Extremophiles! Life in Ice.

A lesson created for a 10th + 11th grade Environmental Science classroom

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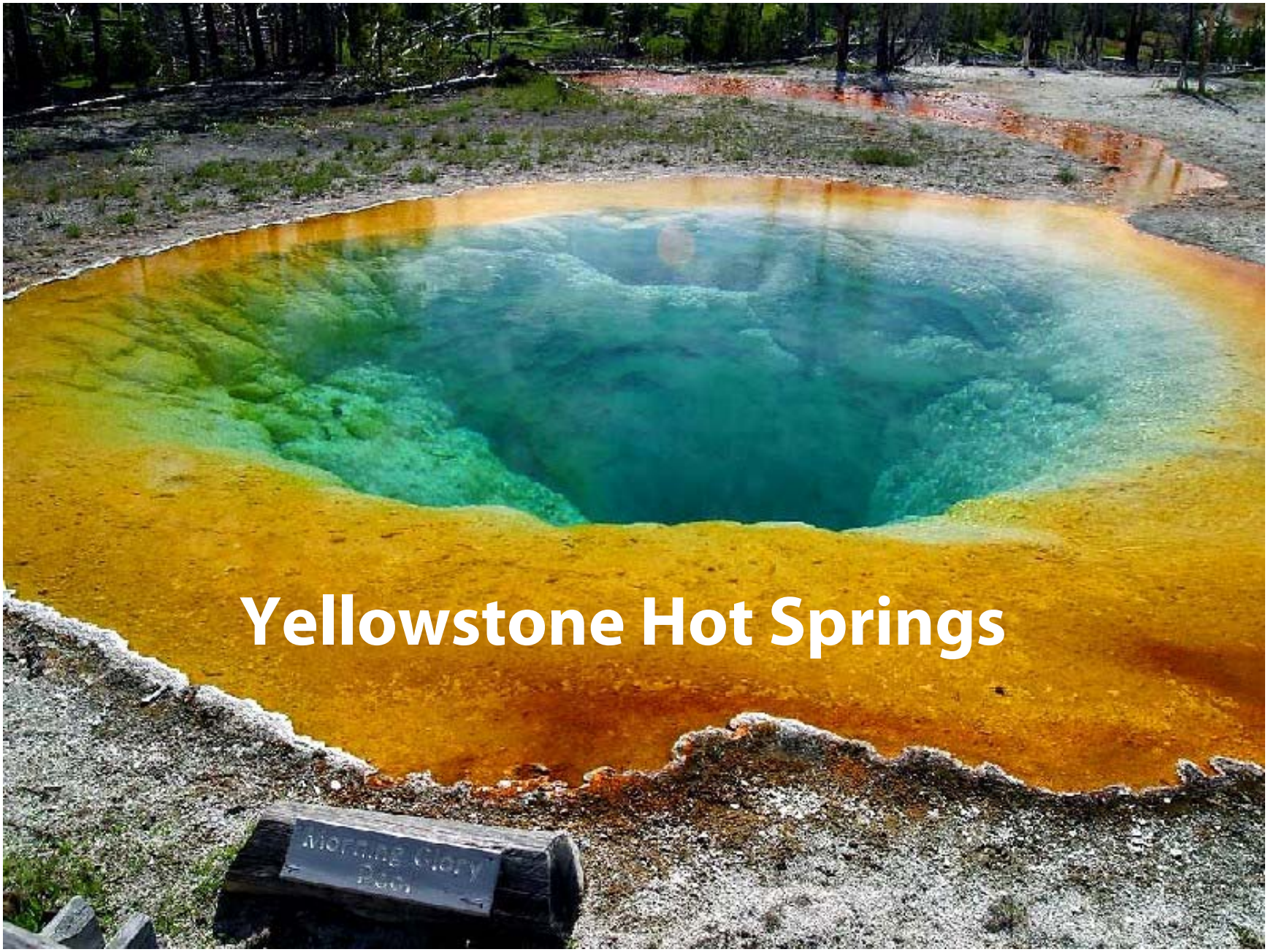
Extremophile: an organism that thrives in and may even require physically or geochemically extreme conditions that are typically detrimental to the majority of life on Earth

