University of Trieste: GLOBAL CHANGE ECOLOGY a.a. 2021-2022

BIODIVERSITY AND ECOSYSTEM FUNCTIONING

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Biodiversity and ecology of pelagic systems

The pelagic domain

71% of the planet surface is covered by sea water

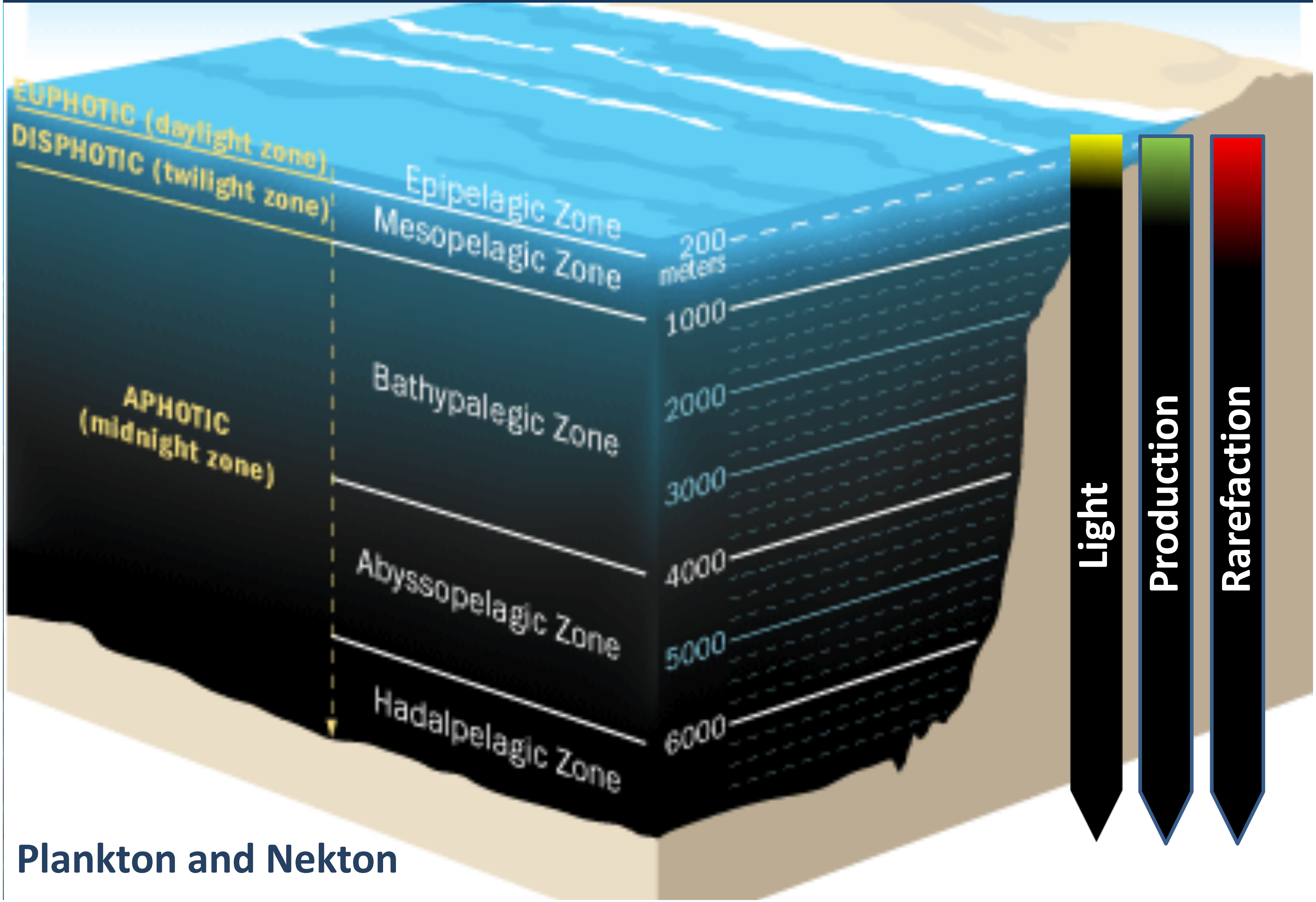
So the pelagic domain is the largest environment on Earth

Pelagic domain includes the neritic province and the oceanic province

Oceanic: waters from continental shelf and beyond

Neritic: waters above the continental shelf, influenced by closeness to land, and benthic domain

The pelagic domain



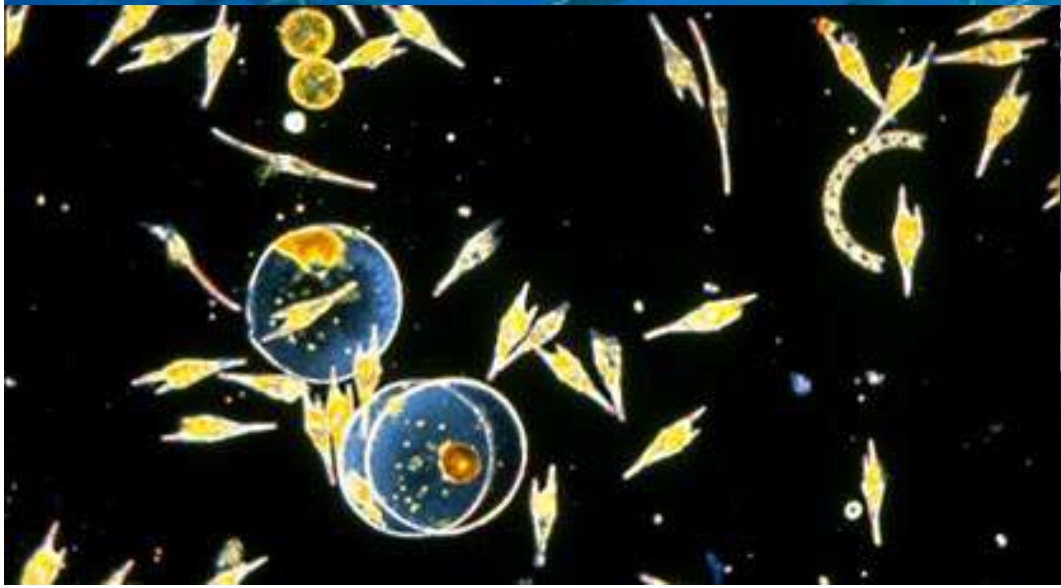
Plankton and Nekton

Plankton

By definition (Hensen) plankton are the "aggregates of passively floating, drifting, or somewhat motile organisms occurring in a body of water, primarily comprising microscopic algae and protozoa”

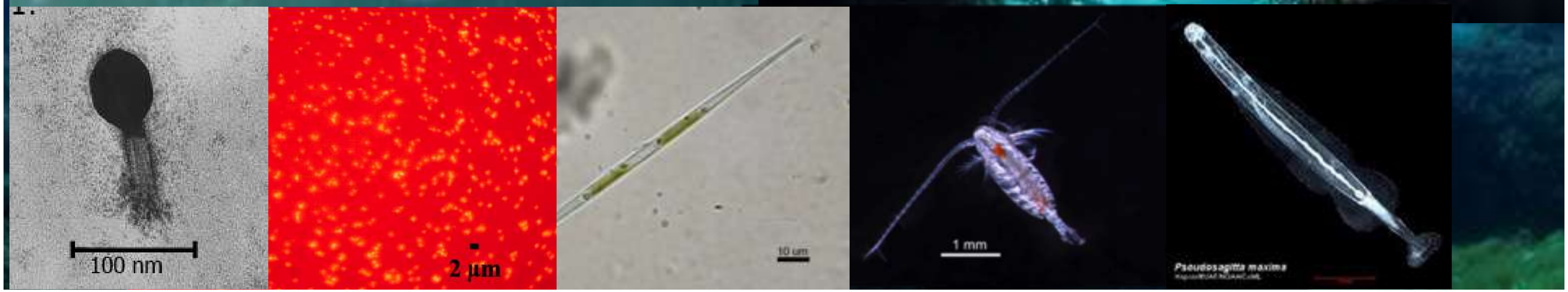
There are also many metazoans, and especially crustaceans, along with gelatinous zooplankton

We can distinguish *autotrophic* plankton, *heterotrophic* plankton, and *mixotrophic*



Plankton size classes

Femtoplankton	0.02-0.2 μm	viruses, bacteria
Picoplankton	0.2-2 μm	auto- and heterotrophic bacteria
Nanoplankton	2-10 μm	auto- and heterotrophic flagellates, small ciliates
Microplankton.	10-200 μm	diatom, dinoflagellates, protozoa, larvae
Mesoplankton	200- 5000 μm	copepods, cladocerans, medusae, ostracods, pteropods, tunicates, larvae
Macroplankton	5 - 10 mm	medusae, chaetognatha, tunicates
Megaplankton	>1 cm	medusae, tunicates, chaetognatha



Plankton categories

Holoplankton: organisms spending their whole life in the water column

Meroplankton: organisms spending part of their life cycle in plankton, and part in other ecological compartments (e.g., benthos, nekton)

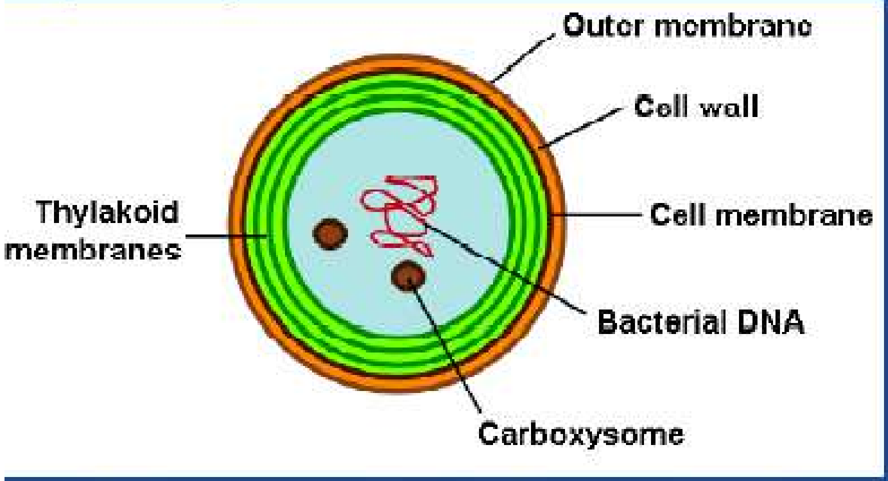
Cyanobacteria

- **Cyanobacteria,** also known as **Cyanophyta,** is a phylum of Bacteria that obtain their energy through photosynthesis.

- They are often referred to as **blue-green algae** because of their superficial resemblance to eukaryotic green algae. They are prokaryotes, not algae.

- **Cyanobacteria** lack internal organelles, a discrete nucleus and the histone proteins associated with eukaryotic chromosomes. Like all bacteria, their cell walls contain peptidoglycan.

Although Cyanobacteria are truly prokaryotic, they have an elaborate and highly organized system of internal membranes which function in photosynthesis.



A Thylakoid is a membrane-bound compartment site of the light-dependent reactions of photosynthesis.

Cyanobacteria

Attached to thylakoid membrane, phycobilisomes act as light harvesting antennae for the photosystems. The phycobilisome components (phycobiliproteins) are responsible for the blue-green pigmentation of most cyanobacteria.

Cyanobacteria are found in almost every conceivable habitat, from oceans to fresh water to bare rock to soil. Most are found in fresh water, while others are marine.

Cyanobacteria include unicellular and colonial species. Colonies may form filaments, sheets or even hollow balls.

