* ORGANISMS: MICROBES AND MACROALGAE

Lecture 4 – Sept 28, 2015

Intro to Marine Science

Instructor: Lauren Bell

Wikimedia commons

* First, to wrap up oceanography modules…

Why do we need to be familiar with physical oceanography to understand the **big issues** of today?

- **Warming temperatures**
  - ✧ Thermal expansion
  - ✧ Interaction of rising sea level w/ tides and storms
- **Pollution**
  - ✧ Water motion determines where pollution goes, collects
  - ✧ Noise (also a wave) travels at different speeds at different ocean depths (i.e., at different water densities)
- **Increased run-off from land to sea**
  - ✧ Freshwater increases stratification
  - ✧ Nutrient loading and dead zones
- **Ocean acidification**
  - ✧ Vulnerable regions, exacerbating effects

* Garbage Patches

Out of sight,
out of mind?

* Microplastics

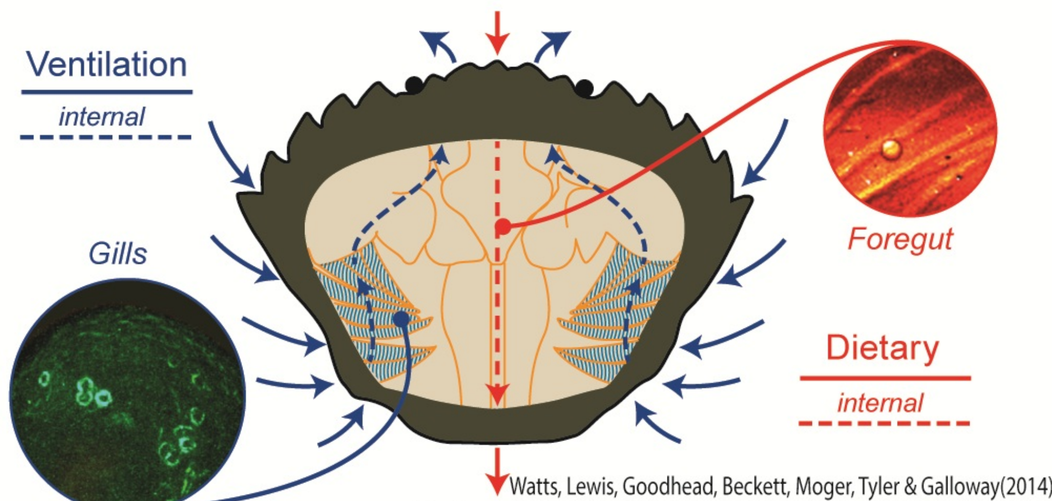
The worst pollution isn't necessarily the kind you can see

245 metric tons produced each year
(that's the weight of 5 mega cruise ships)

Sources:

- Wear and tear from car tires
- Painting/maintenance of boats
- Loss from plastic production
- Washing of textiles
- Cosmetics

Can cause internal injury, false sense of fullness



Watts, Lewis, Goodhead, Beckett, Moger, Tyler & Galloway(2014) Uptake and Retention of Microplastics by the Shore Crab *Carcinus maenas*. Environmental Science & Technology. 10.1021/es501090e

*Noise pollution

- **Sounds travels 4-5x faster in water than air (water more dense)**
- **Certain deep oceanic layers can transmit low frequency sounds thousands of miles - animals may go here to communicate long-range**

<u>Decibel scale:</u>
95 dB – submarine
105 dB – cod
170 dB – Right Whale
192 dB – cargo ship
260 dB – Oil-prospecting air guns

Intense noises may drown out animal noises and/or cause hearing loss and mortality

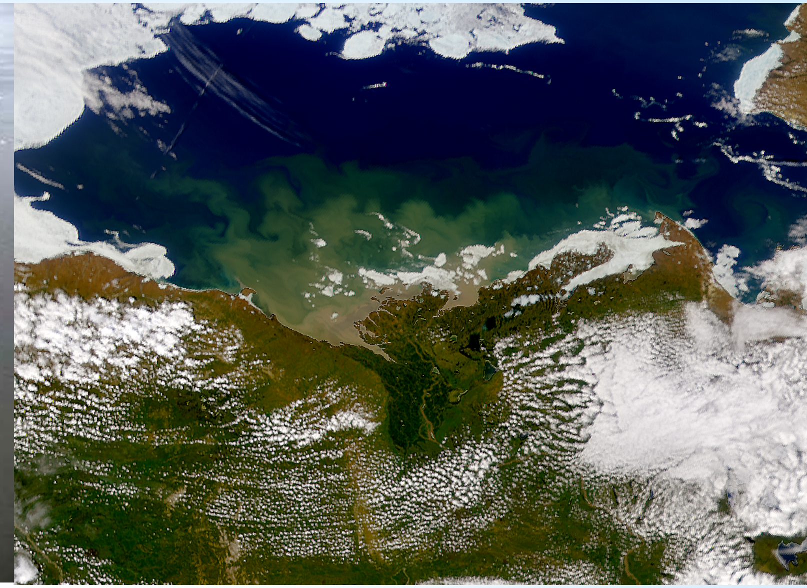
<u>Frequencies:</u>
Whale call frequencies overlap with cargo ships, air guns, submarines, natural noises (animals, wind, lightning)

Sounds close in frequency interfere, may cancel each other out

*Increased terrestrial run-off

GD Clow, USGS

Scenes from the Arctic's Beaufort Sea: coastal erosion and freshwater inputs



SeaWiFS/NASA/Goddard SFC/ORBIMAGE

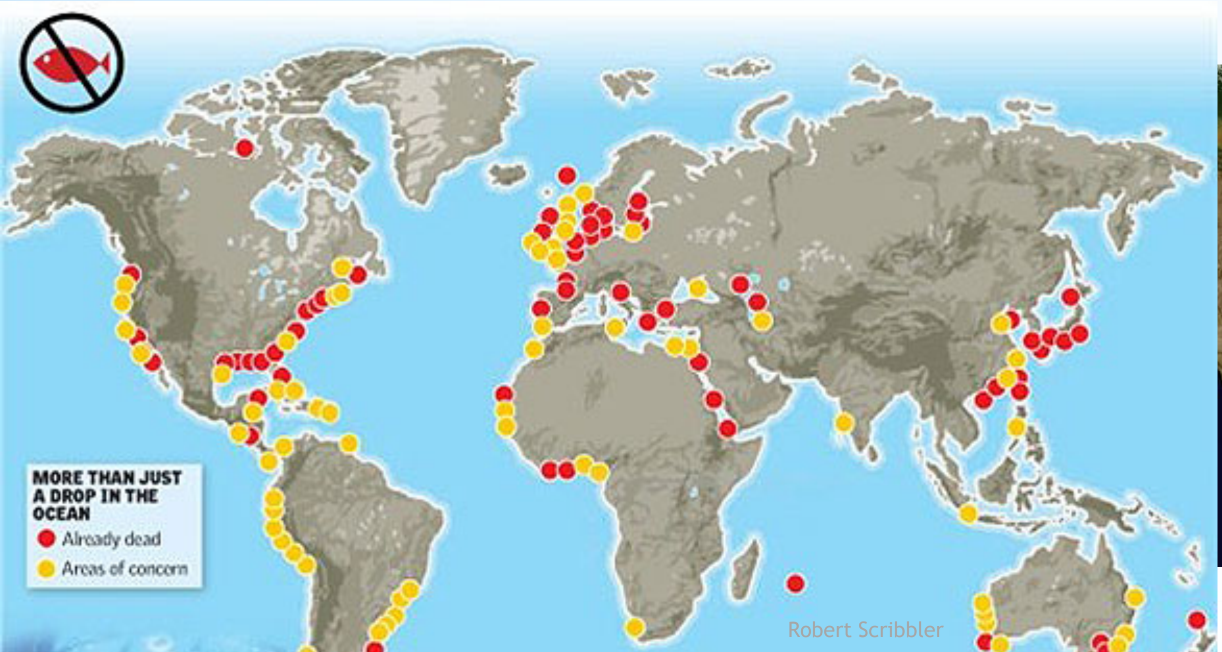
Increased precipitation and storm events =
more terrestrially-derived inputs into the marine environment

We are still understanding the effects…but know of a few:

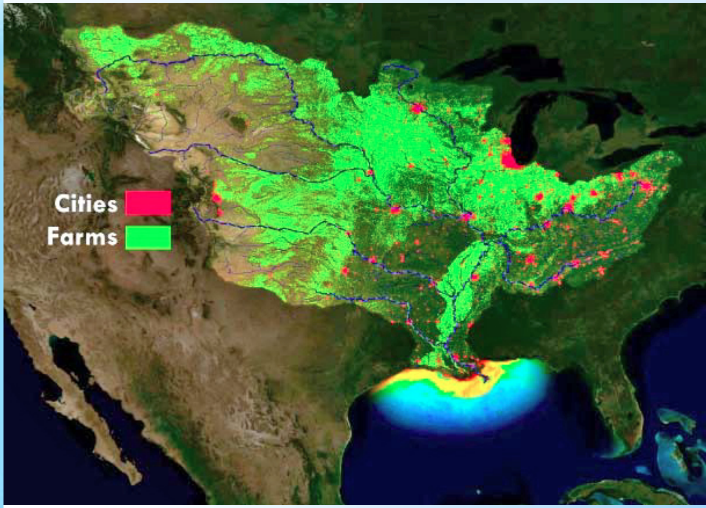
- Increased stratification due to more freshwater inputs
- High sediment loads can inhibit light penetration into surface waters
- Higher terrestrially-derived organic matter influence may alter food sources for marine consumers and change energy dynamics

* Human-caused eutrophication/hypoxic zones

- In areas of high anthropogenic modification (farms, cities, etc.) terrestrial run-off can include fertilizers, pesticides, feces
- Can “overwhelm” the system with nutrients
- Decomposition of terrestrial run-off and of plankton blooms consumes oxygen from water
- Hypoxic zones often called “Dead Zones” – other marine creatures suffocate
- Dead zones maintained due to ongoing human inputs, low mixing

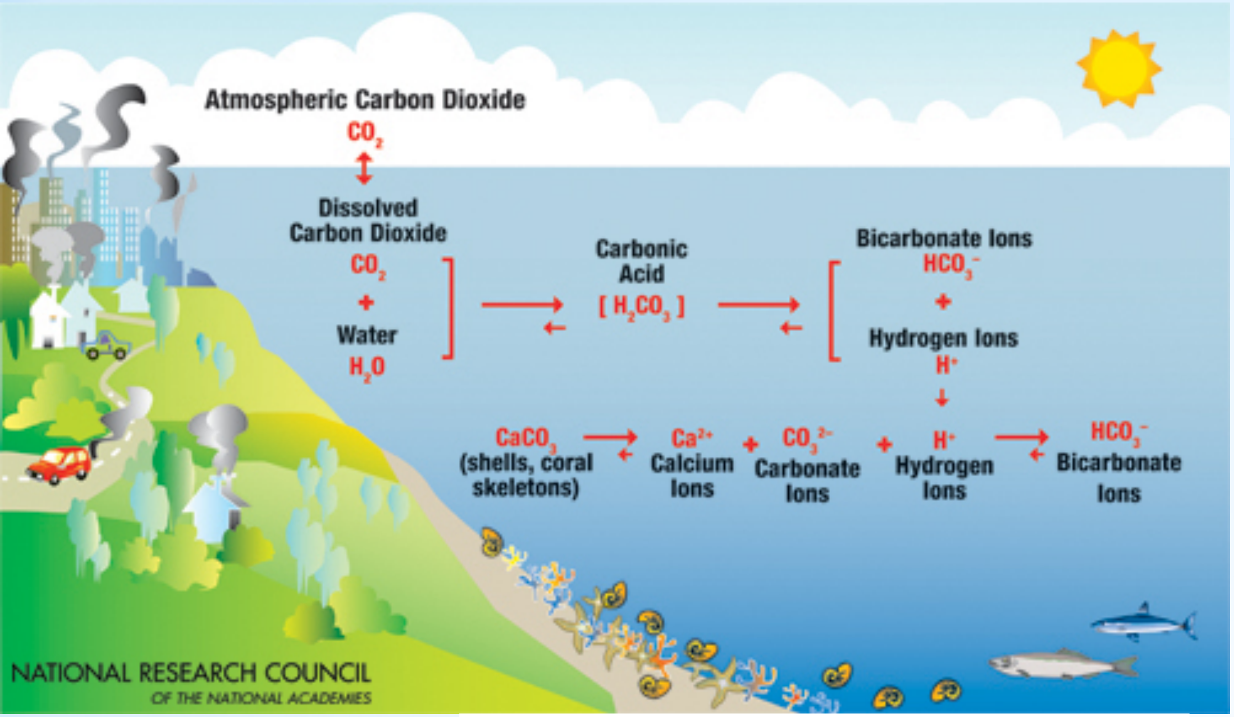


Robert Scribbler



NOAA

*Ocean Acidification



A series of chemical equations:

$CO_2 + H_20 \Rightarrow HCO_{3-} + H^+$

(carbon dioxide dissolves in seawater and forms carbonic acid and release of hydrogen ions, which decreases pH)

