University of Trieste: GLOBAL CHANGE ECOLOGY a.a. 2020-2021

Marine biology – Biodiversity and ecosystem Functioning

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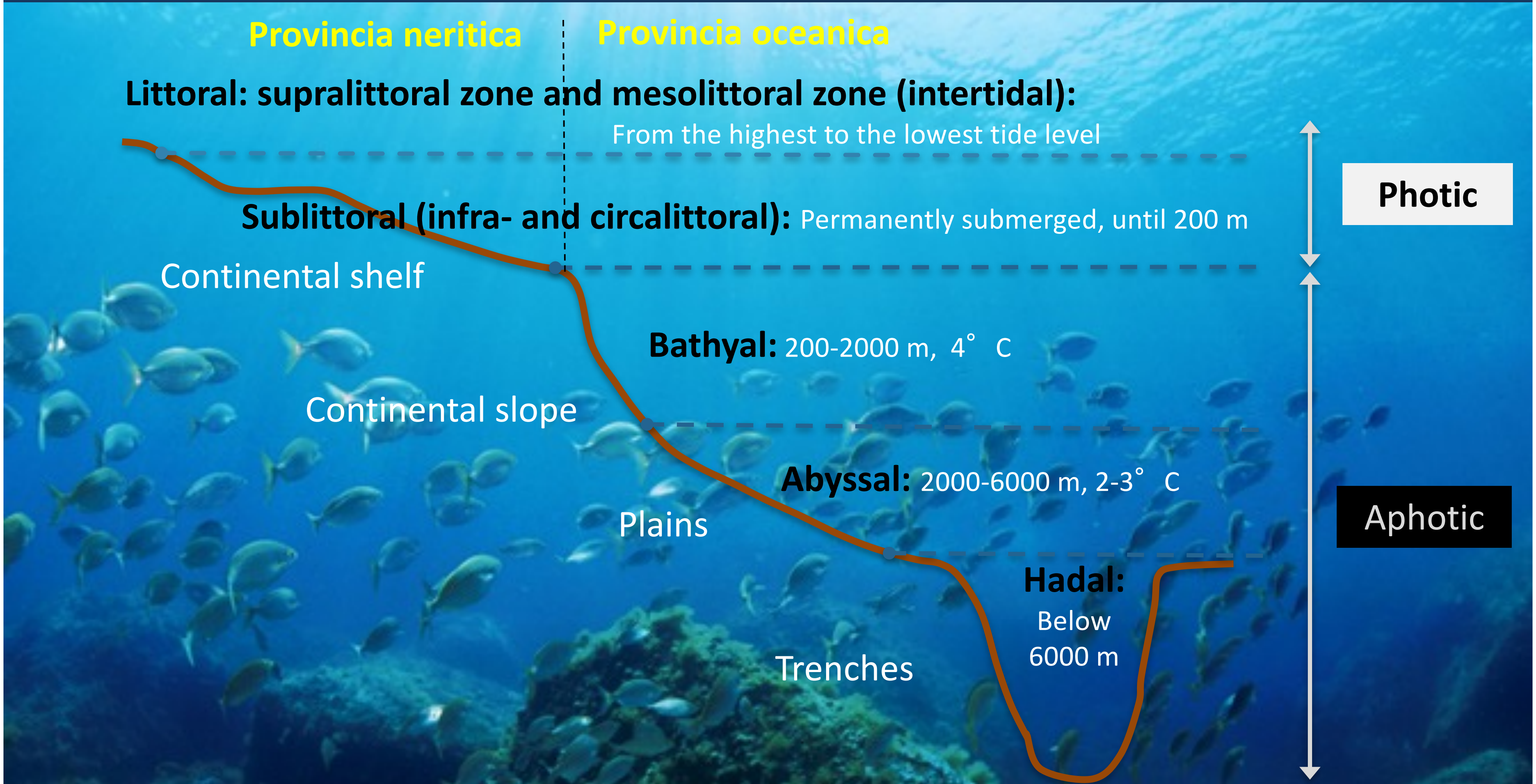
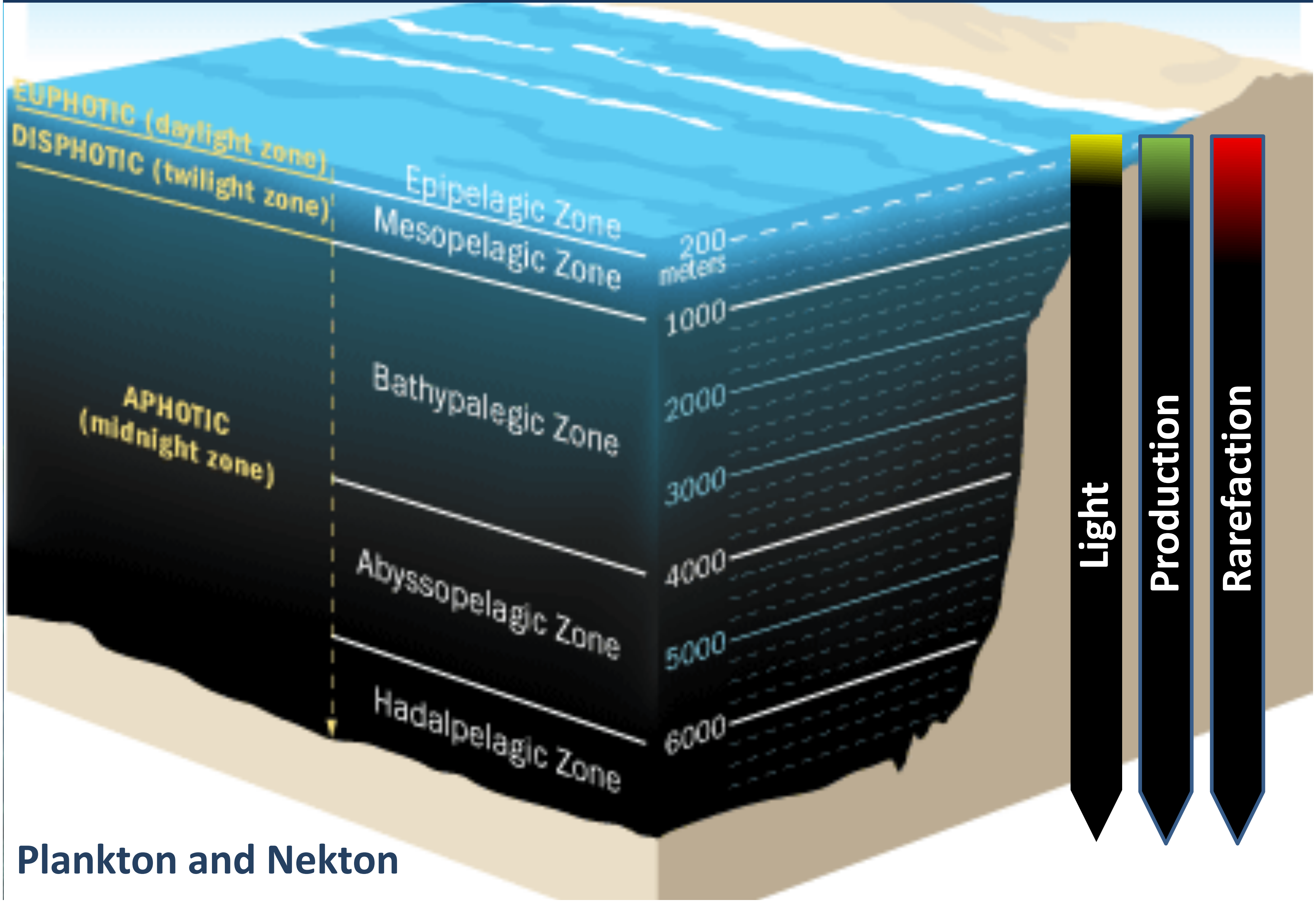
Deep sea ecosystems