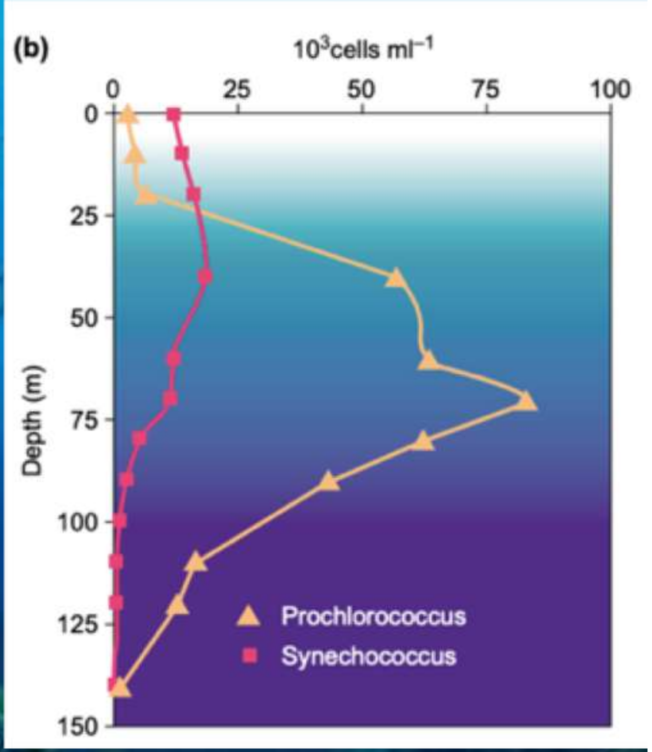
Picoplanktonic cyanobacteria belong to **Chroococcocales** order.

Synechococcus and ***Prochlorococcus*** are the most widespread genera.

Synechococcus likes most surface layers of the water column.

Prochlorococcus lives at the lower limit of the photic zone.

Cyanobacterial abundance = 10^4-10^8 cell/l



Ting et al. 2002

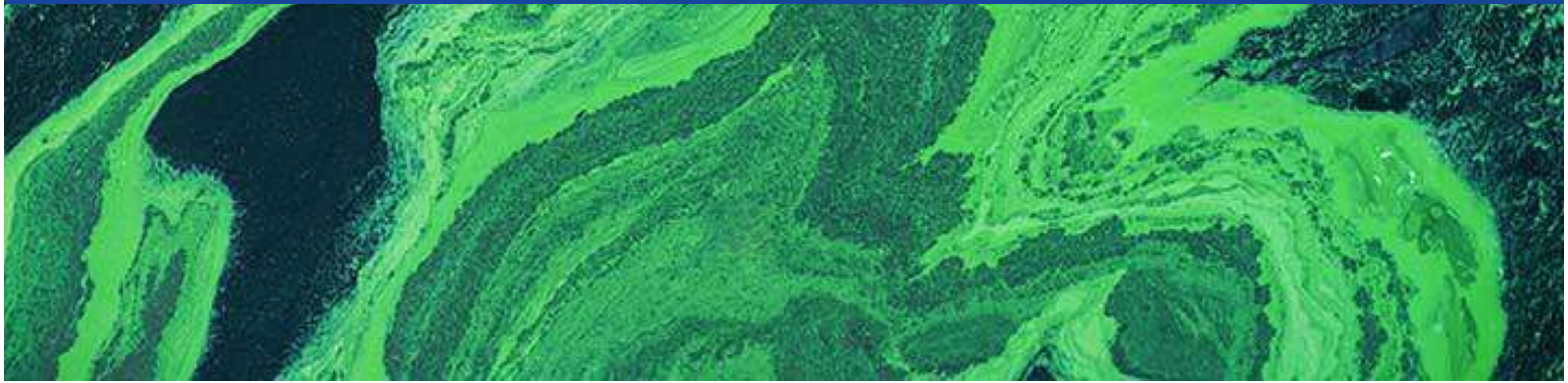
Cyanobacteria: ecological role

The highest picoplanktonic cyanobacteria abundances correspond to eutrophic waters nevertheless they prefer the oligotrophic ones.

The small dimension gives important ecological advantages like a reduced sedimentation rate, a more efficient light energy assumption as also a more efficient inorganic nutrients adsorption.

Liu et al. 1997

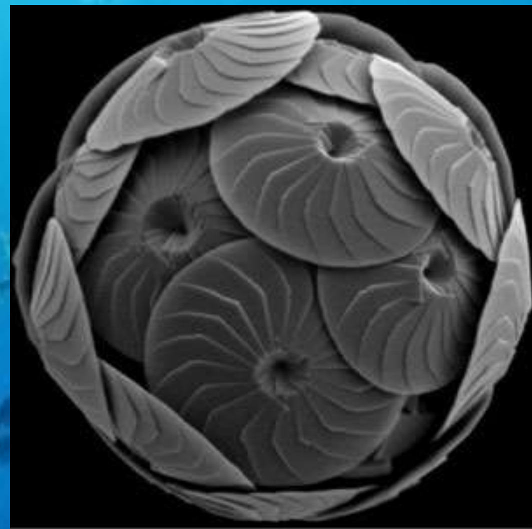
Picoplanktonic cyanobacteria play an important role within planktonic trophic net as primary producers by contributing to carbon organication with percentages ranging from 1 to 90%.



Eukaryotic phytoplankton

Prasinophyceae – green algae

Coccolithophores

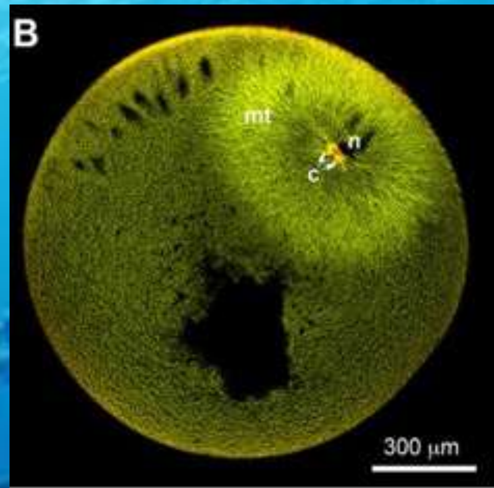


Diatoms

Dinoflagellates

Prasinophyceae

Quadrangular or round cells with up 8 flagella
Greenish colour is due to the prevalence of chlorophyll ‘a’ and ‘b’ as photosynthetic pigments
Mostly marine and planktonic
Individual or aggregated in colonies



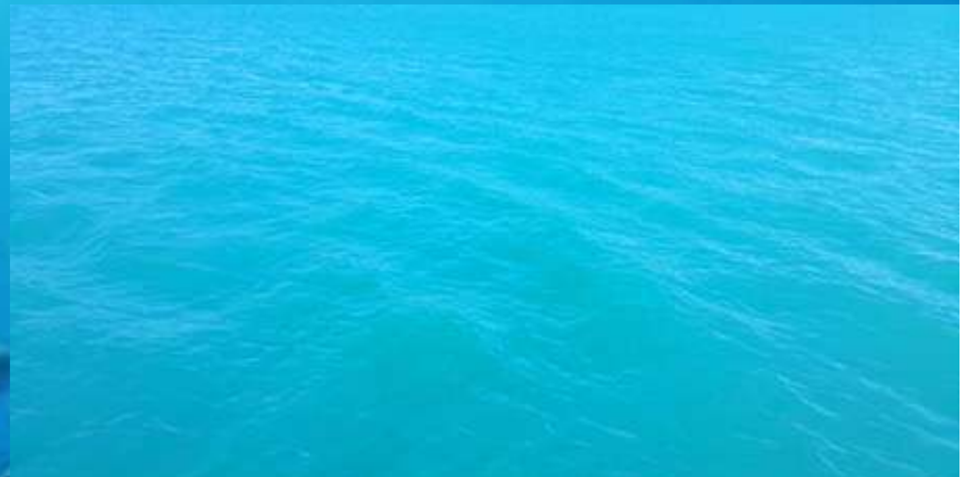
Ostrococcus

Common genera include *Micromonas*, *Ostreococcus* and *Bathycoccus*, the composition of their diversity depending on the environment. In high latitudes, *Micromonas* often prevails, whereas *Ostreococcus* is more prevalent in temperate latitudes
(Grimsley et al., 2012)


Micromonas

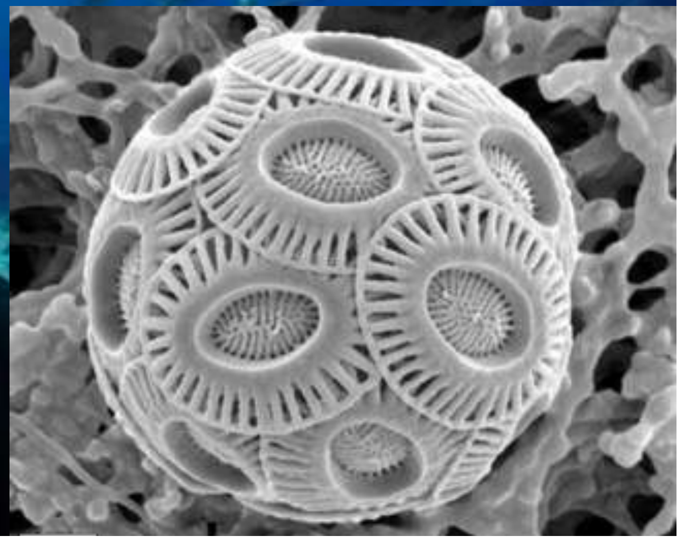
Coccolithophores

Coccolithophorids are clearly identifiable by the presence of typical calcium carbonate plates called coccoliths.
They belong to Prymnesiophyceae



They are usually found on nutrient-poor surface waters, but in some circumstances, with high availability of N and P they form blooms (milky waters).
Coccolithophores are one of the more abundant primary producers in the ocean, and represent a sink of carbonate (chalk).

Emiliania huxleyi is a cosmopolite example from equatorial to sub-polar regions



Other Prymnesiophyceae

Chrysochromulina polylepis

Toxic blooms
Production of toxic metabolites when blooming, during warm period and stable stratification of waters coupled with nitrogen supply.

During late 80's- early 90's blooms occurred in the sea around Denmark and Sweden causing poisoning of many marine organisms including bacteria, protozoans, invertebrates and fish.

Nielsen et al., 1990

Other Prymnesiophyceae

Dimethyl sulphid production

along with cyanobacteria, and other small phytoplankton (Wang et al., 2015)

Climate control

Cooling effect

Phaeocystis sp.