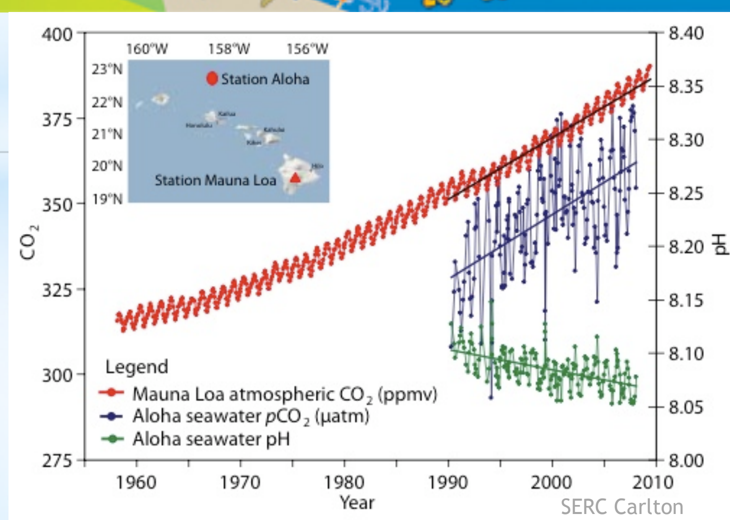
$H^+ + CO_3{}^{2-} \Rightarrow HCO_{3-}$

(hydrogen ions combine with carbonate ions to form bicarbonate)

$CaCO_3 \Rightarrow Ca^{2+} + CO_{3-}{}^{2-}$

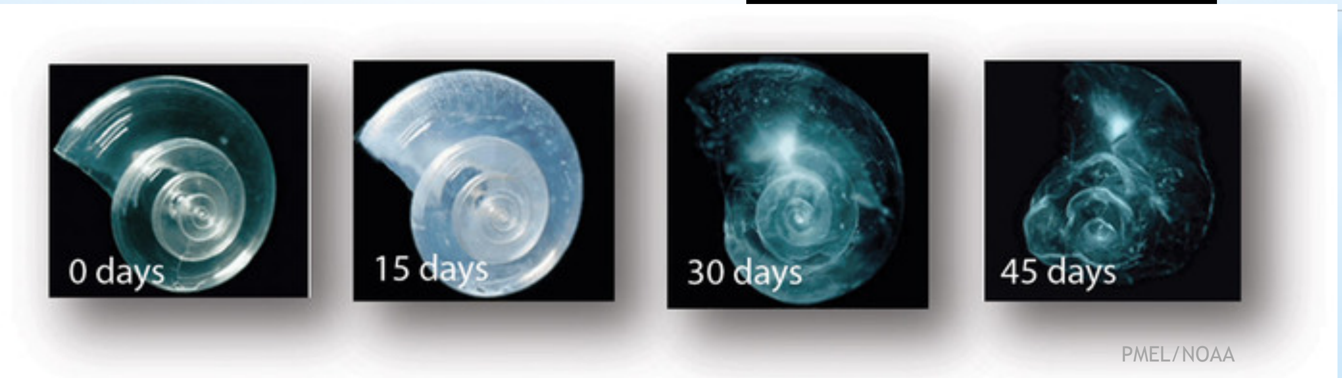
(addition of hydrogen ions to ocean means more carbonate ions are dissolved out of calcium carbonate structures to react with hydrogen ions)

The oceans don't *want* to be acidic – their cure is to dissolve calcium carbonate to "fix" the problem



*Ocean acidification impacts

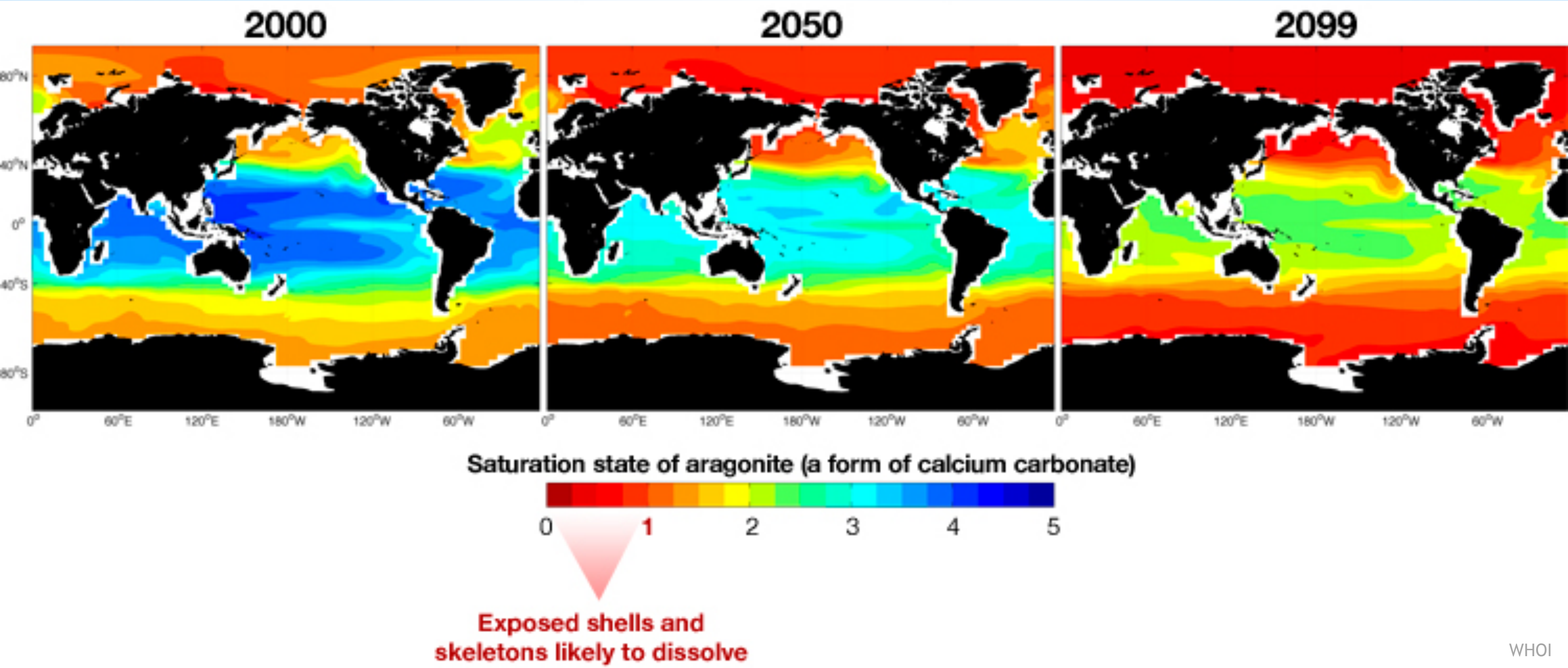
- Ability of shell-bearing organisms to build shells (especially in juvenile stages) may be negatively impacted
- Lower pH may stress animals and affect (+?/-?) their metabolism
- Phytoplankton production may be favored by increased CO_2, though impacts of increased phyto blooms may not be great (think dead zones)



*Where will OA hit hardest?

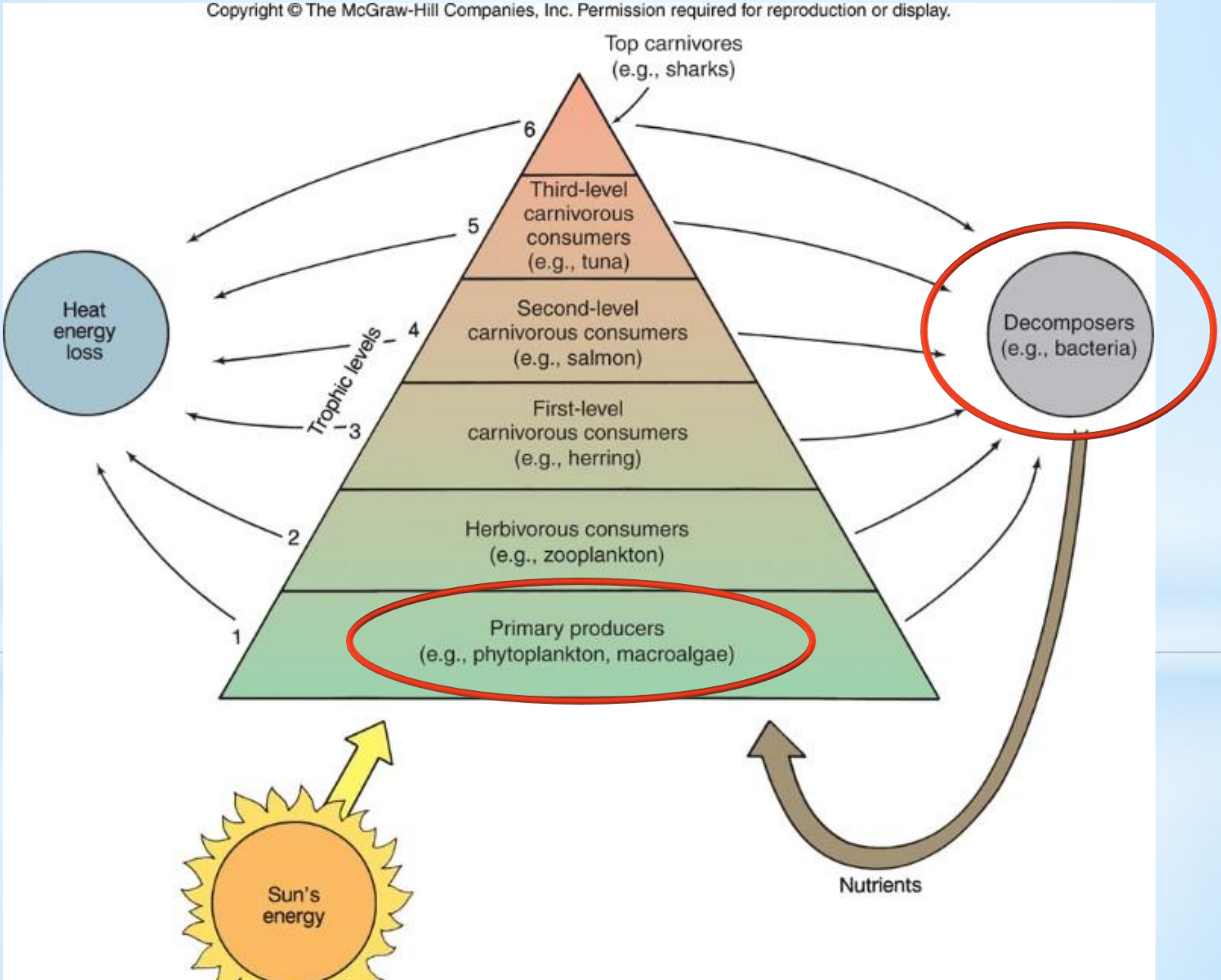
<u>Arctic regions particularly vulnerable in the short term:</u>

- **CO_2 already high in Arctic to begin with**
  high freshwater inputs bring in lots of organic matter, and CO_2 created during remineralization (decomposition)
- **CO_2 more soluble in colder, fresher water**
  (Arctic has an abundance of this)



Microbes and macroalgae

The base of the marine energy pyramid

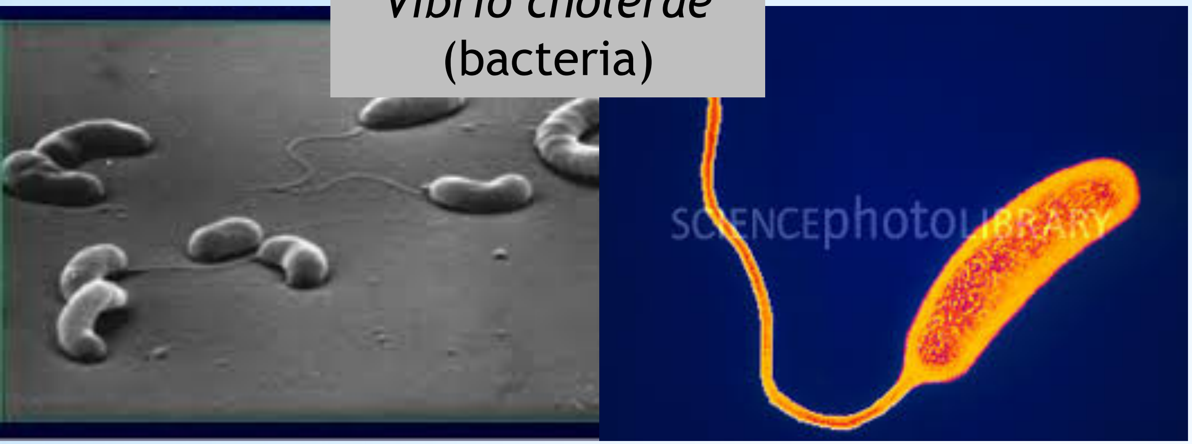


*Learning objectives

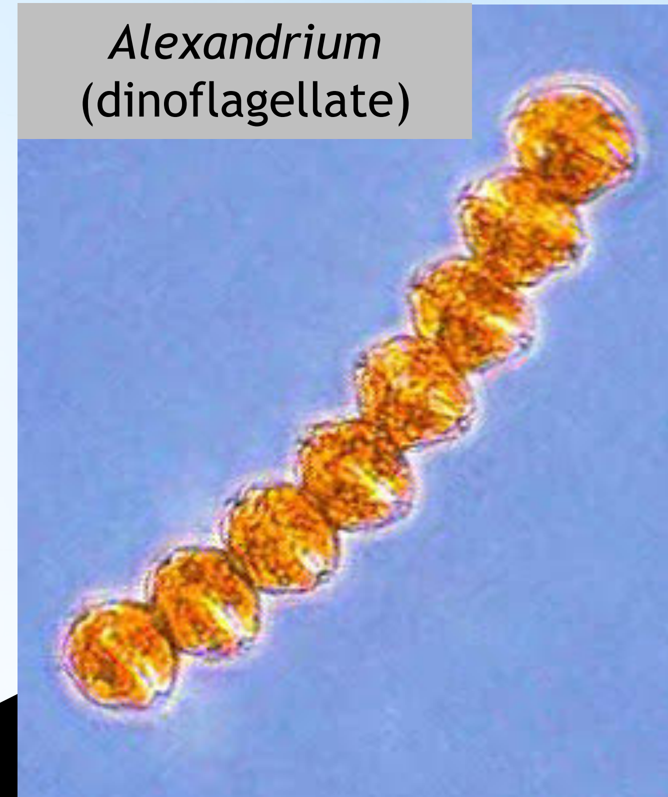
After this lesson, you will be able to:

