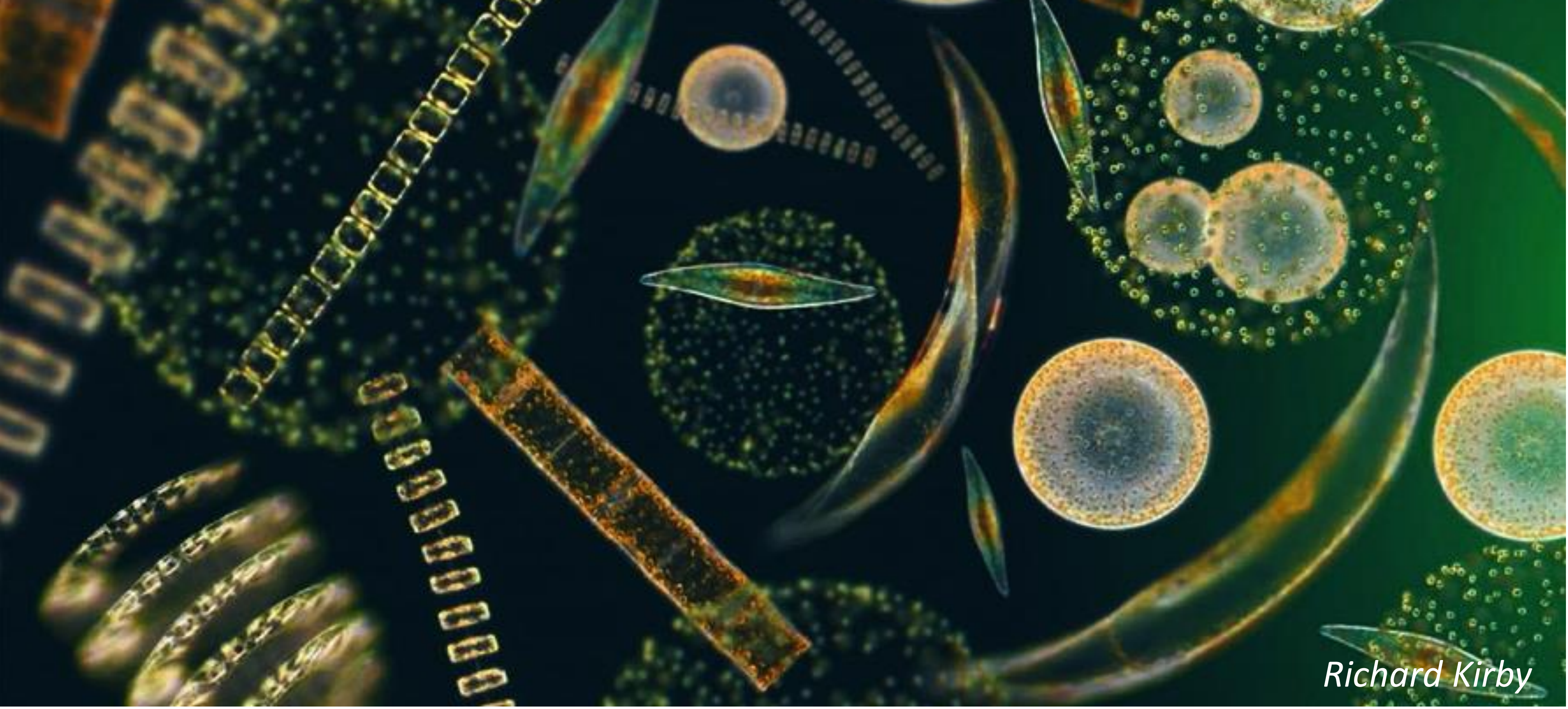



# WHAT ARE PHYTOPLANKTON?

## FOLLOWED BY MORE PHYTOPLANKTON BY MARY JANE

**IVONA CETINIĆ**

NASA GODDARD SPACE FLIGHT CENTER / USRA

@teuta

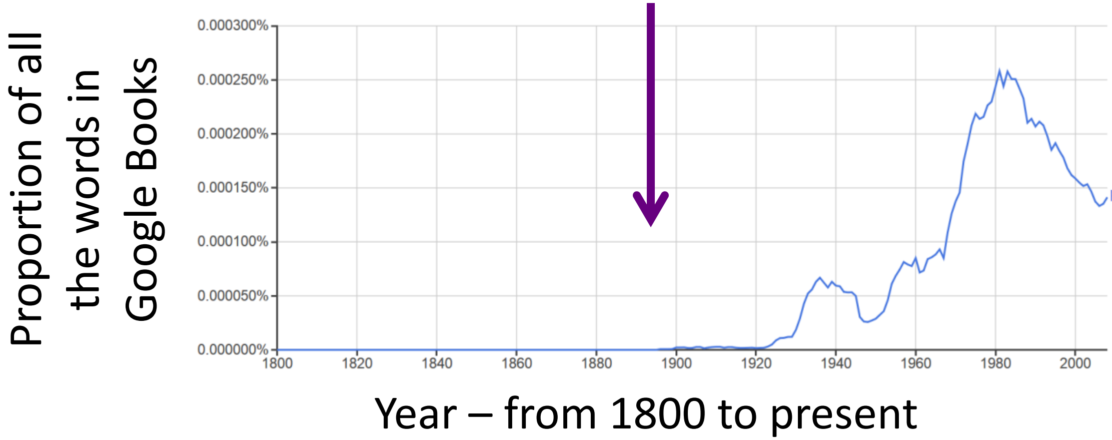
ON THE PIECE OF PAPER PROVIDED, ANSWER THESE THREE QUESTIONS:

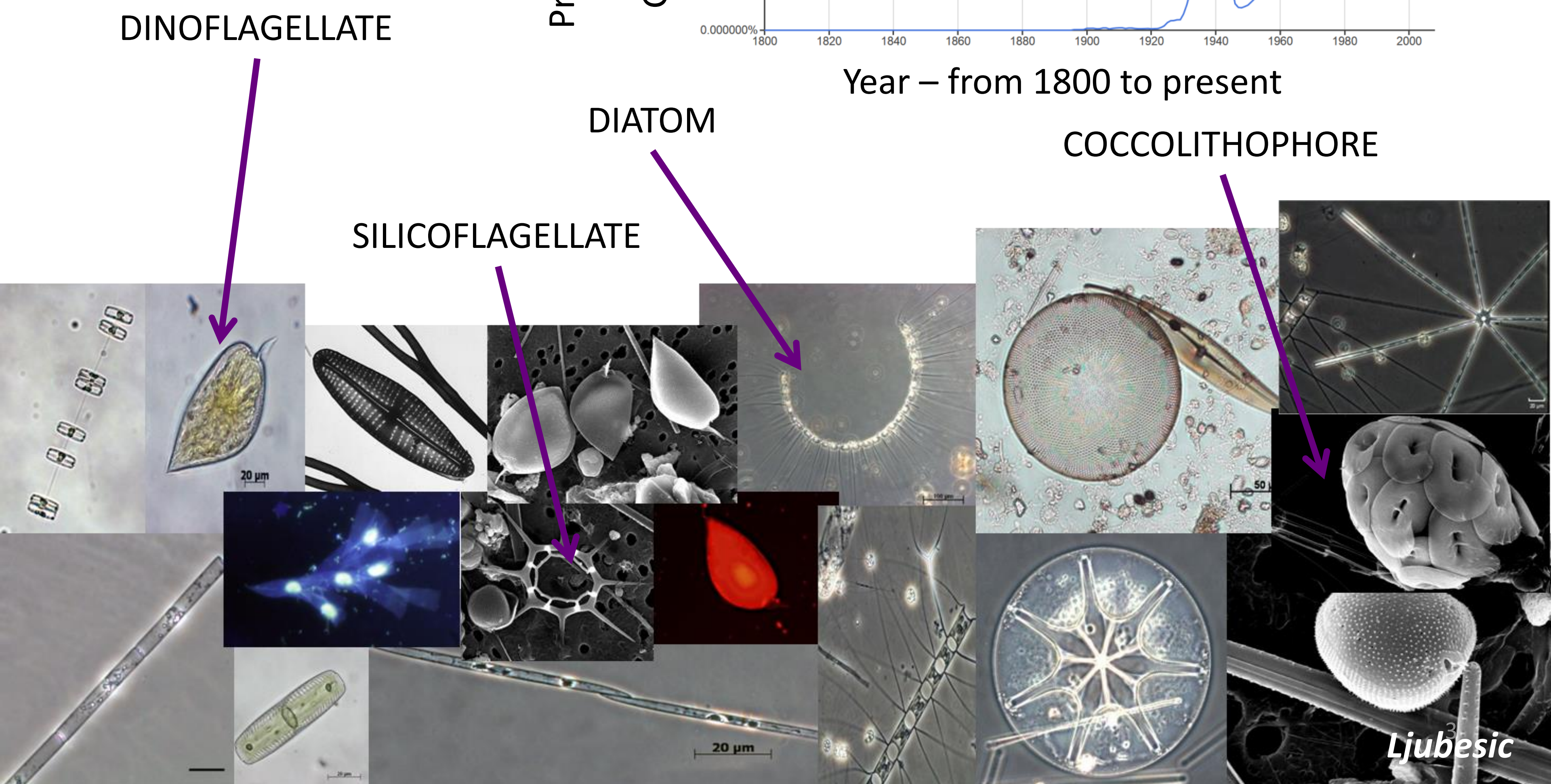
**What are phytoplankton?**
(one sentence max)