Acid Mine Drainage


Yellowstone Hot Springs

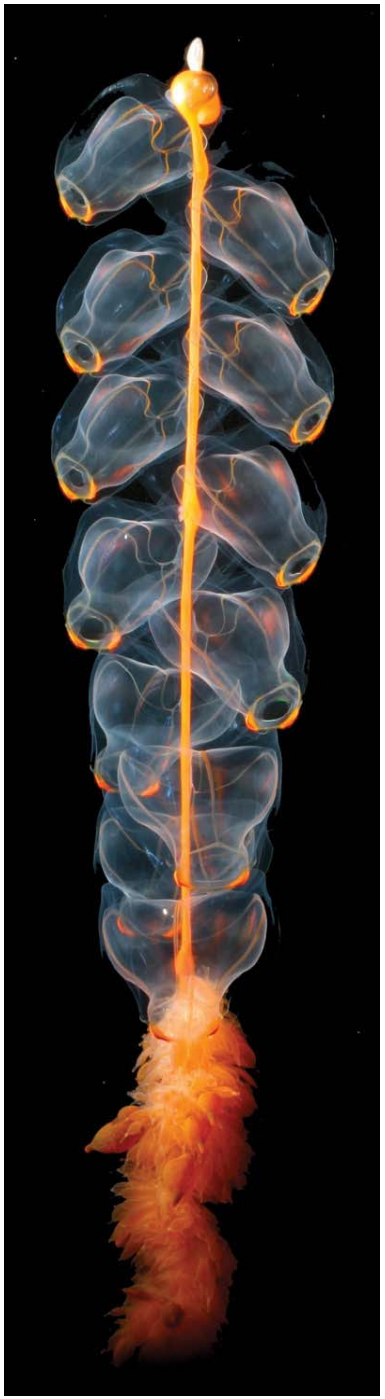
Hydrothermal Vents

Mono Lake : Hypersaline Lake

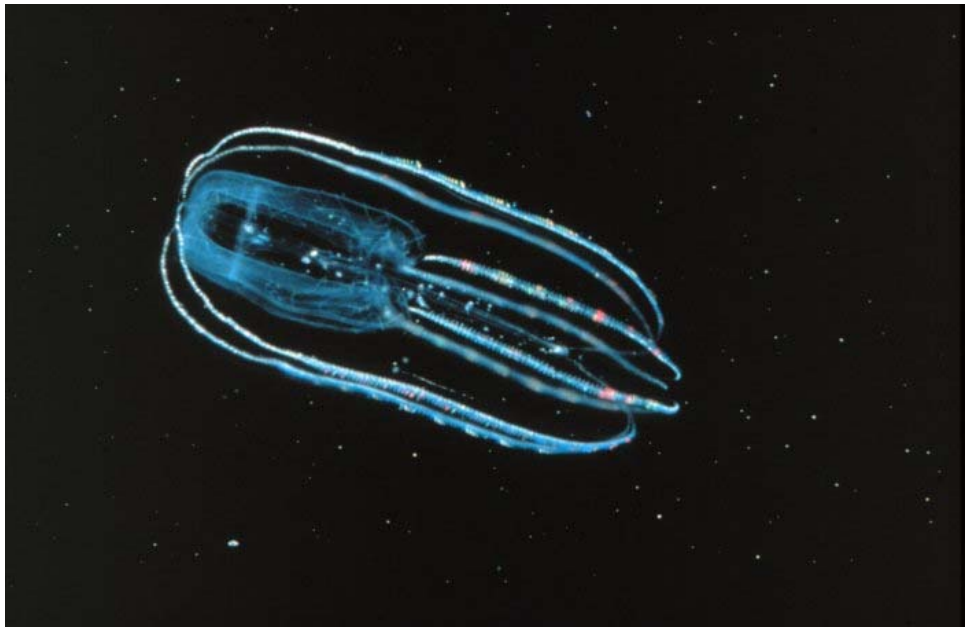
Dead Sea: Hypersaline Sea

Polar Regions

Photo credit: Colleen Kellogg, UW Oceanography



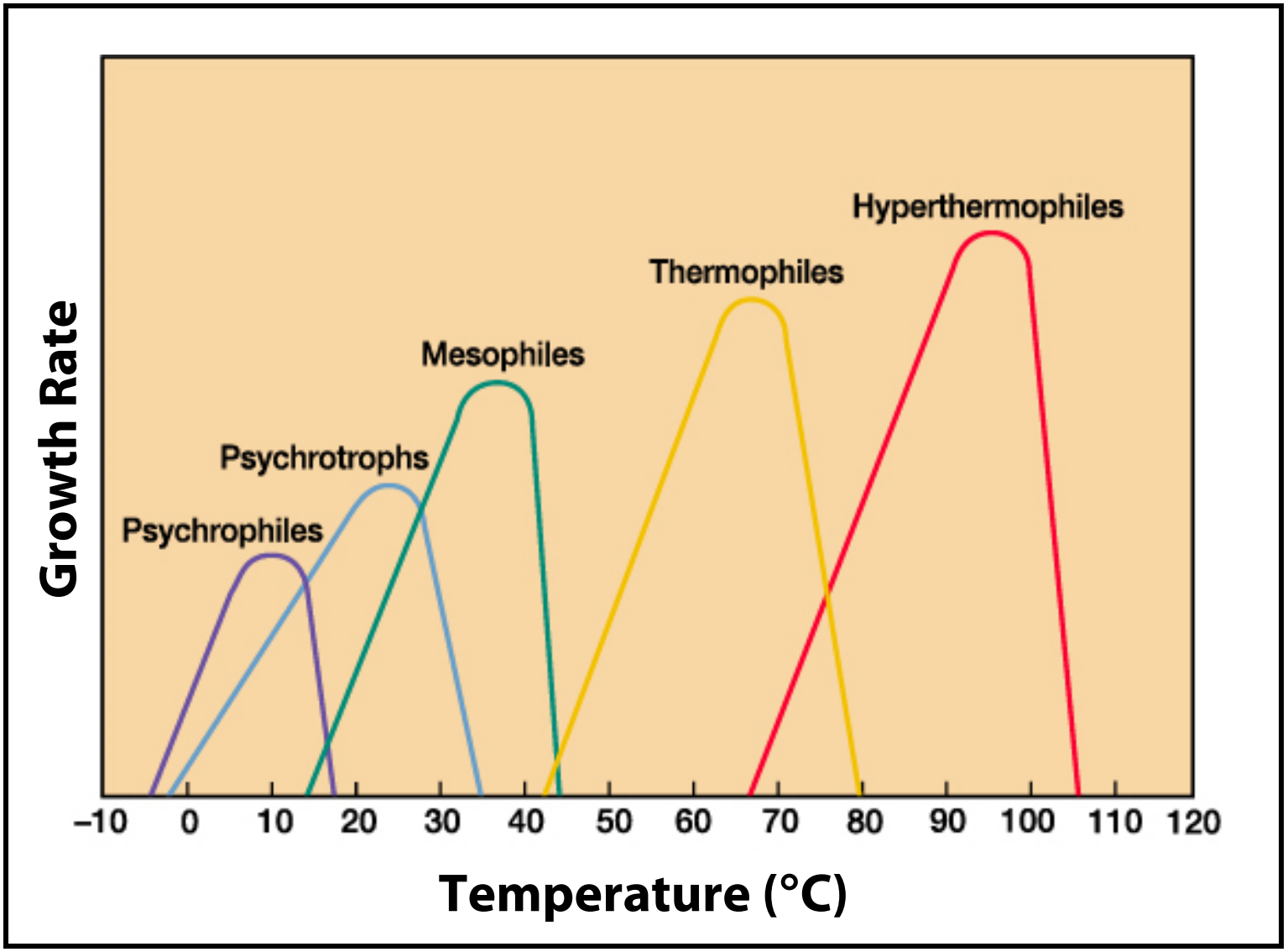
Deep Sea



Extremophiles

	An organism that grows optimally…
Acidophile	At a pH less that 3
Alkaliphile	At a pH greater than 9
Thermophile	At temperatures between 60-80°C (140-176°F)
Hyperthermophile	At temperatures between 80-122°C (176-252°F)
Halophile	At salt concentrations 5x greater than that of the ocean
Psychrophile	At temperatures below 15°C (29°F)
Xerophile	In extremely dry conditions
Barophile	At very high pressures

Extremophile growth

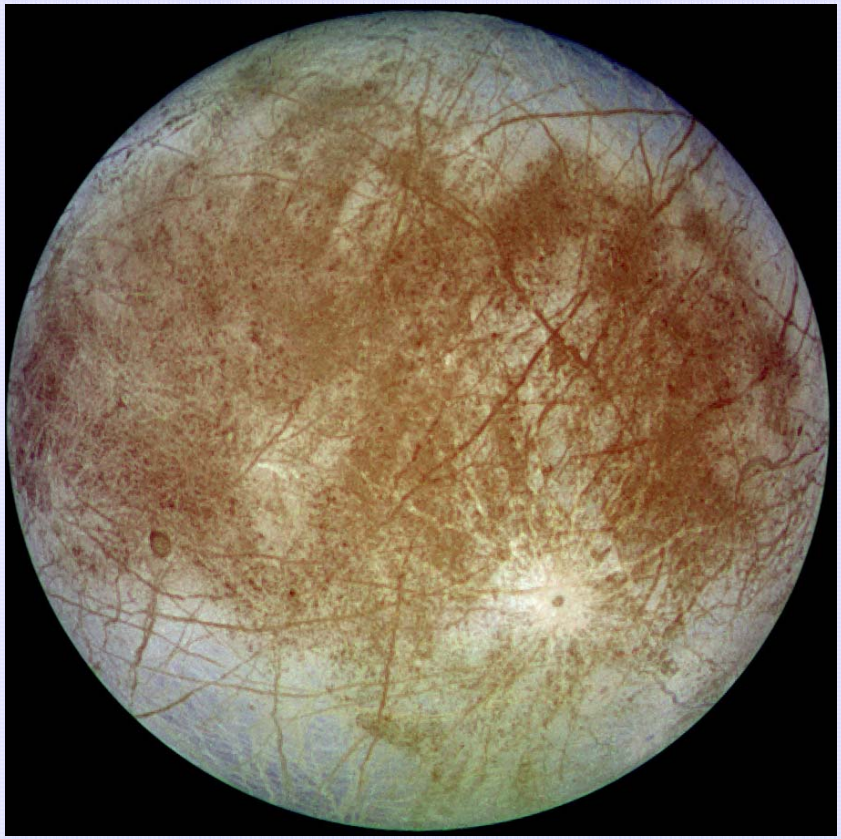


Why study extremophiles?