Bacillariophyceae (diatoms)

Diatoms have a siliceous (SiO_2) skeleton and are found in almost every aquatic environment including freshwaters and soils, in fact almost anywhere moist. They are non-motile, or capable of only limited movement along a substrate by secretion of mucilaginous material along a slit-like

In the sea most are benthic, but about 10,000 species (out of 100,000) are planktonic. Being autotrophic they are restricted to the photic zone. Size range from 2 µm to 2 mm, but many are <200µm

Solitary or grouped in colonies

They are the most productive phytoplanktonic groups

Dominant role in nowadays silicon cycle

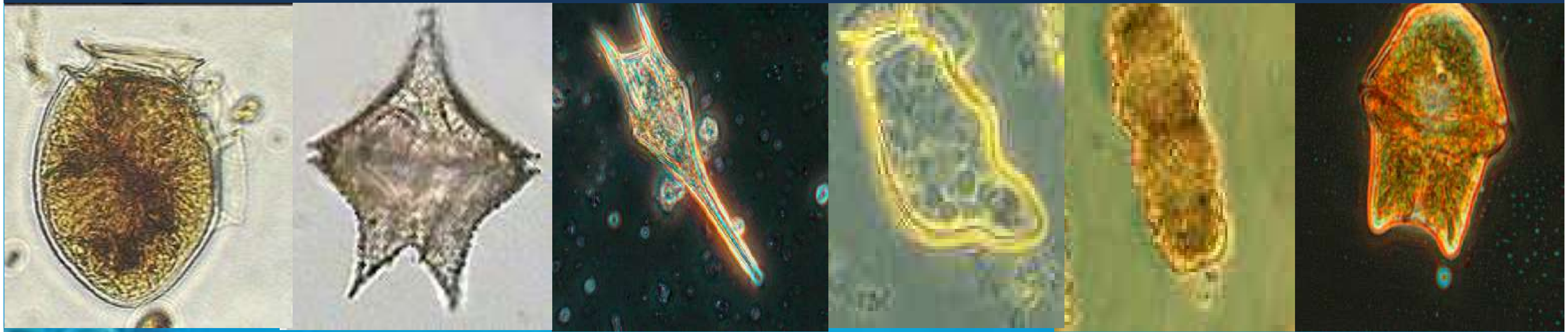
Silicon cycle

Table 5 Silicon budget in the world ocean

Component	Flux (Tmol Si $year^{-1}$)
Inputs	
Rivers, dissolved silicon [$F_{R(grossDSi)}$]	+6.2 ± 1.8
Rivers, biogenic silica [$F_{R(bSiO_2)}$]	+1.1 ± 0.2
Reverse weathering and trapping (estuaries/plumes) (F_{RW})	−1.5 ± 0.5
Groundwater (F_{GW})	+0.6 ± 0.6
Atmosphere (aeolian) (F_A)	+0.5 ± 0.5
Hydrothermal (high and low temperature) (F_H)	+0.6 ± 0.4
Seafloor weathering (F_W)	+1.9 ± 0.7
Total net inputs	*+9.4 ± 4.7*
Outputs (F_B)	
Burial rate (diatoms)	6.3 ± 3.6
Sponges (continental shelves)	3.6 ± 3.7
Total net outputs	*9.9 ± 7.3*
Total production [$F_{P(gross)}$]	*240 ± 40*

Diatoms are the organisms most contributing to production of biogenic silica, and the main pathway it sinks into the deep ocean sediments, along with siliceous sponges

Dinoflagellates



Dinoflagellates are protists which have been classified using both the International Code of Botanical Nomenclature (ICBN) and the International Code of Zoological Nomenclature (ICZN), approximately half living dinoflagellate species are **autotrophs** possessing chloroplasts and about half are **heterotrophs**, some are **mixotrophic** or **endosymbionts**

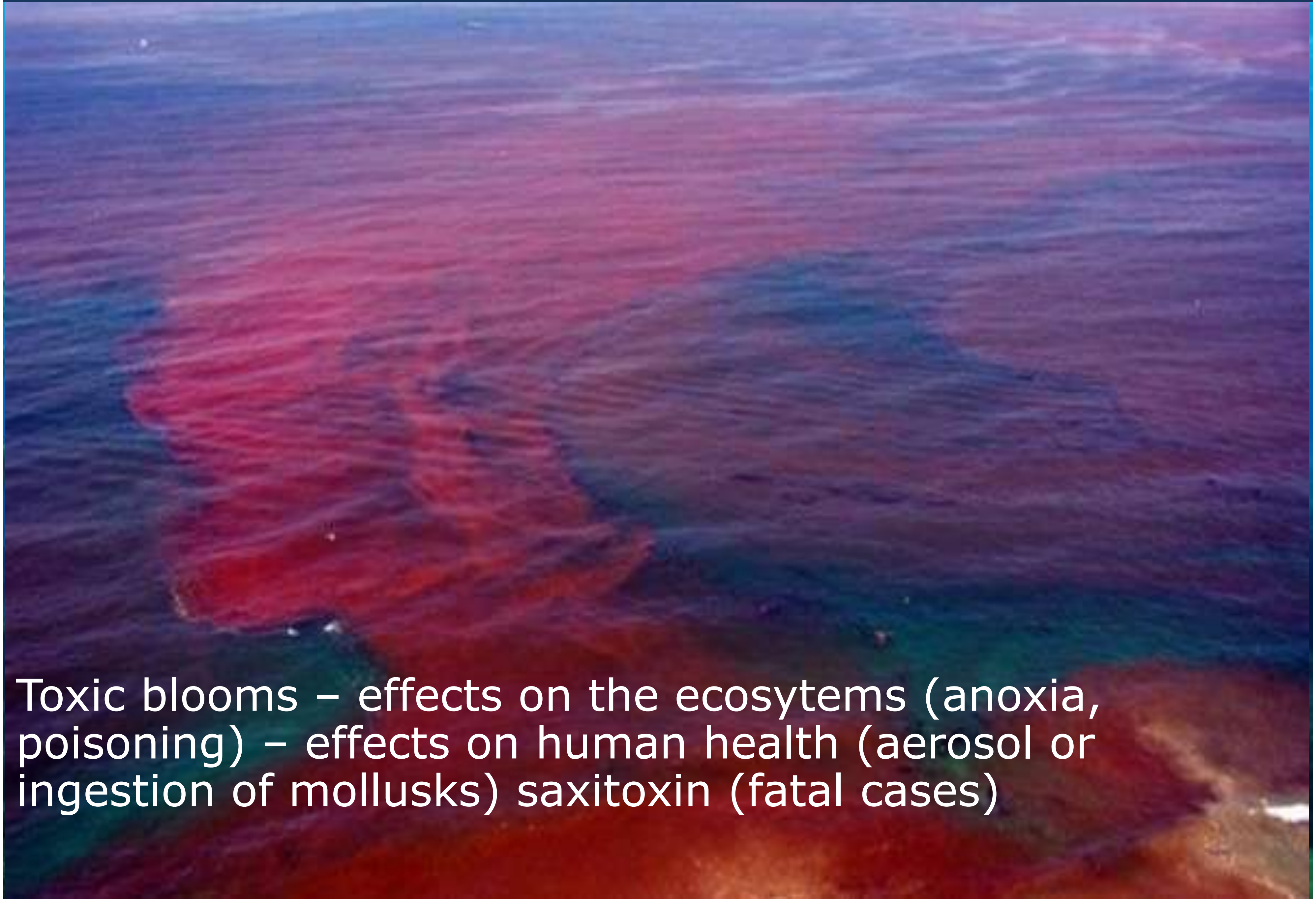
The dinoflagellates are unicellular and show wide variations in morphology. The size of these organisms ranges from 0.001 to 2 mm; however, most of the species have a size below 0.2 mm.

Two flagella and theca (cellulosic)

Dinoflagellates

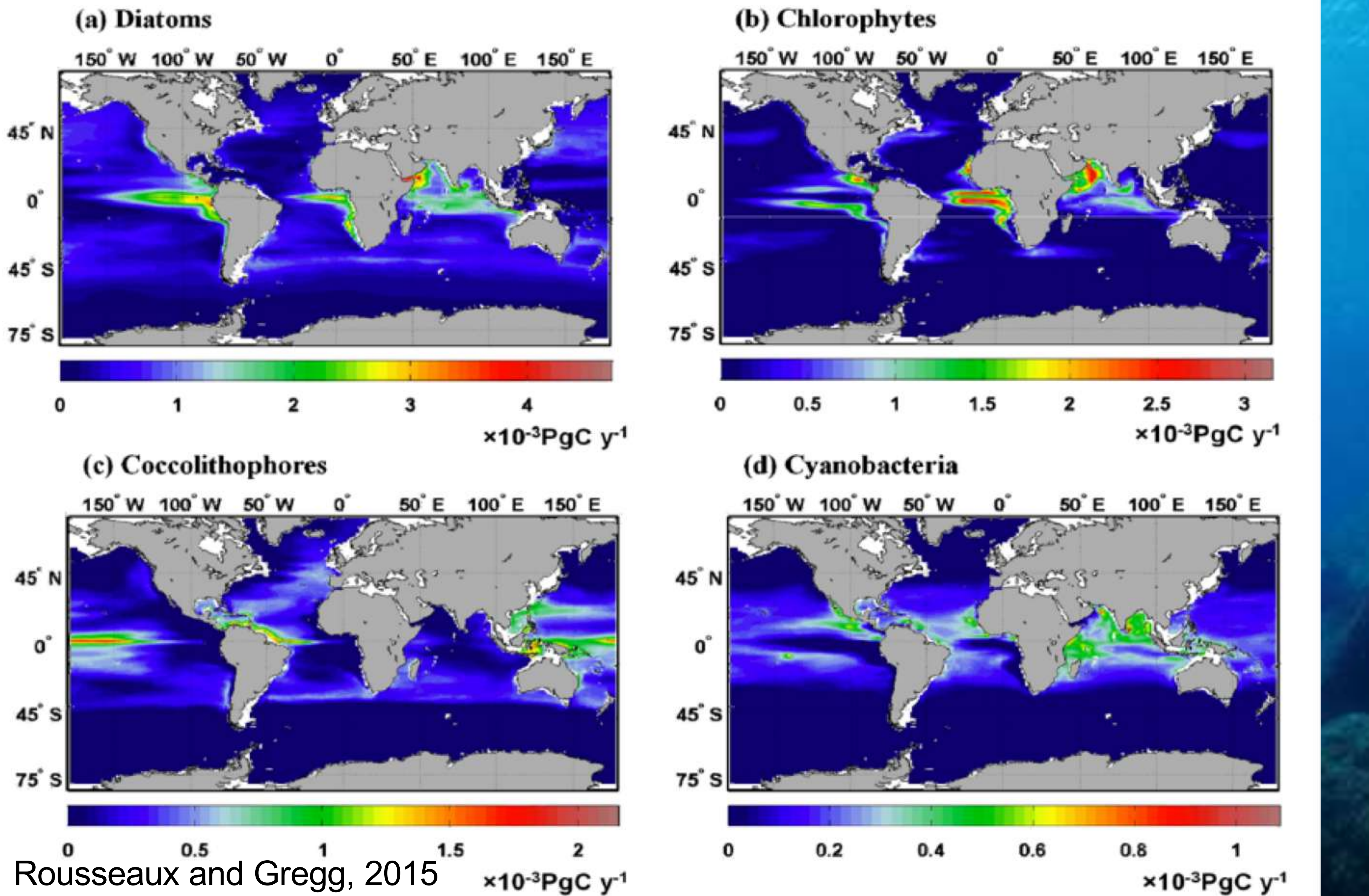
Mechanic stimulation
Luciferase – Luciferin
Bioluminescence

Red tides



Toxic blooms – effects on the ecosytems (anoxia, poisoning) – effects on human health (aerosol or ingestion of mollusks) saxitoxin (fatal cases)

Phytoplanktonic production



Rousseaux and Gregg, 2015

Globally, diatoms contributed the most to the total phytoplankton production (~50%), followed by coccolithophores and chlorophytes (~20%) and cyanobacteria (10%).