**How are phytoplankton assessed?**
(top approach)

**Why are phytoplankton important?**
(top reason)

# *PHYTOPLANKTON*



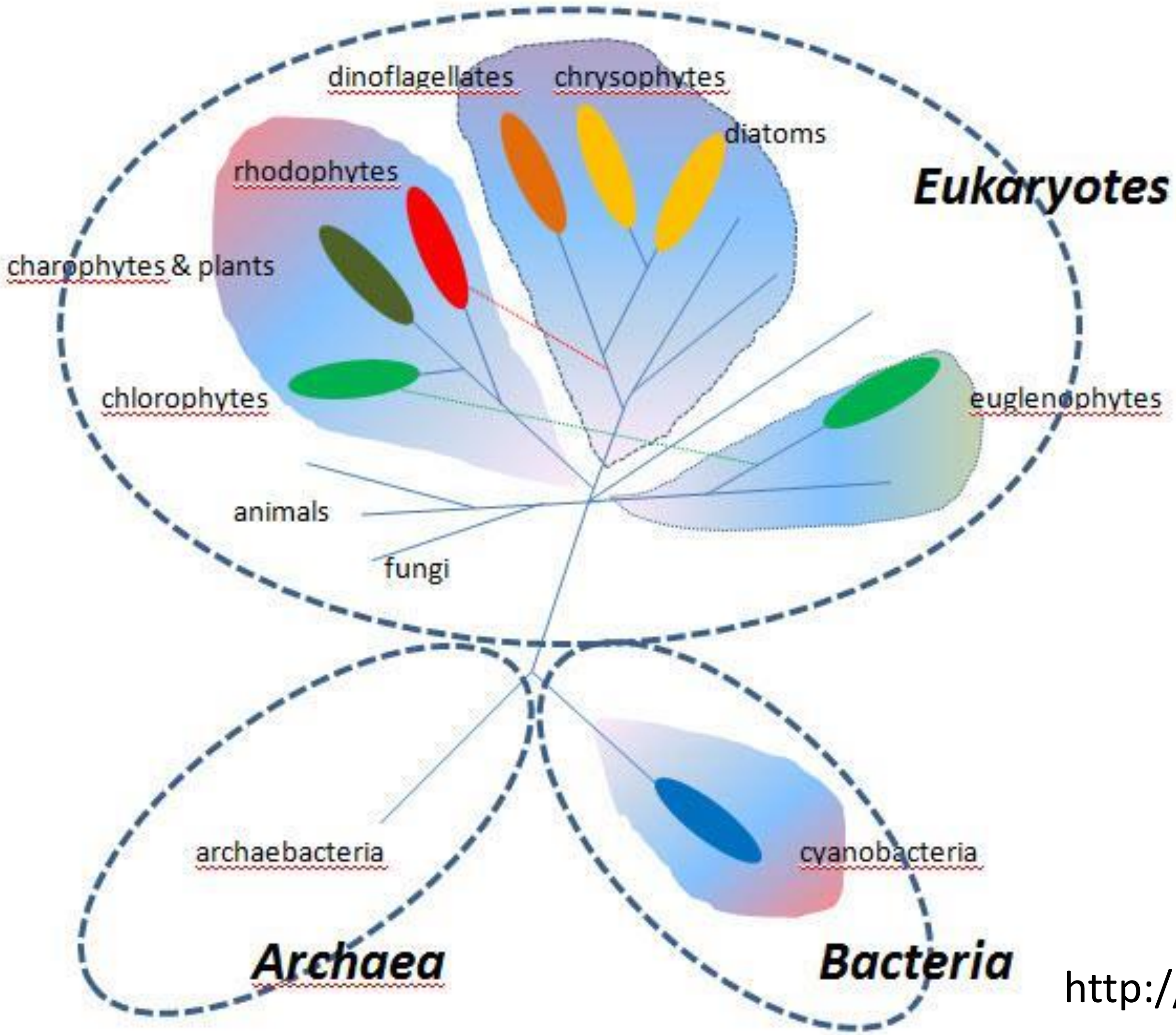



# WHAT ARE PHYTOPLANKTON?

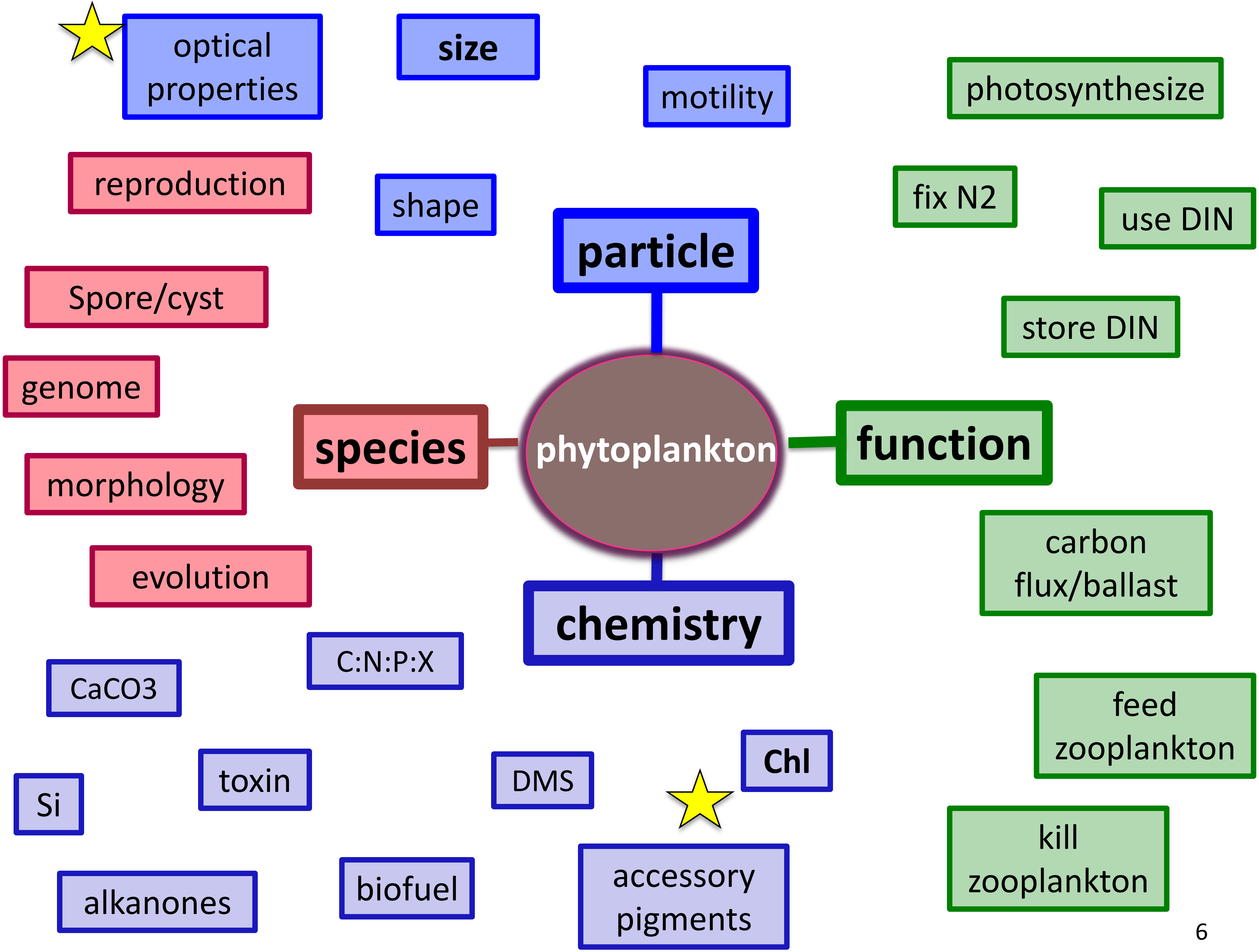
- **Aerobic** (oxygenated environment)
- **Photosynthetic** (pigmented)
- **Oxygenic** (oxygen producing; use sunlight)
- Small, single-celled **particle** (usually) but some form chains, puffs, spheres…)
- Many with **complex morphology** - not all round and uniform (limitation for Mie modeling)