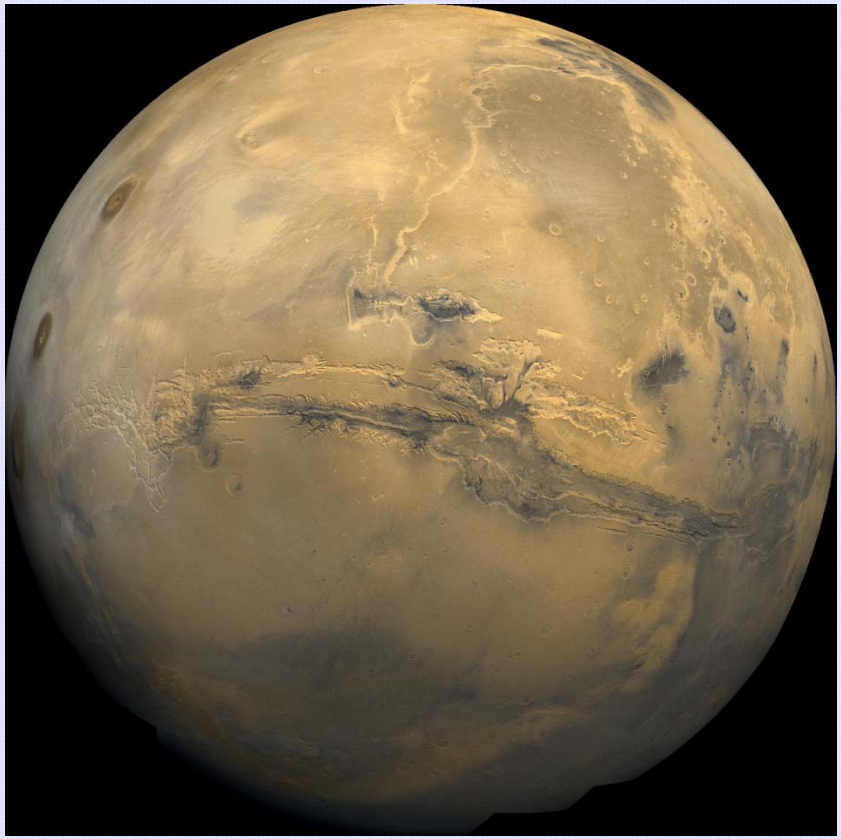
- Help us (scientists and everyone) find and understand the **limits of life on Earth**
- **Extreme conditions** here on Earth may be **similar to conditions on other planets** or moons (Mars, Europa, etc.) – if we know what types of organisms live here maybe this knowledge will **help us find life elsewhere in the universe** (Astrobiology)

Astrobiology:

the study of the origin, evolution, distribution, and future of life in the universe



Europa



Mars

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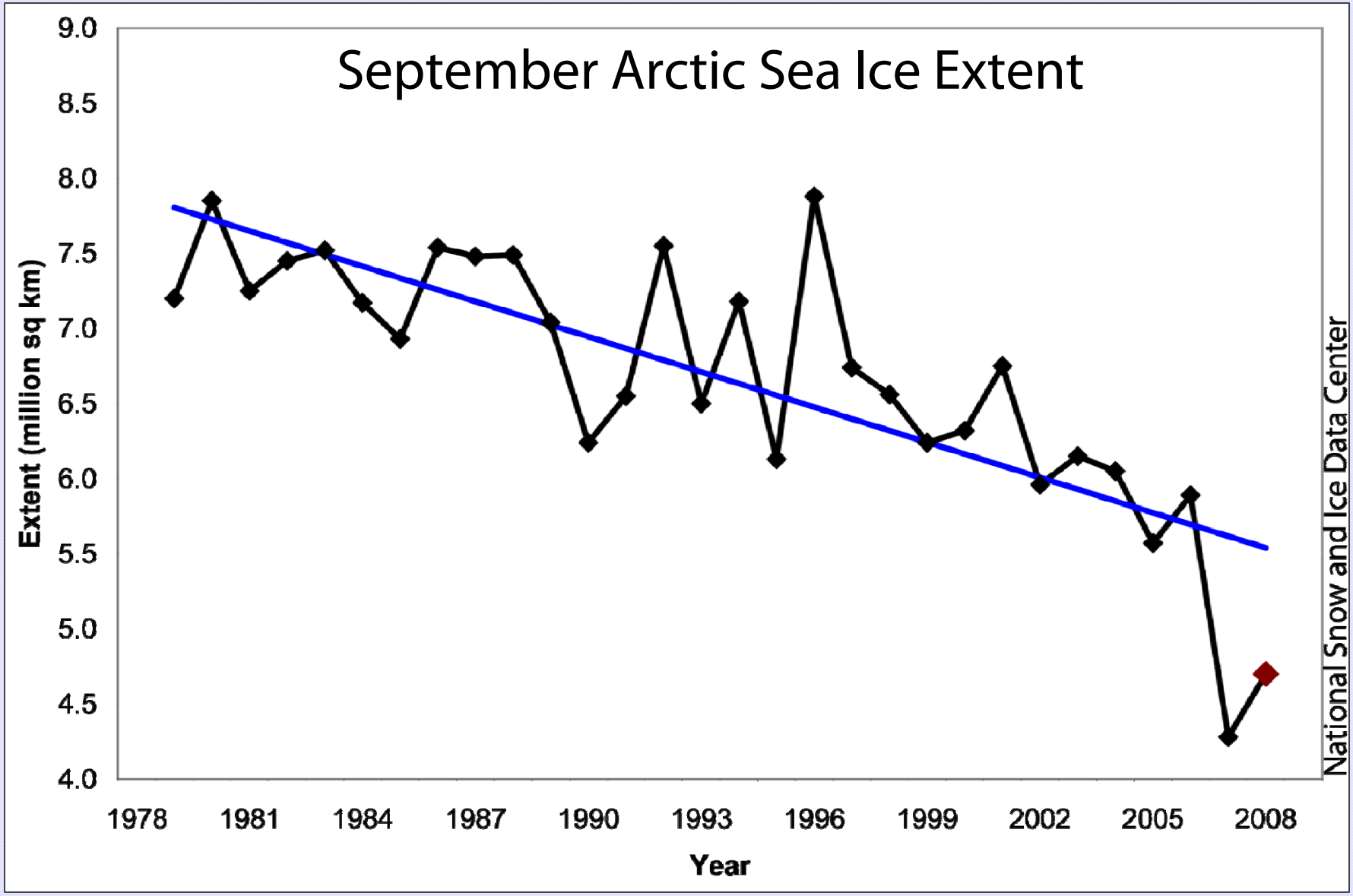
- Studying life in extreme conditions, such as hydrothermal vents, may help us better **understand how life originated on Earth**
- Some extremophiles are **important links in food webs** (and some of these food webs may be affected by climate change)