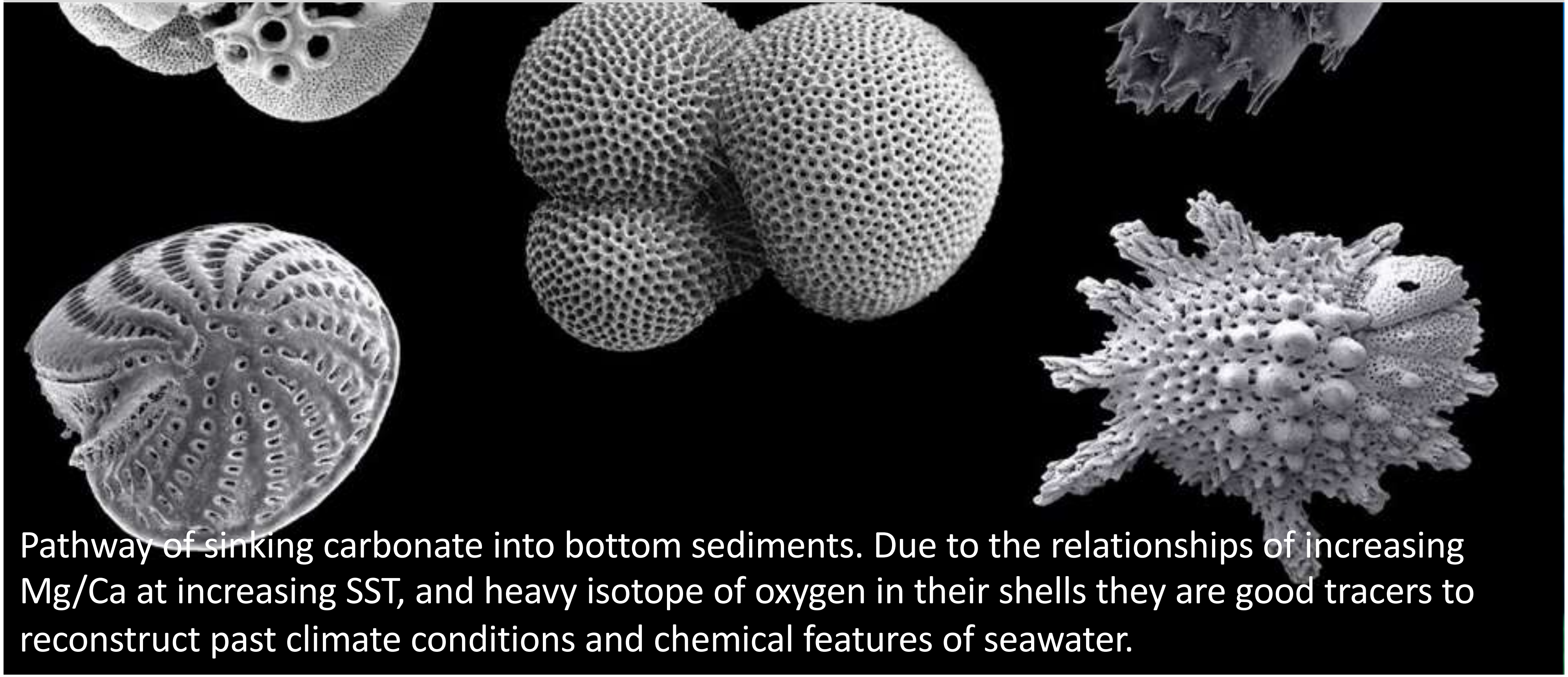
Phytoplanktonic production

The contribution of primary production in oceans (mostly planktonic) is around 50%. (Field et al. 1998)

	Ocean NPP		Land NPP
Seasonal			
April to June	10.9		15.7
July to September	13.0		18.0
October to December	12.3		11.5
January to March	11.3		11.2
Biogeographic			
Oligotrophic	11.0	Tropical rainforests	17.8
Mesotrophic	27.4	Broadleaf deciduous forests	1.5
Eutrophic	9.1	Broadleaf and needleleaf forests	3.1
Macrophytes	1.0	Needleleaf evergreen forests	3.1
		Needleleaf deciduous forest	1.4
		Savannas	16.8
		Perennial grasslands	2.4
		Broadleaf shrubs with bare soil	1.0
		Tundra	0.8
		Desert	0.5
		Cultivation	8.0
Total	48.5		56.4

Foraminifera

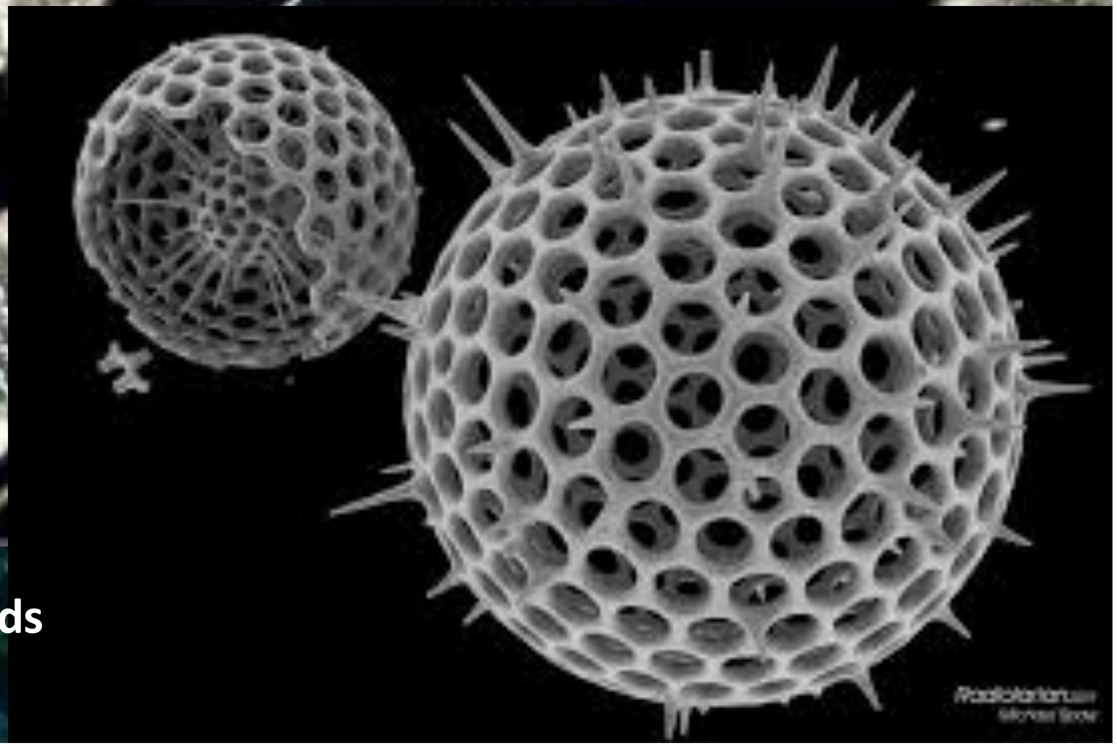
Planktonic foraminifera are marine heterotrophic protists that surround their unicellular body with elaborate calcite shells. Herbivorous and omnivorous species consume phytoplankton, mainly diatoms and dinoflagellates, while carnivorous species prey on copepods, ciliates, and others similar-sized organisms. Typical population densities of planktonic foraminifera range from 1,000 individuals/m³ in polar ocean blooms to 100 individuals/m³ in oligotrophic waters. (Kucera, 2007). A symbiotic relationship with photosynthesizing algae is particularly advantageous in warm oligotrophic waters, where nutrients and food are scarce but light is abundant.



Pathway of sinking carbonate into bottom sediments. Due to the relationships of increasing Mg/Ca at increasing SST, and heavy isotope of oxygen in their shells they are good tracers to reconstruct past climate conditions and chemical features of seawater.

Radiolaria

Radiolaria are planktonic protozoans (0.1-1 mm) living in almost all oceans and seas. More abundant in superficial layers but can be found also in deep sea. They have a siliceous skeleton (capsule). As foraminifera, they are heterotrophic preying on phytoplankton, ciliates, copepods, larvae, etc. They can have photosynthetic symbionts.



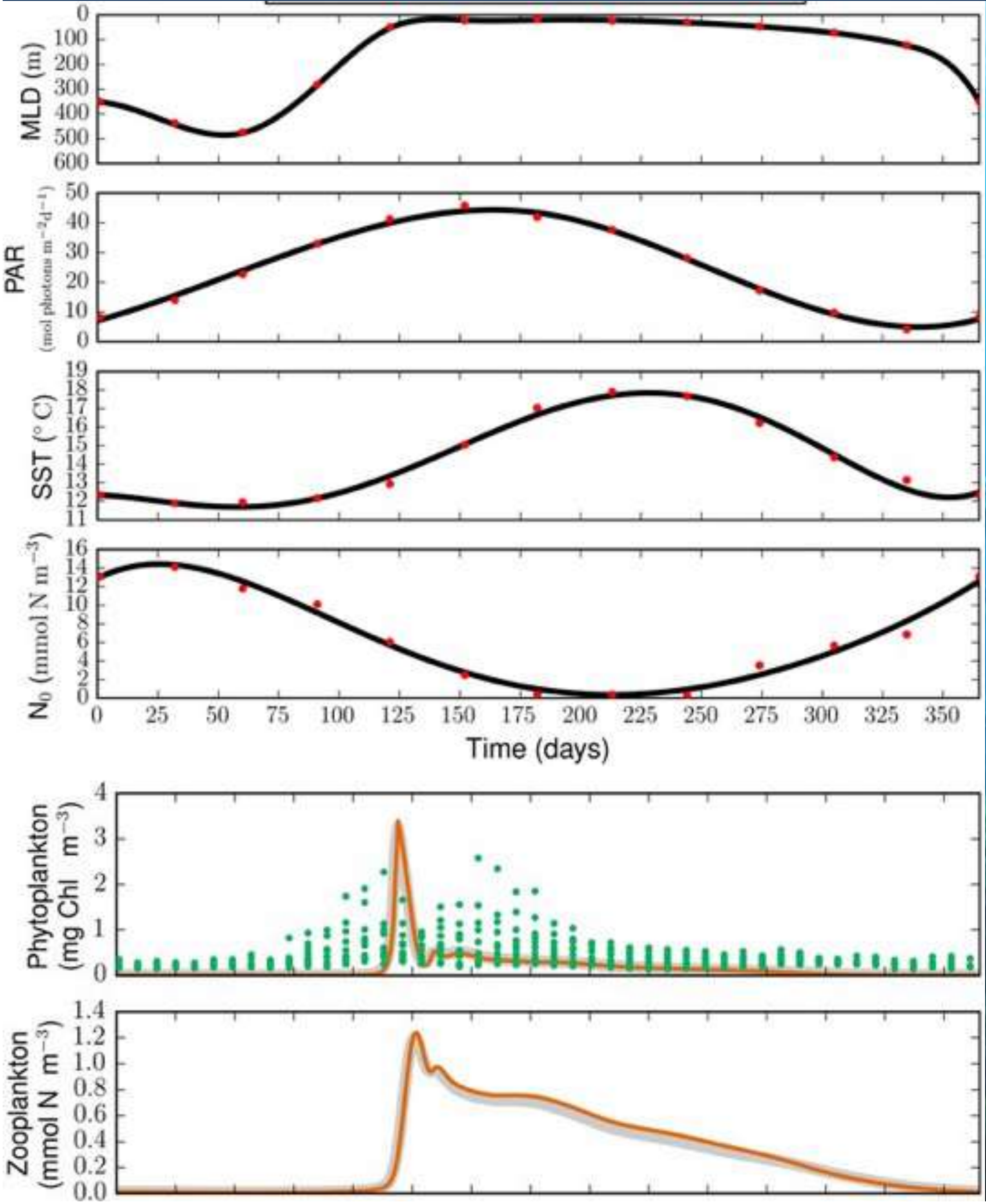
Contribute to silicon cycle and fossil records are used for past climate reconstruction.