# BOTTOM LINE:
# GREAT GENETIC DIVERSITY OF ORGANISMS THAT INTERACT WITH LIGHT IN THE OCEAN.

Keeling et al. 2004




http://www.diatom.org


optical properties
size
motility
photosynthesize
reproduction
shape
fix N2
use DIN
particle
Spore/cyst
store DIN
genome
species
phytoplankton
function
morphology
carbon flux/ballast
evolution
chemistry
C:N:P:X
CaCO3
feed zooplankton
Chl
toxin
DMS
Si
kill zooplankton
alkanones
biofuel
accessory pigments

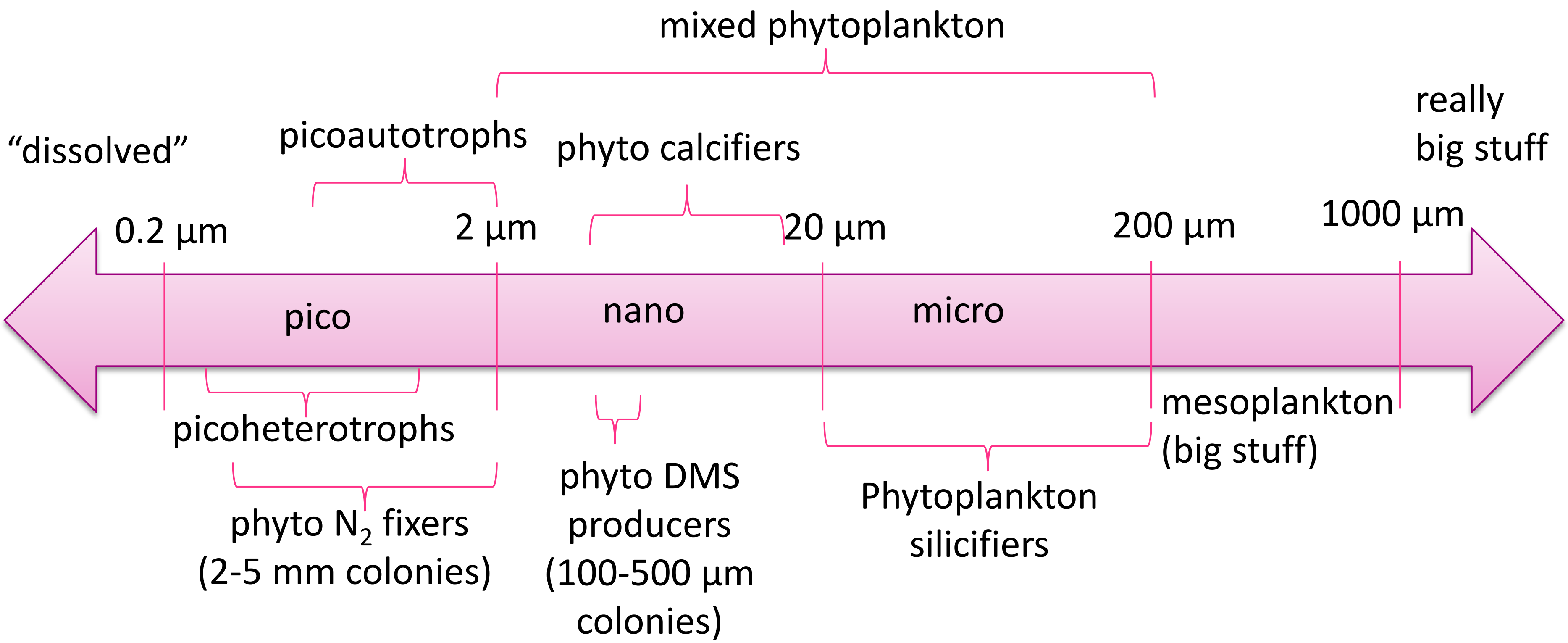
# TAXONOMY - ALL ROLLS BACK TO THE EVOLUTION OF THE TAXA CONCEPT……

## 1) Old, classical system (~ 350 yrs old)

- Classification based on morphological characteristics based purely on light microscopy
- Electron microscopy (ultrastructure)
- Pigmentation


Caron lab, USC

# PHYTOPLANKTON AS A PARTICLE…




Le Quéré et al. (2005)

# Phytoplankton as particles

## – in the ocean, **size matters** and is related to function

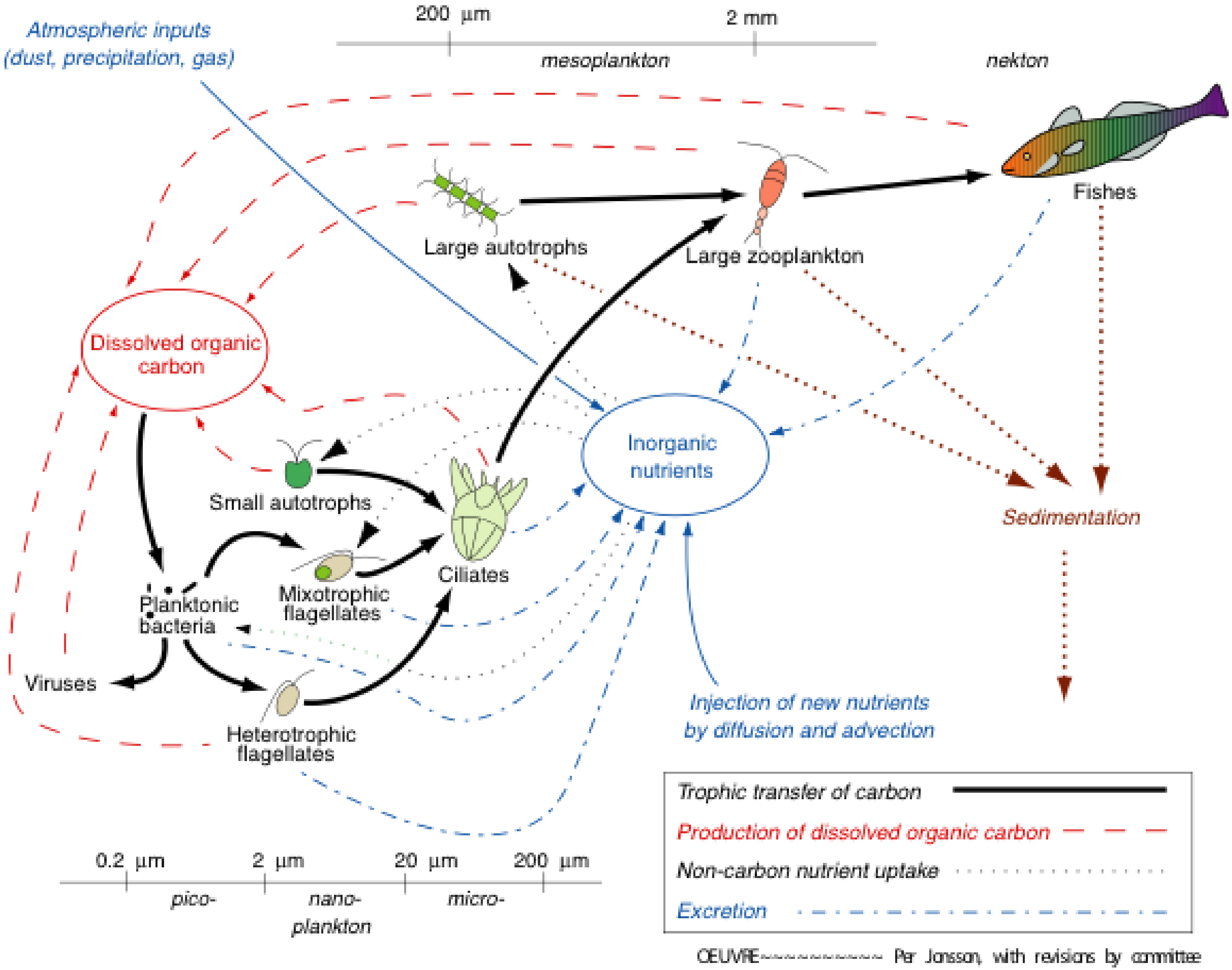
historical nomenclature:

| | | | |
|---|---|---|---|
| net | > 20µm | nano | < 20µm |
| pico | < 5µm | ultra | < 2µm (smallest mostly prokaryotes) |

Size

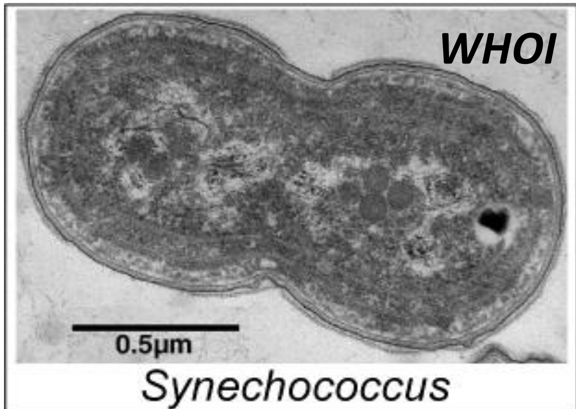
* small cells are mostly spherical; larger cells often non-spherical
* efficiency of dissolved solute capture (diffusion – smaller cells better)
* efficiency of encounter – surface area for contact
* efficiency of aggregation increases with size
* settling – Stokes Law (carbon cycling – small cells don't sink)
* exposure to light (packaging; a*) and UV damage greater for small cells
* carbon content – cell carbon density higher for small cells
* metabolic rates scale to size (specific rate decreases with increasing size)
* **size determines carbon export efficiency** (number of trophic interactions)