- List the major macroalgal and phytoplankton taxa, and compare and contrast their physical structures, life cycles, habitats, and broad global distributions.
- Describe the optimal environmental conditions for marine primary production and how these conditions drive variation in productivity across the world's oceans
- Give examples of how marine algae can directly benefit other marine species, and how they might harm other marine species (and humans!)
- Explain the broad role that marine bacteria, fungi, and viruses play in marine ecosystems
- List some of the tools that marine biologists use to study marine microbes

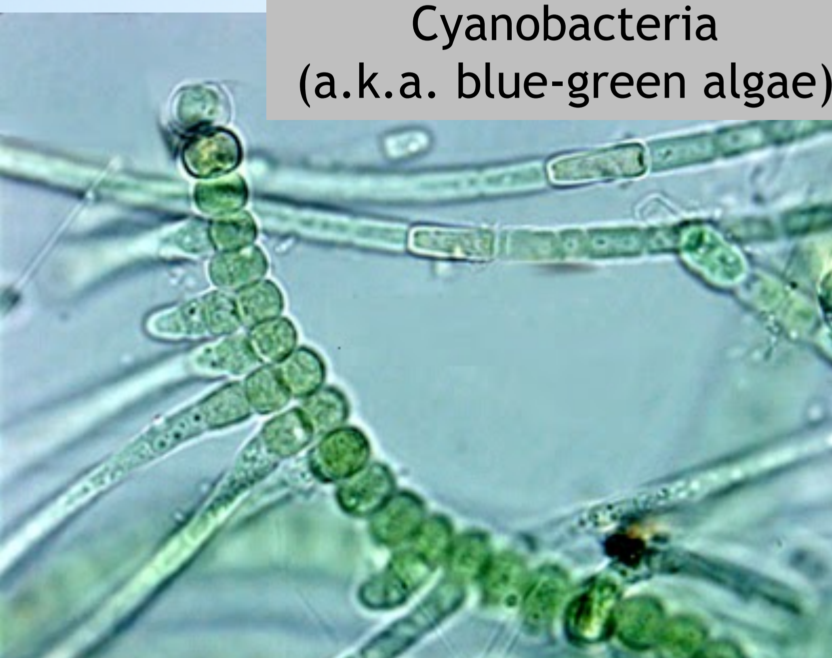
*Microbes and human health



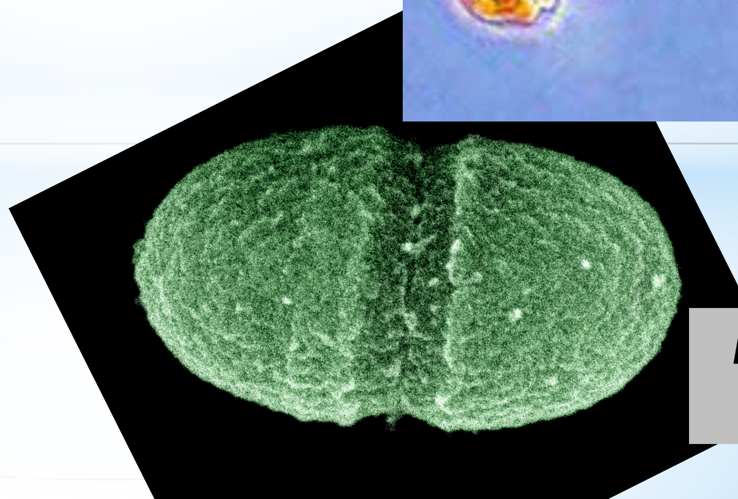
Vibrio cholerae
(bacteria)



Alexandrium
(dinoflagellate)



Cyanobacteria
(a.k.a. blue-green algae)



Enterococci
(bactera)

*Current events - PSP in Homer

DEC officials point to high levels of paralytic shellfish poison (PSP) in blue mussels and oyster samples collected from an oyster farm in Halibut Cove on Sept. 13

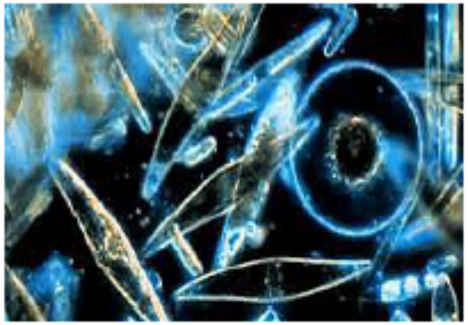
Homer News

Seagrant

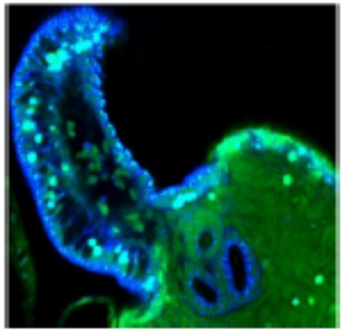
"The increase in PSP toxins could be related to above-average ocean temperatures in Kachemak Bay and the Pacific Northwest, part of a trend that also has seen a rise in domoic acid, another toxin produced by ocean algae, *Pseudonitszchia*. Kachemak Bay did see blooms of *Pseudonitszchia*, but not an increase in domoic acid."
– Homer News, Sept 22, 2015

*The ocean petri dish

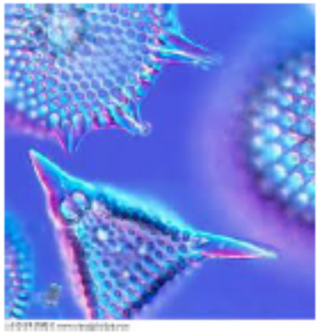
98% of ocean biomass!!!



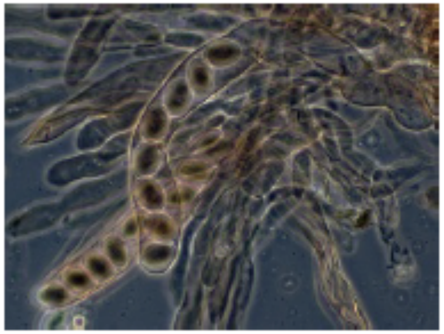
(1)Phytoplankton Diatoms (Photo NOAA)



(2) Bacterium Vibrio fisheri (Photo M.McFall-Ngai)



(3) Protozoa Radiolaria (Photo Visualphoto)



(4) Ascomycete a Fungus-like Bacteria (Photo Deep Sea News)

(5) Marine Virus (Photo DOE)

NOAA FactSheet

"Microbe" can mean lots of different things

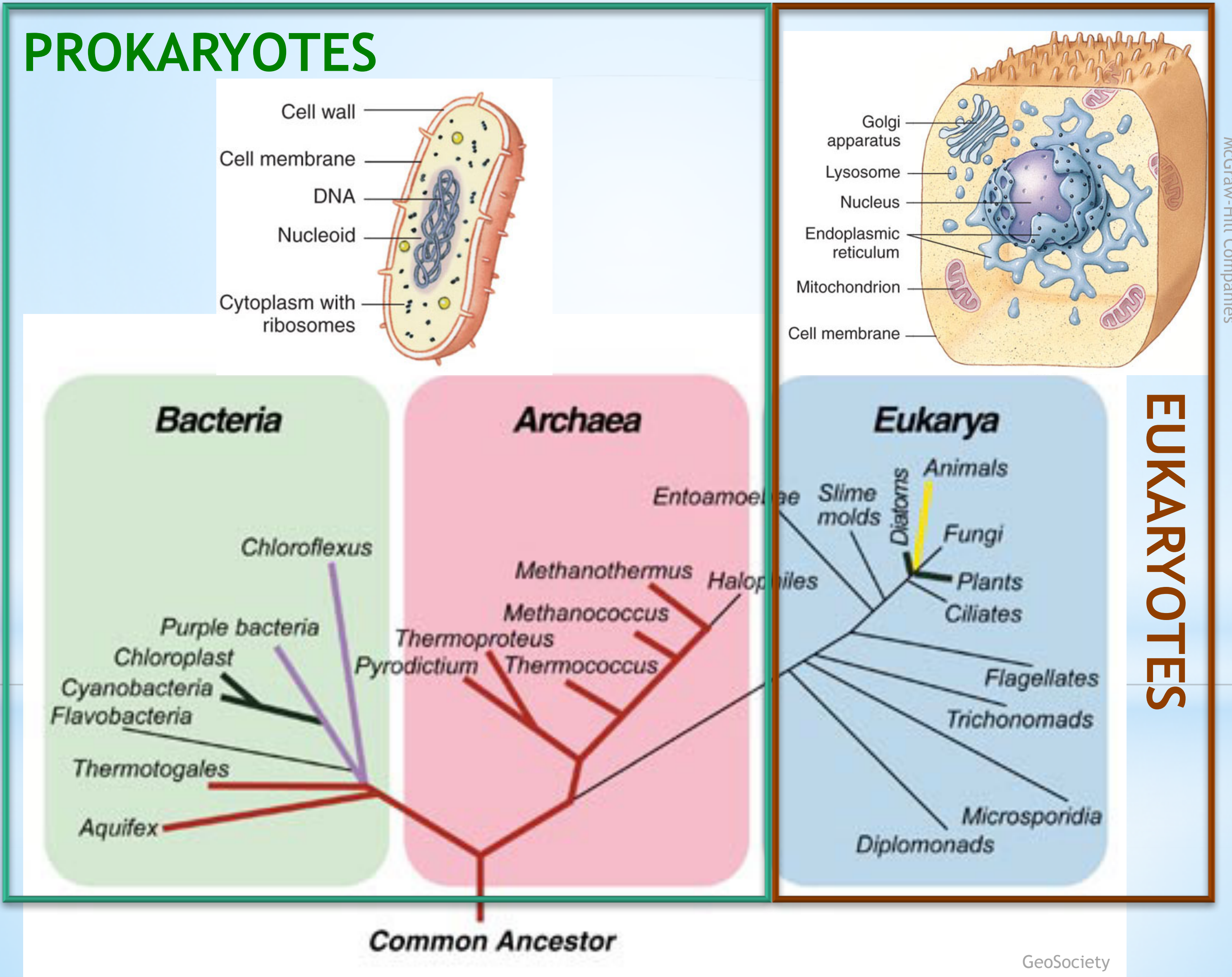
They are all SMALL: $1/8000^{th}$ volume of human cell
$1/100^{th}$ diameter of a human hair
Up to 1 million microbes in 1 milliliter of seawater

Can either be:

PROKARYOTES (cells lack true nuclei or membrane-bound organelles)

or **EUKARYOTES** (cells have true nuclei)

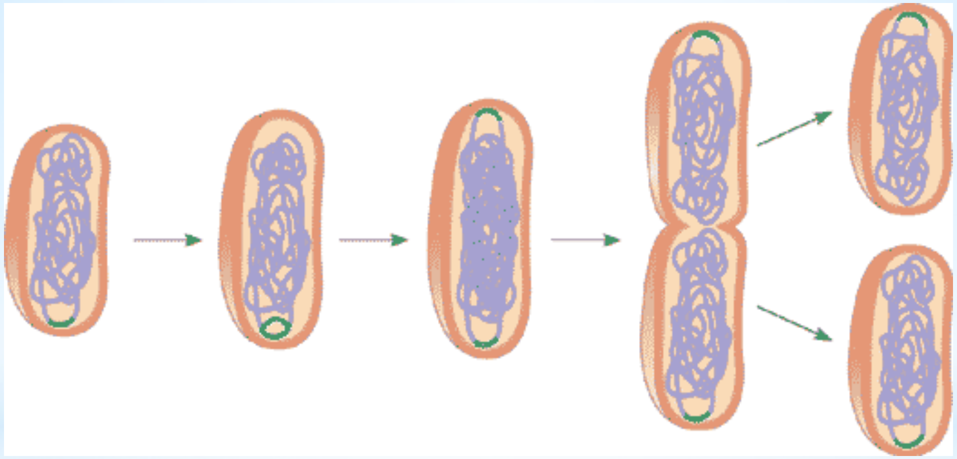
*Our oldest relatives



* Bacteria & viruses: quick responders

Prokaryotes can reproduce….FAST.

Binary fission can take as little as ~20 min



(asexual reproduction)

- "first responders" to environmental change
- short generation time means can adapt and evolve
- scientists view microbes as the "canaries in the (marine) coal mine" for global change

*What do the tiniest guys do?

Recycle nutrients!!