Zooplankton: copepods

Crustaceans. Most of planktonic copepoda are Calanoida and Cyclopoida. Harpacticoida are benthic. A large % is parasitic. Size range between 0.2-1 mm. Everywhere in the ocean from polar to tropical regions, from the surface to the deep sea. They are the most abundant metazoans in the ocean. Feed on phytoplankton, moslty on diatoms.

Represent food resource for many pelagic and benthic species, including many fish (even large fish) and cetaceans

Plankton seasonal cycle



In temperate areas, phytoplanktonic blooms occur in spring-summer. Radiation is low and winter mixing of waters (high hydrodynamism) further reduces light penetration. Remixing waters allows nutrients to increase in shallower waters, preparing the conditions for algal blooms, which require nutrients. In spring, radiation increase, mixing decrease and nutrients are available. So phytoplankton blooms. Zooplankton increases just after the bloom. In tropical areas, blooms occur in spring but drop in summer, since phytoplankton consumes nutrients, and warm and stagnant waters prevent mixing.

Other groups

Chaetognata or arrow worms are common in the zooplankton of marine waters throughout the world and they are present from coastal waters and estuaries to open oceans, and from shallow depths to deep sea.

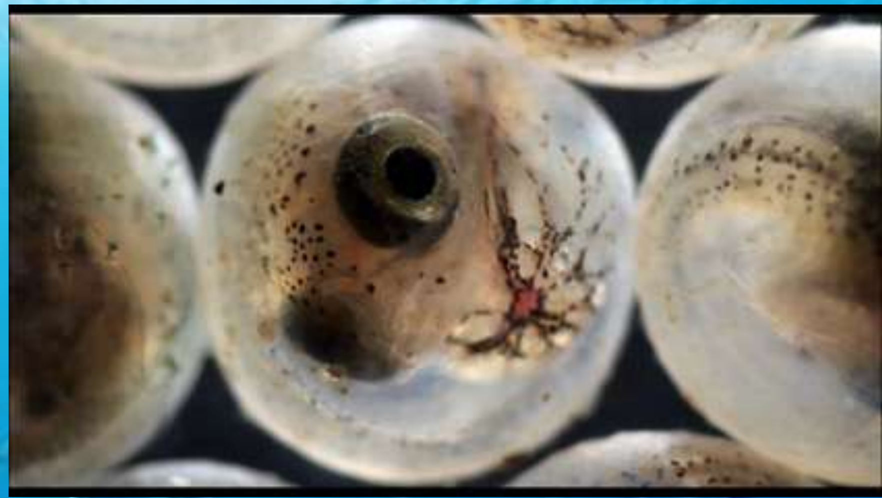
All predators. Grasping spines

Chaetognata are often abundant, ranking second, after copepods, at certain time of year and as they feed at several trophic level, they potentially play an important role in zooplankton trophodynamics.

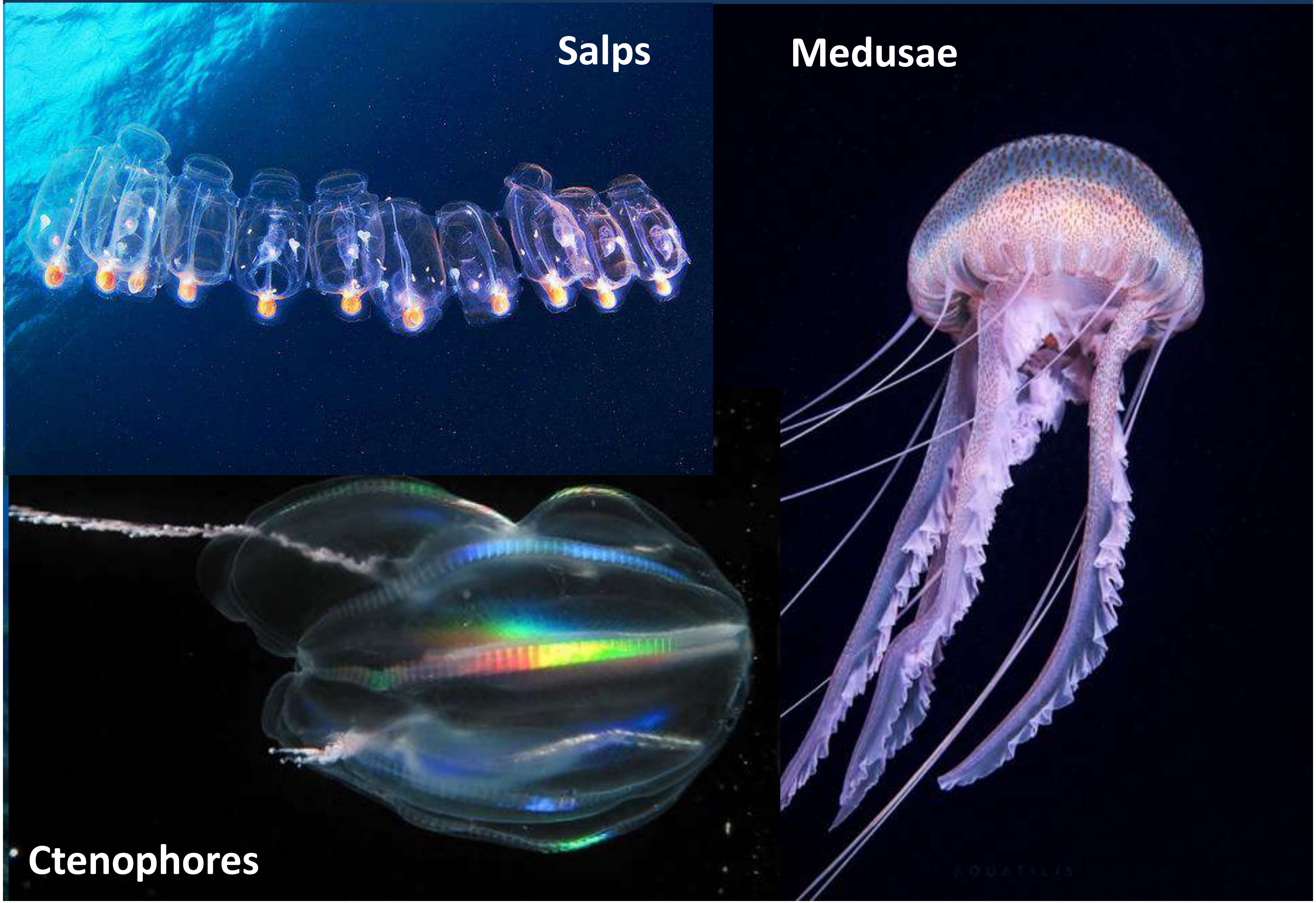
Sagitta enflata is the commonest oceanic chaetognath throughout the tropical and subtropical regions of the world

Ichthyoplankton

- Fish eggs and larvae
- Passively drifting
- Size: 500 µm - >1 cm
- Larvae -> Metamorphosis -> Juveniles



Gelatinous zooplankton



Thaliacea

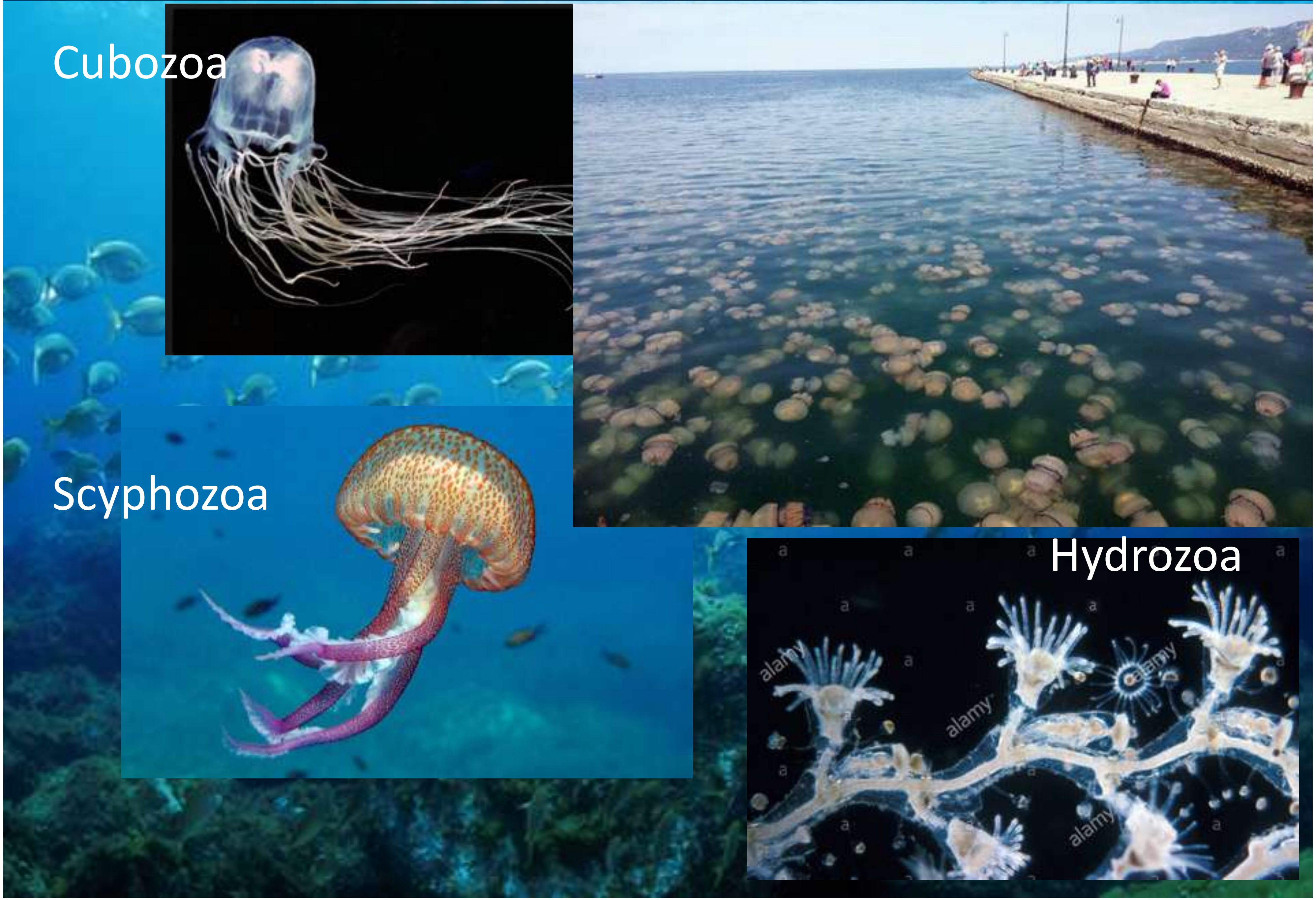
The small salp *Thalia democratica*, for example, can reach abundances of >5000 ind/m^3 , and densities of >1000 ind/m^3 are common during phytoplankton blooms. They are a vector transferring energy to higher trophic levels including fish and marine turtles, as well as for other organisms such as corals, ctenophores, molluscs, crustaceans.