# Size ➔ is also function in food webs & C cycling



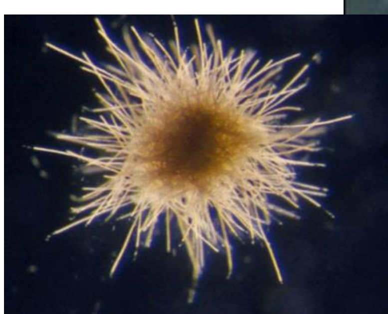

A community consensus view; details and color at <http://www.joss.ucar.edu/joss_psg/project/oce_workshop/oeuvre/report/>

# CYANOBACTERIA

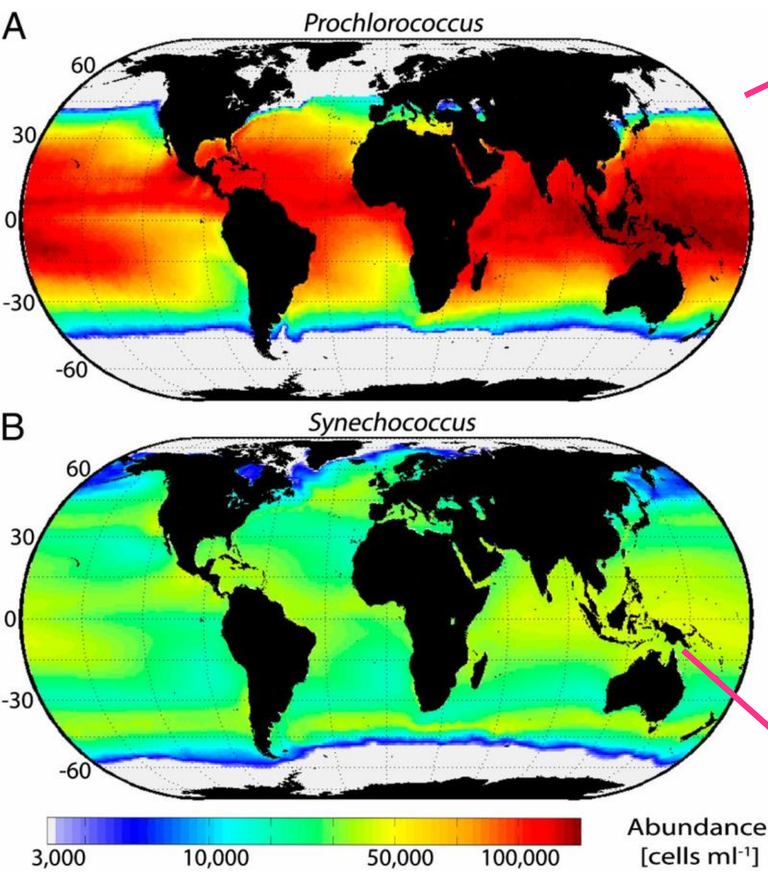


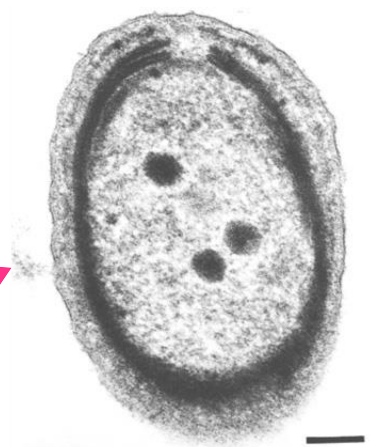
Synechococcus

Prochlorococcus


Trichodesmium (puff)

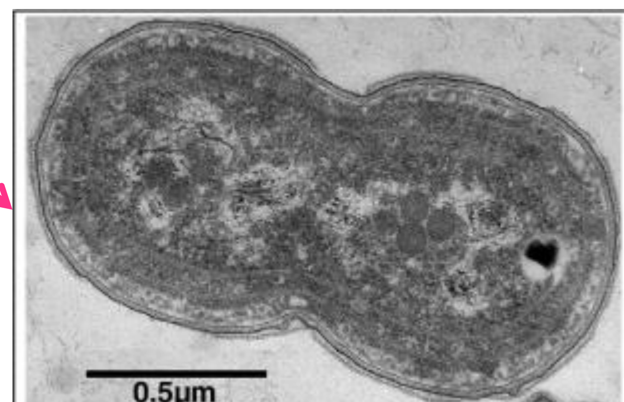
- Includes many of the picoplankton
- Many do Nitrogen Fixation
- Smallest and most abundant phytoplankton in the ocean
- Tropical to cosmopolitan



Electron micrograph of a longitudinal section of Prochlorococcus (isolate MIT 9313 ). Tightly appressed intracytoplasmic lamellae are present near the cell periphery, and carboxysomes are visible within the cell interior. Scale bar, 0.1mm.
(C. Ting, J. King, S.W. Chisholm, 1999)

**Prochlococcus**
Smallest and most abundant.
(~ 0.7 µm)
Diagnostic: very small size,
lack of orange fluorescence,
divinyl chlorophyll a & b.

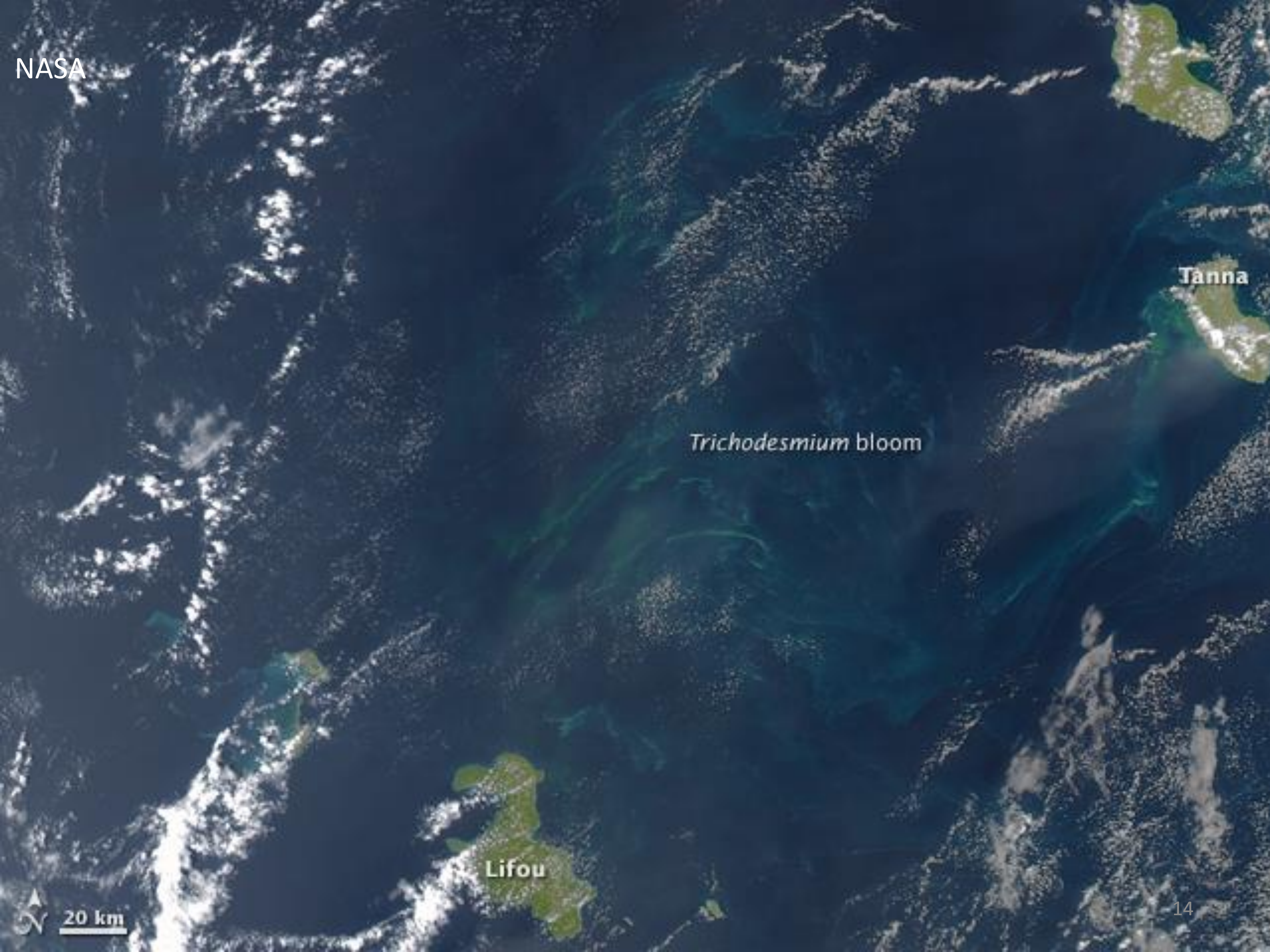



**Synechococcus**
(~ 1 µm)
Diagnostic:
phycoerthyrin pigment fluoresces orange (in contrast to chlorophyll, which fluoresces red.