Sea ice covers ~10% of the ocean



Sea ice volume is declining → Habitat is declining

Arctic Food Web

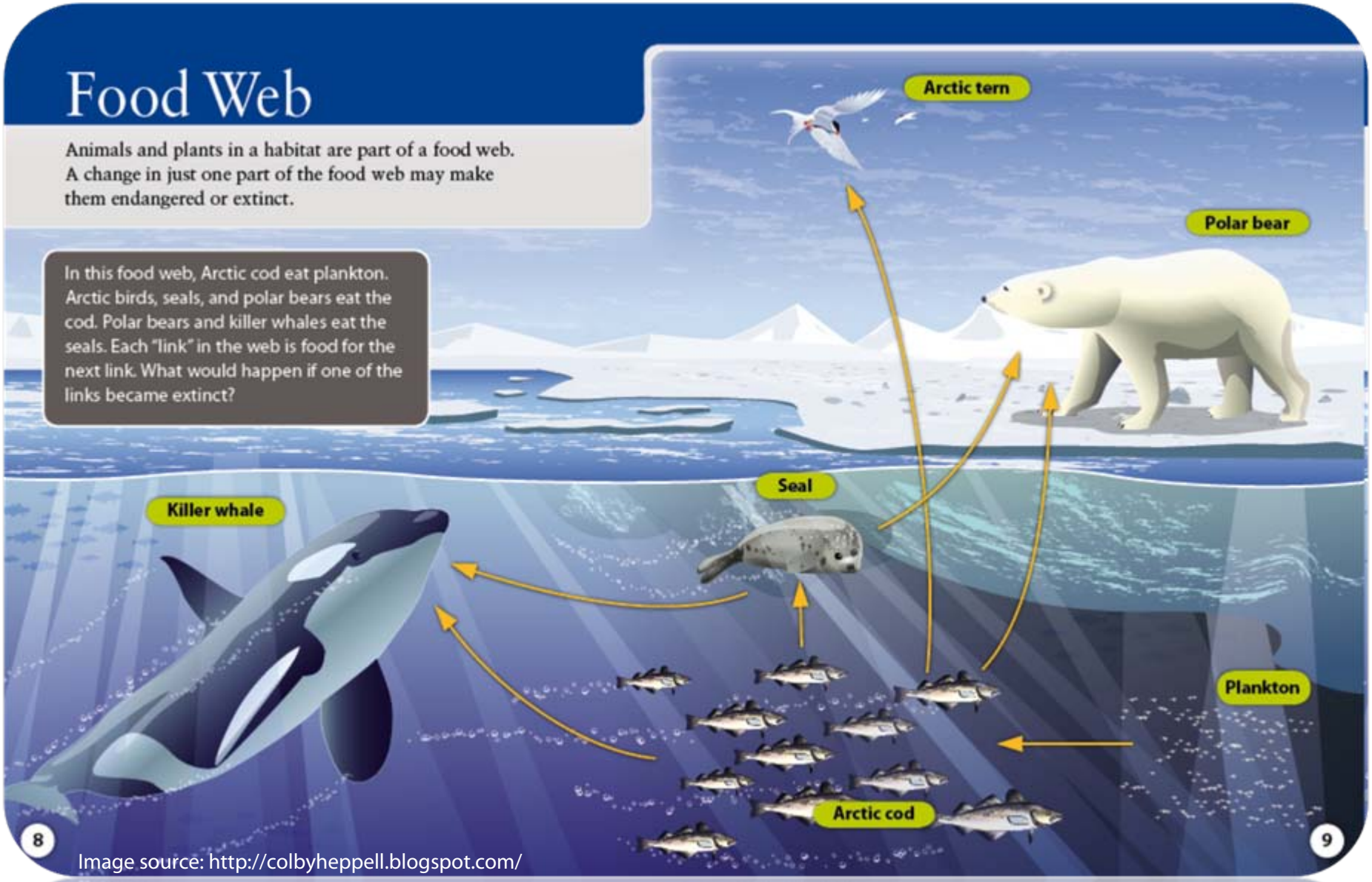
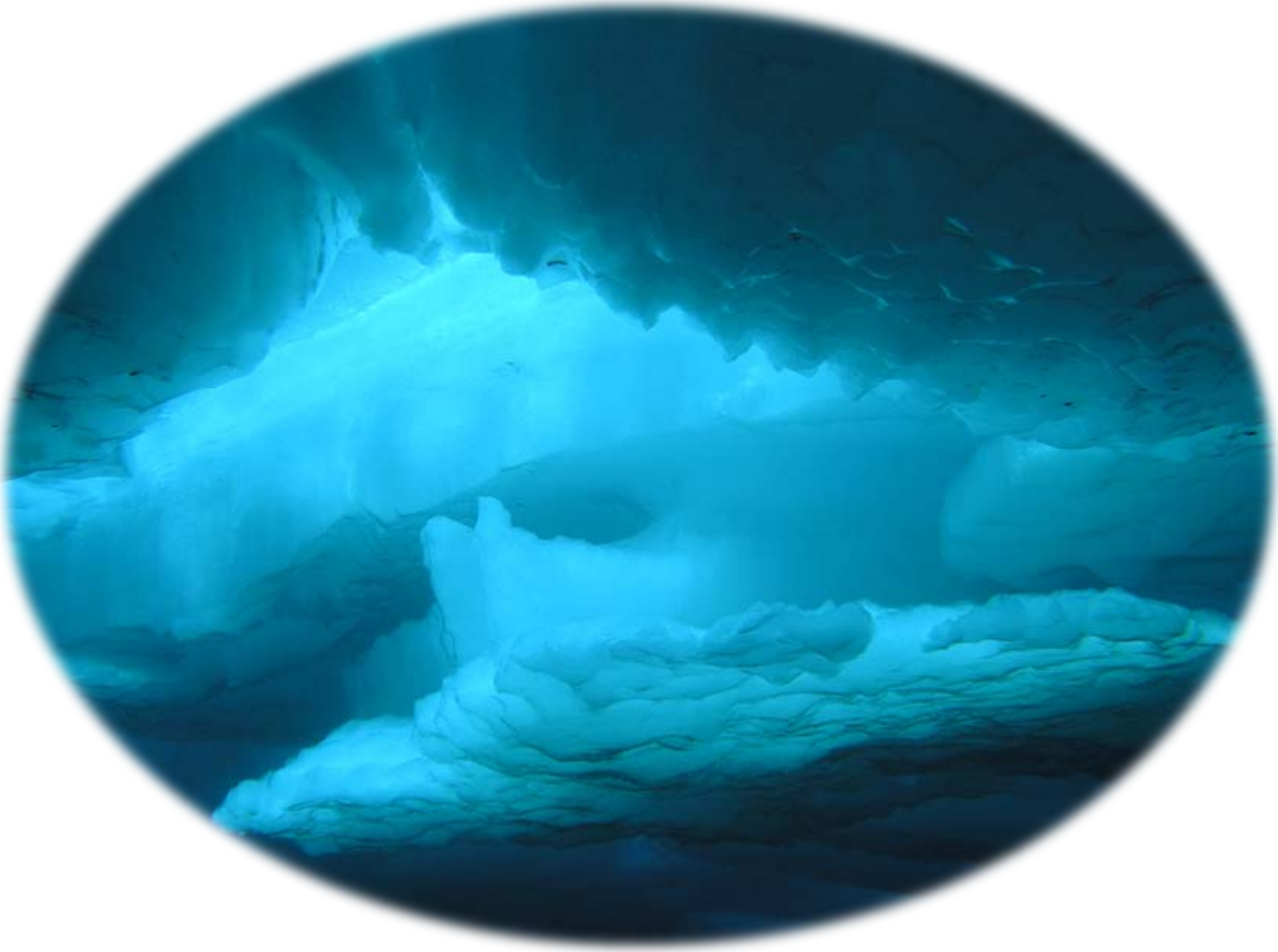


Image source: http://colbyheppell.blogspot.com/



Ice observations activity

Ice Observations

Ice cube #1

What I see	What this means
Before food coloring…	
After food coloring…	

Ice cube #1, before addition of food coloring

Ice cube #1, after addition of food coloring

- Do you think this ice cube is made of salt water or fresh water? _____
- Why?