The deep sea



Waters and sea bottoms under 200 m are considered as deep sea environments
Average depth of oceans is 3850 m
Oceans cover the 71% of the Earth and > 50% of sea bottom is under 3000 m depth
> 84% of surface and 98% of volume are under 2000 m depth

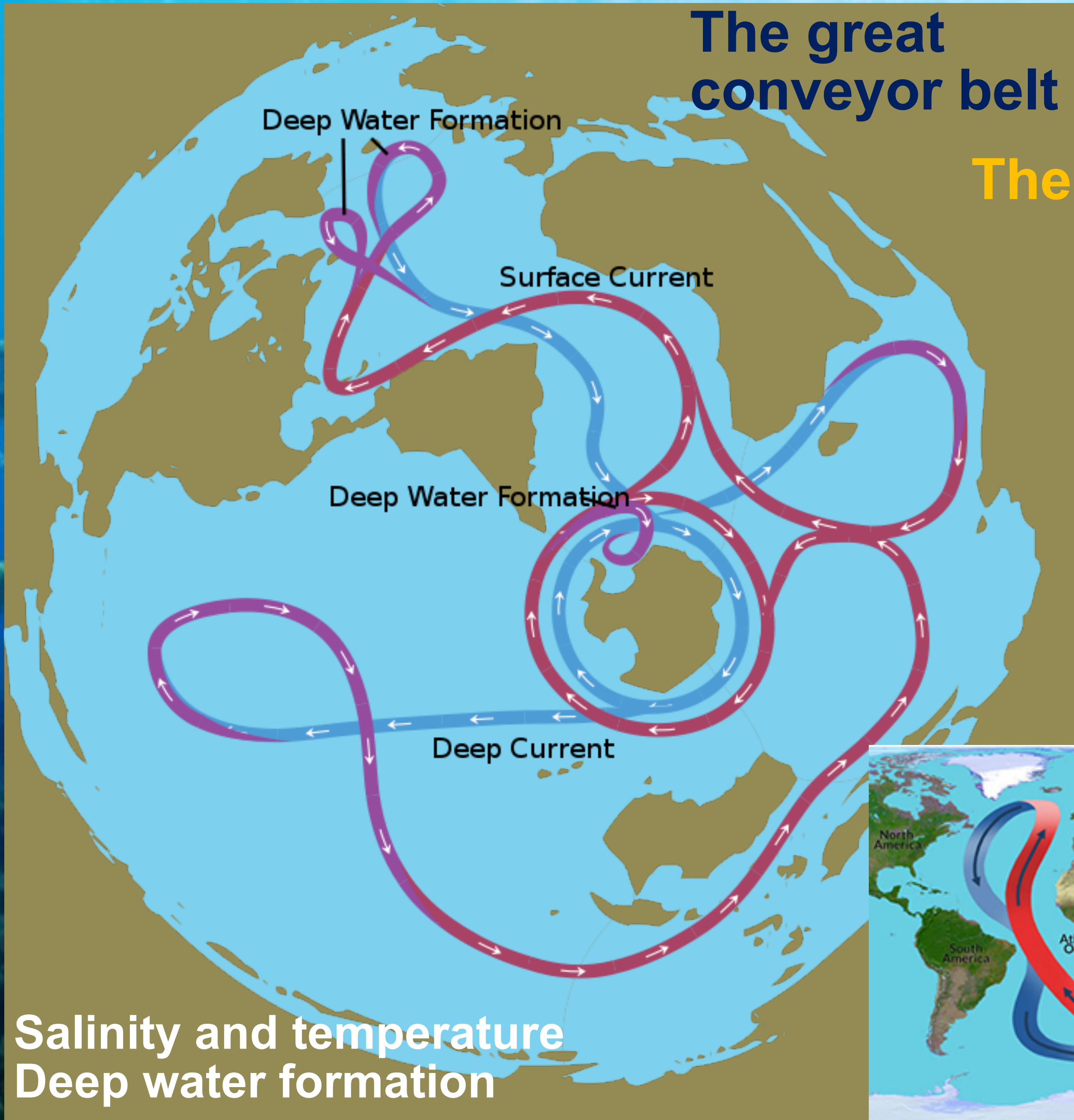
The pelagic domain



Plankton and Nekton

Deep sea circulation

The great conveyor belt