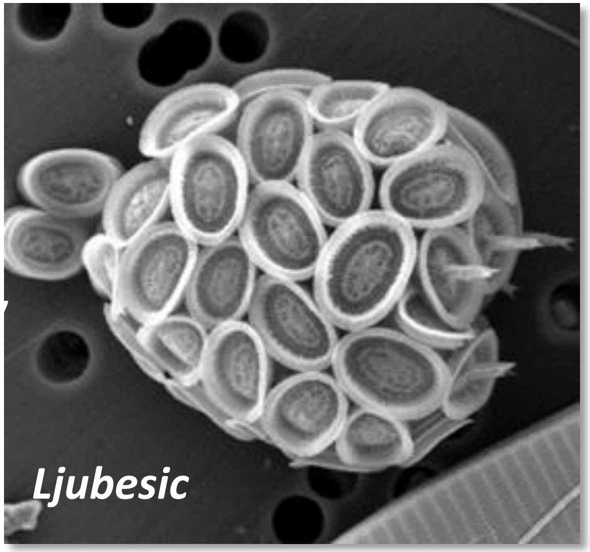
**Pedro Flombaum et al. (2013)**

# Trichodesmium

cyanobacteria, nitrogen fixer, warm waters, puffs and tuffs, phycoerthyrin, Fe may regulate abundance


NASA
Tanna
Trichodesmium bloom
Lifou
20 km

# PRYMNESIOPHYTES




***Phaeocystis***, makes floating with hundreds of cells embedded in a polysaccharide gel matrix

DMSP producers

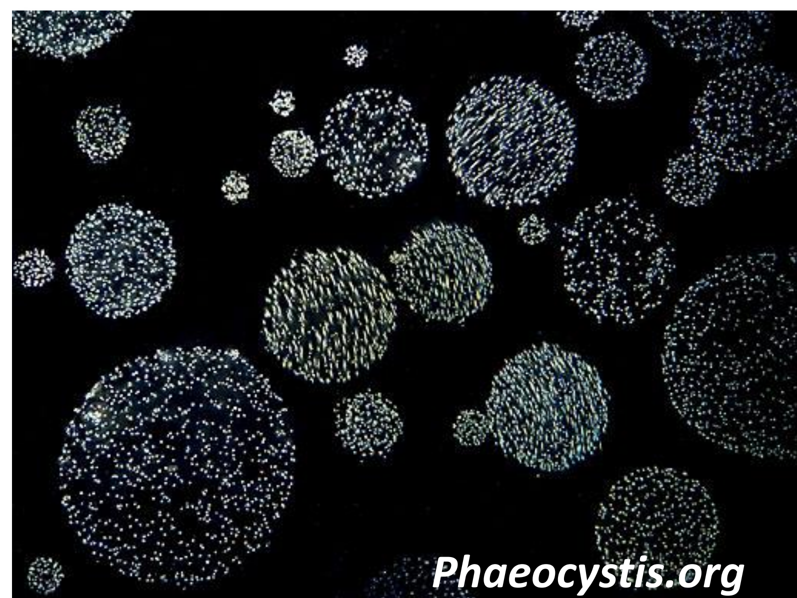
Form ugly foam on beaches in UK (smell of the seaside?)

**Coccolithophores**, calcareous phytoplankton – calcium carbonate “shells”, nano-micro

Sensitive to sea surface temperature - important tool in paleontology

Sensitivity to pH

Important for Carbon Export, climate studies



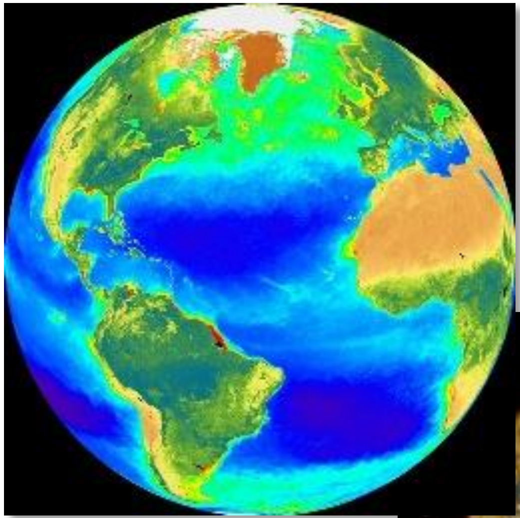

17 August 2011
NASA
Barents Sea
Norway
N
50 km

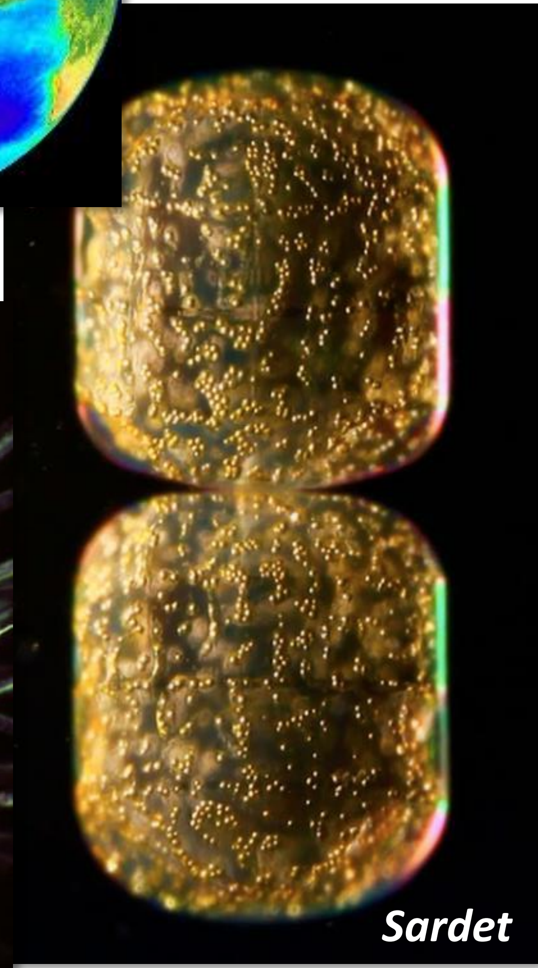
# DINOFLAGELLATES


- Flagellate containing algae
- Plant-like, but sometimes animal like (heterotroph), even predators
- Mostly coastal, warm waters
- Are also often symbionts of benthic and pelagic “heterotrophs”
- Red tide organisms, some toxic

# DIATOMS

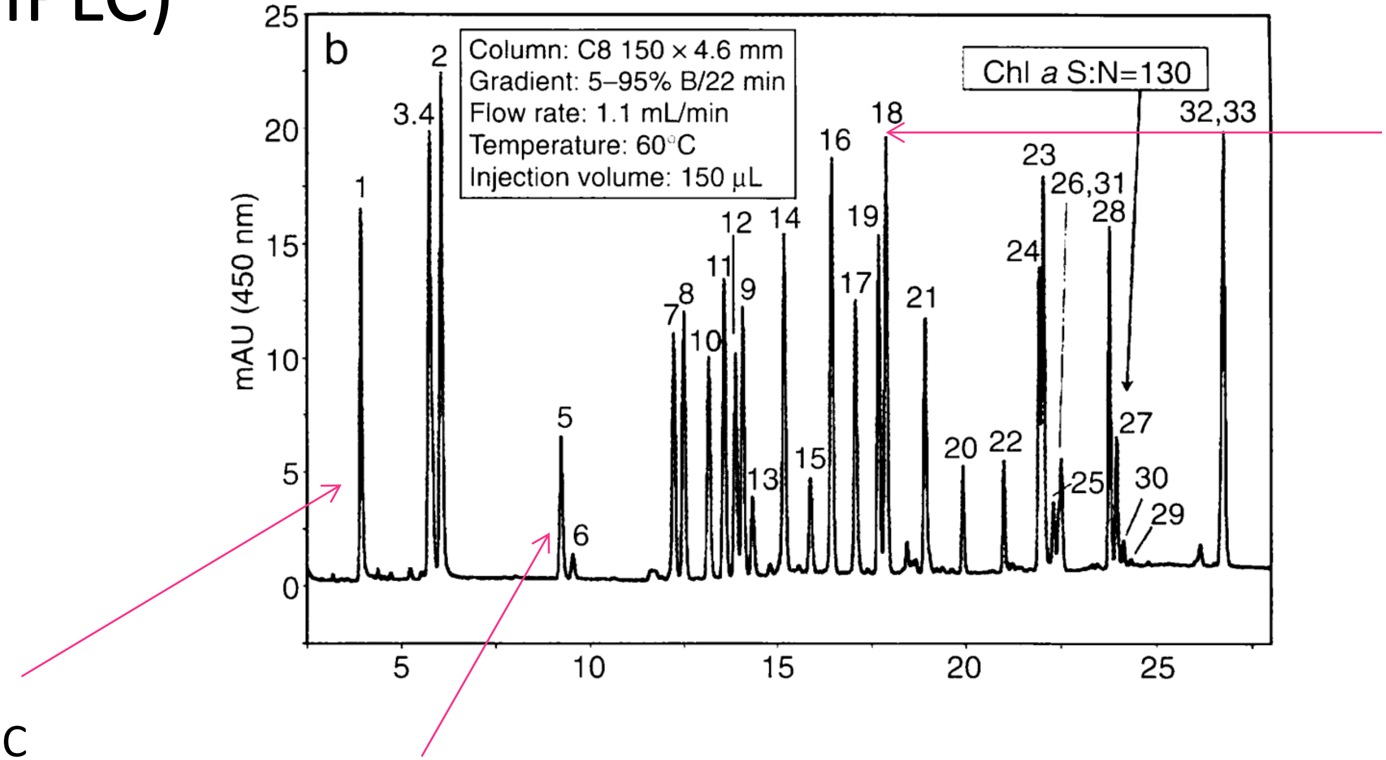
- Most common type of phytoplankton
- Have silica shells
- Single cells occasionally form chains
- Two forms: pennate, centric
- Some toxic (domoic acid)
- Spring bloomers, effective carbon exporters






