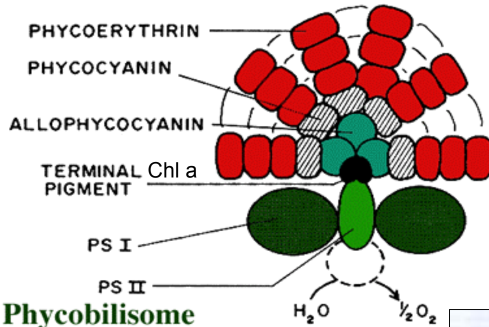
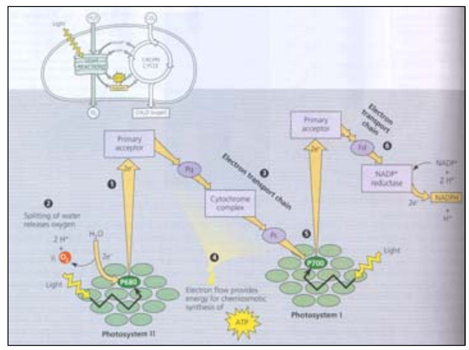


Phycobilisome



Chl a is part of photosystem II

Phytoplankton

Introduction

• Plankton: "the drifters" free floating in the water without association with submerged substrates

• Phytoplankton: (Greek: "plant wanderer") algal components of the plankton (as opposed to zooplankton and bacterioplankton)

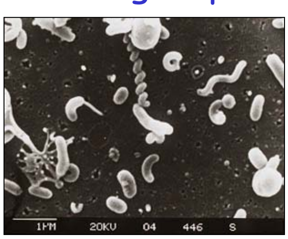
• Mostly microscopic one-celled algae

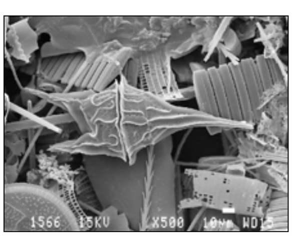
• Well developed communities in oceans and lakes (in general do poorly in flowing waters such as rivers – some in slow moving stretches of rivers)

•Phytoplankton represent a diverse groups of organisms from many taxonomic groups

Size Classes:

Often grouped according to size……..





• Picoplankton = <2 µm

• Nanoplankton = 2-20µm

• Microplankton = 20-200µm (collected in standard plankton nets)

Primary Production

- Phytoplankton are at the base of marine food chains or webs → primary producers

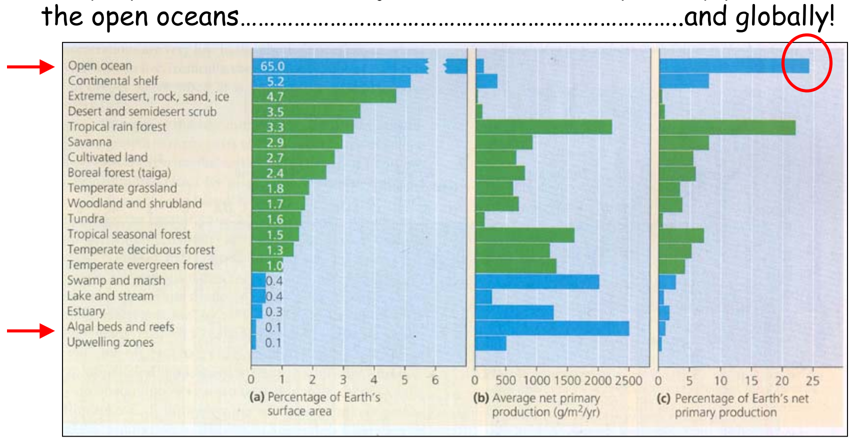
•Primary Production: the amount of light energy converted to organic compounds by an ecosystems autotrophs during a given time period

•Measurements: (rates)
- energy per unit area per unit time (J/m_2/year)
- biomass per unit area per unit time (g/m_2/year)

- Important players→ phytoplankton produce over 99% of the food supply for marine animals

Primary Production

- Phytoplankton are the major contributors to primary production in the open oceans……………………………………………………………and globally!