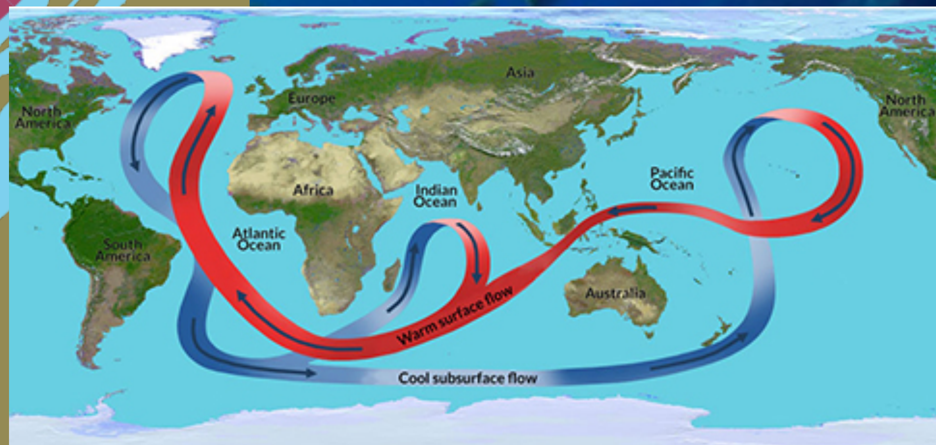


Salinity and temperature
Deep water formation

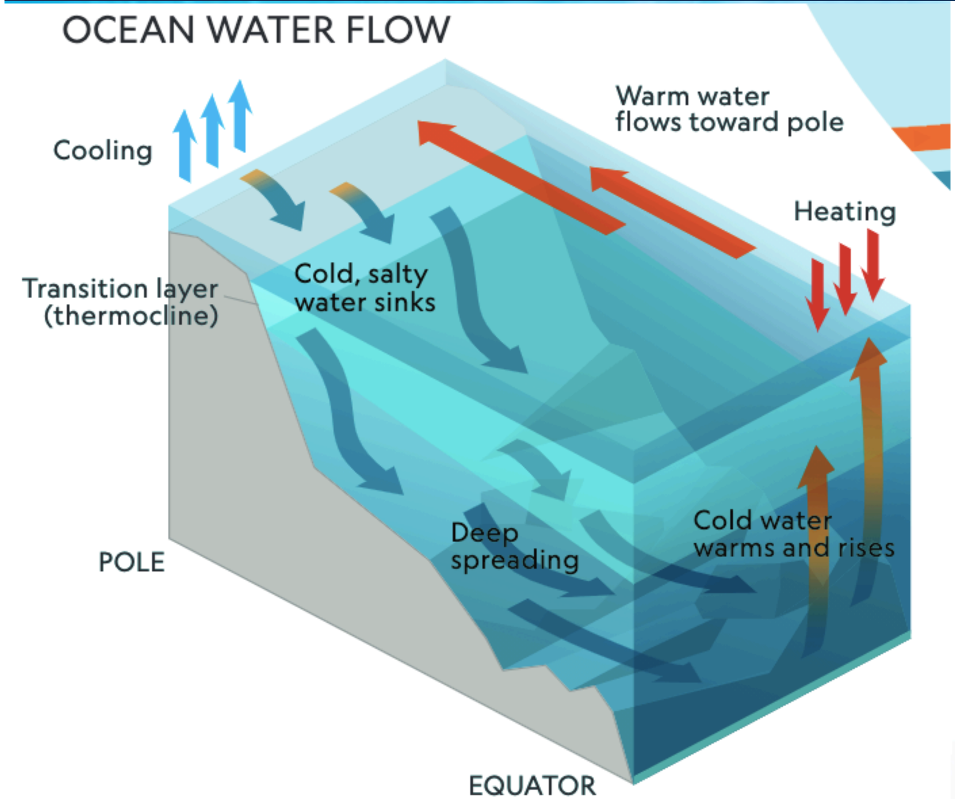
Thermohaline circulation

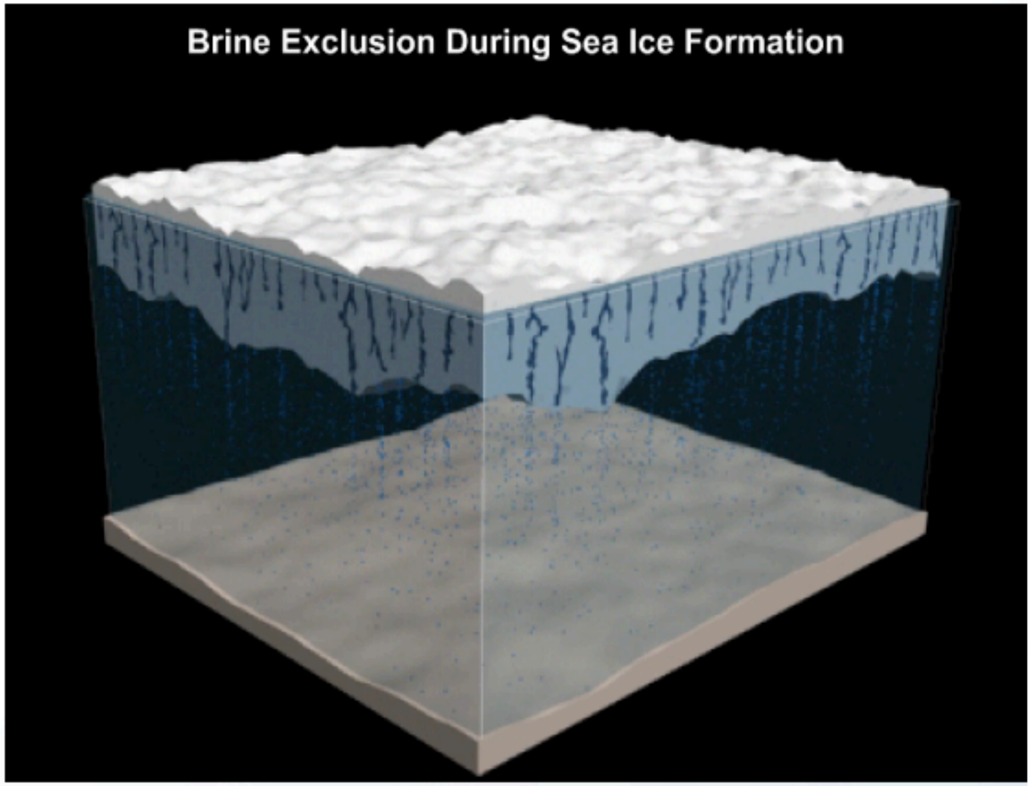
(few cm s^{-1})

In the Atlantic ocean higher mixing between the surface and the deep waters with respect to the Pacific Ocean, where deep water formation lacks. This lead to lower oxigenation and exchange