# Pigments…

## High Preformance Liquid Chromatography (HPLC)

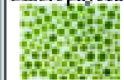
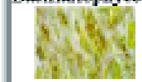
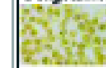



Bidigare, R. R., Van Heukelem, L., & Trees, C. C. (2005)

# Pigments as a taxonomical tool

- CHEMTAX – powerful tool if smart person uses it– careful of environmental condition and local flavors (Mackey, M. D. et al. 1996)
- Other clustering methods

*Pigment composition of the major algal groups*

| Pigments | Blue-Green Algae/ Cyanophyceae  | Red Algae/ Rhodophyceae  | Brown Algae/ Phaeophyceae  | Green Algae/ Chlorophyceae  | Dinoflagellates/ Dinophyceae  | Diatoms/ Bacillariophyceae  | Naked Flagellates  |
|---|---|---|---|---|---|---|---|
| **Chlorophylls** | | | | | | | |
| Chlorophyll-a | ● | ● | ● | ● | ● | ● | ● |
| Chlorophyll-b | | | | ● | | | |
| Chlorophyll-c | | | ● | | ● | ● | ● |
| **Phycobilins** | | | | | | | |
| Phycocyanin | ● | ● | | | | | |
| Phycoerythrin | ● | ● | | | | | |
| **Carotins** | | | | | | | |
| ß-Carotin | ● | ● | ● | ● | ● | ● | ● |
| **Xanthophylls** | | | | | | | |
| Diadinoxanthin | | | • | | • | ● | • |
| Fucoxanthin | | | ● | | • | ● | ● |
| Lutein | | ● | | ● | | | |
| Peridinin | | | | | ● | | |
| Alloxanthin | | | | | | | ● |
| Zeaxanthin | ● | ● | • | ● | | | |

# TAXONOMY - ALL ROLLS BACK TO THE EVOLUTION OF THE TAXA CONCEPT……

## 1) Old, classical system (~ 350 yrs old)

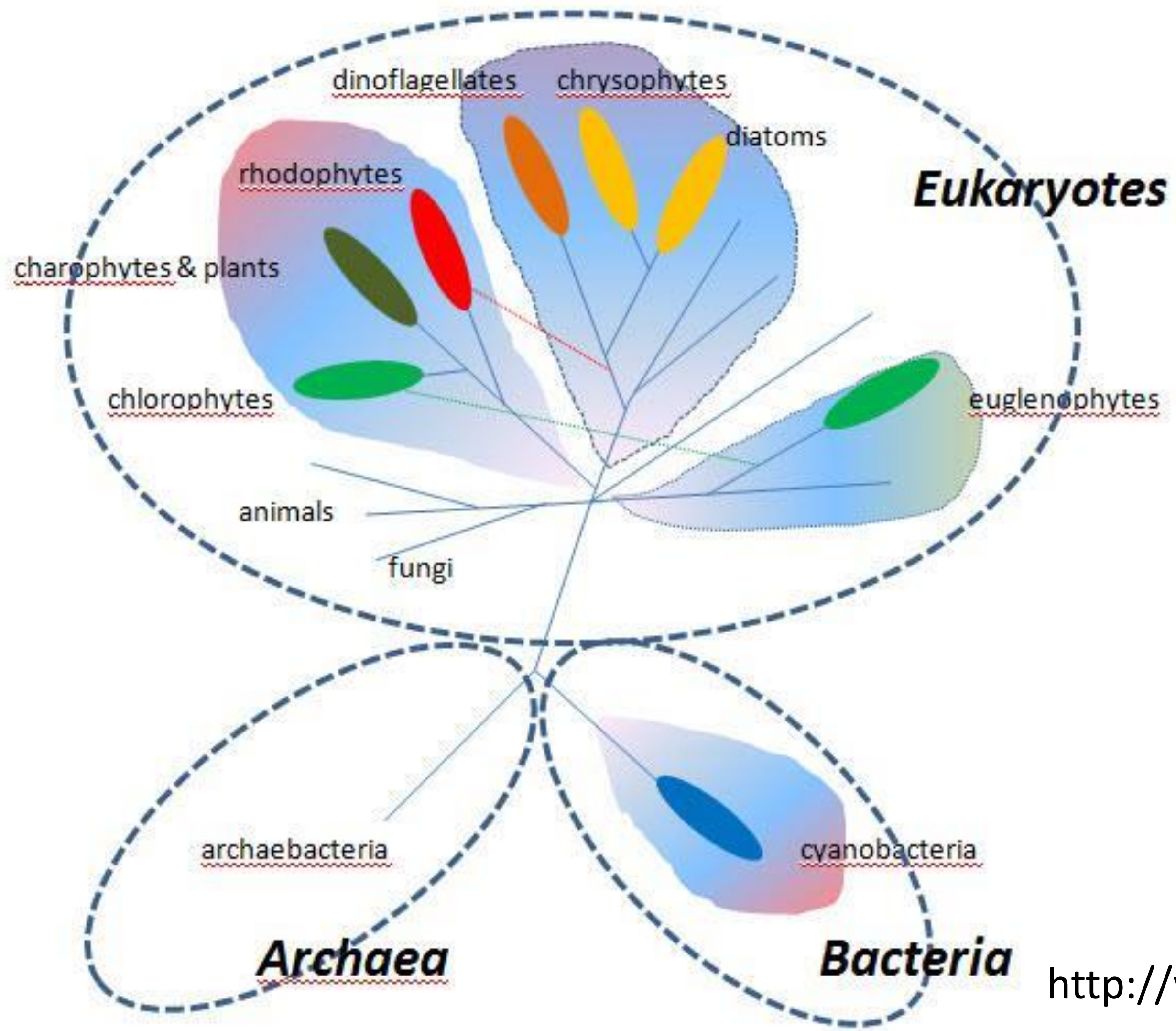
- Classification based on morphological characteristics based purely on light microscopy
- Electron microscopy (ultrastructure)
- Pigmentation

## 2) Modern system of algal classification (20-ish yrs old)

- DNA based (genetics, genomics… proteonomics)