Table I. Comparison of Salp, Pyrosome, and Doliolid Traits

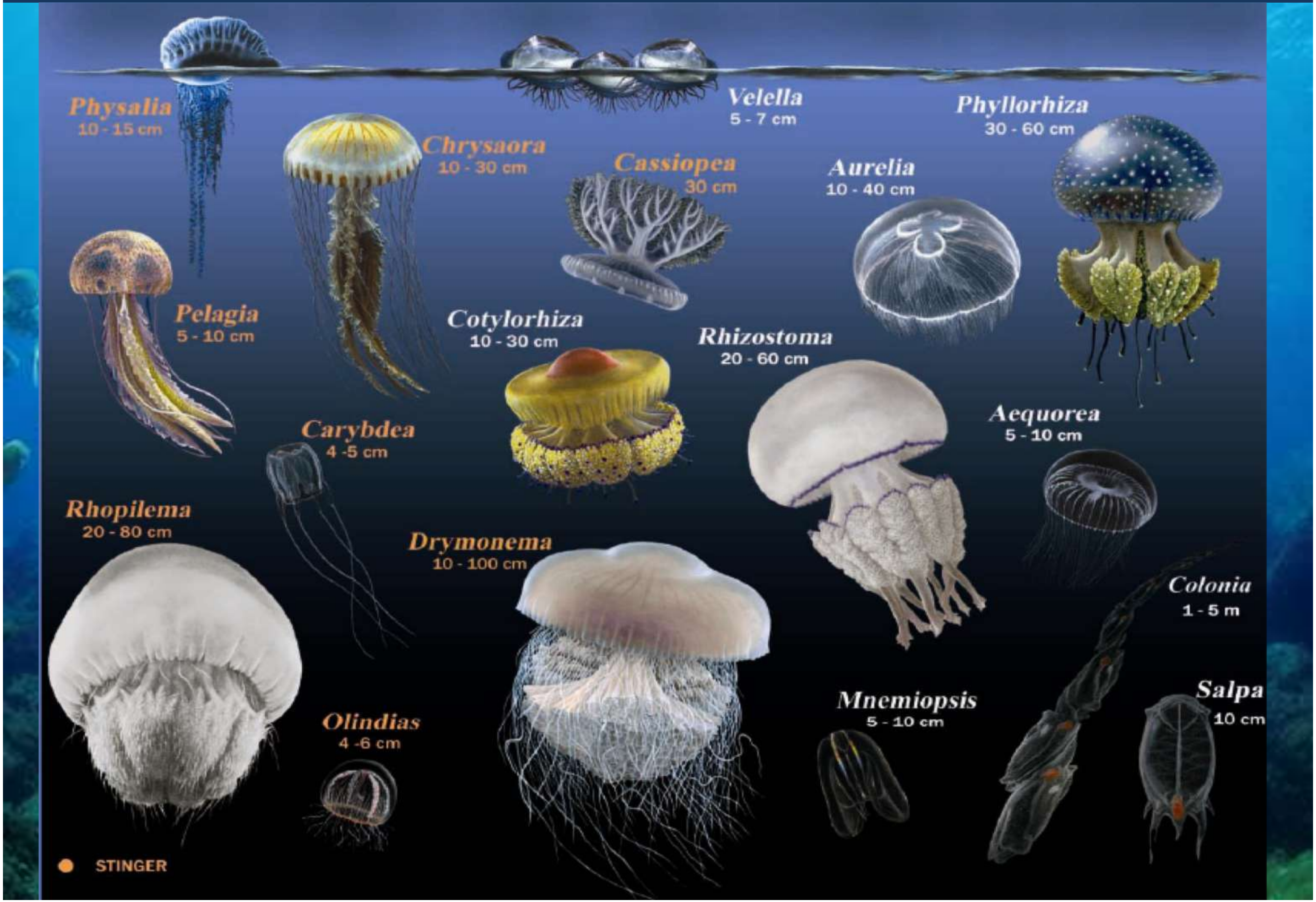
	Salpida	Pyrosomatida	Dolioida
Diversity	48 species	8 species	23 species
Size Range	0.5–190 mm	1 cm to 20 m	0.5–5 mm
Lifecycle	Alternation between sexual aggregate and asexual solitary generations	Internal fertilization and embryonic development	Complex life cycles and zooid specialization; asexual oozoids produce asexual phorozooids, which produce sexual gonozooids
Feeding method and range	Filtration; <1 µm to 1 mm	Filtration; >10 µm	Filtration; 2–50 µm
Propulsion	Exiting water provides propulsion	Exiting water provides propulsion	Muscle bands provide propulsion
Swarming location	Coastal, shelf, and oceanic	Warm open ocean between 50°N and 50°S	Coast and shelf break
Known predators	202	65	~10

Salps produce large, fast-sinking (up to 2700 m day^{-1}), carbon-rich (up to 37% DW) fecal pellets, contributing disproportionately to carbon flux compared with other zooplankton (Henschke et al., 2016).

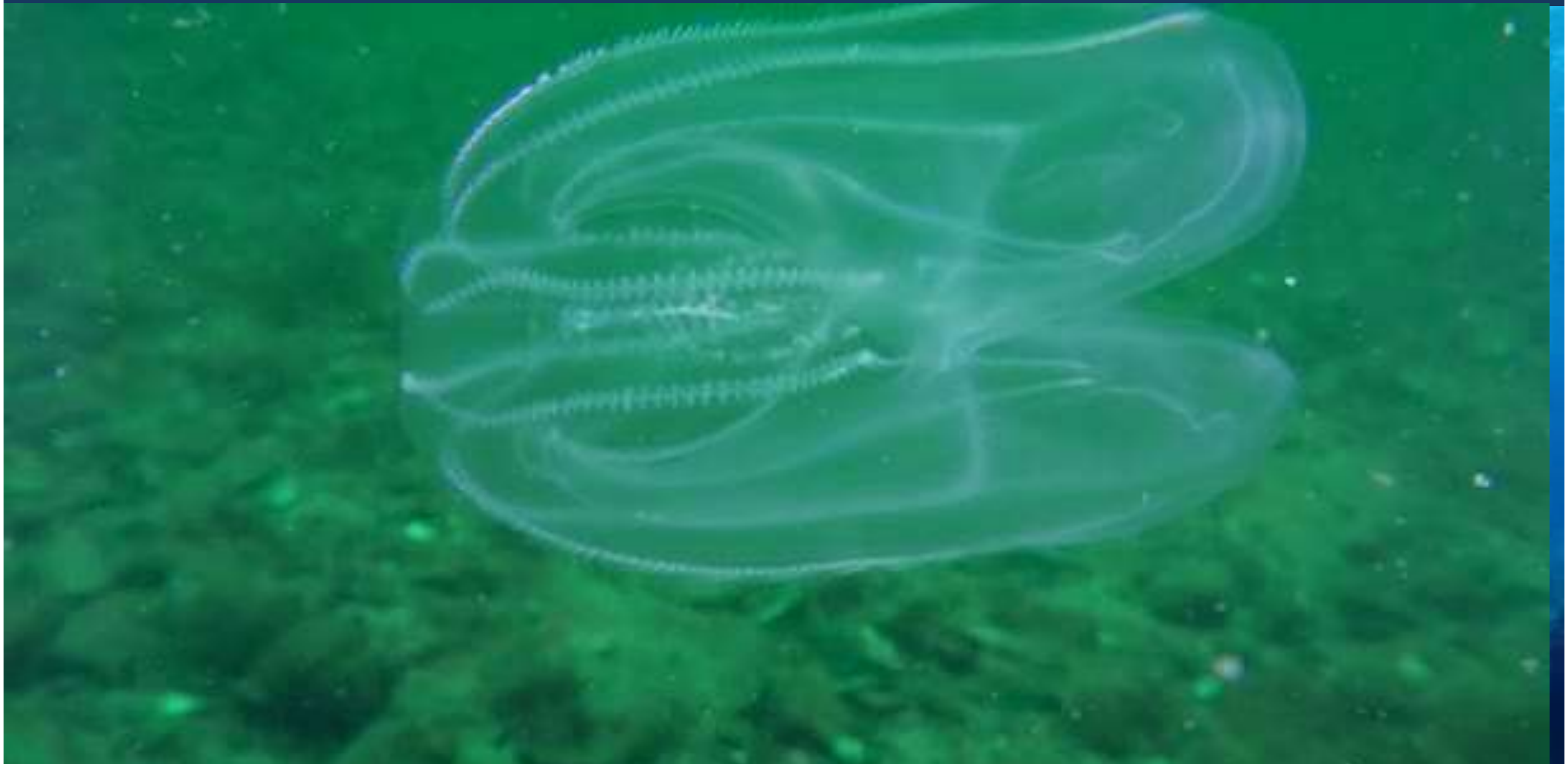
Jellyfish



Common jellyfish in the Mediterranean



Ctenophora



Mnemiopsis leidyi is robust to sharp variations in the environment, tolerating temperature from 6 to >30° C and salinity from 3-38 psu. In 1980s it caused the fishery collapse in the Black Sea. First record in the Mediterranean dates back to 1990 in the Aegean Sea. In 2005 was recoderd in Croatia, and along the Apulian coast in 2016 (Cilenti et al., 2016).

Nekton

Nekton includes all animals able to actively move against currents.

They can be pretty marine (e.g., fish), or living most of their life in the sea (e.g., sea turtles) or exploiting marine resources in the water column (e.g., seals)

Common traits across taxa

Different taxonomic groups exhibit similar body structure as an adaptation to pelagic life.

Anatomic structures or physiological strategies for buoyancy

High mobility and ability to move over large distance

Senses

Euphasiacea and shrimps

Euphausiacea (Krill) are shrimp-like crustaceans that are extremely abundant in polar waters, both arctic and Antarctic.
They reach very large biomass and sustain whole trophic webs, and very large animals rely on them for food.

Cephalopods

Efficient predators
Highly developed sensorial structures

Fish

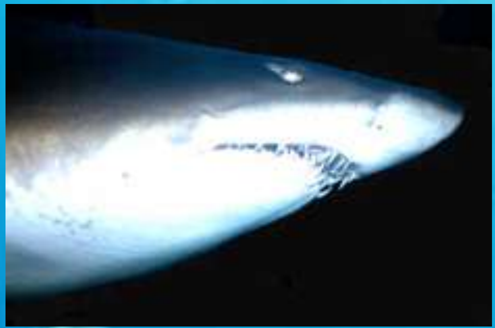
Sphyraena barracuda

Mola mola

Thunnus thynnus

Manta birostris

Chondrichthyes



Carcharias taurus

Squatina squatina

Mustelus mustelus

Cetorhinus maximus

Carcharodon carcharias

Scyliorhinus canicula

Alopias vulpinus

Prionace glauca

Sphyrna zygaena

Osteichthyes

Blenniformes

Atheriniformes

Carangiformes

Clupeiformes

Lophiiformes

Perciformes

Scombriformes

Tetraodontiformes

Zeiformes

Pleuronectiformes

Reptiles

Adults in the sea

Juvaniles come back to the sea

They lay eggs in sand

Cetaceans (Mysticetes)

Balaenoptera physalis

Common

Balaenoptera acutorostrata

Occasional

Megaptera novaeangliae

Accidental

Cetaceans (Odontocetes)