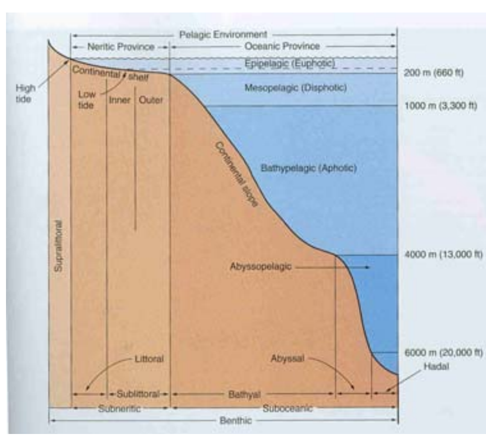
•Photosynthesis carried out primarily by:
- Phytoplankton – open ocean
- Macroalgae – along the coast

Environmental Factors

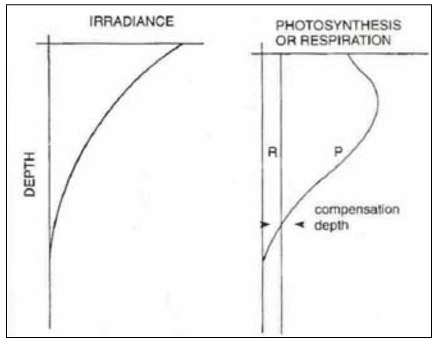
- Light
- Nutrients
- Stratification

Light

- Major factor limiting new cell production
- Limited to growth in the photic zone – near the surface
- Photic zone
    - euphotic zone <200m (good light)
    - disphotic zone 200-1000m (small but measurable light)



Light (cont.)



- Compensation depth = depth at which photosynthesis is equal to respiration (net production = 0)
- Below this depth = phytos die (can't grow and deplete reserves)
- Above this depth = phytos grow and are happy

Light (cont.)

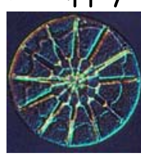
- Chloroplasts
  - Some loss of plastids (secondarily lost but phylogenetic trees show common origin)
- Pigments
  - Different species have different ones
  - All that have chloroplasts have Chl a
- Some have:
  - carotenoids (can help protect from UV light)
  - phycobillins (common in reds, cyanobacteria)
  - xanthophylls (common in browns)

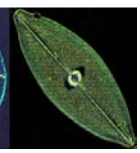
Nutrients

- Major factor limiting new cell production (especially N, Fe)

- Nutrient Sources:
  - Rivers, streams, and agriculture (runoff)
  - Upwelling
  - Recycling (messy eaters)
  - Atmosphere (CO_2, N_2)

- Nutrient uptake:
  - Advantage of small size
  - Simple diffusion to supply nutrients and remove wastes - large SA/V ratio

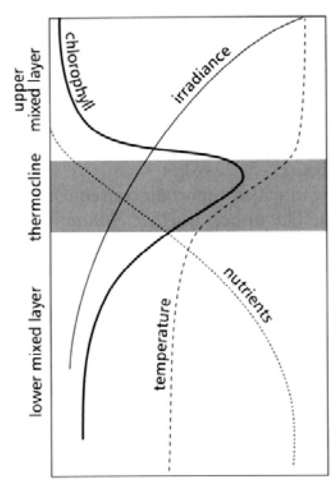


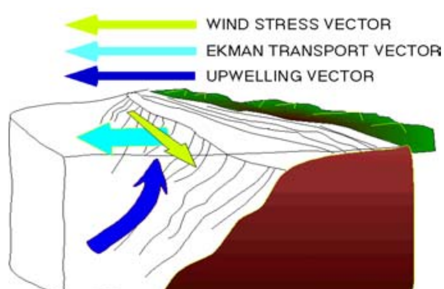


Nutrients (cont.)

Upwelling

Nutrients are generally low in surface waters higher at depth





COASTAL UPWELLING

Seasonal Upwelling

- Spring (locally) offshore winds
- Cause Blooms

Importance of Iron….

