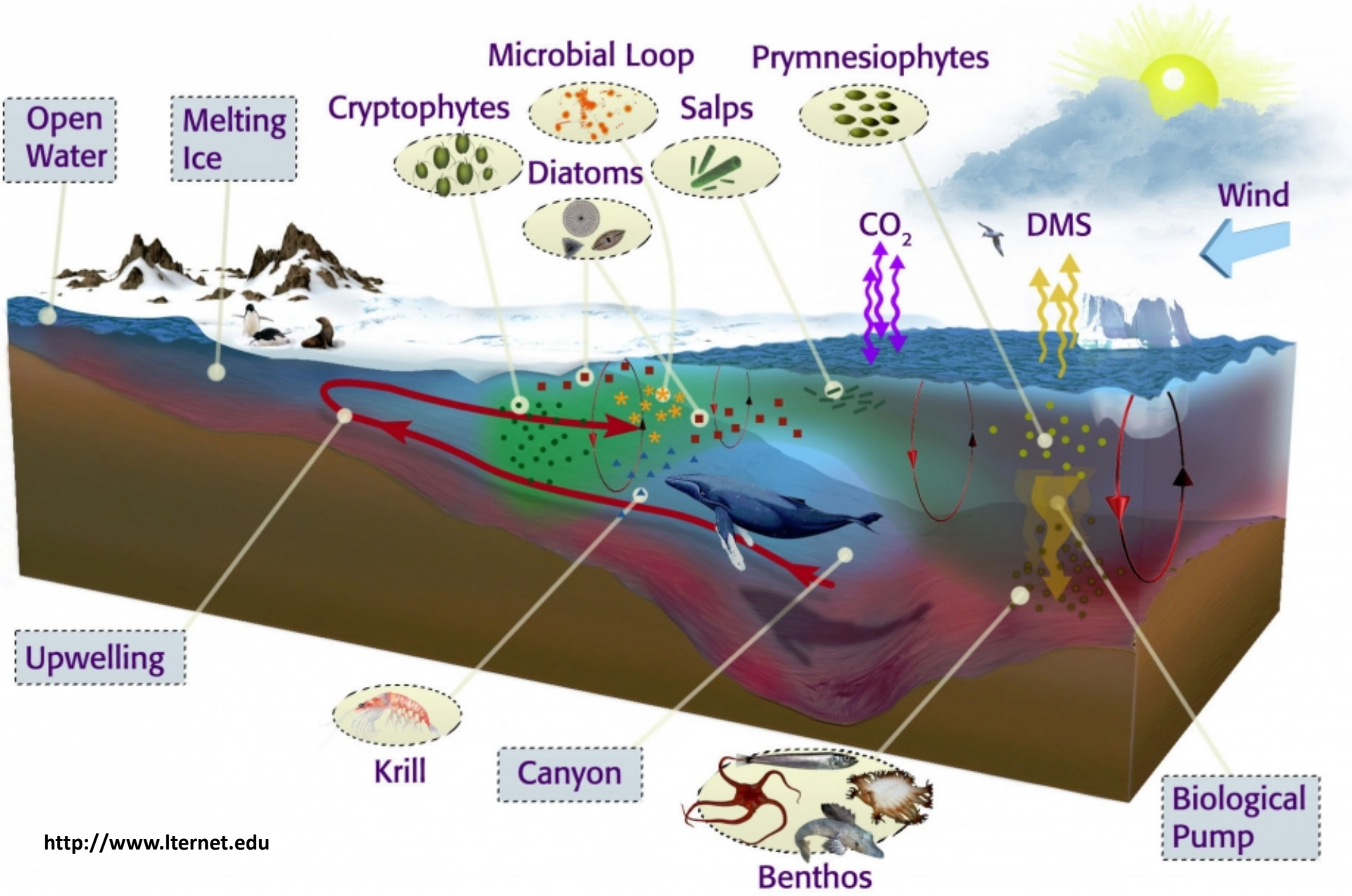
3. How do diatoms and small crustaceans access sea ice to feed on algae trapped in the ice?