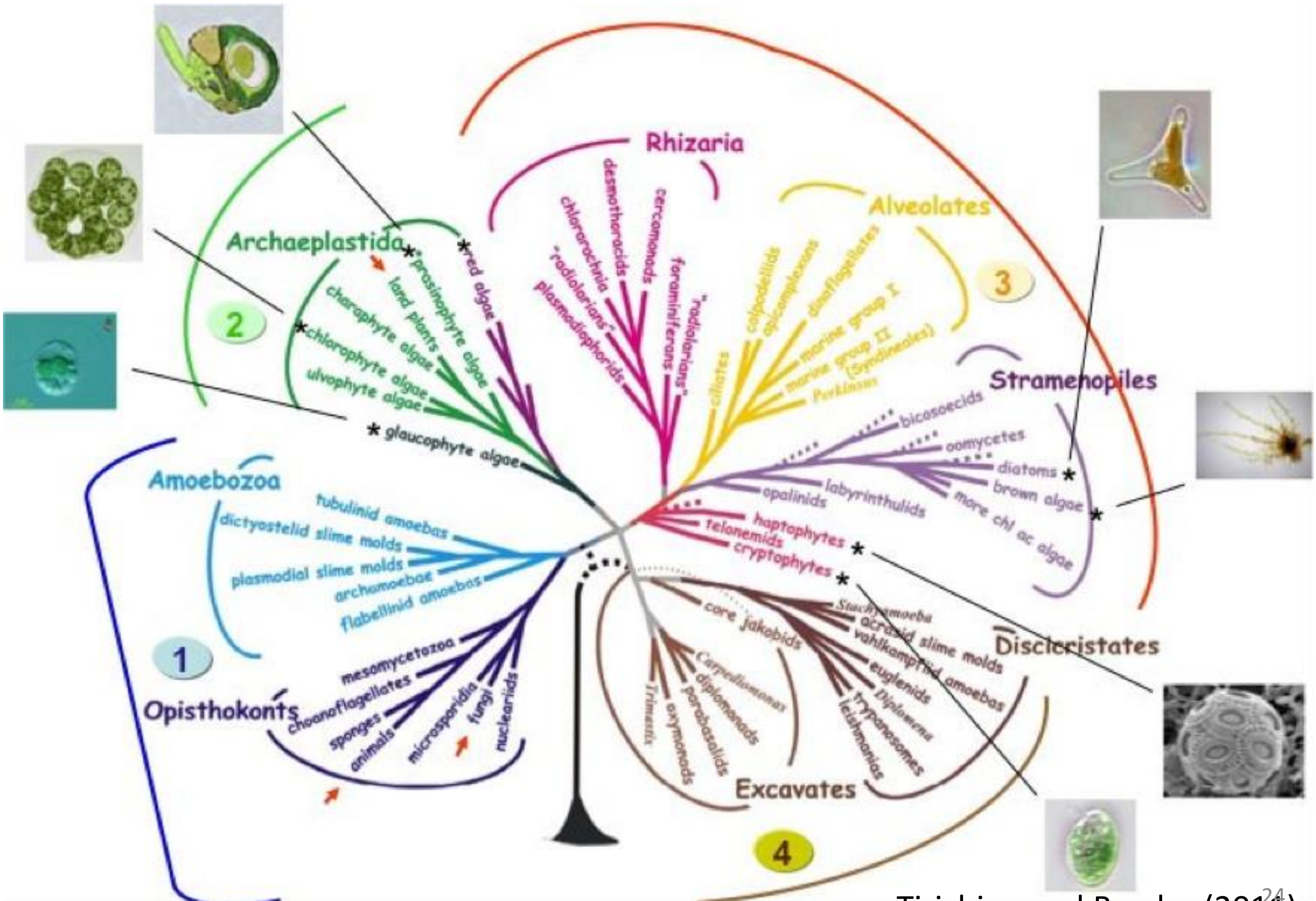
Cool & easy read - Caron (2013), *Journal of Eukaryotic Microbiology*

# VERY SIMPLE TREE OF LIFE (EMPHASIS ON PHYTOPLANKTON)



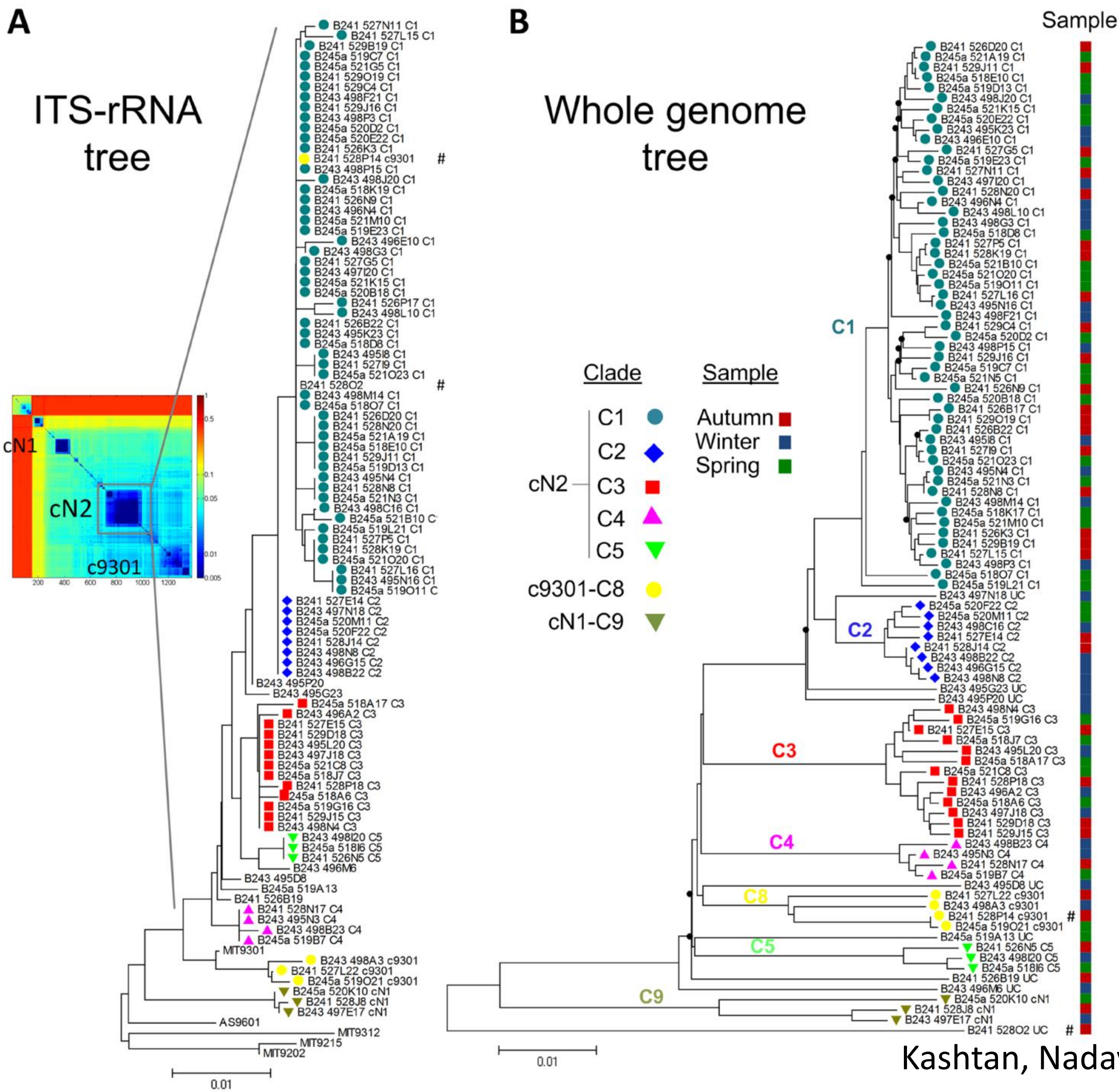

http://www.diatom.org

# EUKARYOTE PHYLOGENETIC TREE




Tirichine and Bowler (2011)

# PROCHLOROCOCCUS PHYLOGENETIC TREES

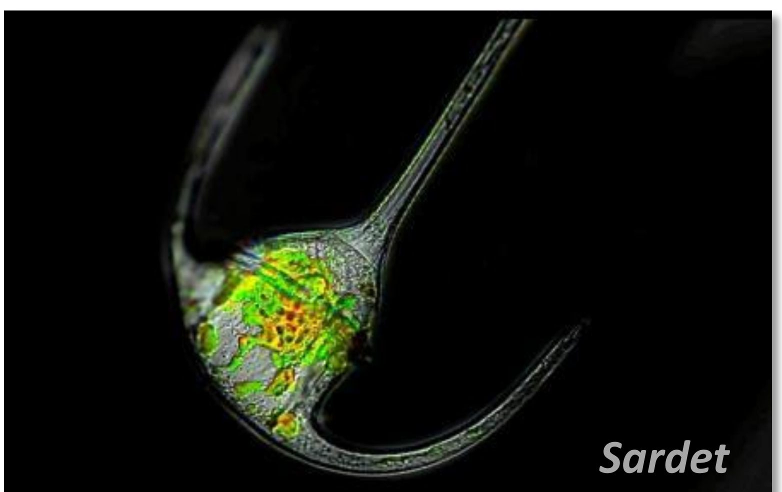



Kashtan, Nadav, et al. (2014)

# IT ALL ROLLS BACK TO THE EVOLUTION OF THE TAXA CONCEPT……

3) PHYTOPLANKTON FUNCTIONAL TYPES - physiological and ecological criteria

"…group of organisms (irrespective of taxonomic affiliation) that carry out a particular function, e.g. a chemical process such as calcification, silicification, nitrogen fixation, or dimethyl sulfide production; functional groups are also sometimes referred to as 'biogeochemical guilds'."