- In nitrogen rich waters – what is limiting???
- NH_4^+ (Amonium) is utilized directly
- NO_3^- (Nitrate) assimilation by nitrate reductase requires iron
- Algae need iron to utilize Nitrate (NO_3^-) as a nitrogen source

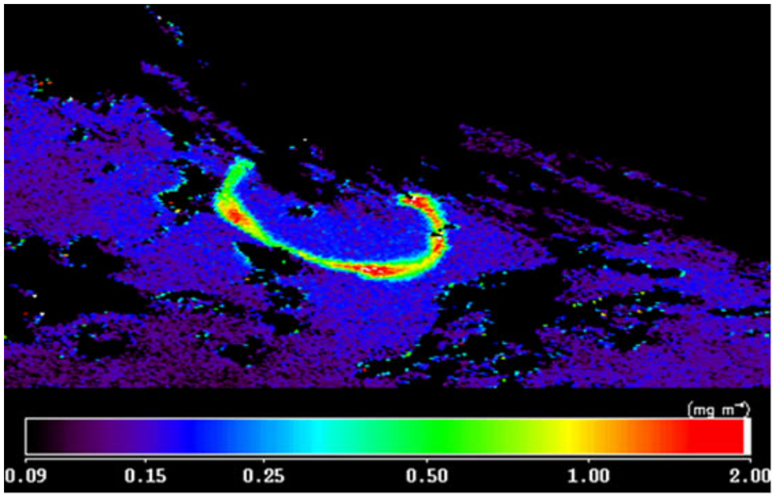
Importance of Iron….

"With half a shipload of Fe, I could give you an ice age"

John Martin's Hypothesis
- 1988 (MLML)
- iron limits phytoplankton production in nutrient rich seas

Reasoning:
- Phyto bloom would take CO_2 out of the atmosphere
- CO_2 is a greenhouse gas causing global warming

- Iron addition experiment in the southern ocean (500 miles south of the Galapagos Islands– Mid November 1993
- John died of cancer before he could see the outcome
- Phytoplankton ↑ 85X
- Expt. repeated in 1995 with similar results



Satellite picture of a phytoplankton bloom in the Southern Ocean induced by iron fertilization
(** not experiment from '93-95)

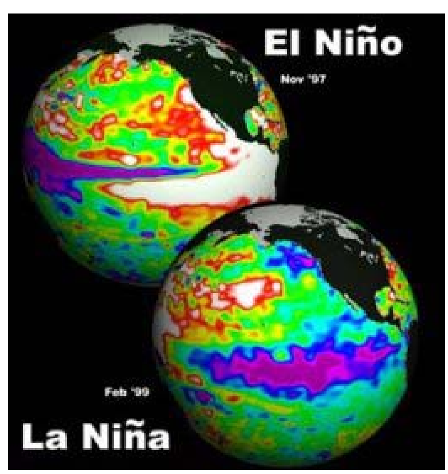
Nutrients (cont.)

El Nino / La Nina

El Nino / La Nina influence on nutrients:

- El Nino – Warm water blocks upwelling of nutrient – lowers phytoplankton abundance

- La Nina – surface waters cool, bringing cold nutrient rich water to surface (upwelling) – raises phytoplankton abundance



Nutrients (cont.)

Eutrophication


Too much of a good thing (primarily in lakes and nearshore coastal habitats):

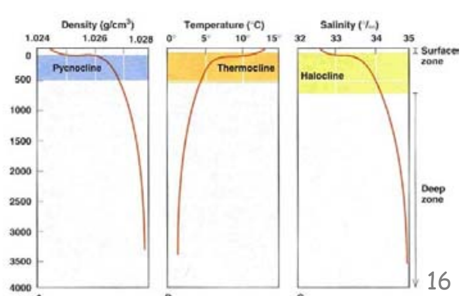
- Excess nutrients can cause eutrophication
- Over enrichment of N + P
- Excessive growth of algae out-competes other organisms

Stratification of Water Column Influences Light and Nutrients

Stratification:
•development of layers of water with different densities
• boundary between these density layers is the pycnocline
• barrier to vertical mixing

Set up by:
- •Thermocline – temp gradient
- •Halocline – salinity gradient

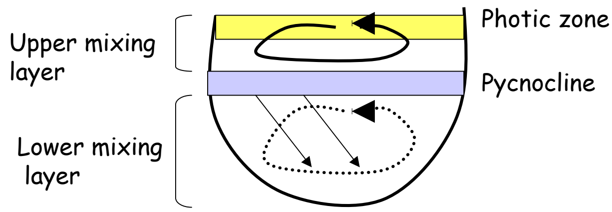
Changes in different seasons
- •Summer = shallow
- •Winter = deeper



Stratification (cont.)