4. Describe the krill lifecycle and why it is a keystone species in Antarctica.

5. What controls the distribution of krill around Antarctica?

Salp, or tunicate

Krill and salp both add to the 'biological pump' to sequester carbon in bottom sediments



http://www.lternet.edu

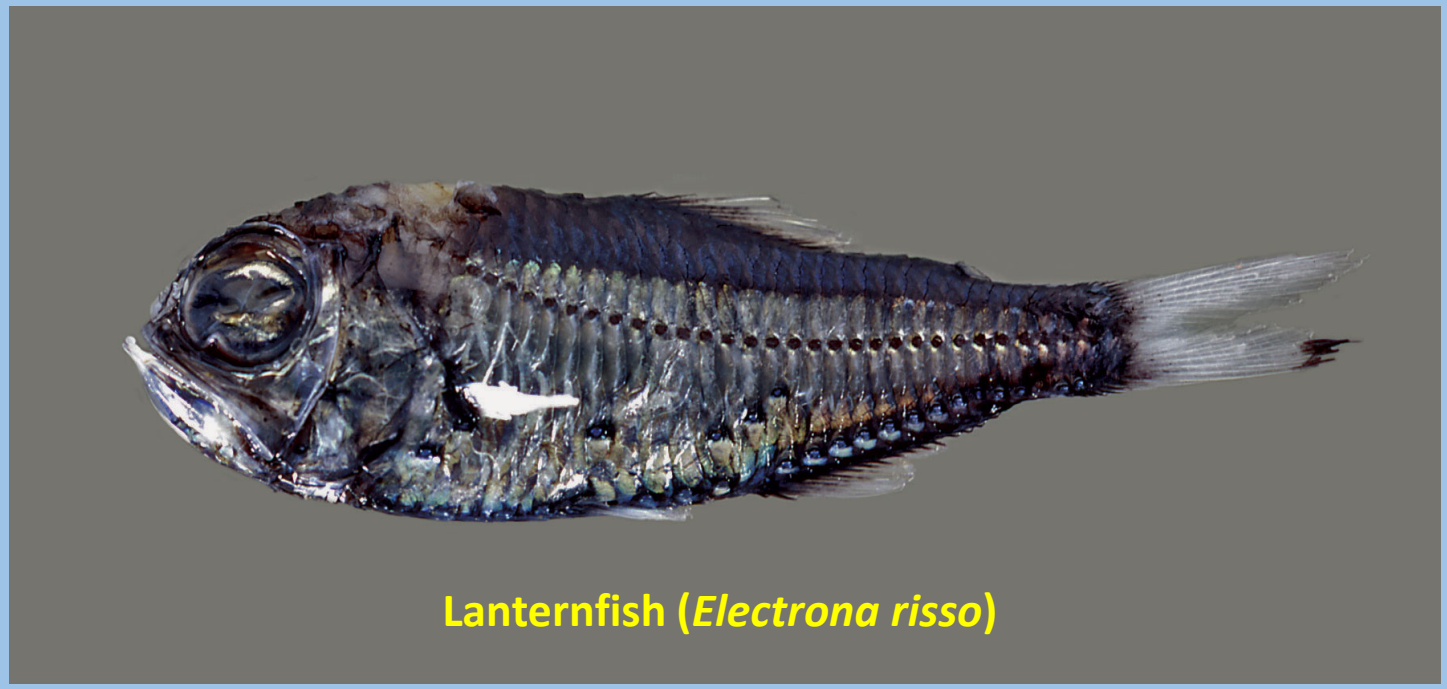
Ice Fish
Suborder Notothenioidei

--dominant group on continental shelf of Antarctica

--over 100 species, adapted to cold shelf waters, most are endemic to Antarctica

--benthic, no swim bladder with neutral buoyancy

--produce an antifreeze glycoprotein



Lanternfish (*Electrona risso*)

Antifreeze Glycoproteins

--found in Notothenioids, but also some other vertebrates, plants, fungi, bacteria

--a class of polypeptides that bind to ice crystals and prevent growth

--several types, all developed independently

--first isolated and described in Antarctic fish by Dr. Art DeVries

https://bradyinantarctica.wordpress.com

Antarctic Silverfish
Pleuragramma antarcticum

--another Notothenioid also known as a cod icefish
--like krill, it is considered a keystone species
--common prey item for seals, penguins and other seabirds
--spawn near surface, larval and juveniles remain in upper water column, then migrate to deep waters