IOCCG Report 15, (2014)

Another great read

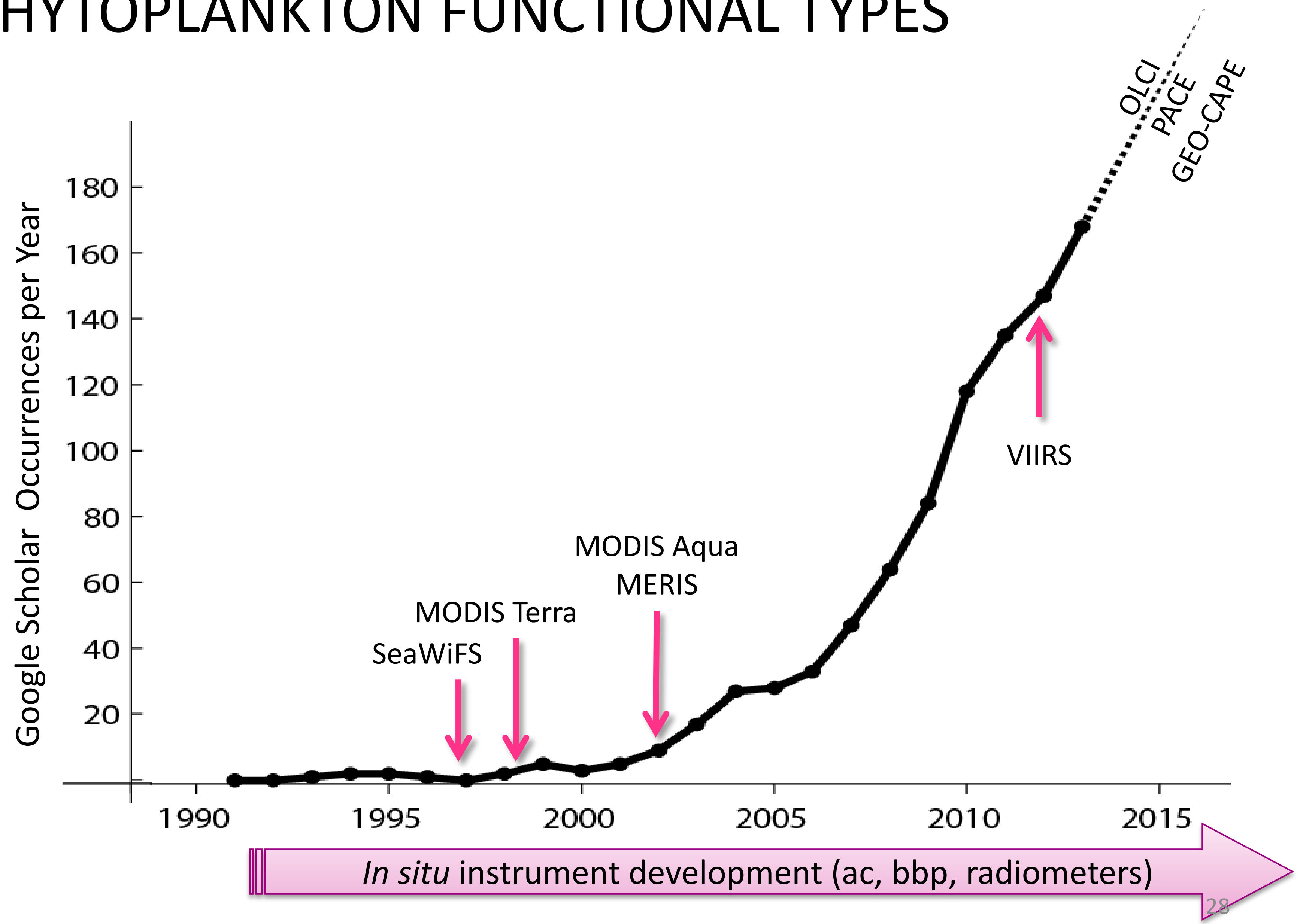
# Phytoplankton as functional types:

## Functional type

- autotrophic, oxygenic, oxygen evolving
- size and shape
- transformer of specific nutrient ($N_2$ fixer, $CaCO_3$ precipitator, silica polymerizer, etc.); **ballasting to enhance C flux**; specialized nutrient-up take pathways, sequestering mechanisms; unique C:N:P:trace metal ratio
- nutritional value to higher trophic organisms, such as essential fatty acids, toxins or development disrupters, paleo markers
- ability to live in turbulent vs. stratified environment
- motility for enhancing nutrient acquisition, encounter gametes, avoiding predation
- what else ??

**Chemical composition** – relates to function, species, etc. For optics, pigments are key (& sometimes unique) chemicals. But it C we really want?

# PHYTOPLANKTON FUNCTIONAL TYPES



# WHY STUDY PHYTOPLANKTON FUNCTIONAL TYPES with OPTICS?

# HOW TO STUDY PHYTOPLANKTON FUNCTIONAL TYPES with OPTICS?

Focus on specific morphological and structural features that impact light

- Specific pigment structure leads to specific optical signal
- Specific size will lead to specific optical signal (then we talk about Particle Size Classes)

Focus on taxa specific ecological traits and trophic states

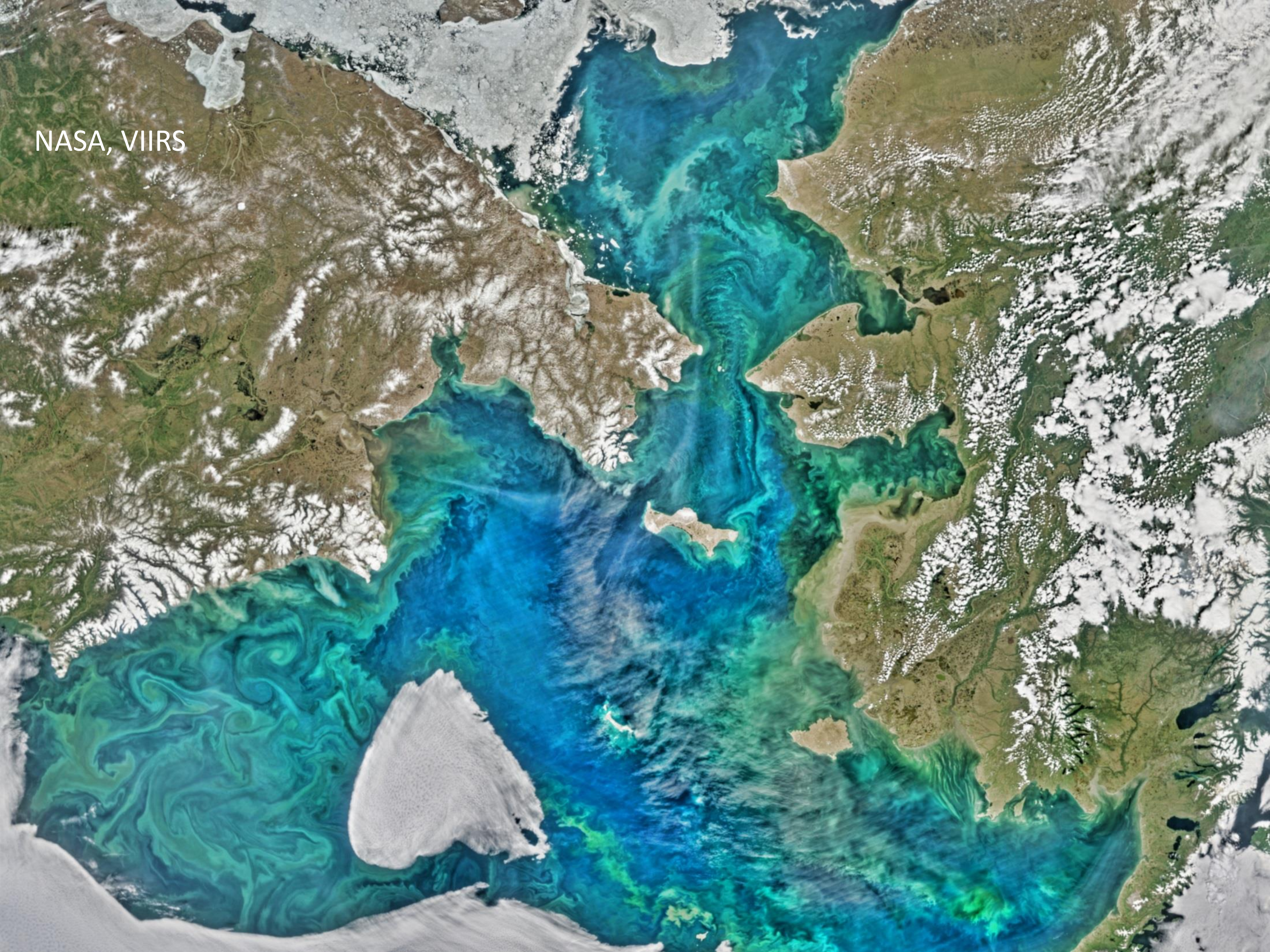
- E.g. Certain chlorophyll/ IOP concentration infers specific community composition

# HOW (Feasible is) TO STUDY PHYTOPLANKTON FUNCTIONAL TYPES with OPTICS?

You will be able to answer that question in the end of this class

Remember!

- **Know your friends and your enemies**
- **Be realistic**
- **Validate**


NASA, VIIRS