Stratification influences:

- time spent in the photic zone
- nutrient availability (e.g. nutrients sink)



•The photic zone is often shallower than the mixed layer but cells circulating in the mixed layer are continually brought into the photic zone

•Pycnocline limits vertical mixing to the upper regions of lakes and oceans, once cells sink below it they are lost from the pop.

Ecology

Population Growth of Phytoplankton

Pop growth = rate of new cell production – rate of cell loss (sedimentation/sinking + grazing)

•Floating and sinking

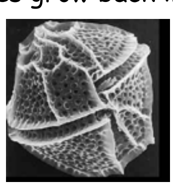
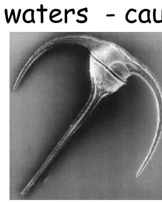
•Grazing

Floating and Sinking

- Most phytos are denser than water + tend to sink
- Stay suspended by water movements and viscous (resistance of fluid to something moving through it) drag (mechanical force of a solid moving through a fluid)
- Viscous drag slows sinking rates
- Shape: Elongate cells have more SA/V ratio than spherical cells – slow sinking in elongate
- Colonial chain forming arrangements slow sinking
- Water mixing suspends cells
- Gas vesicles of cyanobacteria decrease density and produce positive buoyancy

Adaptations to slow sinking or aid in resuspension….

- Dinoflagellates:
  - spines break off in rough waters – cause sinking
  - spines grow back in calm waters - cause floating

- Some species replace carbs with lipids as a storage product (oils = more buoyant)
- Ionic exchange:
  - move ions in and out of cell to increase or decrease density
- Swimming with flagella (phototaxis)

Ecology

Grazers

Herbivores reduce phyto pops by….

•Suspension feeding (filter water)

•Direct feeding

•May remove size specific individuals

•May remove less resistant Phyto species – non-toxic spp

•Results in patchy distributions

Grazers may also ↑ Phyto pops by releasing nutrients through excretion (positive effect)

Ecology

Grazers (cont.)

Phyto defenses:

- Increase rates of production
- Mucilage sheaths
- Thick walls
- Hard external coverings
- Spines are more for buoyancy but could also protect
- Form colonies (become too large for some zooplankton to handle
- Chemical deterrents (toxic species)

Phytoplankton as indicators of changing environments

•phytos depend upon sunlight, water, and nutrients

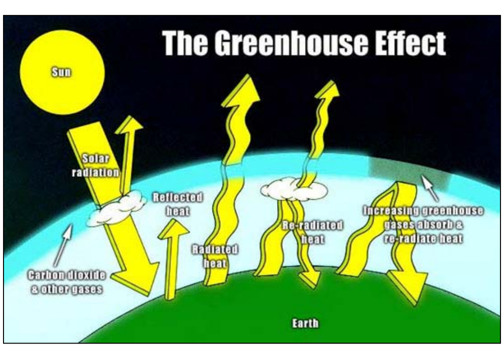
•variance in any of these factors over time will affect phyto concentrations

•phytos respond very rapidly to environmental changes

•Changes in the trends for a given phyto population (i.e. density, distribution, or pop growth rates) will alert scientists that environmental conditions are changing

•Good indicator for change in the environment

Phytoplankton influence on global climate



•CO_2 major constituent of greenhouse gases contributing to global warming

•Phytoplankton use CO_2 for photosynthesis

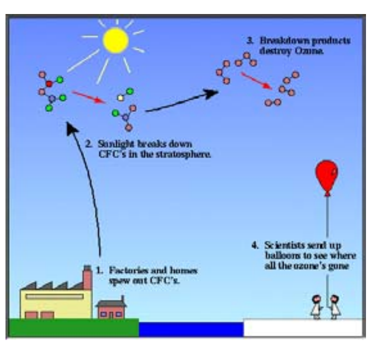
•More phytoplankton = more CO_2 gets pulled from the atmosphere