Deep water formation





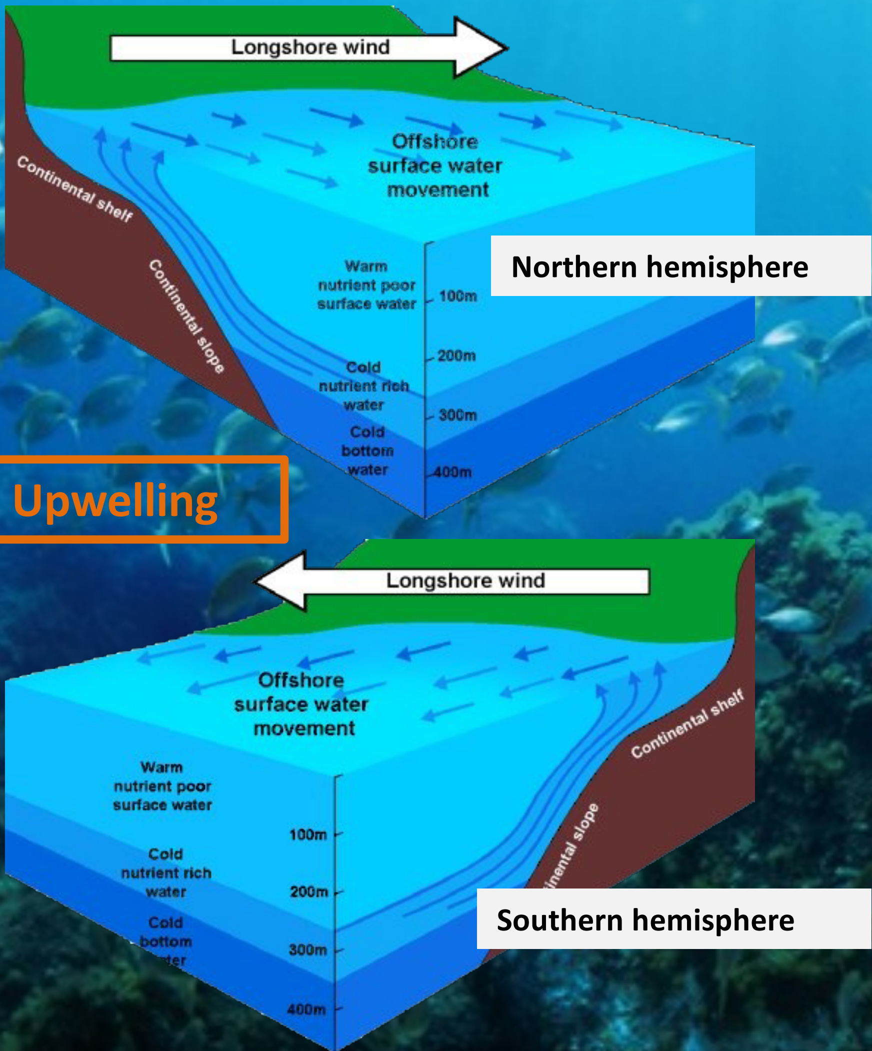
Cold polar winds cause evaporative cooling of seawater, and increase of salinity

Ice formation further increase salinity through brine exclusion

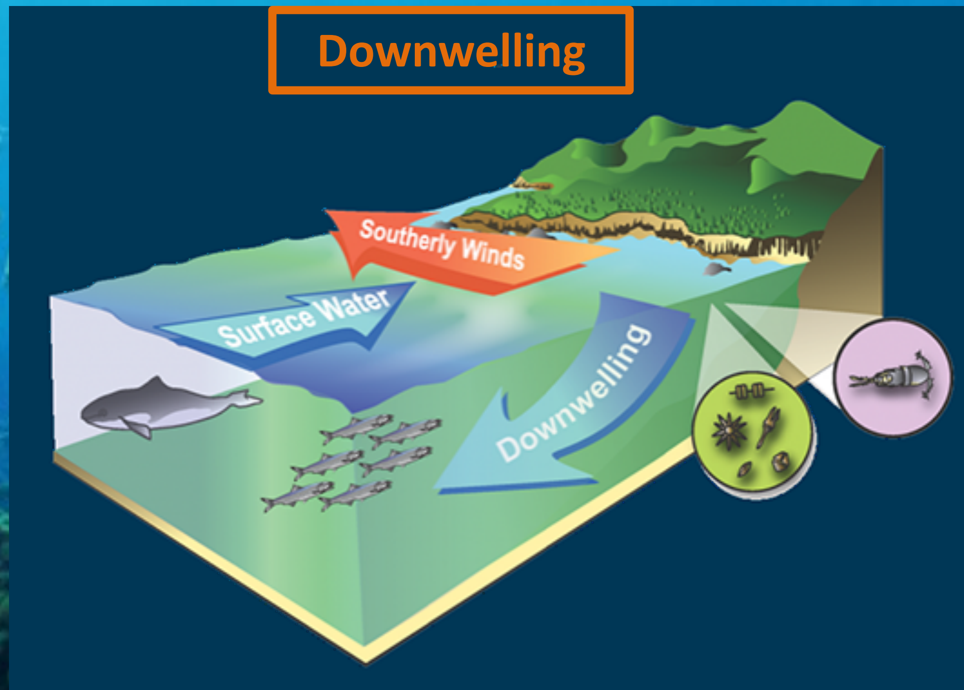
Increased salinity and cooling of waters lead to dense water masses that sink, moving towards the deep ocean, representing the cold engine of the ocean circulation

Distribution, factors and processes

Vertical circulation is also important for the functioning of marine ecosystems. It allows replacing warm and nutrient-poor surface waters with cold and nutrient-rich waters from the bottom, and to transport oxygen towards the bottom



Upwelling



Winds and Earth's rotation generate water movements from the surface to the bottom and vice versa along the coast, but also in open waters