Bacteria, viruses, and fungi absorb the dissolved, recycled matter that is too small for bigger animals to eat, and use it for energy or release it back into the water

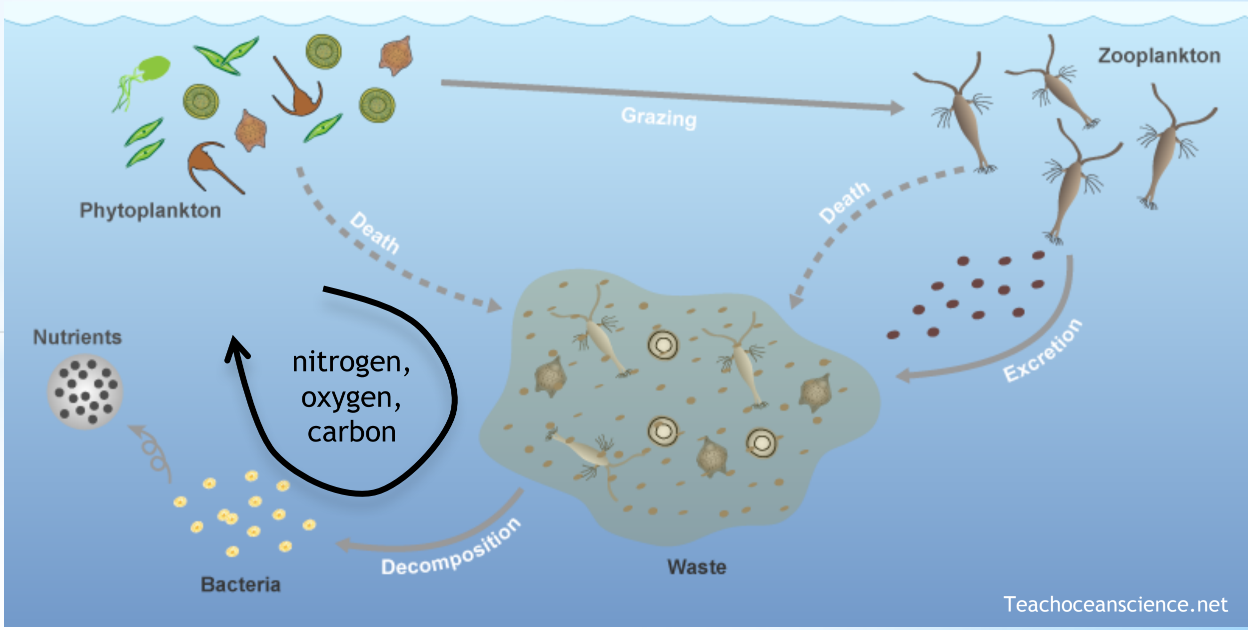
Bigger animals can also eat these microbes, and pass this energy up the food chain

This dissolved matter can include:

- ✧ Carbon, metals (iron)
- ✧ Plastics, oil

Microbes also "fix nitrogen" making N biologically available to other animals

$N_2 \Rightarrow NO_3$ or NH_4

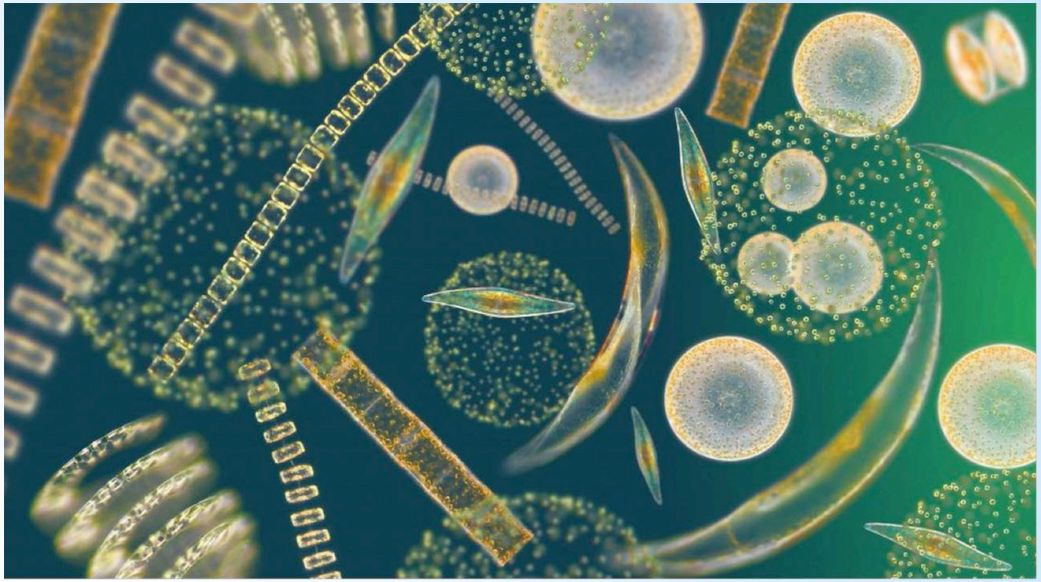


*Phytoplankton

Derived from Greek:
phyto = "plant"
plankton = "drifter, wanderer"

50-85% of world oxygen production

Remove CO_2 from atm



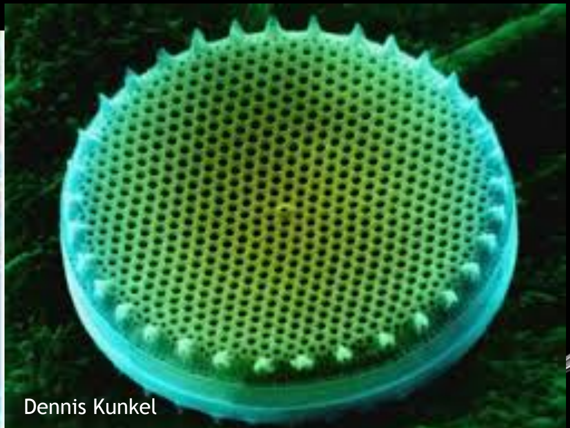
PNAS

THE BIG THREE TAXA:

Cyanobacteria

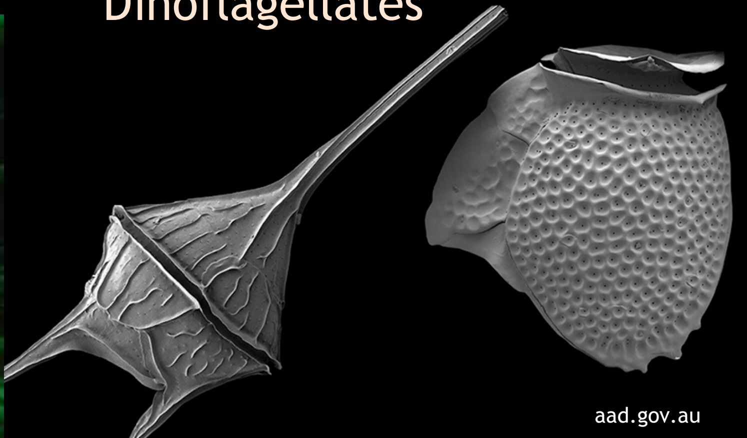
World.edu

Diatoms



Dennis Kunkel

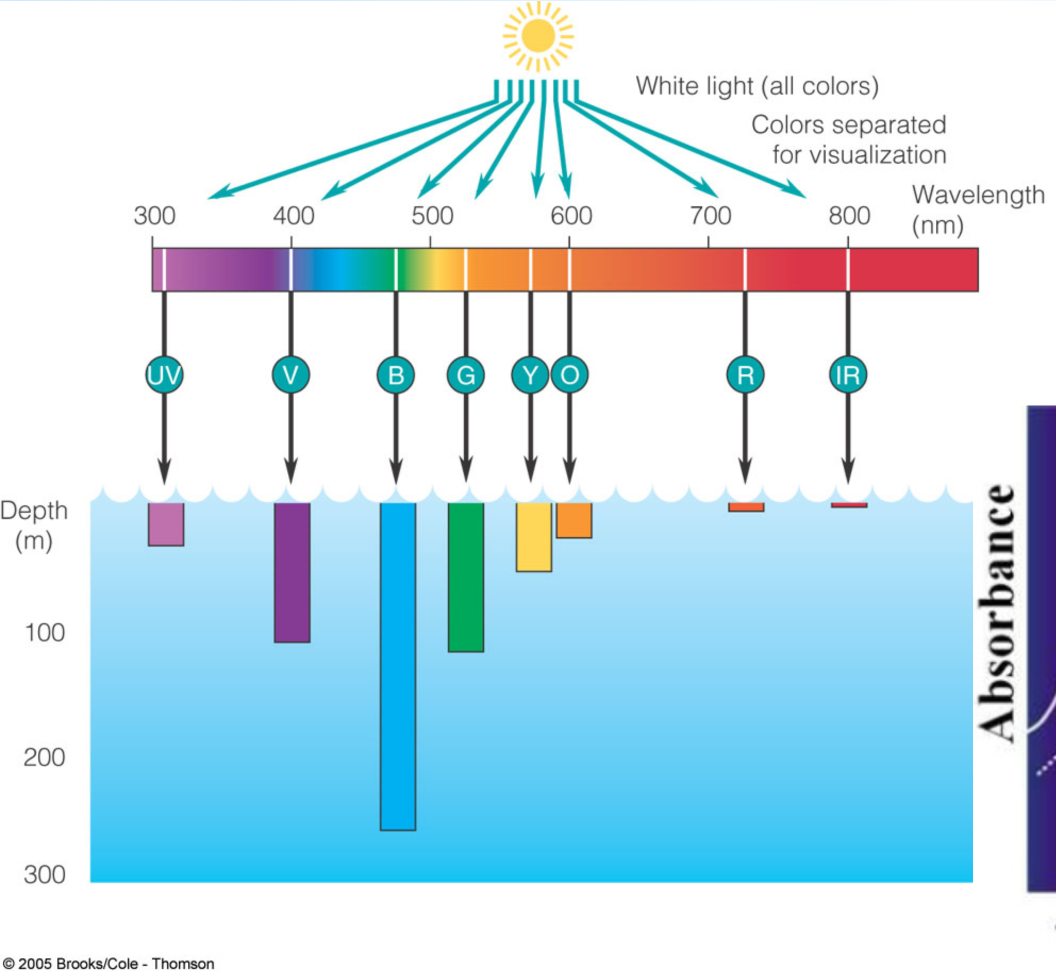
Dinoflagellates



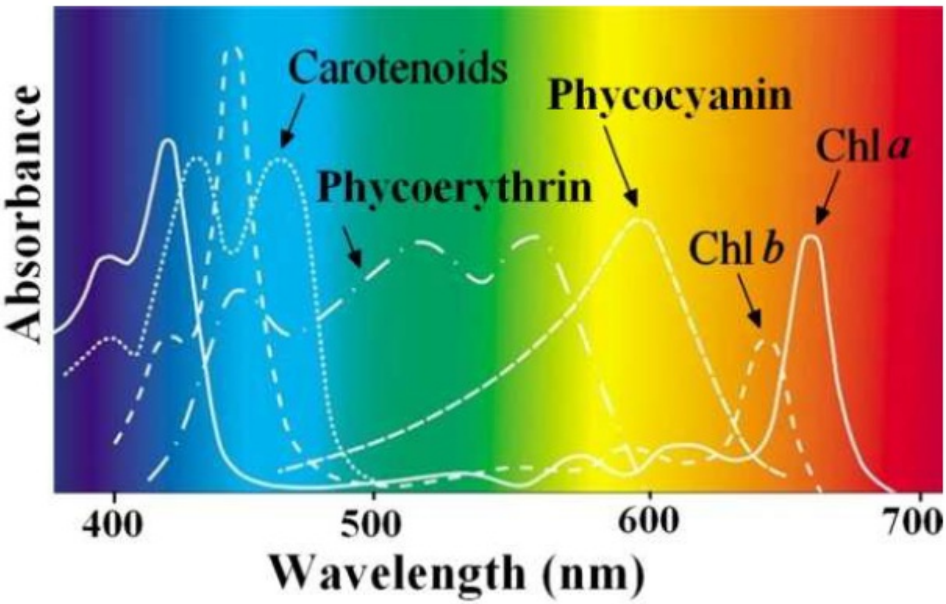
aad.gov.au

*Photosynthesis

The process of making high-energy organic compounds from low-energy inorganic compounds, using light



- Algal "pigments" = in chloroplasts, capture photons (light)
- Every photosynthesizing species has its own characteristic set of specific pigments
- Allows each species to absorb a certain spectrum of light



*Primary production

light!

carbon dioxide + water → organic carbon + oxygen + water

<u>Primary productivity:</u> amount of "product" created by photosynthesis per unit time and per unit area (or volume)

Examples: grams Carbon per square meter per year
milligrams Carbon per square meter per day

Factors controlling primary productivity and type of phytos:

1) Light (energy)
2) Availability of nutrients

Also…
3) Temperature
4) Stratification (how mixed are surface waters?)

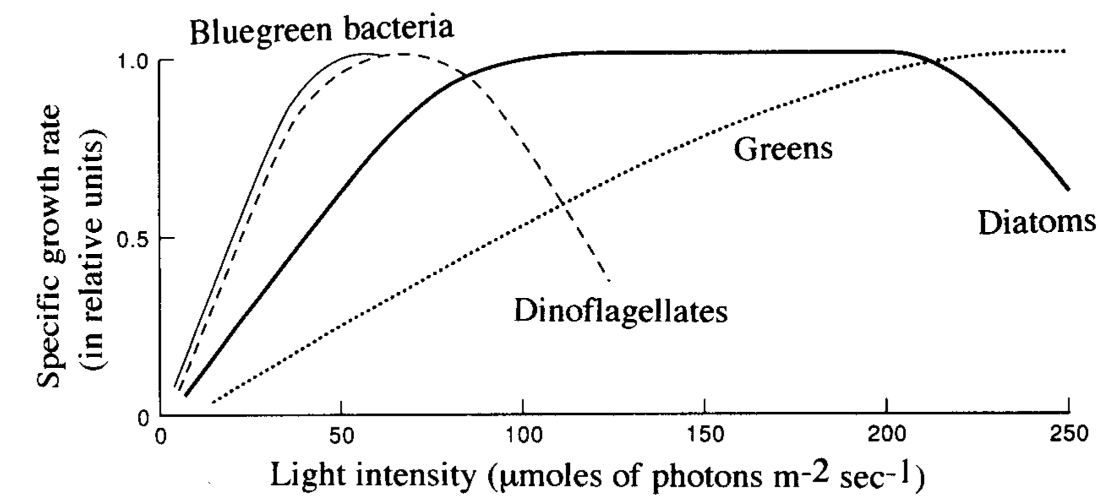


FIGURE 2-5. Specific growth rates in relation to light intensity in four maj groups of marine producers. Adapted from Raven and Richardson (1986).