•Lower greenhouse gases = less retention of heat

Effects of Ozone Layer Depletion on Phytoplankton Production

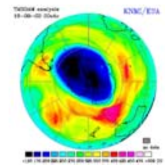
- Ground level ozone is a human health hazard (component of smog)
- Stratospheric ozone is good (absorbs harmful UVB to keep it from reaching earth)
- Depletion occurring in the Antarctic - since late 1970's
- Caused by human production of chlorofluorocarbons (CFC's - chemicals used in spray cans, foam packaging, and refrigeration materials)

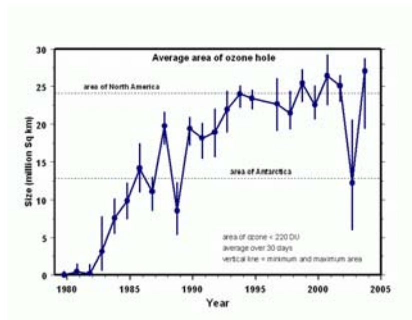
Effects of Ozone Layer Depletion on Phytoplankton Production



- CFC's are catalyzed into a reaction (by cold temps (-78°), and sunlight) to produce chlorine monoxide (ClO)
- The ClO combines with stratospheric ozone (O_3) to chemically destroy it

Effects of Ozone Layer Depletion on Phytoplankton Production





- Ozone (O_3) depleted seasonally in the spring
- Results in seasonal ozone hole
- Persists for 2-month period over Antarctica then travels to New Zealand and Australia
- The hole is now the size of North America (~9 million square miles)

Effects of Ozone Layer Depletion on Phytoplankton Production

Effect of ozone depletion on phytos:

- Increase in UVB radiation (wavelength most damaging to DNA)
- Decrease in phytoplankton production during this period (among other things)

**Arctic ozone hole not as bad as Antarctic (Arctic low temps do not last as long)

Phytoplankton Diversity

Division: Cyanophyta (blue-greens)
Division: Chlorophyta (greens)
Division: Dictyocophyta (siliciflagellates)
Division: Xanthophyta (yellow-greens)
Division: Euglenophyta (fresh water)
Division: Chrysophyta (golden algae)
Division: Haptophyta (coccolithophores)
Division: Pyrrophyta/Dinophyta (dinoflagelates)
Division: Bacillairophyta (diatoms)
  Order: Centrales
  Order: Pennales

** most groups have a non-photosynthetic group
*** this is not a comprehensive list

Division: Bacillariophyta (Diatoms)

•Most abundant group

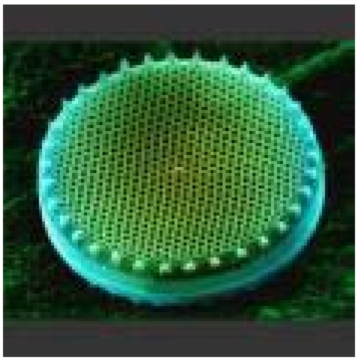
•Unicellular, sometimes colonial (chain forming)

•Found in almost every aquatic habitat (major component of marine)

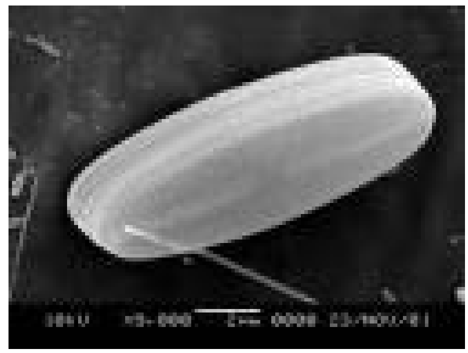
•Can be planktonic or benthic

Diatoms (cont.)

Order: Centrales



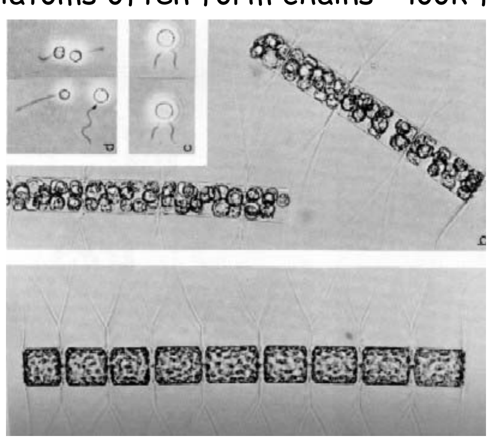
Order: Pennales



Centric vs. Pennate morphologies

Diatoms (cont.)