Ice cube #2

Ice cube #2, before addition of food coloring

Ice cube #2, after addition of food coloring

What I see	What this means
Before food coloring…	
After food coloring…	

- Do you think this ice cube is made of salt water or fresh water? _____
- Why?

Salinity Taste Test

The water in the pores and channels of sea ice is quite salty. Even more, how salty the water in the channels and pores is depends on where you are in the sea ice (closer to the bottom of the ice or closer to the top, for instance). Do a taste test to decide which water you think represents the water that exists in the following places. Mark you predictions in the table below.

Water Type	Solution color
Arctic Lake Water	
Arctic Ocean Water	
Brine in the bottom horizons of Arctic Sea Ice	
Brine in the top horizons of Arctic Sea Ice	

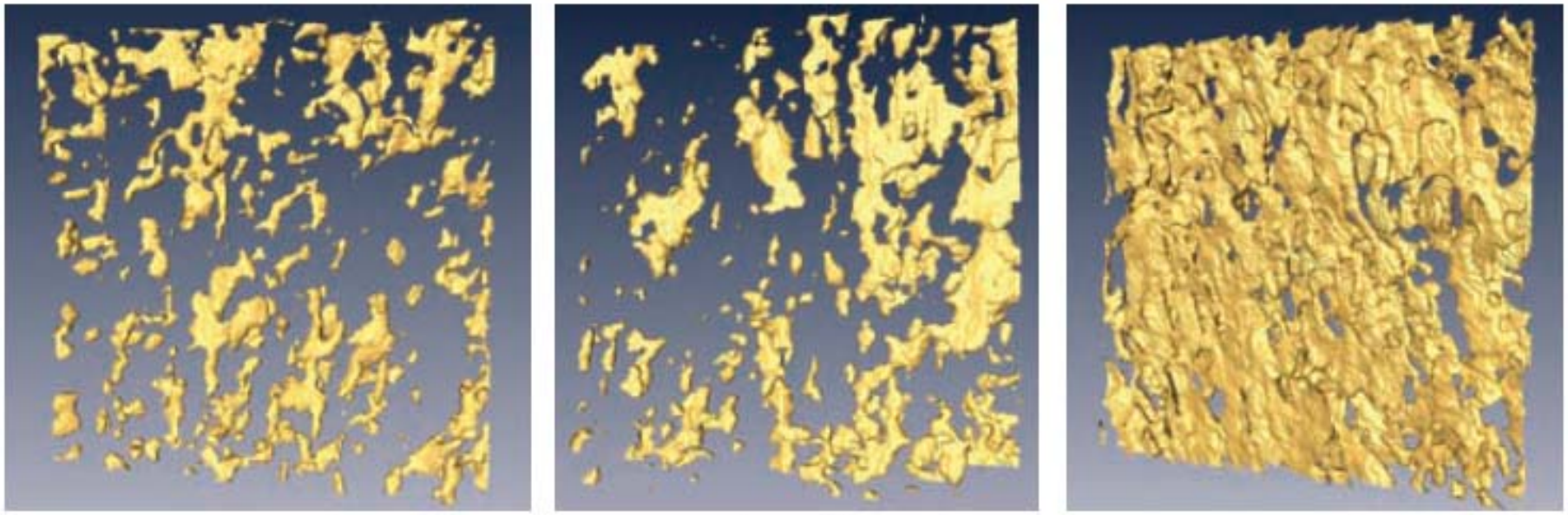
What led you to make each of these matches?

Salinity Taste Test Activity

Colder ice = More salty brine

Pictures of thin-sections of ice.

Yellow indicates brine pores and channels. Gray indicates ice.



(a) $T = -15\,^{\circ}\mathrm{C},\ \phi = 0.033$ $T = -6\,^{\circ}\mathrm{C},\ \phi = 0.075$ $T = -3\,^{\circ}\mathrm{C},\ \phi = 0.143$

Colder Ice

Temperature

Porosity (how porous or "holey" the ice is)