*Size (and shape) matter!

SIZE (max length or diameter)

0.0001 cm — Viruses

Cyanobacteria

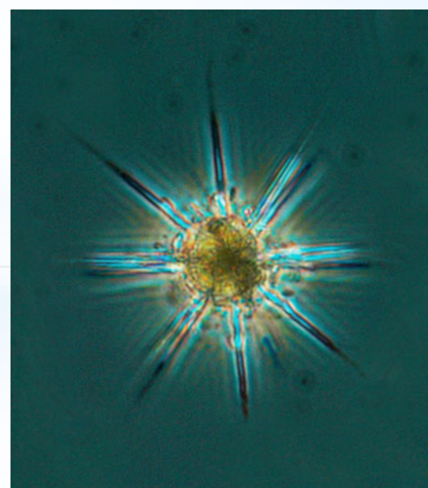
0.002 cm — Dinoflagellates
Diatoms
Ciliates

Large phytoplankton

2 cm — Zooplankton

How to maintain yourself in surface (well-lit) waters?

- Size (smaller sinks slower)
- Shape (greater surface area/volume sinks slower)
- Movement (phytos with flagella)
- Buoyancy (accumulation of oils)



SPINES – a great way of increasing surface area

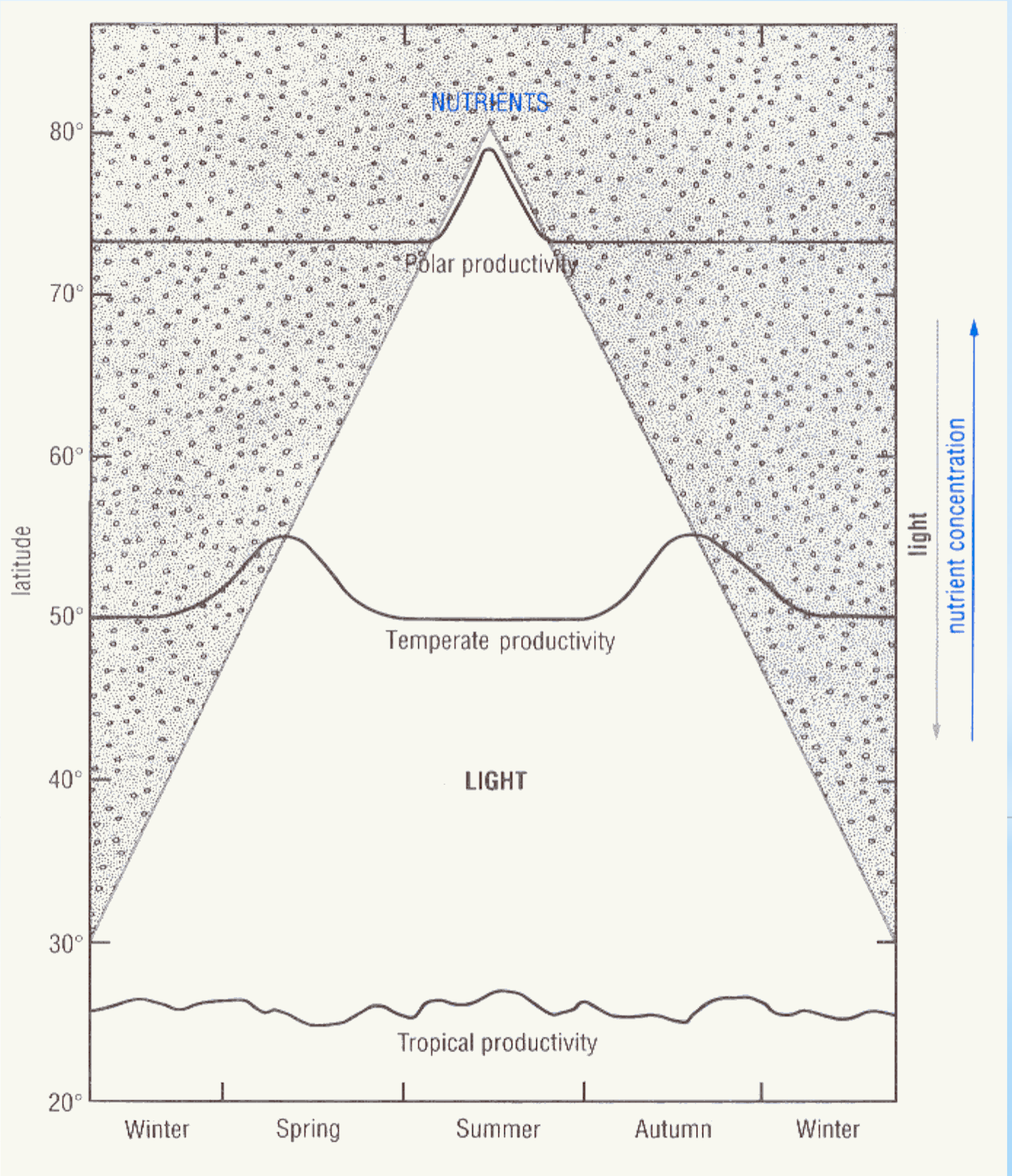
* Productivity by season and latitude

Nutrients – used up by photosynthetic processes. If there is a “dark” period, they have time to regenerate.

Balance between nutrients and light availability by latitude leads to variation in primary productivity regime.

High latitudes:
  Lots of nutrients, low light. When light does hit, big productivity peak.

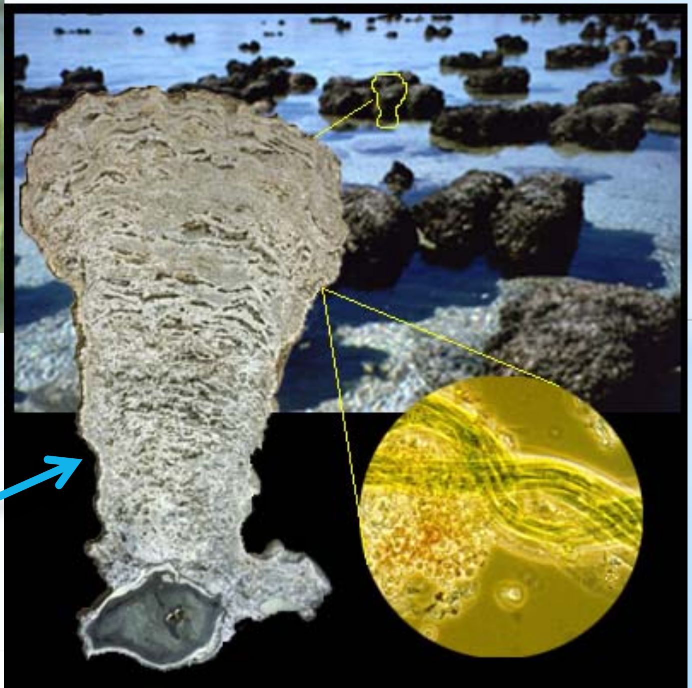
Low latitudes:
  Lots of light, low nutrients. Low level productivity sustained through year.



*Some bacteria make oxygen!

Cyanobacteria (prokaryotes) can photosynthesize – of the oxygen produced by marine organisms, bacteria contribute at least half

Cyanobacteria (sometimes incorrectly referred to as blue-green algae) may have been the first photosynthetic organisms on earth



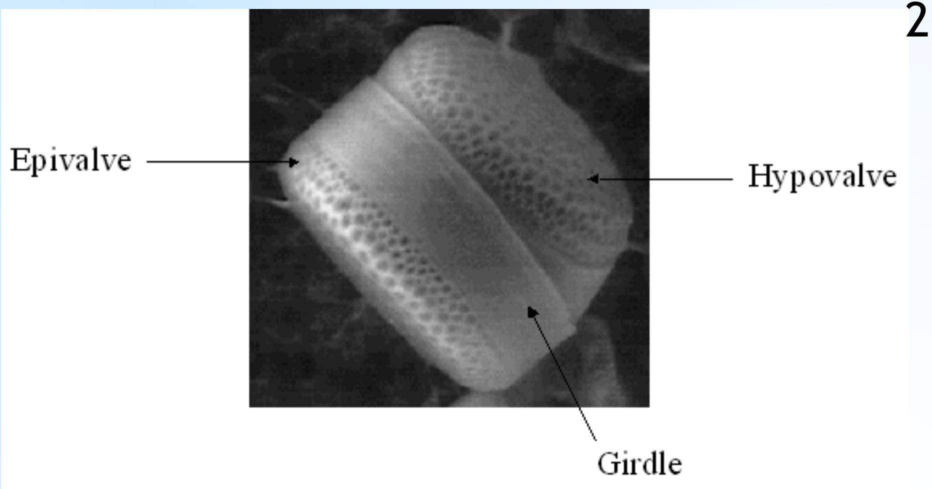
Theory is that modern plants' chloroplasts evolved from cyanobacterial ancestors!

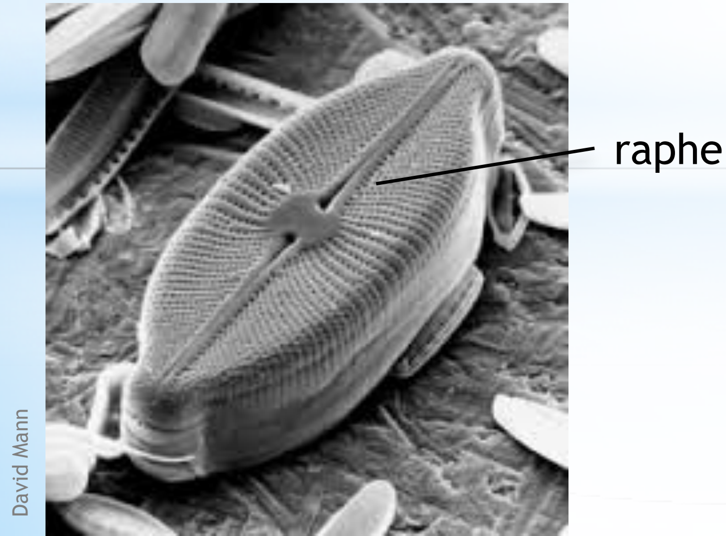
Some of world's oldest fossils = **stromatolites** 3.5 billion y.o.

*Diatoms

EUKARYOTES

Single-celled, but can form chains
Silica skeleton: "frustrule"
Sink easily, contribute to seafloor deposits
Can contain oil to keep afloat





2 types:

Centrales

- Mostly pelagic (open ocean)
- 2 skeletal 'sections that fit together
- Not capable of own movement
- Most common

Pennates

- Have a **raphe** - a groove in silica skeleton
- Can secrete mucus out of raphe, used to move