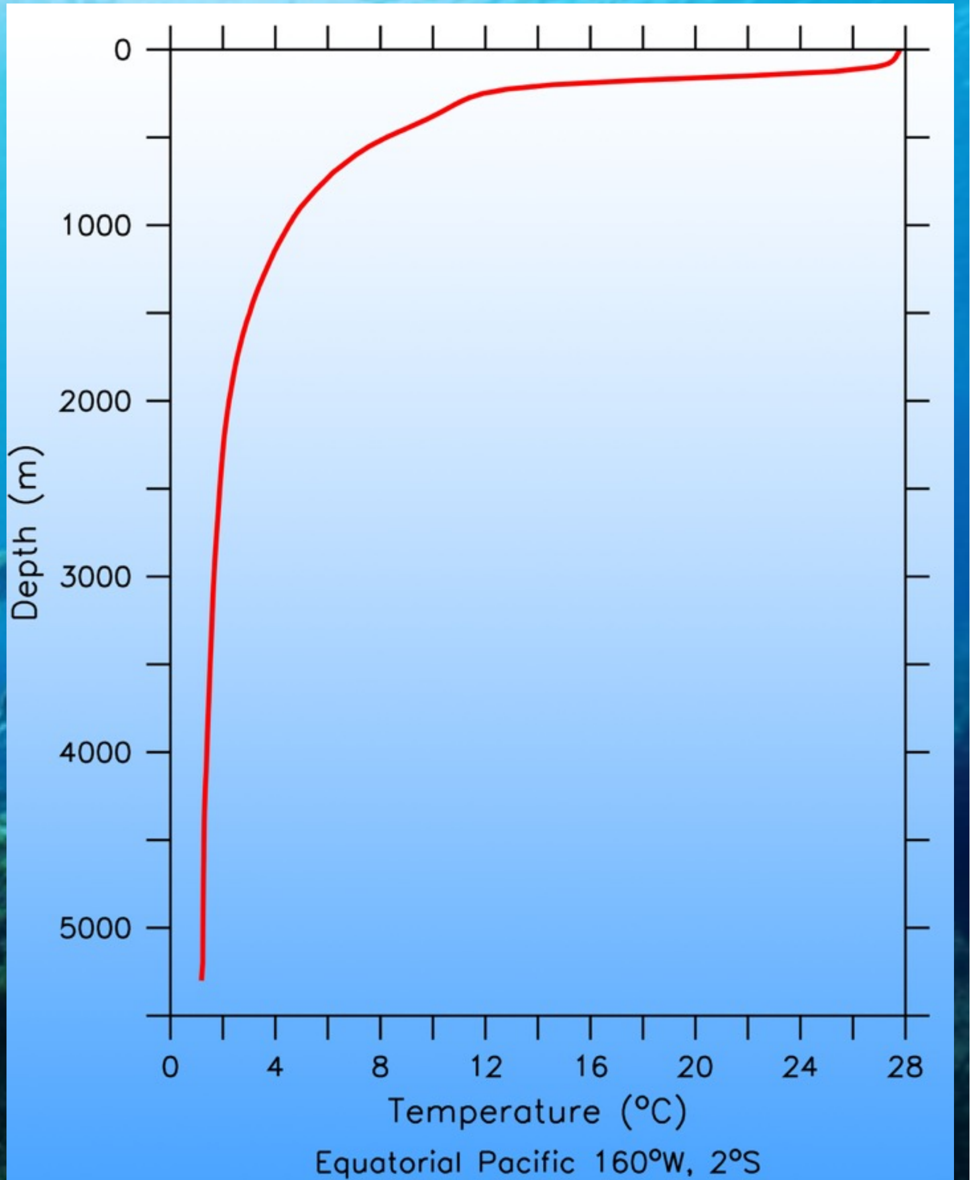
Main environmental features

Temperature < 4° C (-1.9° C)
Temperature > in the Mediterranean Sea (about 12° C)

Salinity: constant 34.8 (2000 m)
34.65 (> 6000 m)

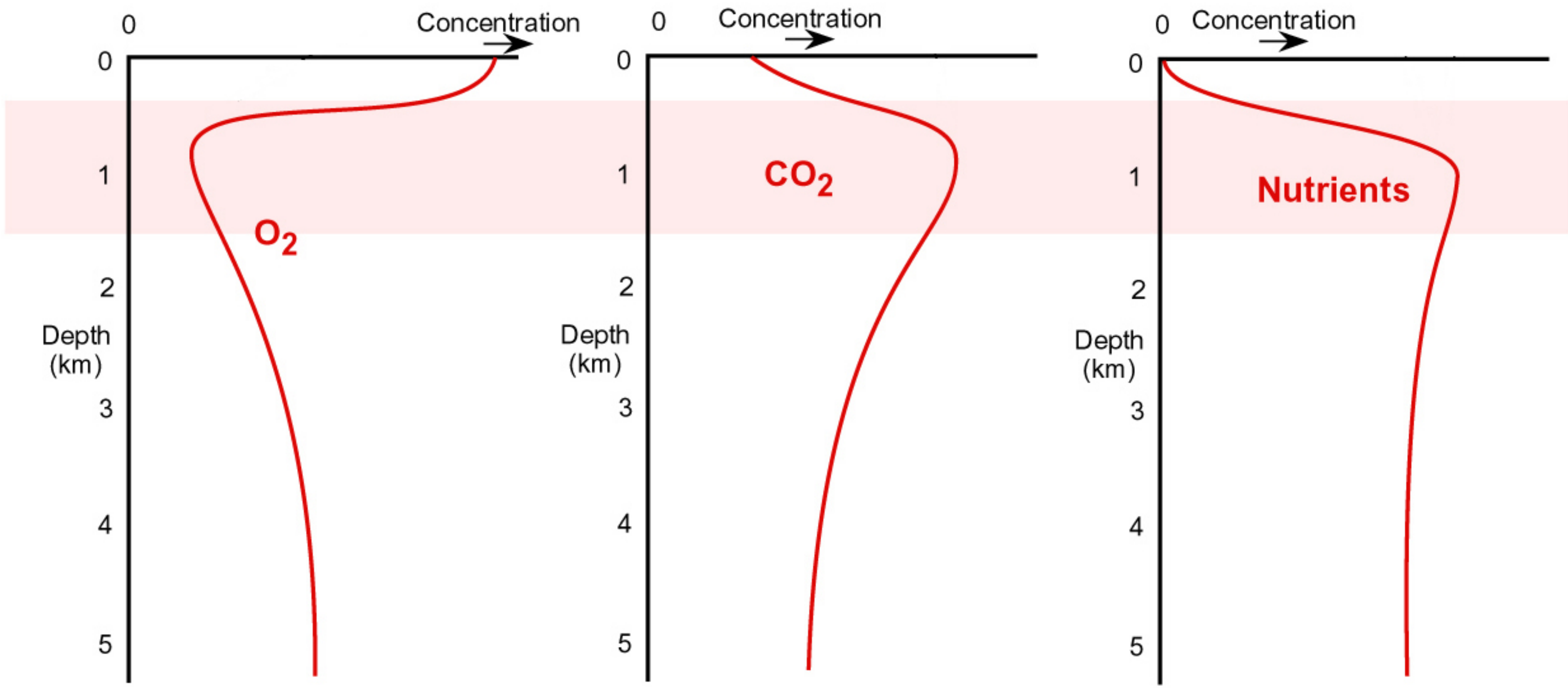
Hydrostatic pressure: very high, influence on metabolism (> 400 atm)