Centric diatoms often form chains – look filamentous

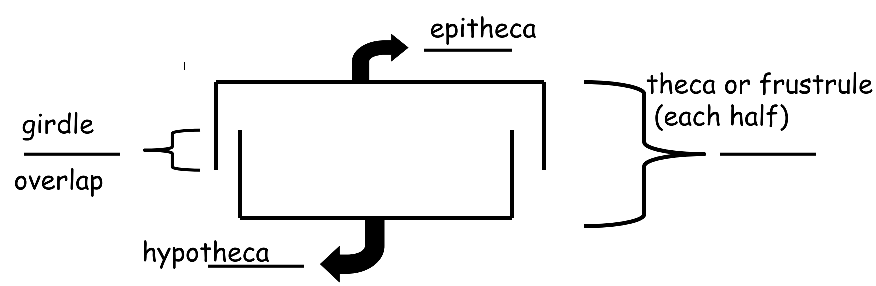


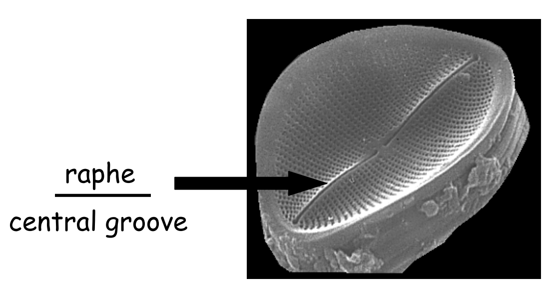
Diatoms (cont.)

Morphological terms:

- Two-part boxlike cell walls called “frustrules”
- Cell walls composed of silica (abbreviation for silicon dioxide, SiO_2)
- Girdle is area of overlap of frustrules

Diatom Morphology





Diatoms (cont.)

Movement

- They secrete crystalline structures through holes in the raphe or frustrules
- These structures expand in H_2O
- This causes movement in opposite direction
- Movement regulated depending on which holes they secrete through

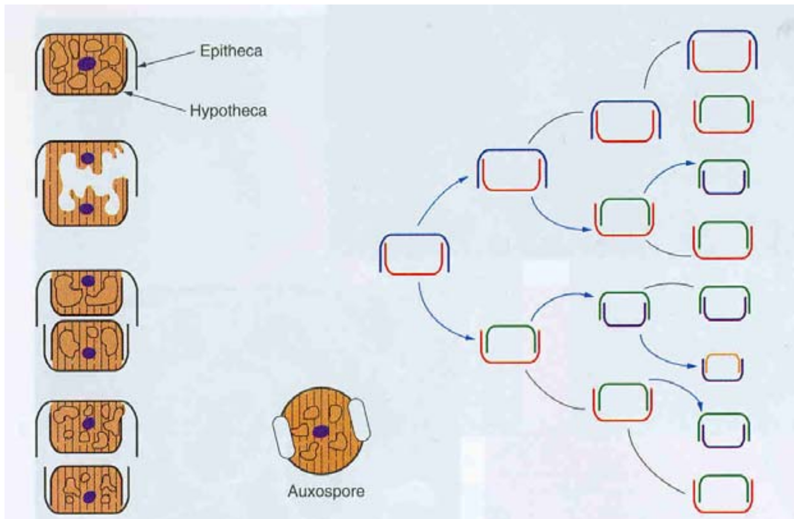
Diatoms (cont.)

Reproduction

- Division rates exceed one per day
- Asexual and sexual

Diatoms (cont.)