*Diatom pores

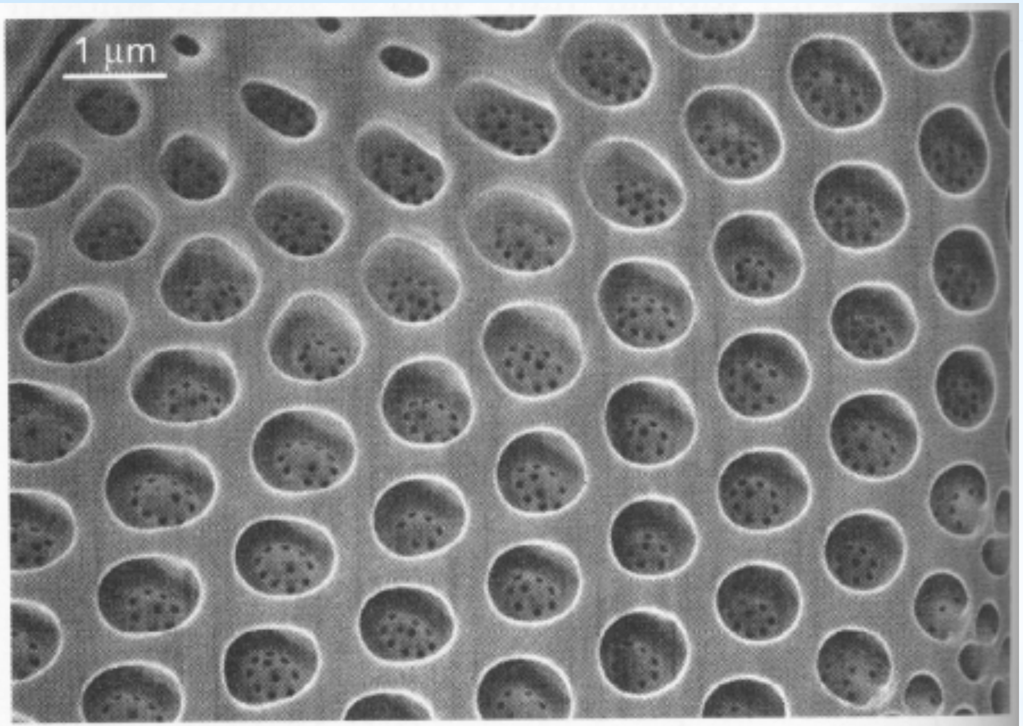


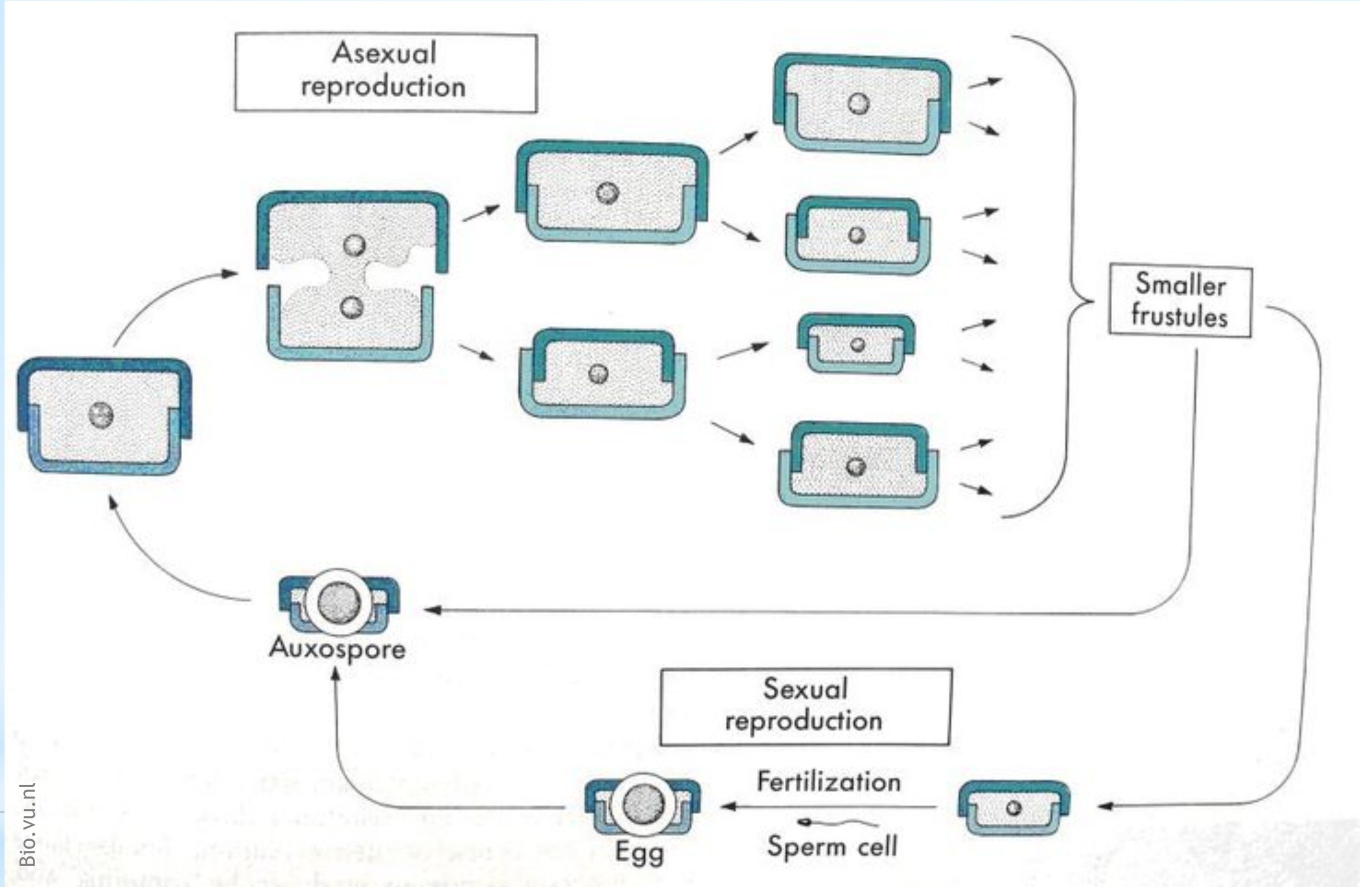
Figure 12–19 High-resolution low-voltage scanning electron microscopic view of poroid areolae in *Mastogloia angulata*. (From Navarro, 1993)

Aerolae: pores through diatom's silica skeletons

Allow gases and nutrients in

Used to ID different diatom species

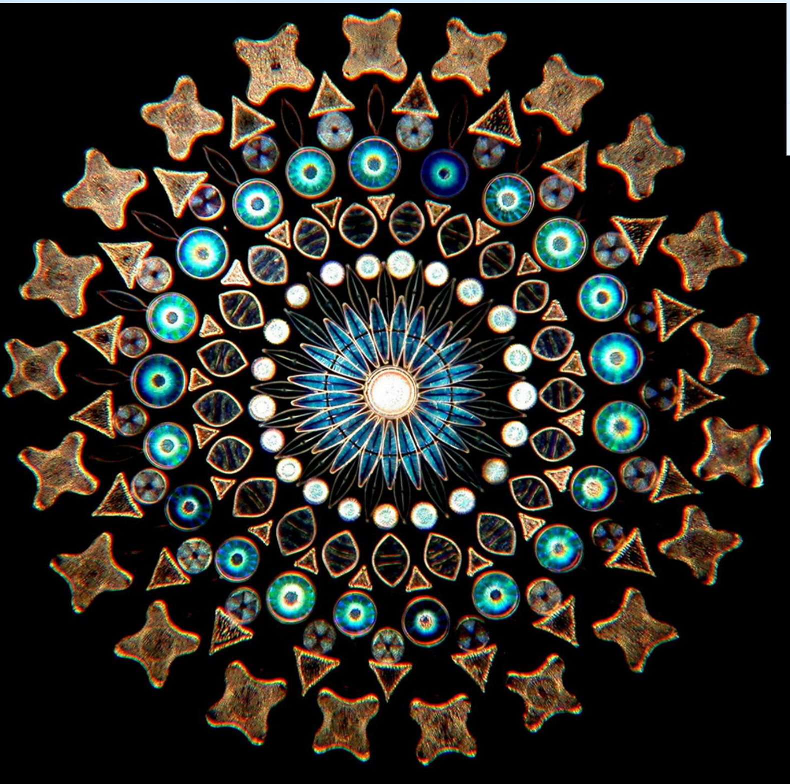
*Diatom reproduction (centrales)

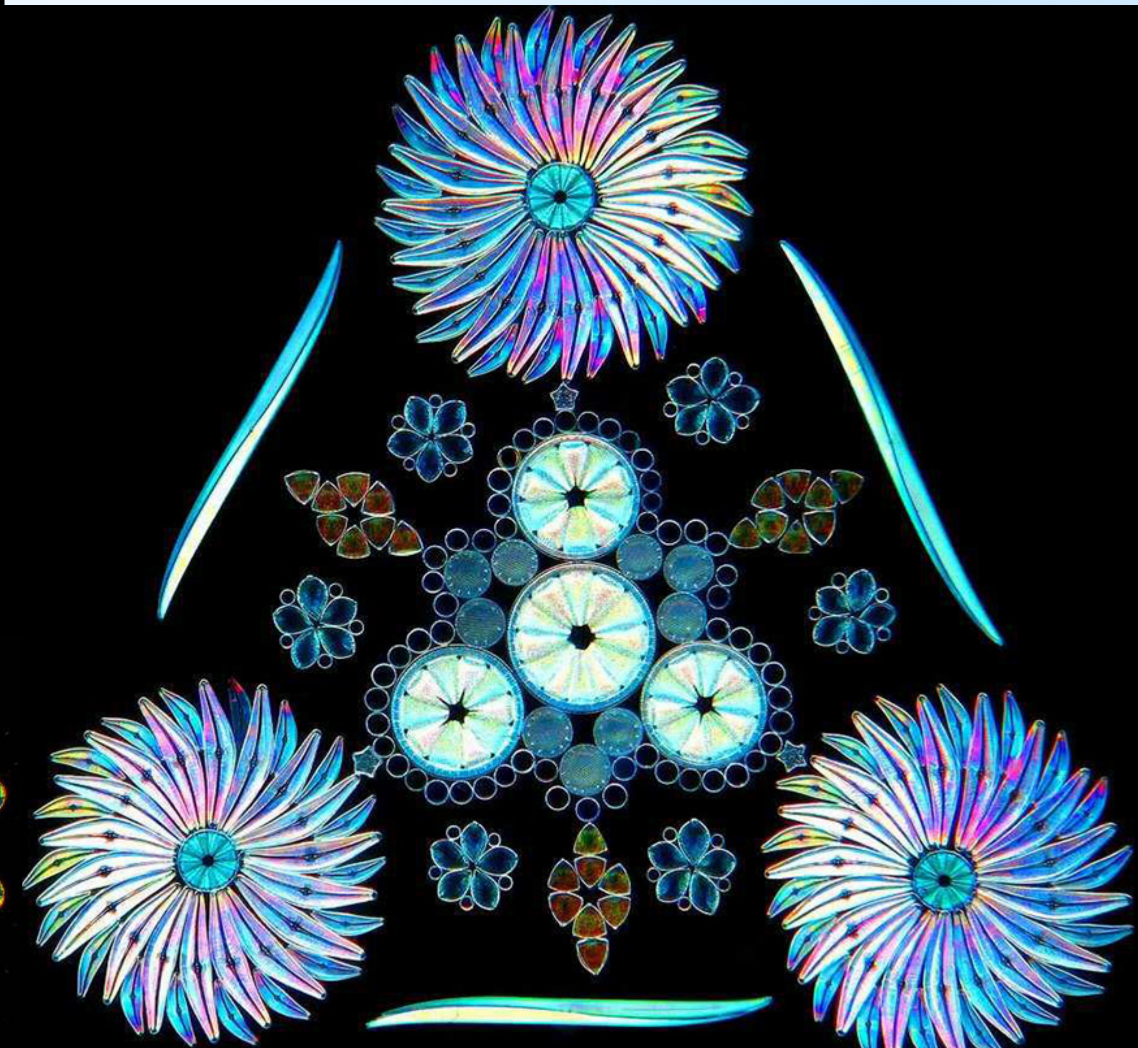


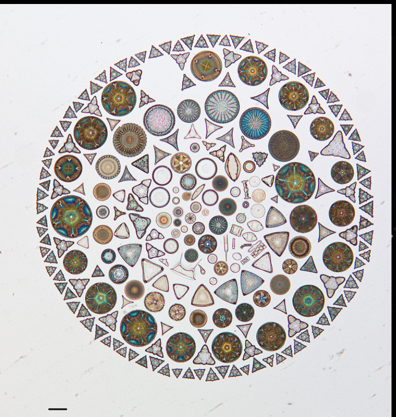
- Asexual reproduction by cell division can only go on so long…get too small!
- Sexual reproduction restores size
- Sperm do have flagella – can direct movement!