Warmer Ice

Golden et al. GRL, 2007

Life in Sea Ice

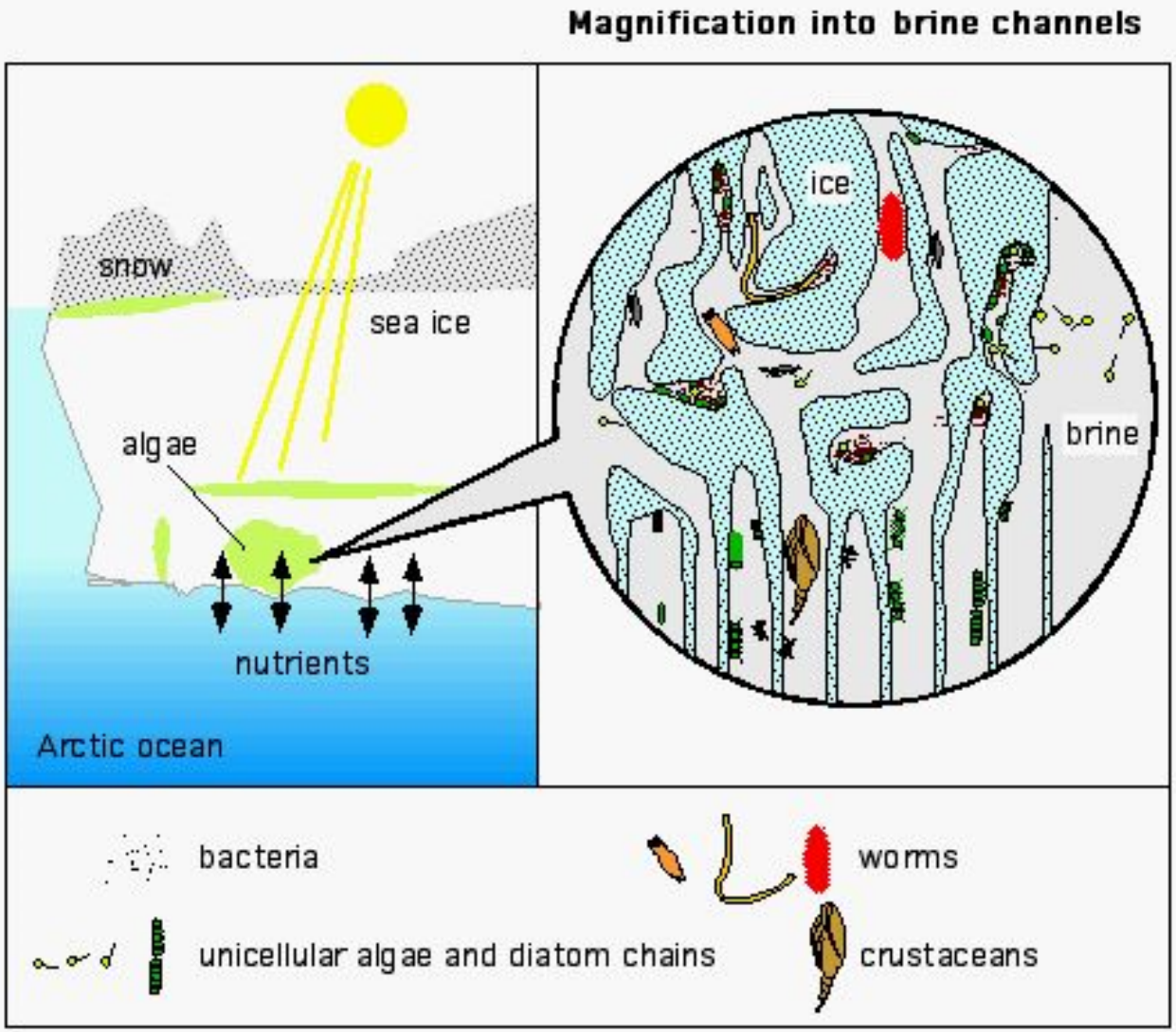
Temperature range: -2 to -55°C

Salinity of brines: up to 7x seawater

Concentration of bacteria: >100,000 per milliliter of brine

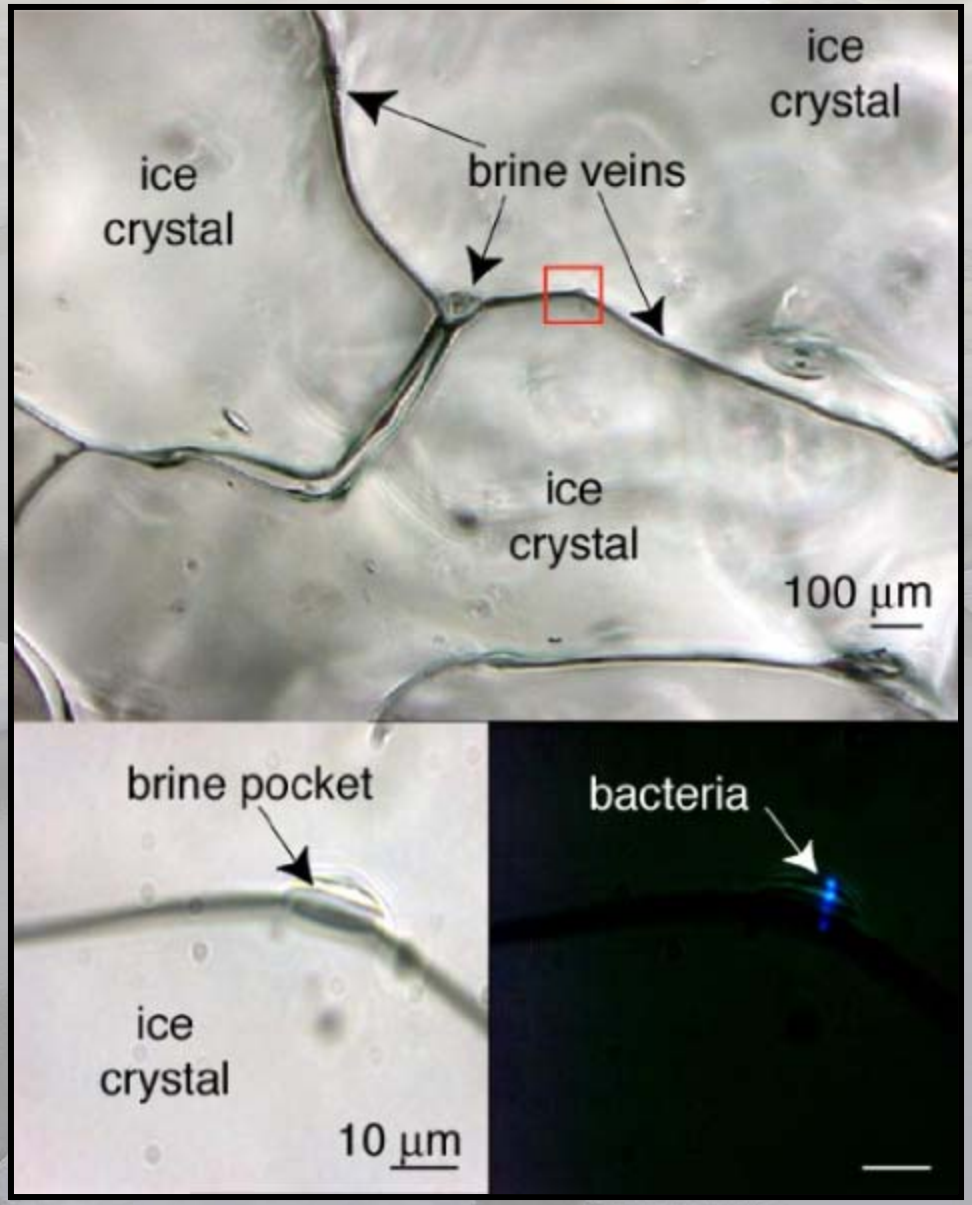
Concentration of viruses: >1,000,000 per milliliter brine

Life in Sea Ice



Microbes in sea ice

Remember these guys are important **decomposers** and **recyclers**. They are also a **food source for other microorganisms**.



Effects of extreme environment

- Increased lipid and protein rigidity
- Ice crystal growth in/outside cells (causing cells to burst!)
- High concentrations of salts can breakdown or degrade proteins

Cellular adaptations of psychrophiles

- More flexible enzymes
- Cold-shock proteins
- Antifreeze proteins
- Exopolymeric substances (snot-like stuff that microbes secrete around themselves for protection)

(more) Life in Sea Ice

Ice Algae

Photo courtesy Doug Allen, Change in Arctic Marine Production (CAMP) Project.