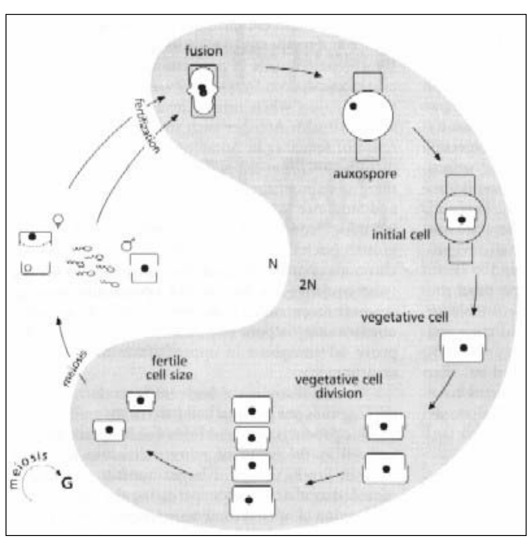
Asexual Reproduction



37

Diatoms (cont.)

General Life History…..



38

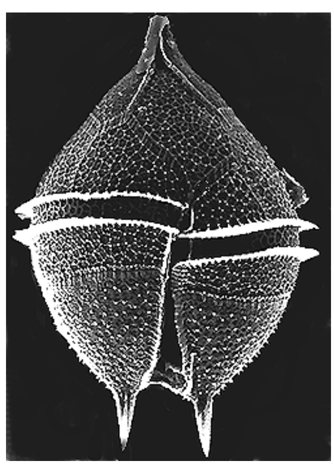
Diatoms (cont.)

<u>Only phytoplankton with economic value</u>

Diatomaceous earth:

- Mined for filtration purposes , water filters (porous)
- Pesticides (plugs up trachea)

Division: Dinophyta (Pyrrophyta)



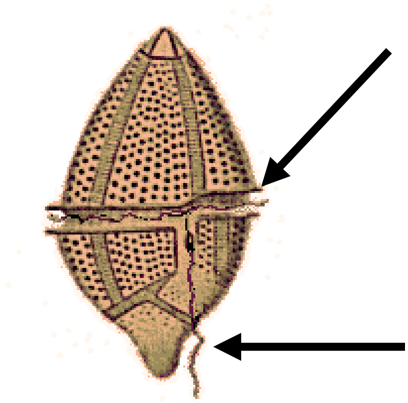
Greek: Pyrrhos = "fire"
after bioluminescent forms

Dinoflagellates

Greek: "whirling flagella"

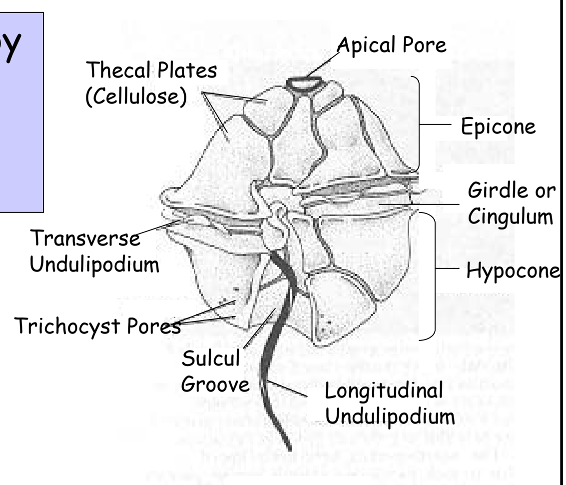
Morphology

• Posses two unequal flagella (at right angles to each other)
• cell wall made up of cellulose plates (a carbohydrate) which easily decomposes



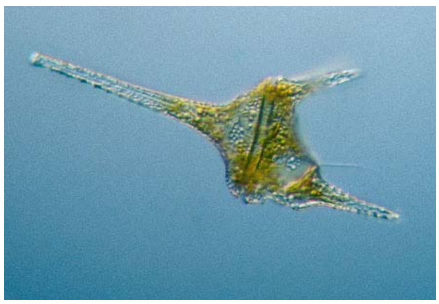
Morphology (cont.)

Determine Genus by the number and arrangement of thecal plates



Spines

- Larger SA/V
- Helps to stay suspended in water column



Movement

• have a slight capacity to move into more favorable areas to increase productivity

•use flagella to move

• whiplash flagella lies in groove (suclus), when it beats it is propelled in the opposite direction

• band-shaped flagella encircles the dino and lies in a groove (cingulum), this flagella allows for turning and maneuvering

• some dinoflagellates (<5%) have eyespots that allow detection of light source (mostly fresh water)

•trichocysts???