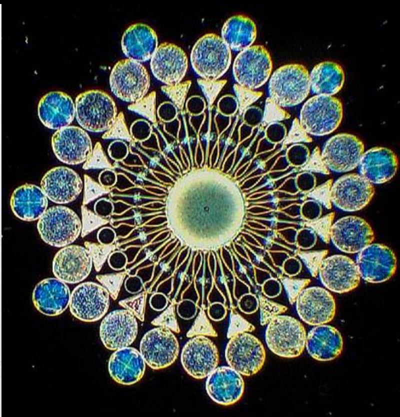
*Diatom art

Watch – The Diatomist, Klaus Kemp (4:26)
https://vimeo.com/90160649



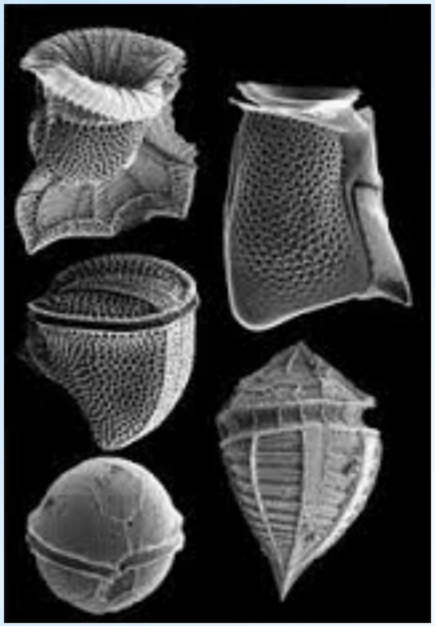




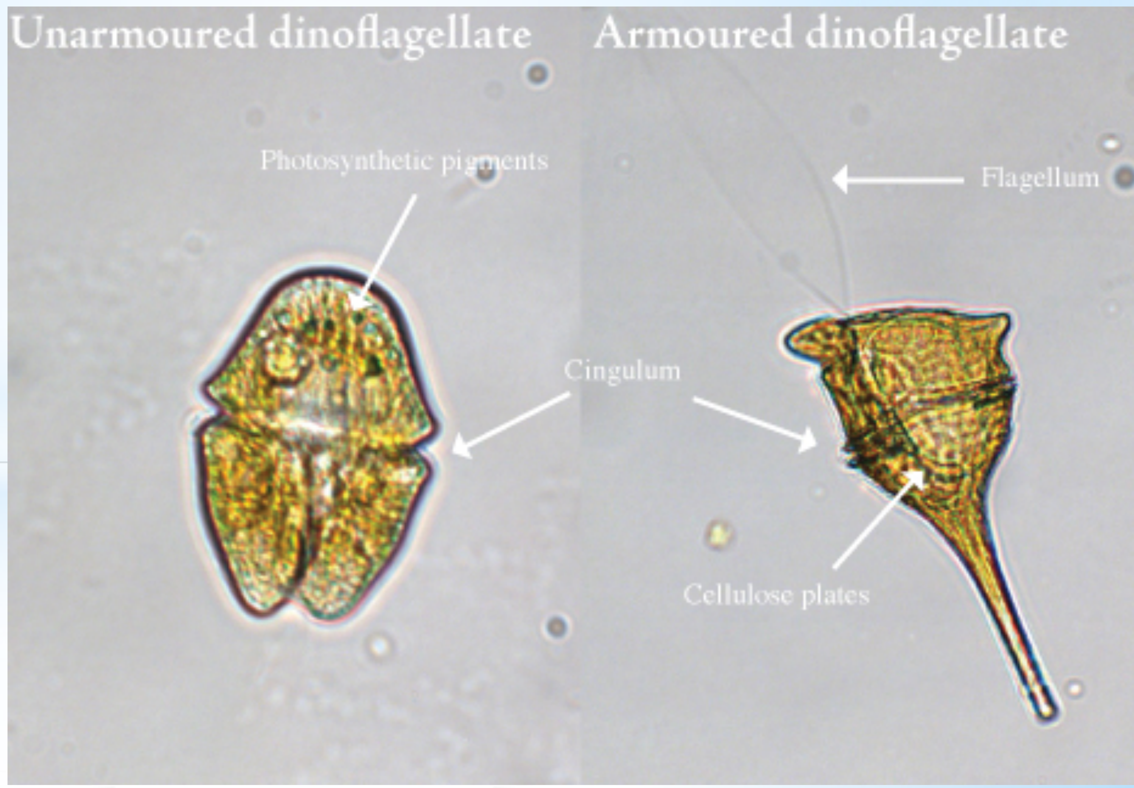


*Dinoflagellates

EUKARYOTES



Mostly unicellular
Cellulose skeleton: “theca”
Most have 2 flagella – able to move
Can contain oil to keep afloat
Some both photosynthesize and capture prey!
Commonly symbiotic with larger organisms



Dissimilar flagella:
- 1 wrapped around middle – “spin”
- 1 out the end – “directional”

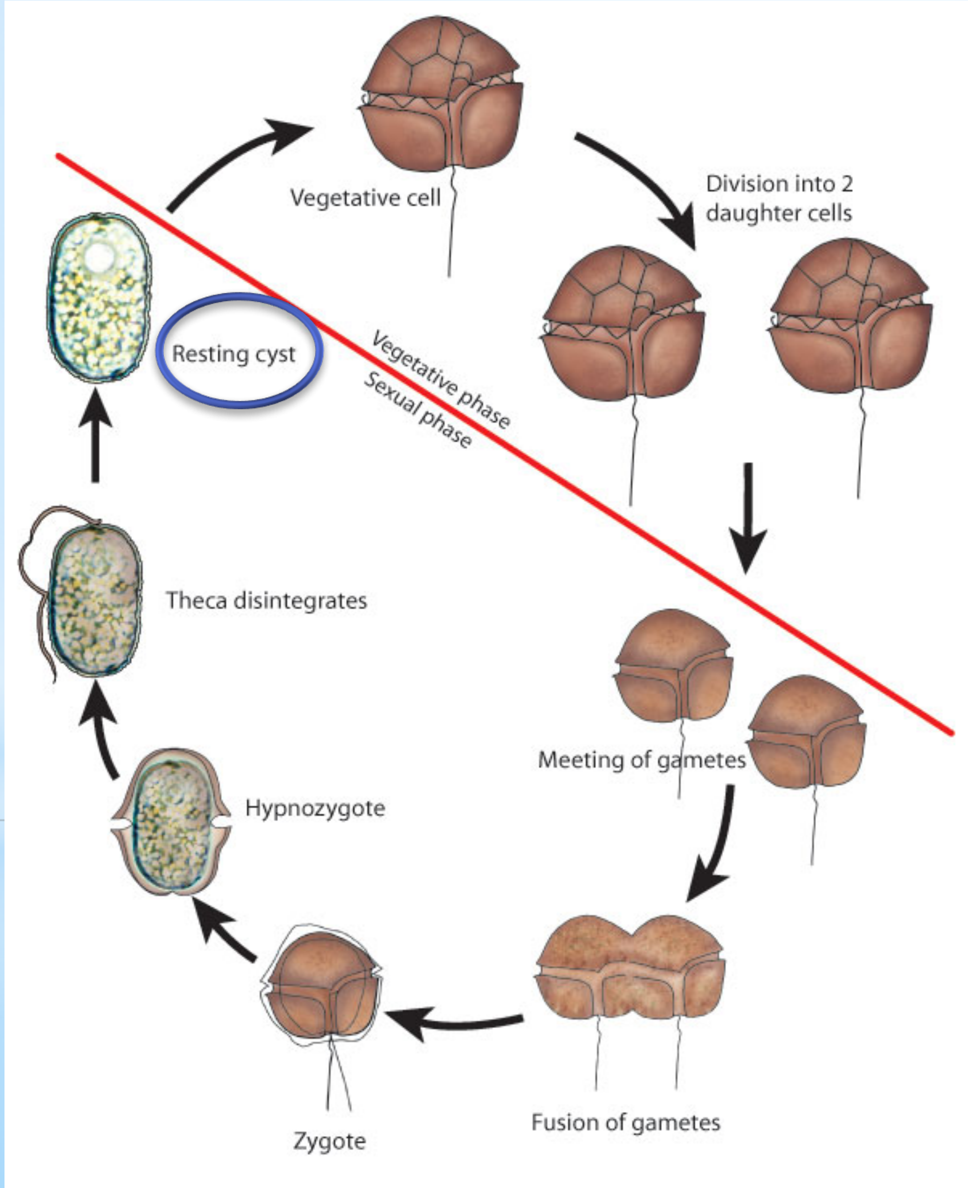
*Dinoflagellate predators

Some dinos can both photosynthesize and capture prey for energy!

- Extend a type of feeding structure called a **pallium** to surround another microbe
- Liquify what's contained by the **pallium**, then bring back in to integrate with its own cell

Dinoflagellate seen extending its pallium around a diatom chain

*Dinoflagellate reproduction



Similar to diatoms – asexual and sexual phases

Dinoflagellates also have a resting cyst phase – a hearty form that can sink to benthos and "hibernate" for seasons or years

Resting cyst phase can be triggered by environmental conditions, makes dinoflagellates very resistant to stress, also means hard to get rid of

*Phytoplankton blooms

Rapid increase in one or more species due to specific environmental conditions

HABs: Harmful Algal Blooms

some dinoflagellates can produce harmful neurotoxins

can accumulate in tissues of filter feeders = **paralytic shellfish poisoning (PSP)**

Mussels –

Filter large amounts, high tolerance

Within 1 hr can accumulate enough toxin to kill a human

Within 1 more hour, can be flushed from system

Butter clams –

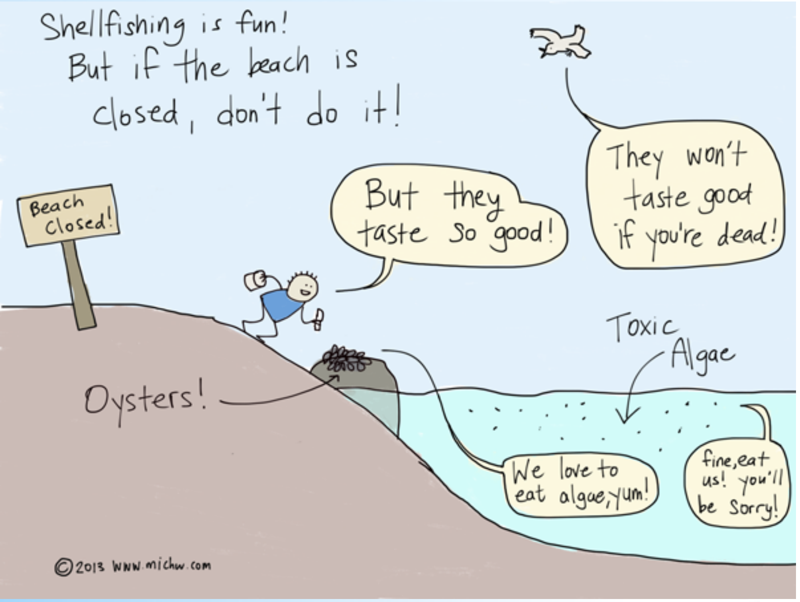
Chemically bind toxins to their tissues

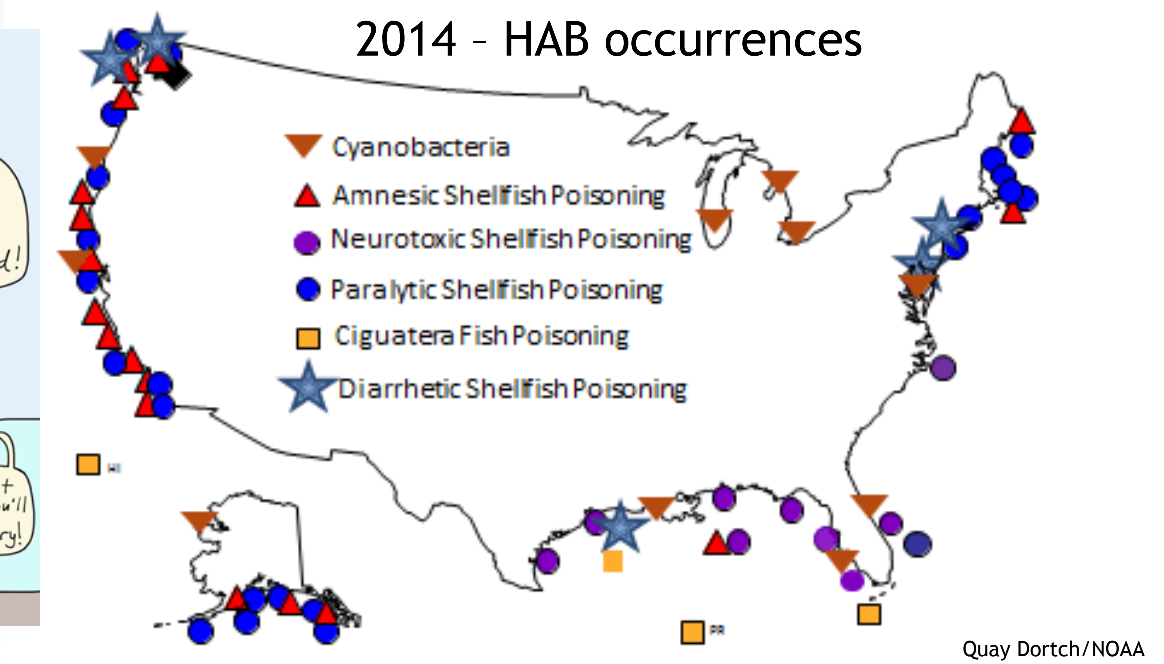
Can retain toxins for up to 2 years after feeding

*HABs and climate change

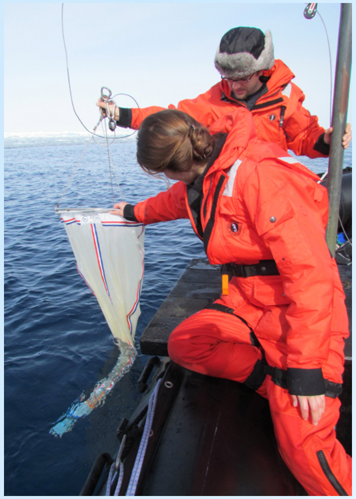
1) Increasing temperatures
   - HAB-causing plankton can outcompete other plankton when water temps are higher
2) Increasing carbon dioxide concentrations
   - More CO_2 available may lead to higher growth rates

Consequences to world fisheries??

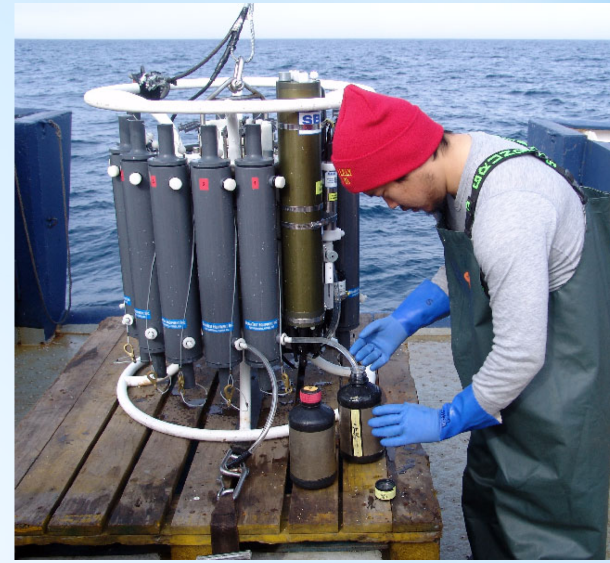




*Studying microbes



Collecting water samples
(nets will crush the littlest ones!)



NOAA

Collecting using plankton nets
(only for the biggest ones!)