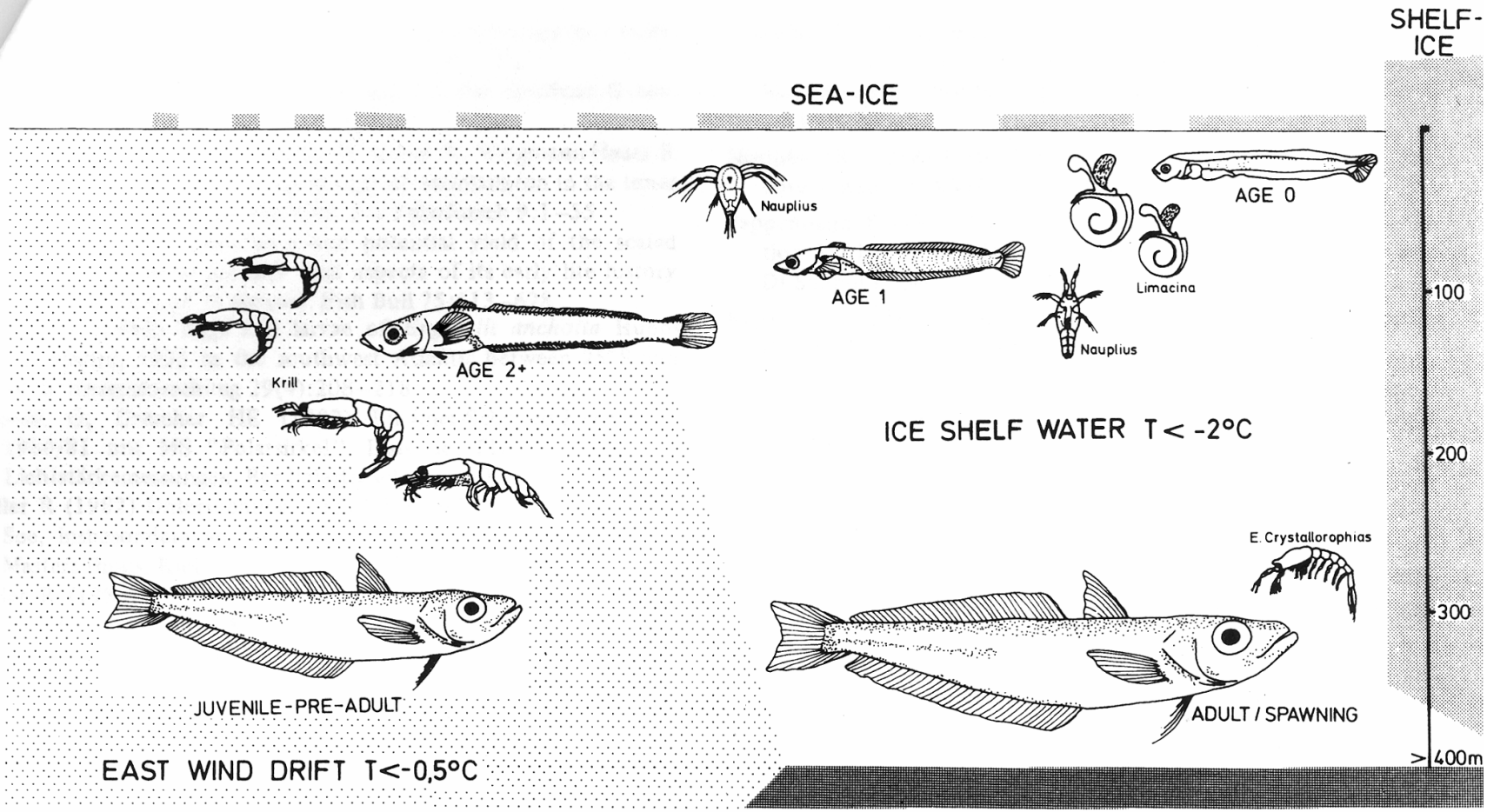


Fig. 6. Schematic life-cycle of *P. antarcticum* in the Weddell Sea

Hubold (1985)

Silverfish inhabit deeper waters with age and live up to 14 yrs.
However, adults can occur in all depths of water (Hubold 1984).

Family Channichthyidae

--less than 1% hemoglobin in blood
--gain oxygen through the skin, no scales
--transparent

http://phys.org

FAMILY CHANNICHTHYIDAE

- First seen off the coast of Bouvet Island in 1927
  - Validated in 1954 by Ruud in *Nature* paper
- Has crocodile like face/mouth
- Lacks scales and hemoglobin
- Depth range from 4-600m
- Large distribution

BLOOD OR LACK THEREOF

- Channichthyes lack hemoglobin which is used to bind oxygen and transport it throughout the body
- Only known vertebrate with ‘white’ blood
- Have larger heart and blood vessels than other fish of same size
- Some species lack both hemoglobin & myoglobin
  - 6 of 16 species lack myoglobin