Grampus griseus

Globicephala melas

Tursiops truncatus

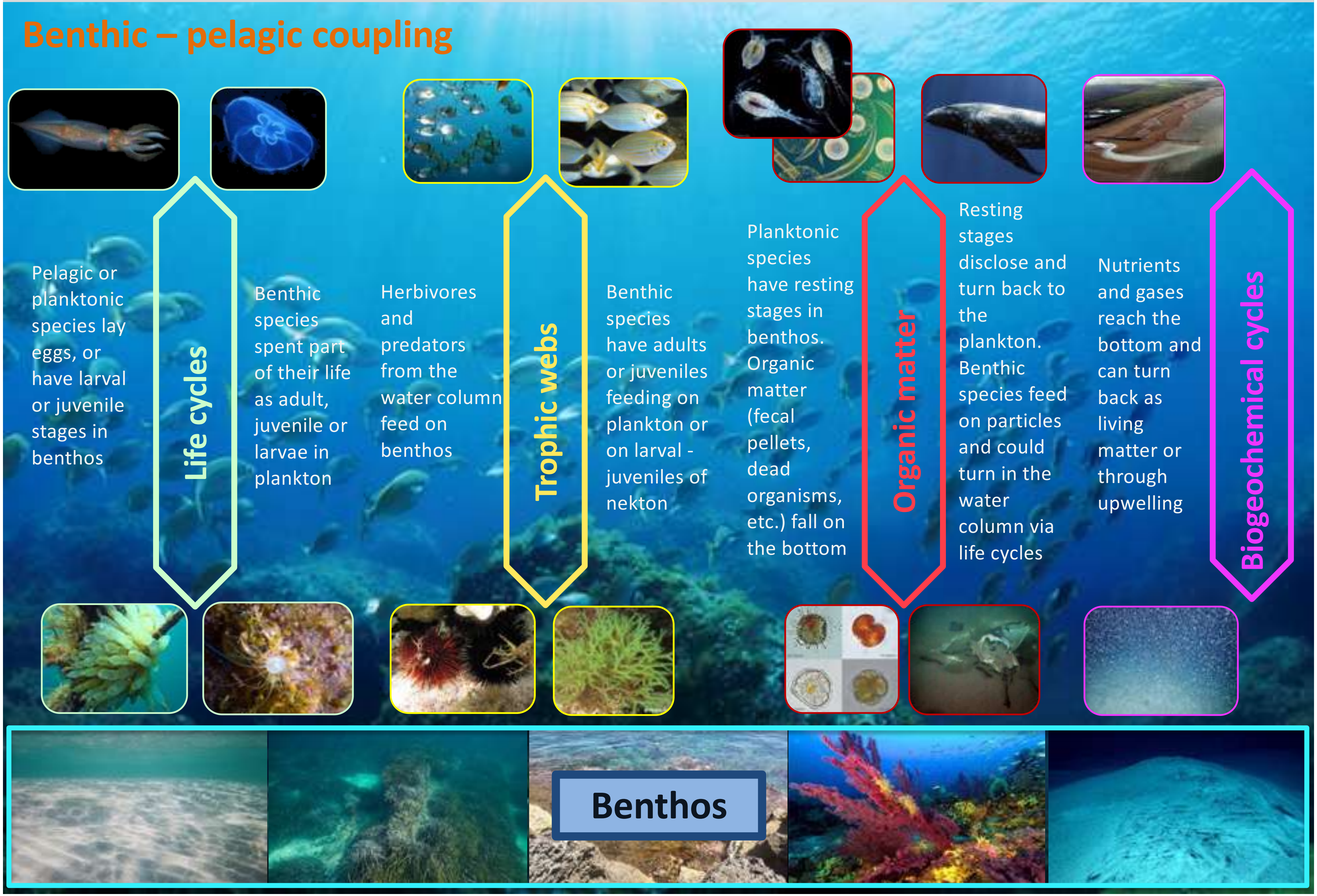
Physeter macrocephalus

Stenella coeruleoalba

Orcinus orca

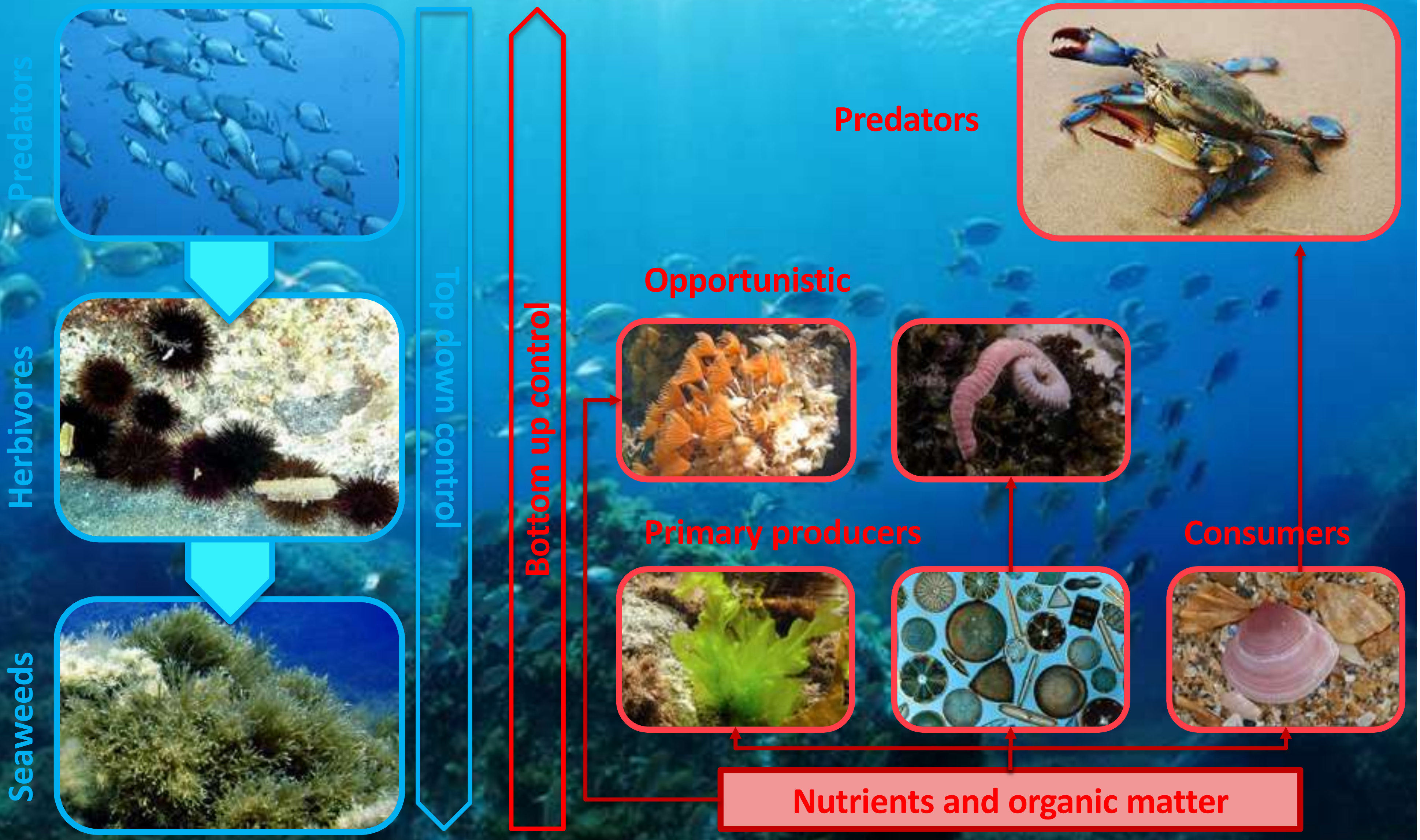
Other mammalians

Benthic-pelagic coupling

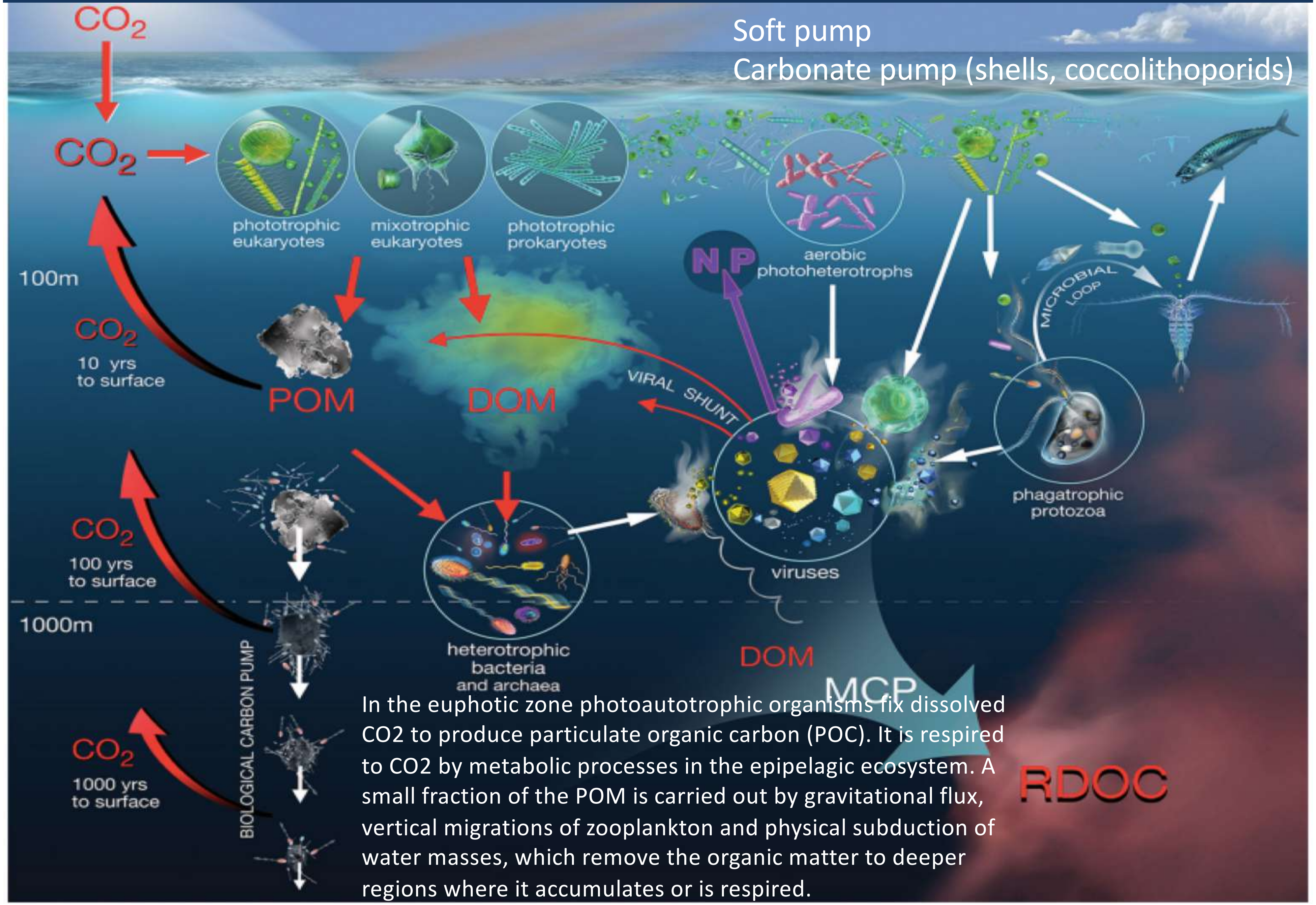


Trophic webs

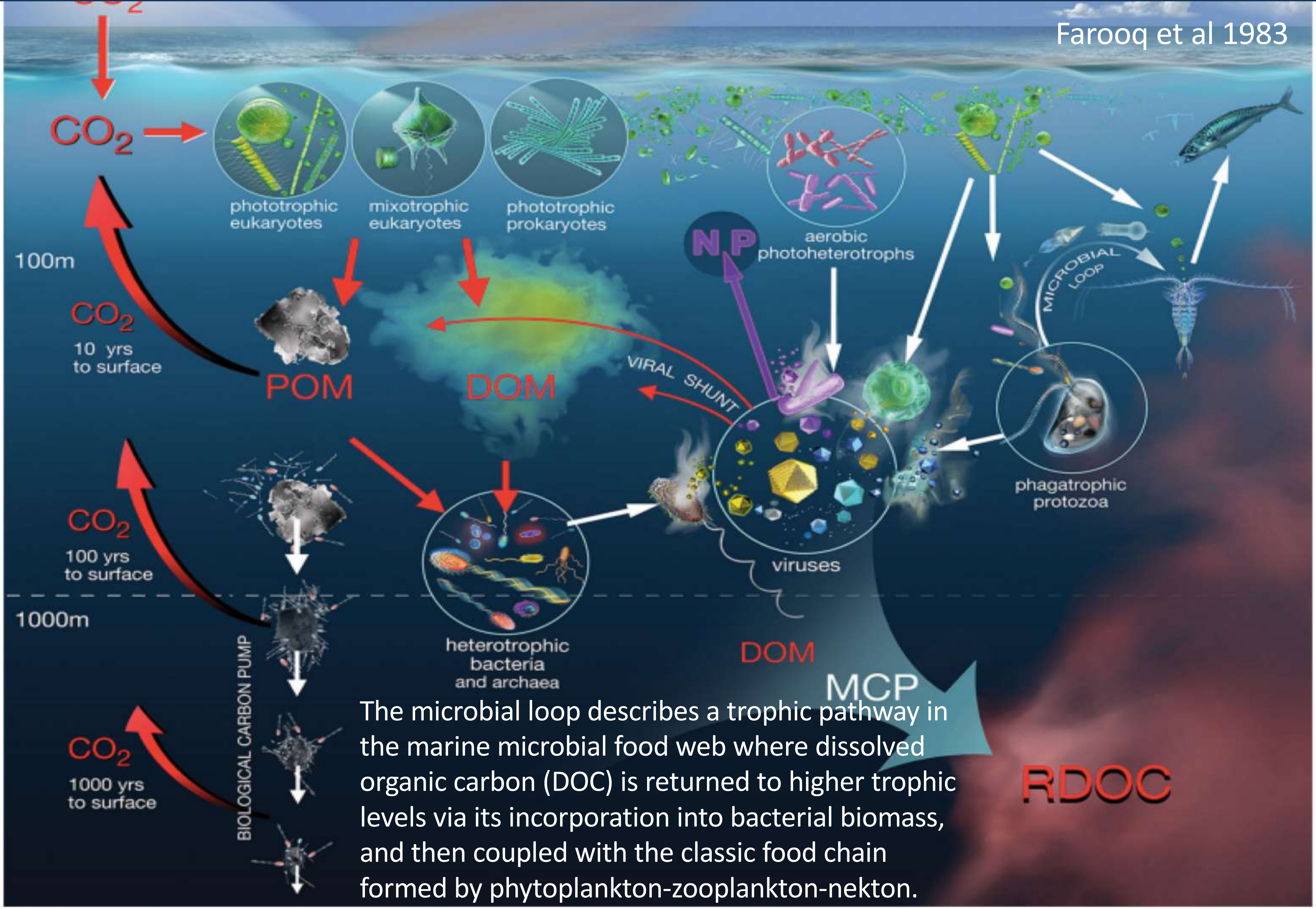
Top-down and bottom-up processes



Biological Carbon Pump



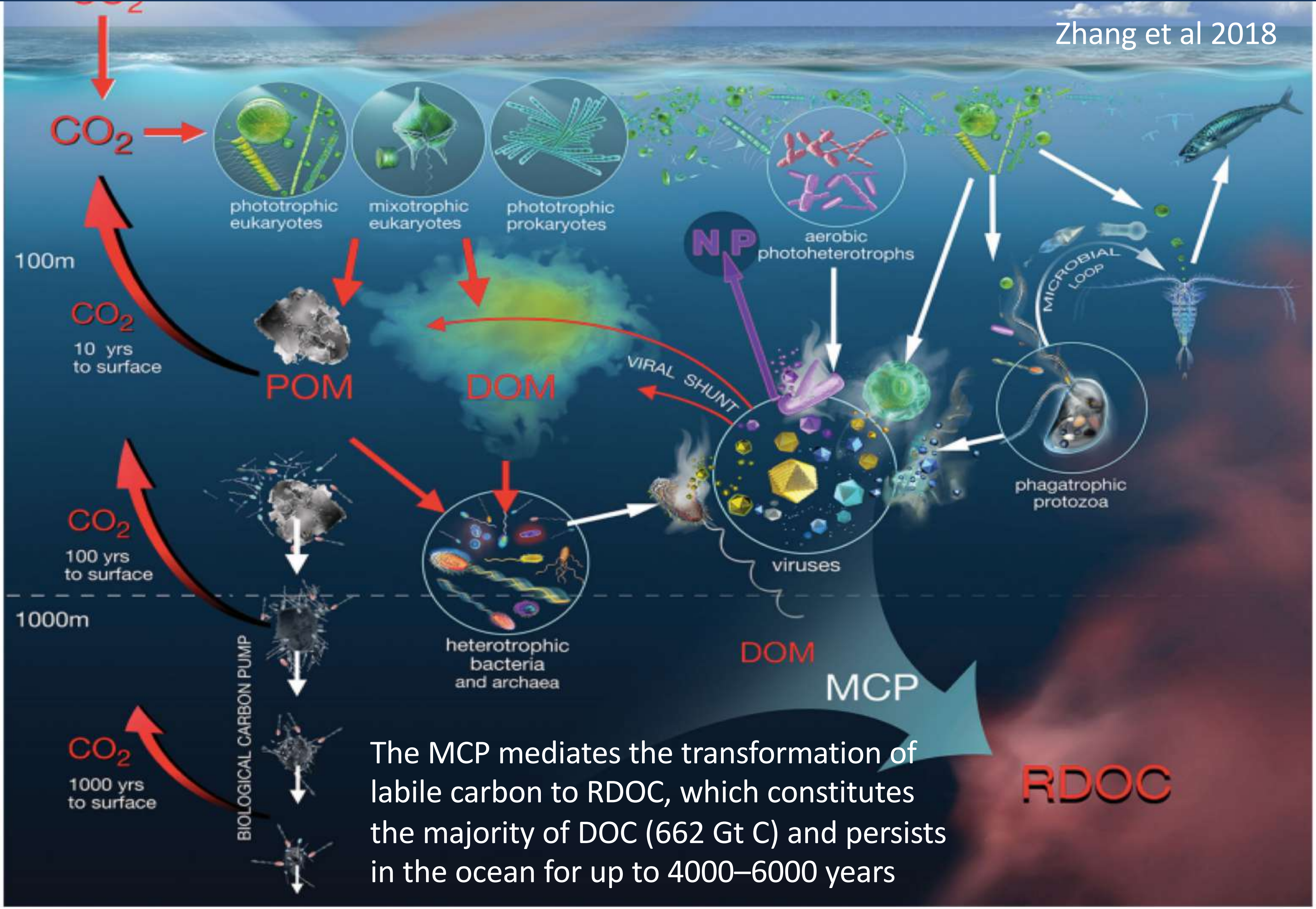
Microbial loop



Farooq et al 1983

The microbial loop describes a trophic pathway in the marine microbial food web where dissolved organic carbon (DOC) is returned to higher trophic levels via its incorporation into bacterial biomass, and then coupled with the classic food chain formed by phytoplankton-zooplankton-nekton.