Subtrate: hard bottoms uncommon, mostly incoherent

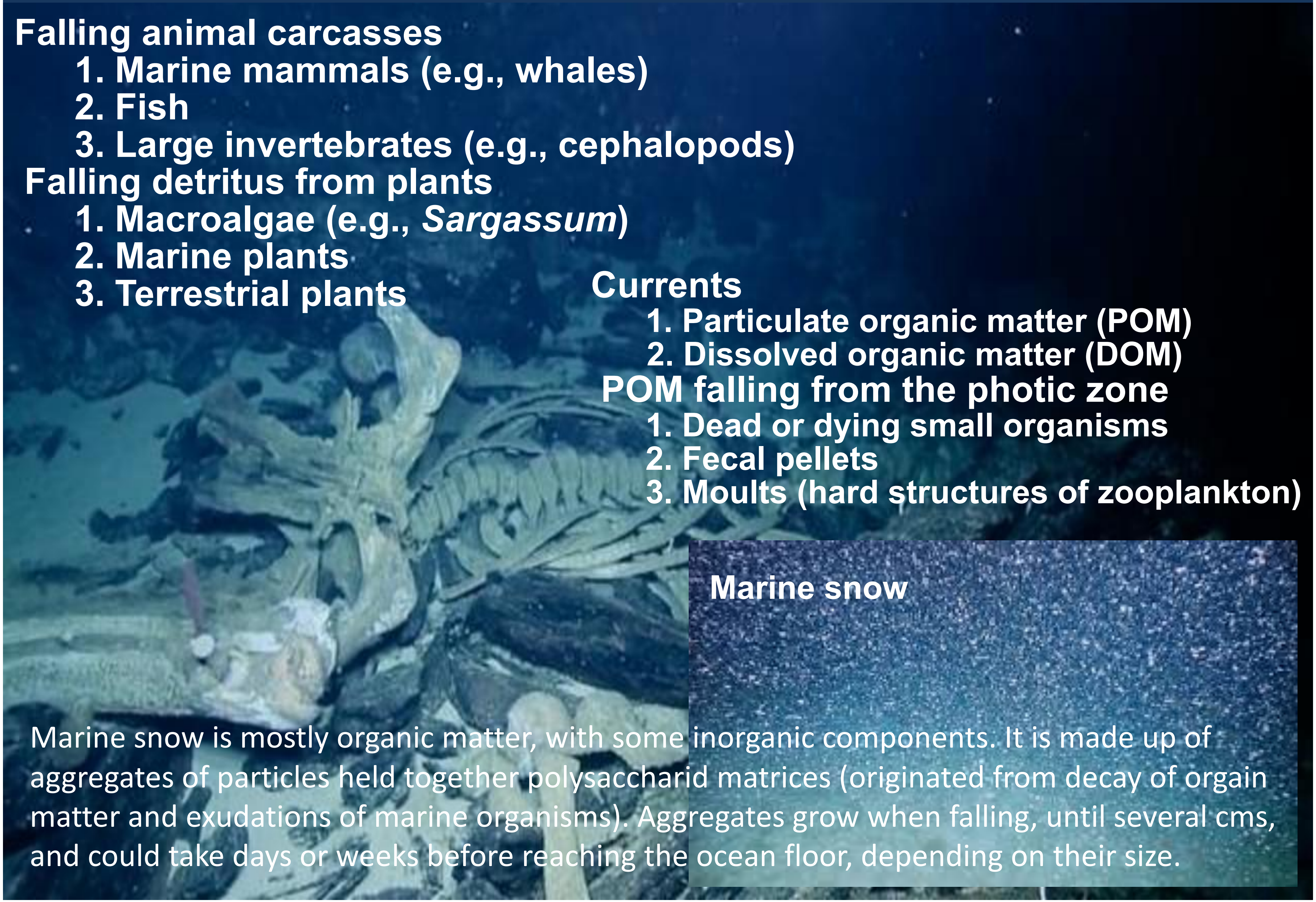


Main environmental features

In the photic zones oxygen is produced by macroalgae and plants, that consume carbon dioxide and nutrients. O_2 decreases with depth due to decline of photosynthetic activity and oxidation of organic matter, whereas CO_2 and nutrients increase due to respiration and increased solubility (high P and low T). Min of O_2 and max of CO_2 and nutrients is achieved at about 1000 m. Below this threshold, nutrients remain stable, O_2 slightly increases due to oxygenation from the surface through currents, and CO_2 slightly decreases due to reduced respiration rates (rarefaction of organisms)



Matter and energy



Falling animal carcasses

1. Marine mammals (e.g., whales)
2. Fish
3. Large invertebrates (e.g., cephalopods)

Falling detritus from plants

1. Macroalgae (e.g., *Sargassum*)
2. Marine plants
3. Terrestrial plants

Currents

1. Particulate organic matter (POM)
2. Dissolved organic matter (DOM)

POM falling from the photic zone

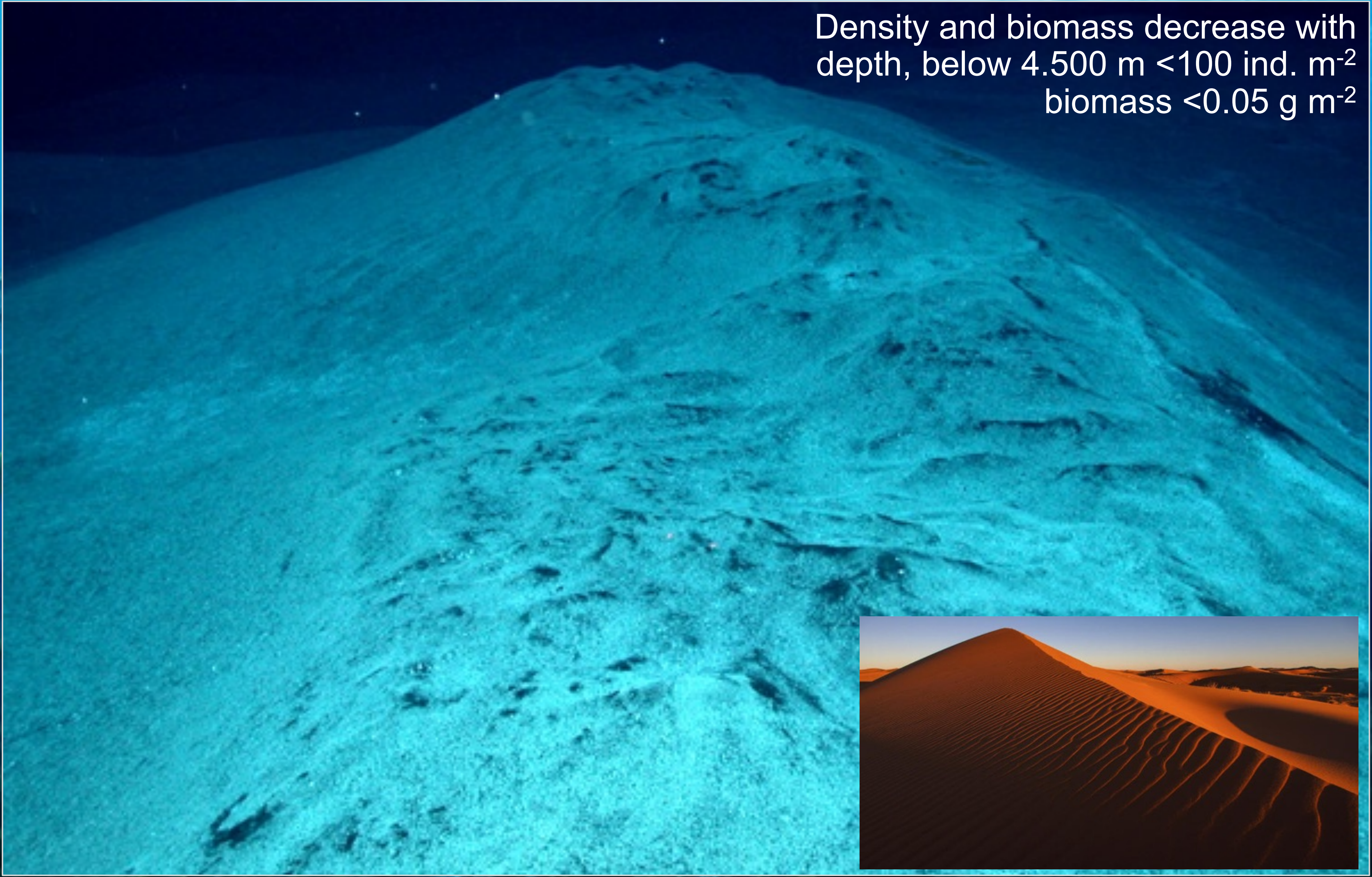
1. Dead or dying small organisms
2. Fecal pellets
3. Moults (hard structures of zooplankton)