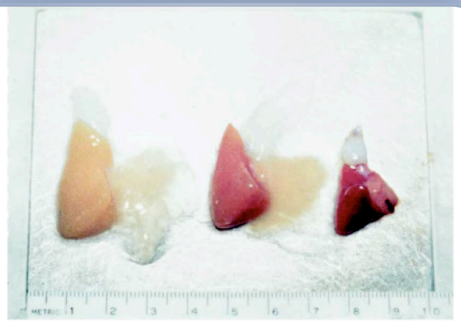


Fig. 2. Hearts from three species of notothenioid fishes. The channichthyid icefish *Chaenocephalus aceratus* has a pale yellow ventricle (far left) and lacks myoglobin (Mb) protein expression. The channichthyid icefish *Chionodraco rastrospinosus* expresses myoglobin protein and displays a rose-colored ventricle (middle). The related notothenioid species *Notothenia coriiceps* has a characteristically red ventricle (far right) associated with the presence of myoglobin protein. Note that both channichthyid hearts are considerably larger than that from the red blooded species despite all having been dissected from animals of equivalent body mass. (Figure is from Moylan and Sidell, 2000.)

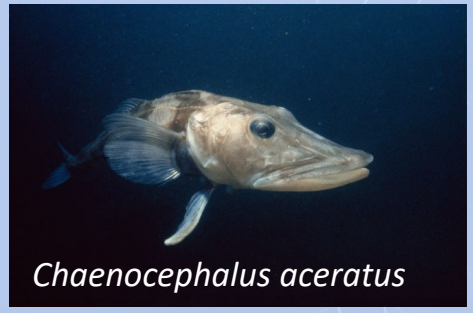


Fig. 1. Lack of circulating hemoglobin and red cells is the signature characteristic of Antarctic icefishes. These two tubes contain freshly drawn blood from a hemoglobin-expressing notothenioid fish (*Notothenia coriiceps*) on the left and a hemoglobinless Antarctic icefish (*Chaenocephalus aceratus*) on the right.

Deep Sea Benthos

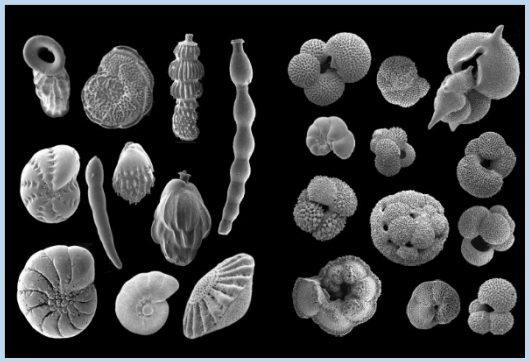
Not as isolated as Antarctic continental shelf, so fauna is not dominated by endemic species

Very little known about this region, but thought to have higher diversity than continental shelf

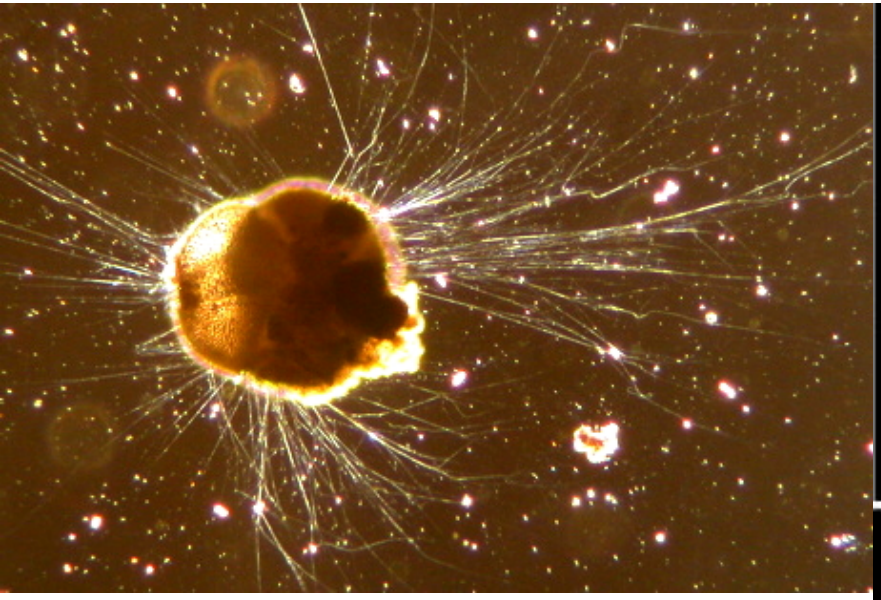
ANDEEP, program to target deep sea benthos in Southern Ocean, 2002 and 2005