Ice Algae Adaptations

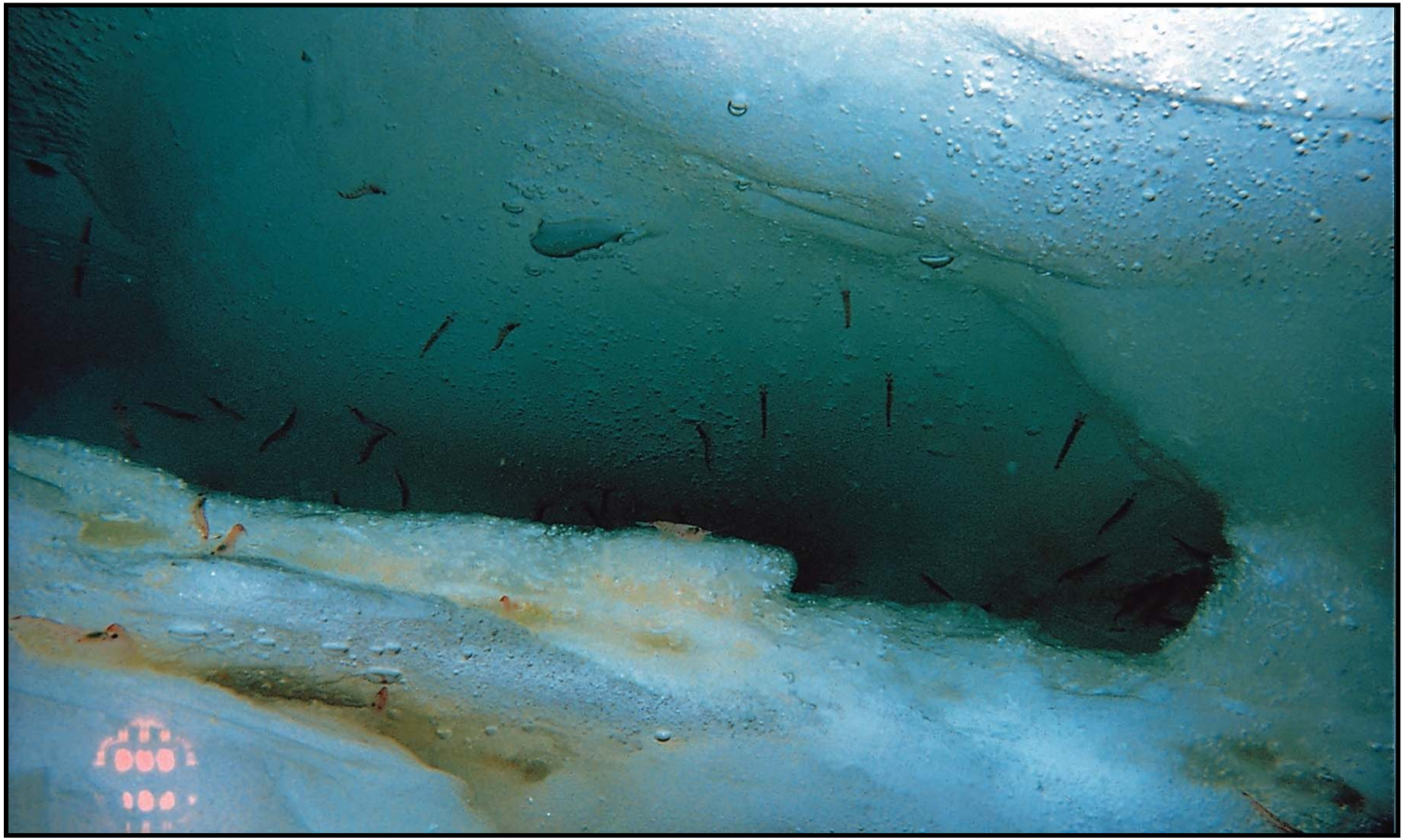
- Survive all winter long (with no sunlight!)

- Can photosynthesize, once there is some sunlight, at temperatures well below freezing

- Produce compounds to protect from UV radiation

- Produce exopolymeric substances to protect from ice, cold and to help anchor them in place in the ice

Krill feeding on ice algae



Krill Adaptations

Can reduce body size when resources are low!

Arctic Cod

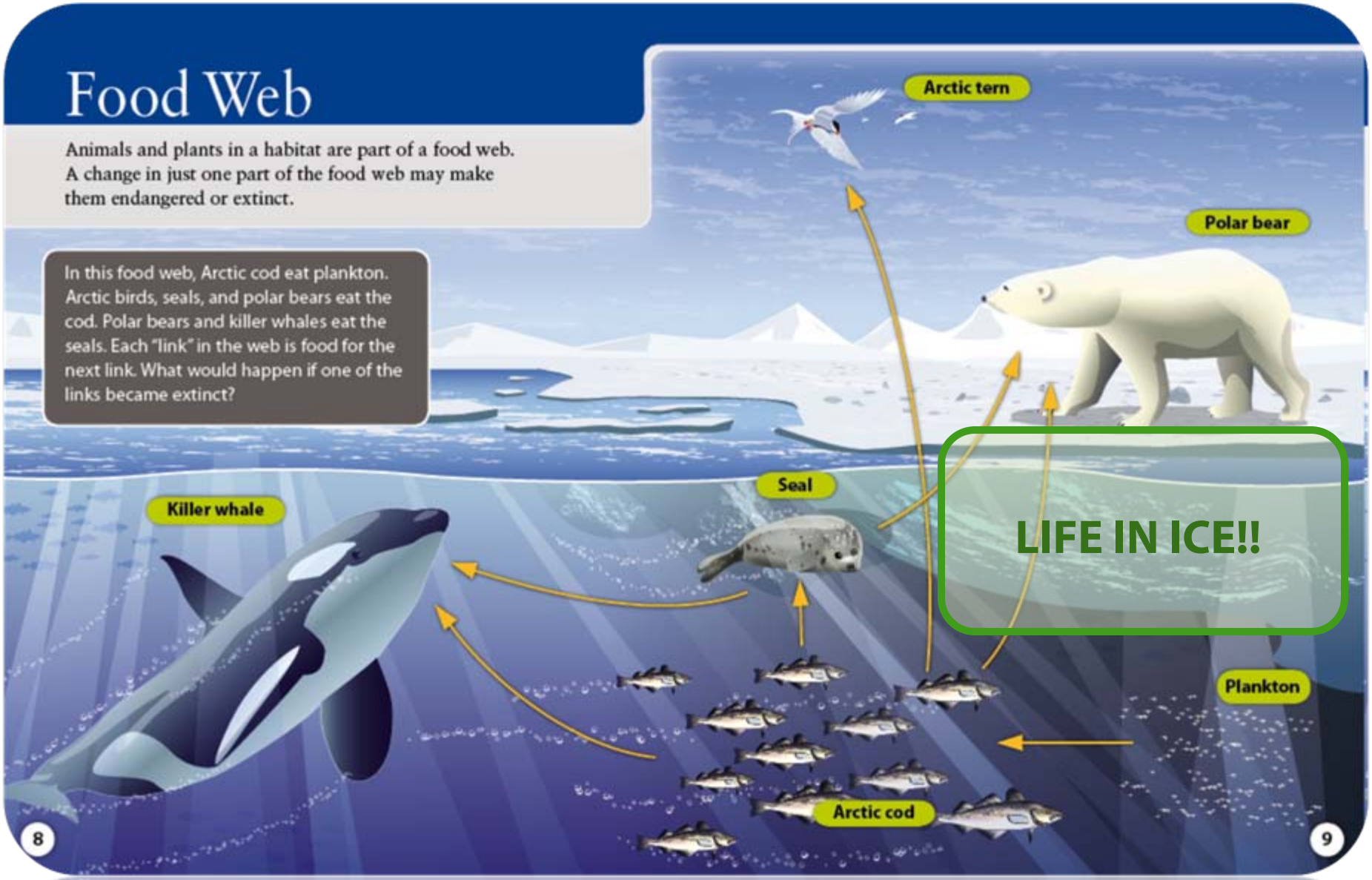
- have **antifreeze proteins** in their blood

Polar Bears

- Have **thick layer of fat underneath skin**
- **Oily fur coats** (make it **easy to shake off freezing water** after swimming, allowing for **quicker drying**)
- **Keen swimmers:** Large feet help in swimming