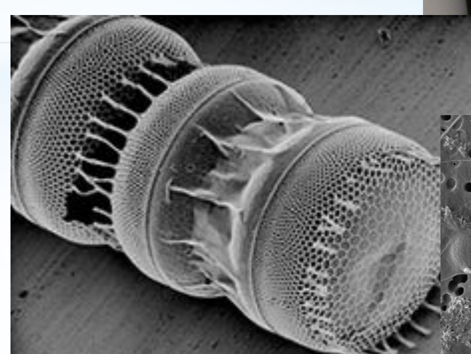
NOAA

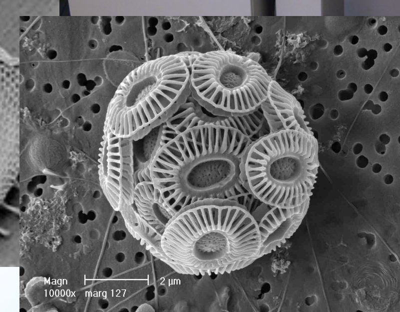
Sorting and identifying

Scanning Electron Microscopy

mtu.edu

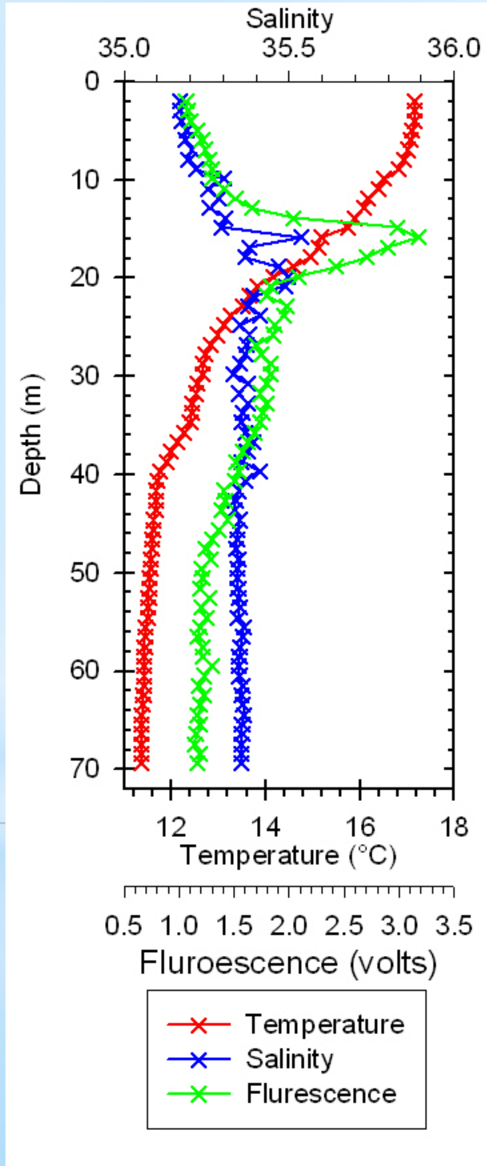
Batch DNA analyses





Jeremy Young

*Estimating primary productivity



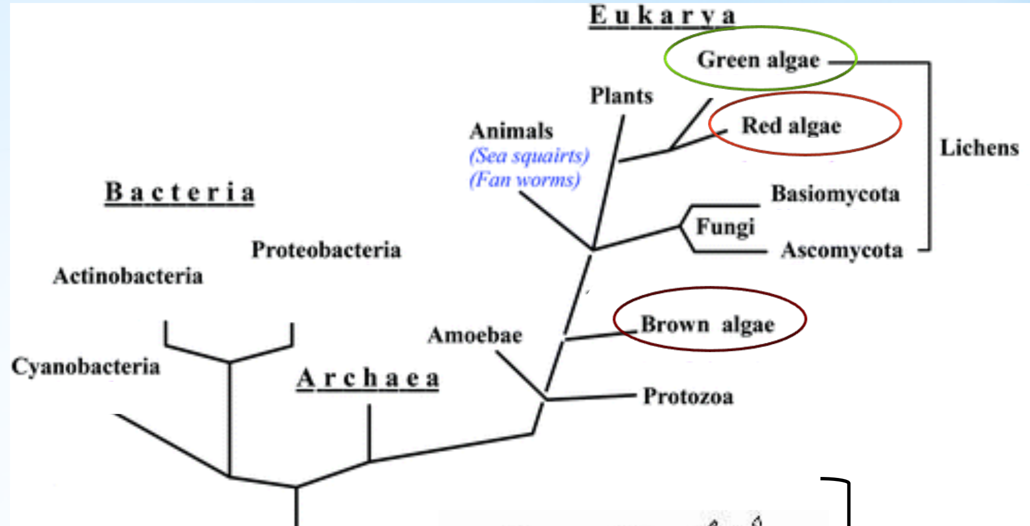
Standard practice is to quantify chlorophyll content

(what is this really telling you?)

Can use a "fluorometer" to measure the in-situ (in water) fluorescence as a proxy for chlorophyll content and thus photosynthetic activity

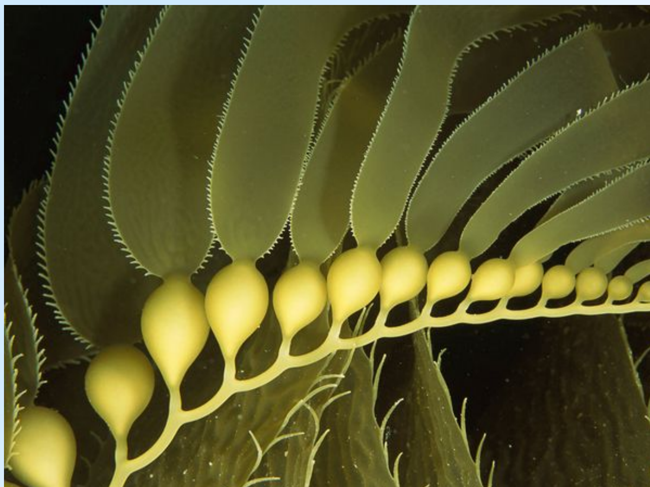
Fluorescence: caused by excitation of photosynthetic pigments by hitting with photons (just like sunlight would do)

*Macroalgae - the seaweeds



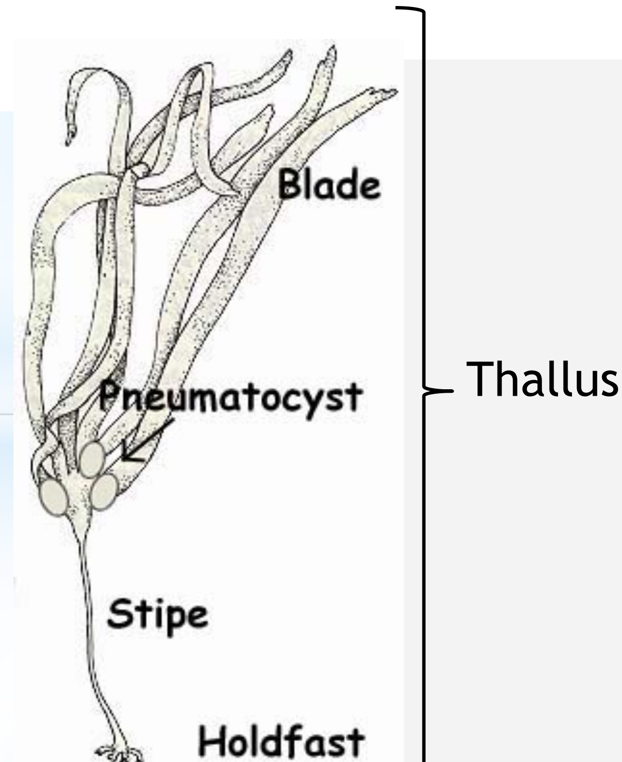
3 groups:

Browns (Phaeophyta)



Reds (Rhodophyta)

Greens (Chlorophyta)

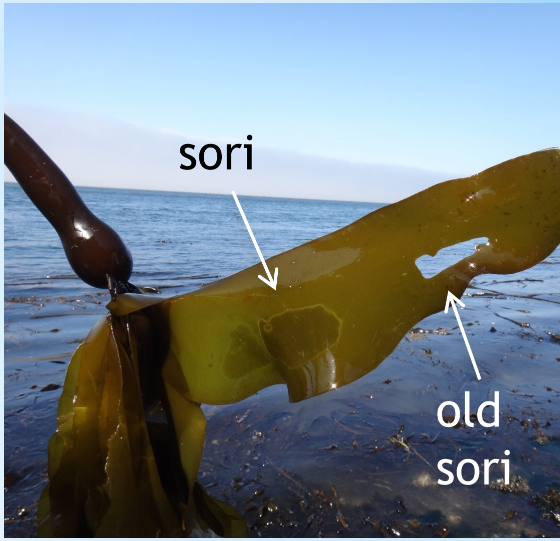


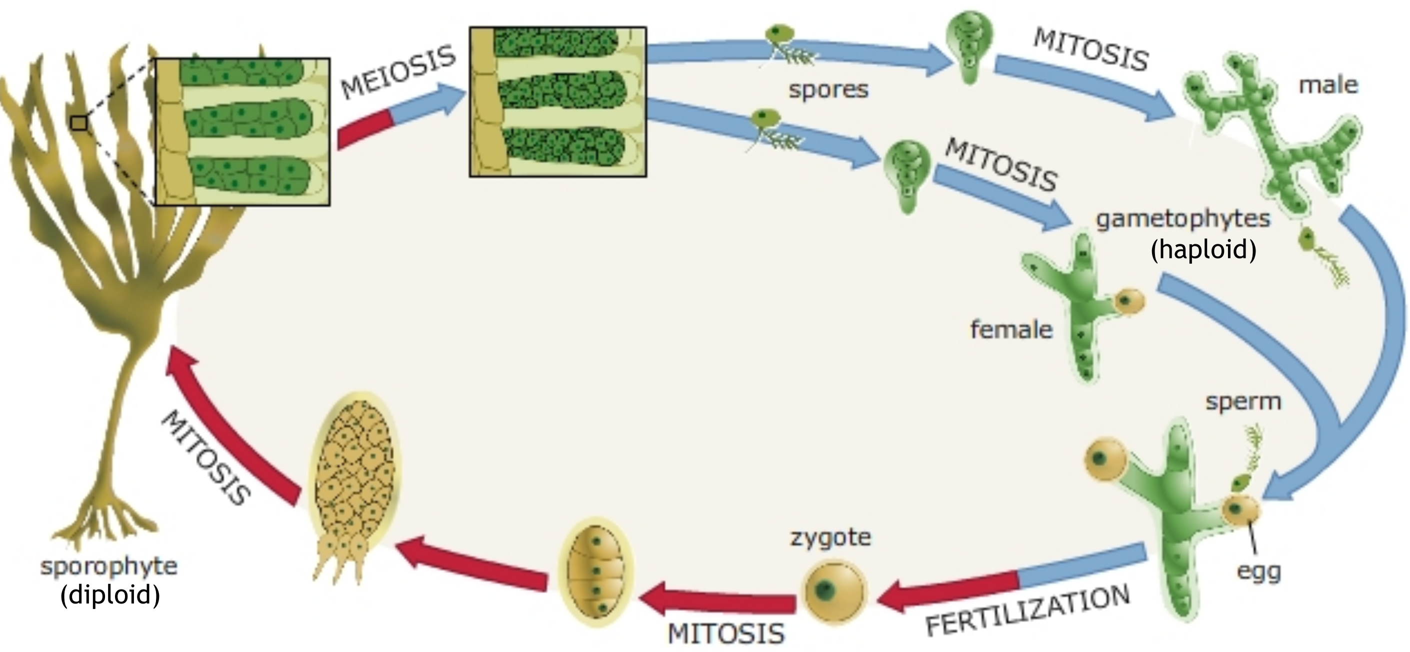
*Reproduction

Alternating life stages - asexual and sexual reproduction (true for most all of the macroalgae!)

For kelps:

- Gametophytes can be microscopic – don't see this life stage
- "Sporophyll" = specialized, reproductive blades
  - → have "sori" = area of spore growth and release





Adapted from *Biological Science* by Freeman © 2008 Pearson Education, Inc.

*Brown algae

- 1500-2000 species (almost all marine)
- Large and highly visible!
- Some species can grow 60 cm per day, to maximum of 60 m (200 ft) total
- Used as food by humans
- Create algal "forests" – centers of high productivity and biodiversity

Rockweed (*Fucus*)

Sea moss

Kelp

"Brown" because of pigment FUCOXANTHIN

*Red algae

- 5000-6000+ species (most are marine)
- Due to photosynthetic pigments, can absorb light at greater depths than other algae, can live deeper
- Coralline algae secrete hard shell of coralline around them – reef building!
- Also used as food by humans
- Used to produce ‘agars’ = gelatin (might be in your ice cream!)

“Dulse” – eaten all over the world

Coralline algae
(upright or encrusting)

“Red” because of pigment PHYCOERYTHRIN

*Green algae

- 8000+ species (mostly non-marine)
- Includes many of the phytoplankton
- Unicellular forms can live **symbiotically** with other organisms
- Usually finer, more fragile than other algal groups
- Typically found at shallower depths
- Surprise! Also eaten by humans

Sea lettuce (*Ulva*)

Sea hair

M. Lindeberg

Spongy cushion (*Codium*)
(a.k.a. tar blobs)

"Green" because of pigments CHLOROPHYLL *a* & *b*

* Environmental conditions for macroalgae growth

Need:

- Adequate **light** in the correct color spectrum
- Adequate **nutrient** and gas concentrations in the water
- Tolerable **temperature** range
- Stable substrate to hold on to
- Tolerable wave and tidal exposure

sound familiar?



* ORGANISMS: MICROBES AND MACROALGAE

Start thinking about your proctor for MIDTERM EXAM during week of Oct. 19th

If need help, talk to Emy Roles – aroles@uas.alaska.edu

See you next week – Oct. 5th

Wikimedia commons