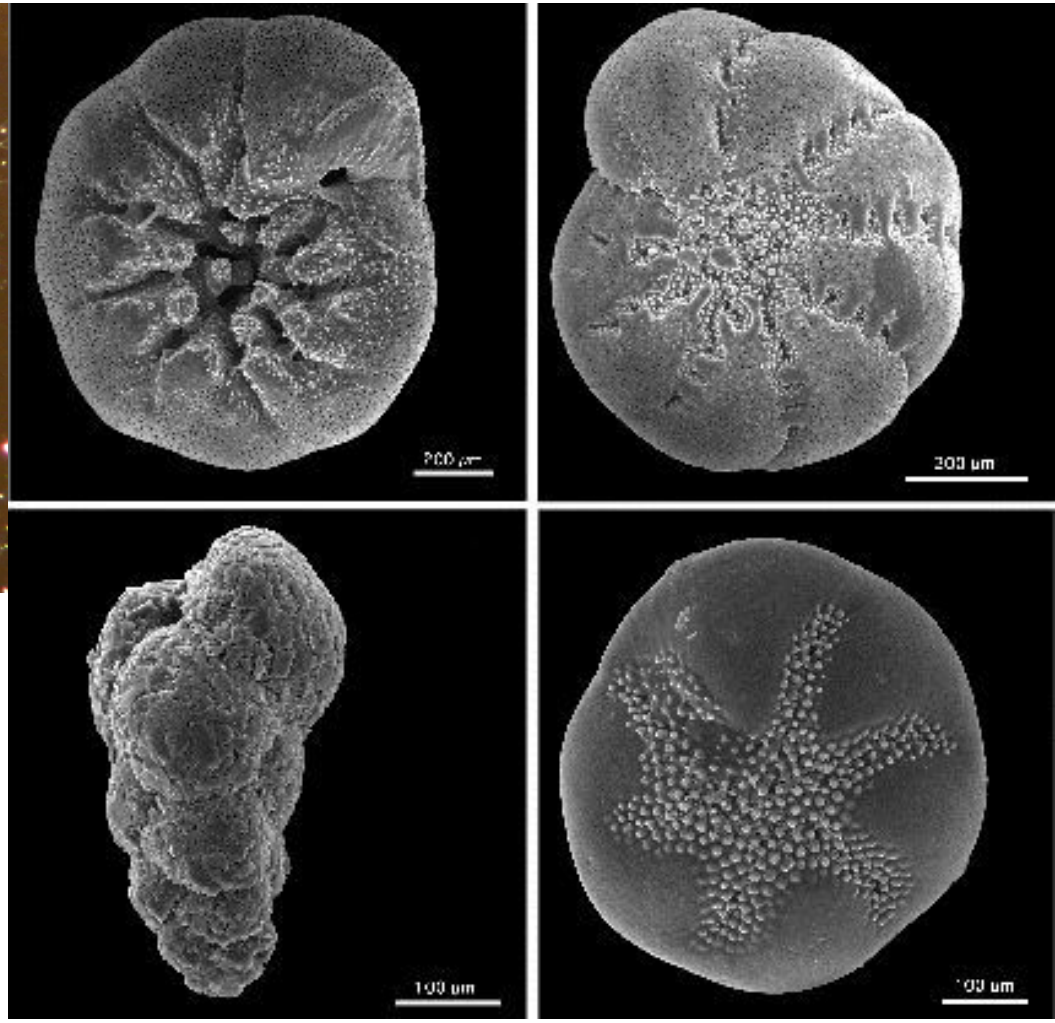
Many species may have originated from Ross and Weddell Seas, making the continental shelf around Antarctica a 'biodiversity pump'