Marine snow

Marine snow is mostly organic matter, with some inorganic components. It is made up of aggregates of particles held together polysaccharid matrices (originated from decay of orgain matter and exudations of marine organisms). Aggregates grow when falling, until several cms, and could take days or weeks before reaching the ocean floor, depending on their size.

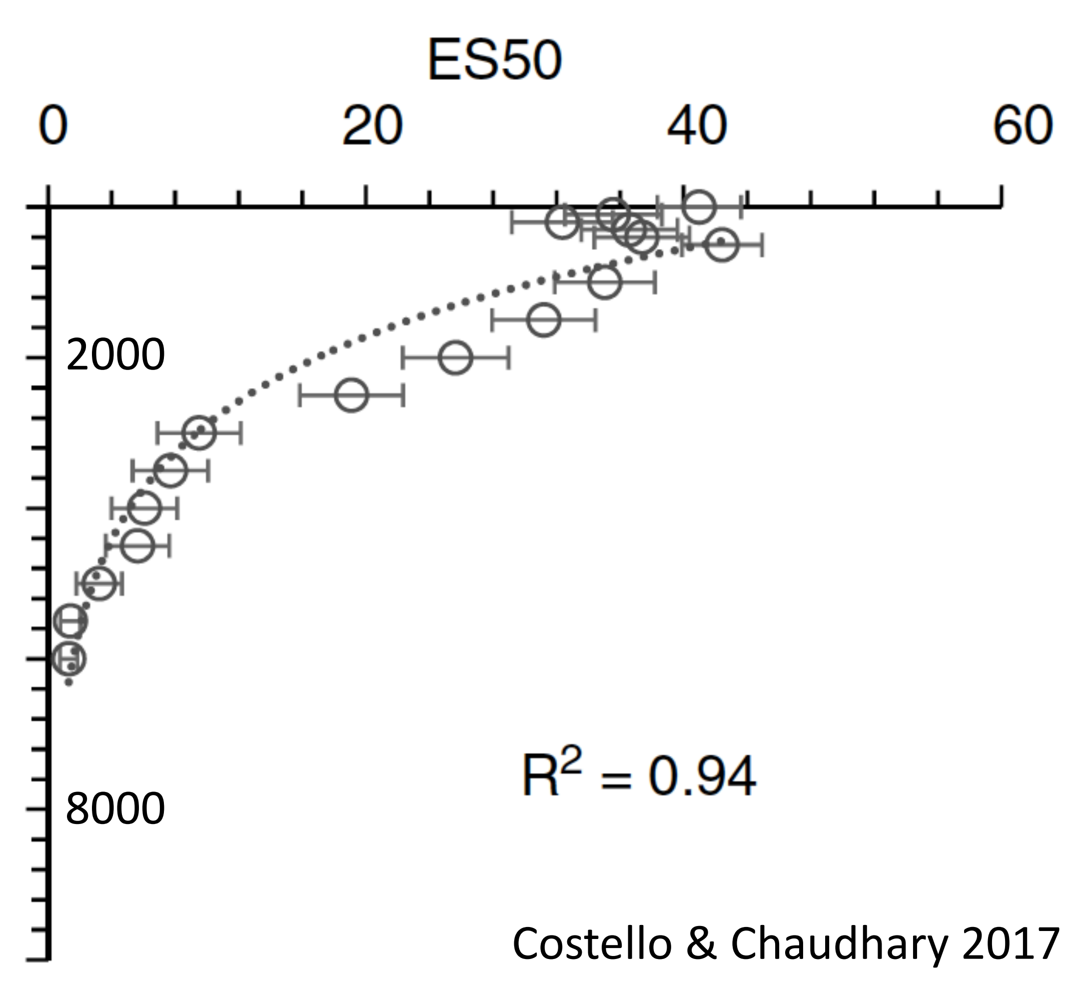
A desert?

Density and biomass decrease with depth, below 4.500 m <100 ind. m^{-2}
biomass <0.05 g m^{-2}



Azoic theory of Forbes, half of 19th century

Stability-Time hypothesis



Sanders (1968) proposed a general model which he called the Stability-Time Hypothesis. This model says that physical instability in an environment prevents the establishment of diverse communities. However, if physically stable conditions persist for a long period of time, speciation and immigration will cause species diversity to increase gradually. Thus, high diversity in the deep sea is a result of the great long-term stability of that environment. Basic to his view is the idea that each species must occupy an increasingly narrow, specialized niche.