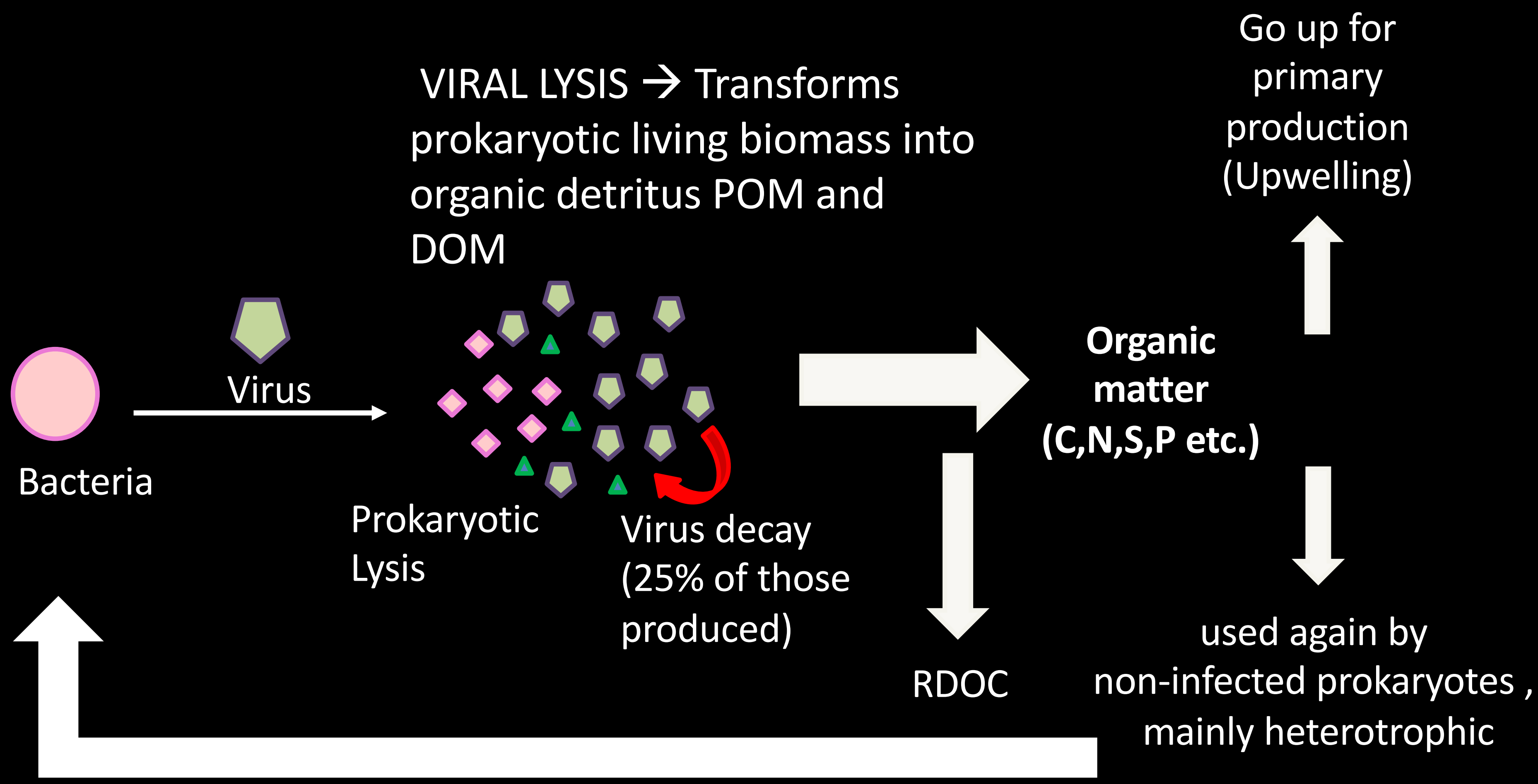
Microbial Carbon Pump



The MCP mediates the transformation of labile carbon to RDOC, which constitutes the majority of DOC (662 Gt C) and persists in the ocean for up to 4000–6000 years

Viral shunt

This process sustains a high prokaryotic biomass and provides an important contribution to prokaryotic metabolism, allowing the system to cope with the severe organic resource limitation of deep-sea ecosystems



The viral shunt, releasing on a global scale , **37-50 megatons of carbon per year**, is an essential source of labile organic detritus in the deep-sea ecosystems

Functioning

Processes – Functions – Goods and services