Recent evidence for gene flow in bipolar species of Foraminifera



Foraminifera





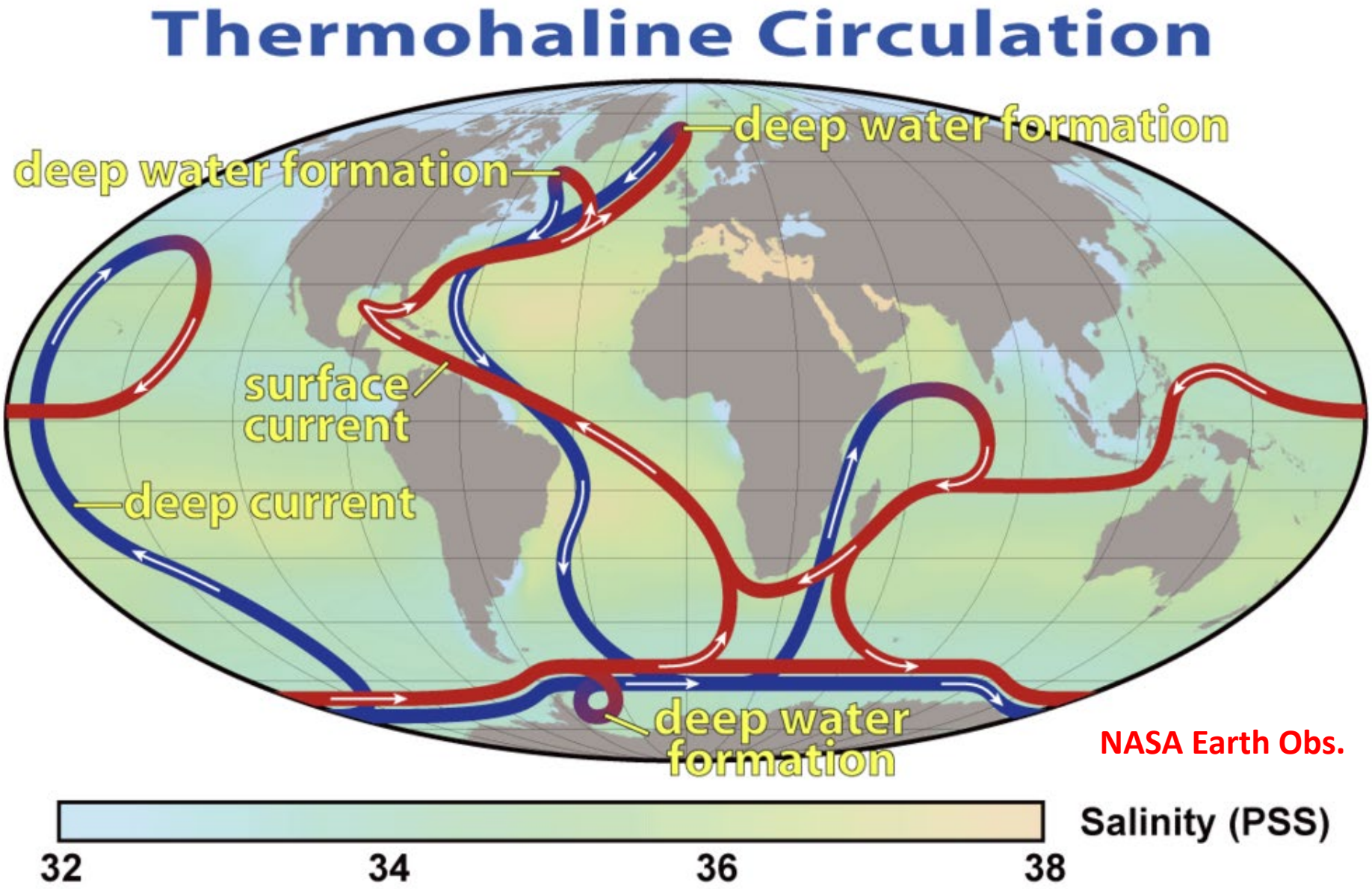
Largely benthic marine species
~10,000 living, 40,000 fossil species

Most < 1mm in size

Use ‘arms’ to prey on copepods and other small inverts, other forams

Foram $CaCo_3$ ‘tests’

Photos: Wikipedia.org



Circumpolar deep water (CDW)

Also get gigantism in Antarctic waters

Giant Isopod *Glyptonotus antarcticus*

Can reach 20 cm length, 70 g weight

Gigantism in many marine invertebrates in Antarctica may be related to the cold, oxygen-enriched waters

Oxygen exchange in salt water is more difficult, but oxygen use in cold water is slower, less demand

This may select or allow for larger body sizes in marine inverts in this region

Quiz

1. What are salp and when do they dominate in the Southern Ocean?

2. What marine species contribute to the ‘biological pump’?

3. What are forams and the ‘biodiversity pump’ in deep sea benthos?

4. What physiological characters are associated with Antarctic fish in the groups Notothenioidei and Channicthyidae?

5. Why does gigantism occur so frequently in Antarctic marine invertebrates?