Feeding and Plastids

• can be heterotrophic (eats food) or autotrophic (makes own food)

• use flagella to capture prey; trichocysts??

• some show secondary loss of plastids

• if they are photosynthetic and have plastids, then the plastid has a triple membrane

•pigments:
- chl a,c
- xanthophyll
- peridinin (makes red in red tides) (carotenoid)

Mesocaryotic

The dinoflagellate nucleus is unusual:

•do not have histones (basic proteins which the DNA coils around)

• Dinoflagellates have more DNA in their nucleus than other eukaryotes

• DNA fills half the volume of the cell. (up to 400 chromosomes)

• chromosomes are attached to the nuclear membrane

•the nuclear membrane does not break down

• chromosomes remain condensed during mitosis **and interphase**

• they do unwind for DNA replication

•This unusual nuclear situation is termed **mesokaryotic**

Division: Dinophyta (Pyrrophyta)

Bioluminescense

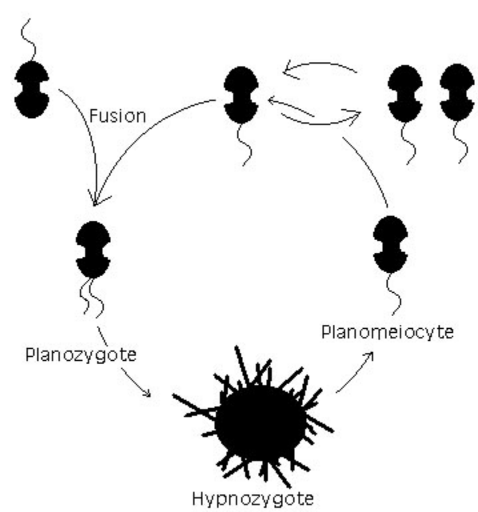
- ancient mariners thought "the burning seas" were of supernatural origin
- the next hypotheses were that the light was emitted from salt molecules or burning phosphorous
- In 1830, scientists agreed it was biological in origin
- Dinophyta are the primary contributors to bioluminescence in the marine habitat
- In bioluminescence, energy from an exergonic (spontaneous; energy released) chemical reaction is transformed into light energy
- Compound responsible is luciferin (term for general class of compounds) which is oxidized and results in the emission of light

Division: Dinophyta (Pyrrophyta)

Life History

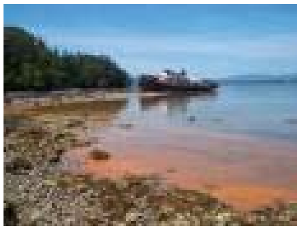
Normal conditions:
→Asexual

Stressful conditions:
→Fuse with another dino to form hypnozygote (resilient resting stage)



Division: Dinophyta (Pyrrophyta)

Red Tides

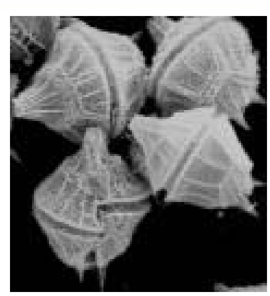


- major contributors to red tides
- abundant from Spring to Fall (April – September in northern hemisphere)
- [Conc.] up to 2 million dinos/liter

Division: Dinophyta (Pyrrophyta)

Red Tides (cont.)

- Potential tragic human epidemic in Massachusetts in 1972
- No deaths, 30 cases reported
- From *Gonyaulax* which causes paralytic shellfish poisoning
- Symptoms similar to drunkenness:
  - Incoherent speech
  - Uncoordinated movements
  - Dizziness
  - Nausea
- Documented cases throughout the world include
  - 300 deaths
  - 1750 nonfatal cases
- There is no known antidote
- Critical period passes within 24 hrs.



Another Toxic Dinoflagellate:

- Ciguatera fish poisoning

- Affects humans who eat fish poisoned by *Gambierdiscus toxicus* accumulated in fish

- Two potent toxins:
  - Ciguatoxins
  - Maitotoxins

- Diarrhea for 2 days, general weakness for 1-2 days after

- Affects 10,000 to 15,000 people annually

- Common in the Tropics