Photo credit: Colleen Kellogg, UW Oceanography

Arctic Food Web



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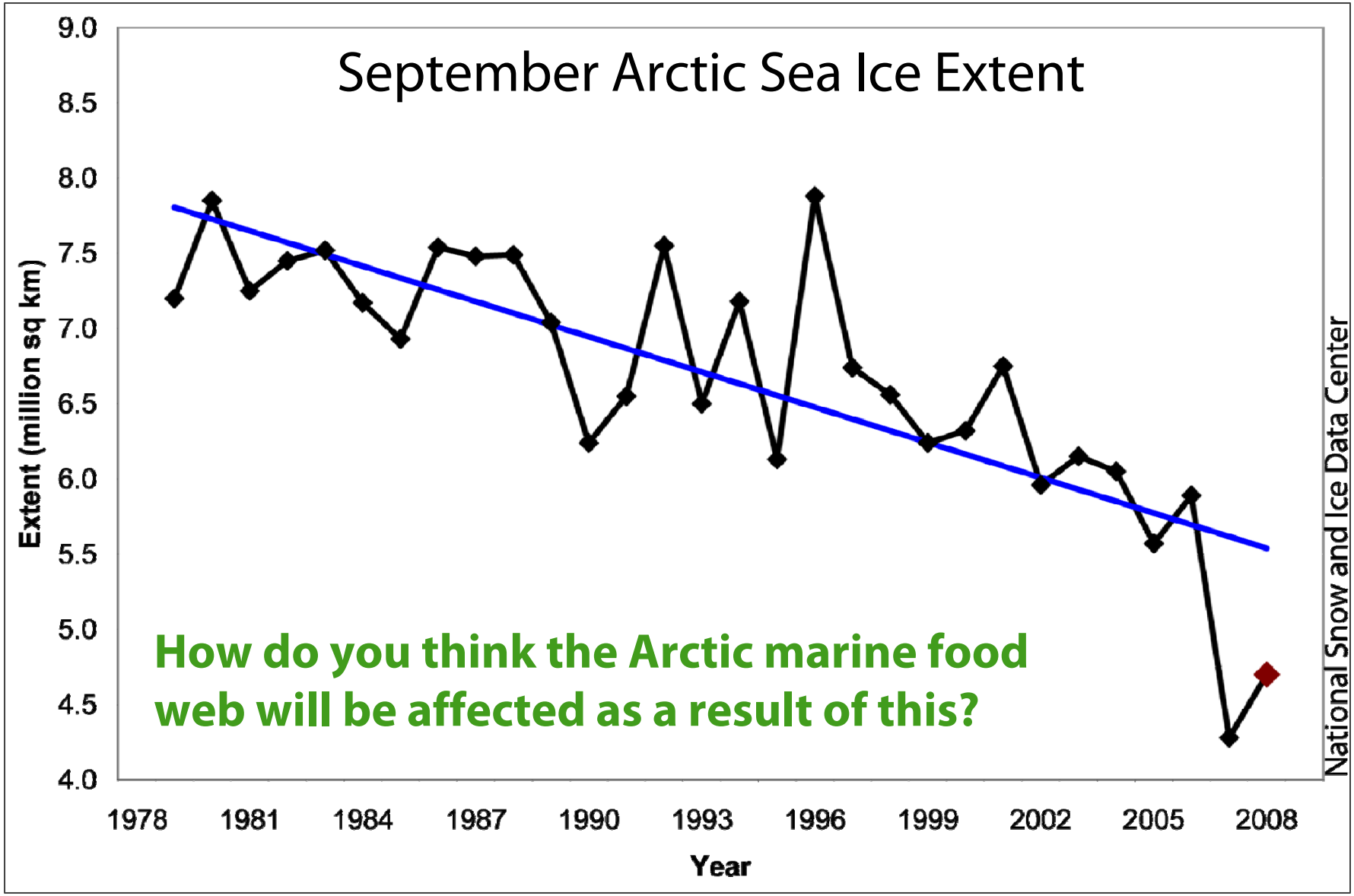
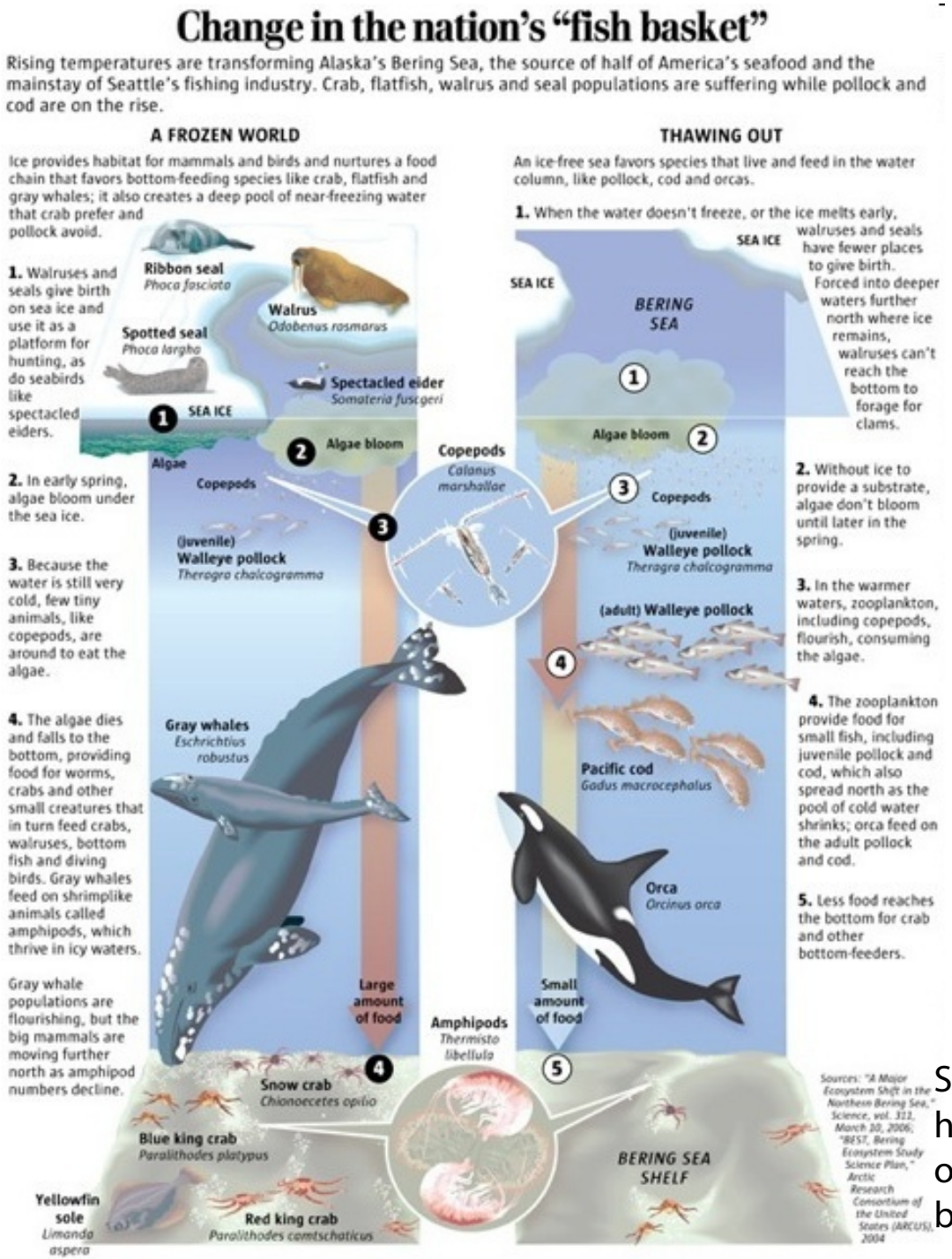


Climate change's impact on polar food webs



Source: http://seattletimes.nwsource.com/news/local/beringsea/