However…

1) Feeding behaviour are quite general: many are detritivorous, or filter-feeders, and some predator
2) In most cases species rely on different type of food
3) Low densities imply individuals to interact with many different species
4) Large areas and rarefaction decrease competition (Dayton and Hessler, 1972)

Heterogeneity

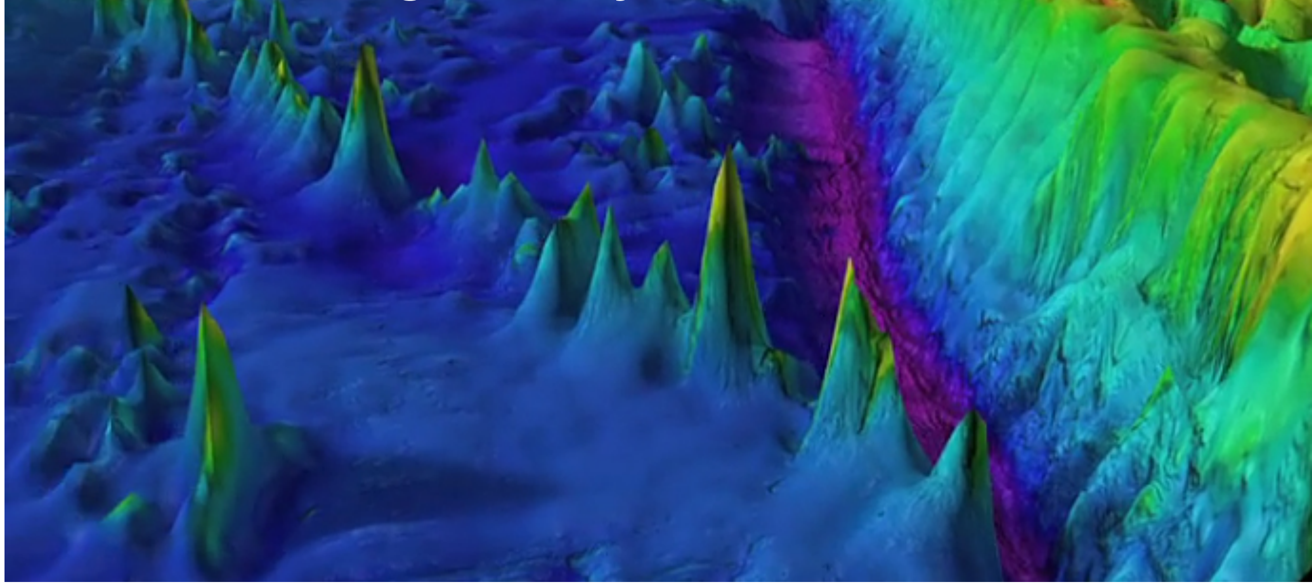
Habitat
mud flats, sea mounts, volcanos, trenches, canyons

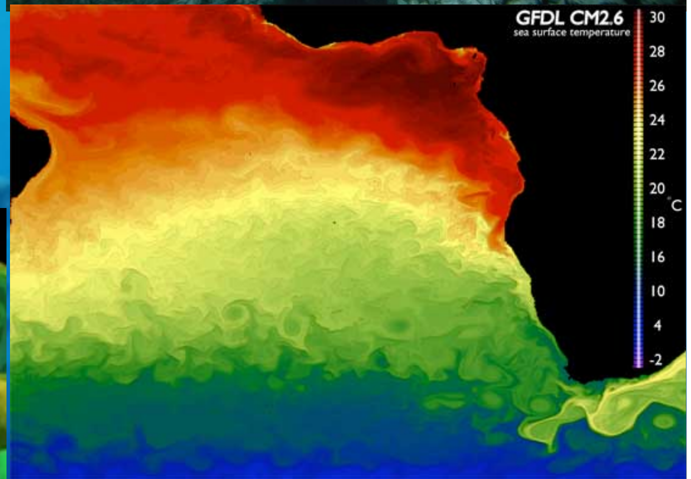
Hydrodynamism
Currents: there are areas of intense hydrodynamis
Eddies: cyclons 50-200 km with high energy flow

Variability:
interannual variations in conditions

Sea bottom perturbation:
resuspension of sediments in slope areas
bioturbation (microscale and small scale)

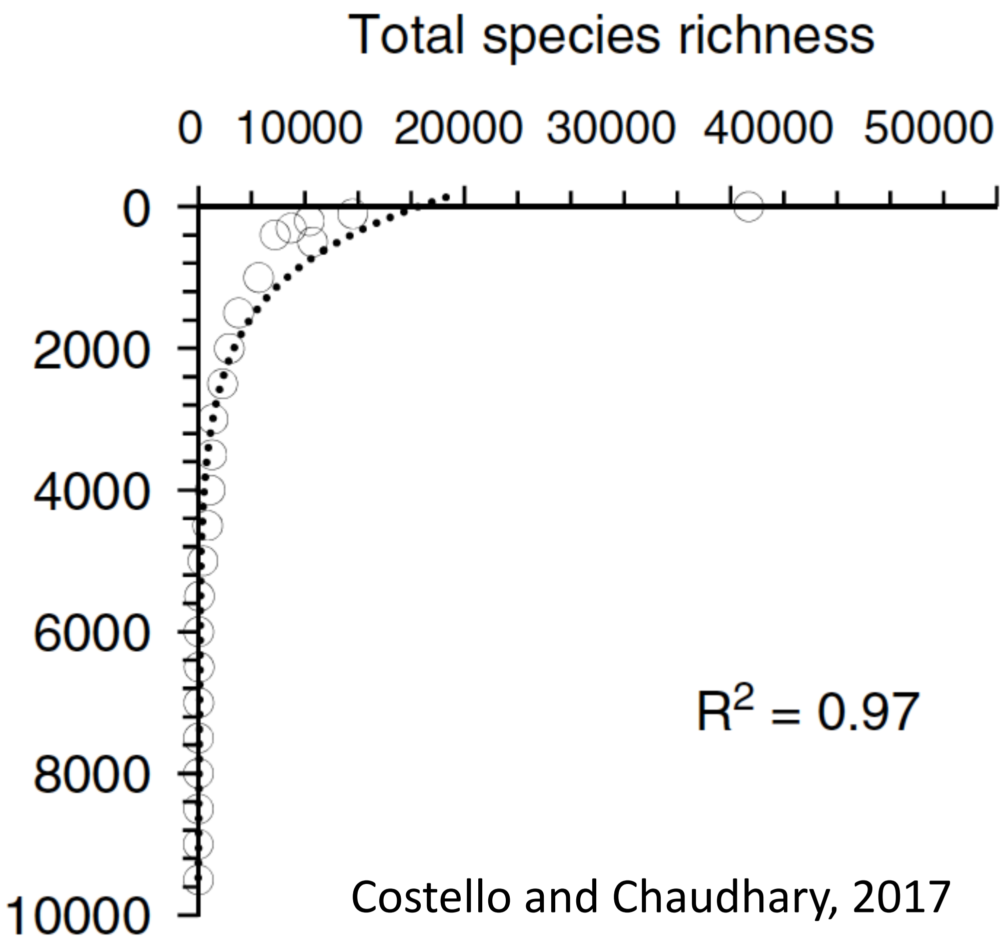
Resources:
food is heterogeneously distributed





Biodiversity

Biodiversity in the deep sea is lower than in shallower environments. However, we explored only the 1% of this system, and there could be many species still to be discovered.



Costello and Chaudhary, 2017

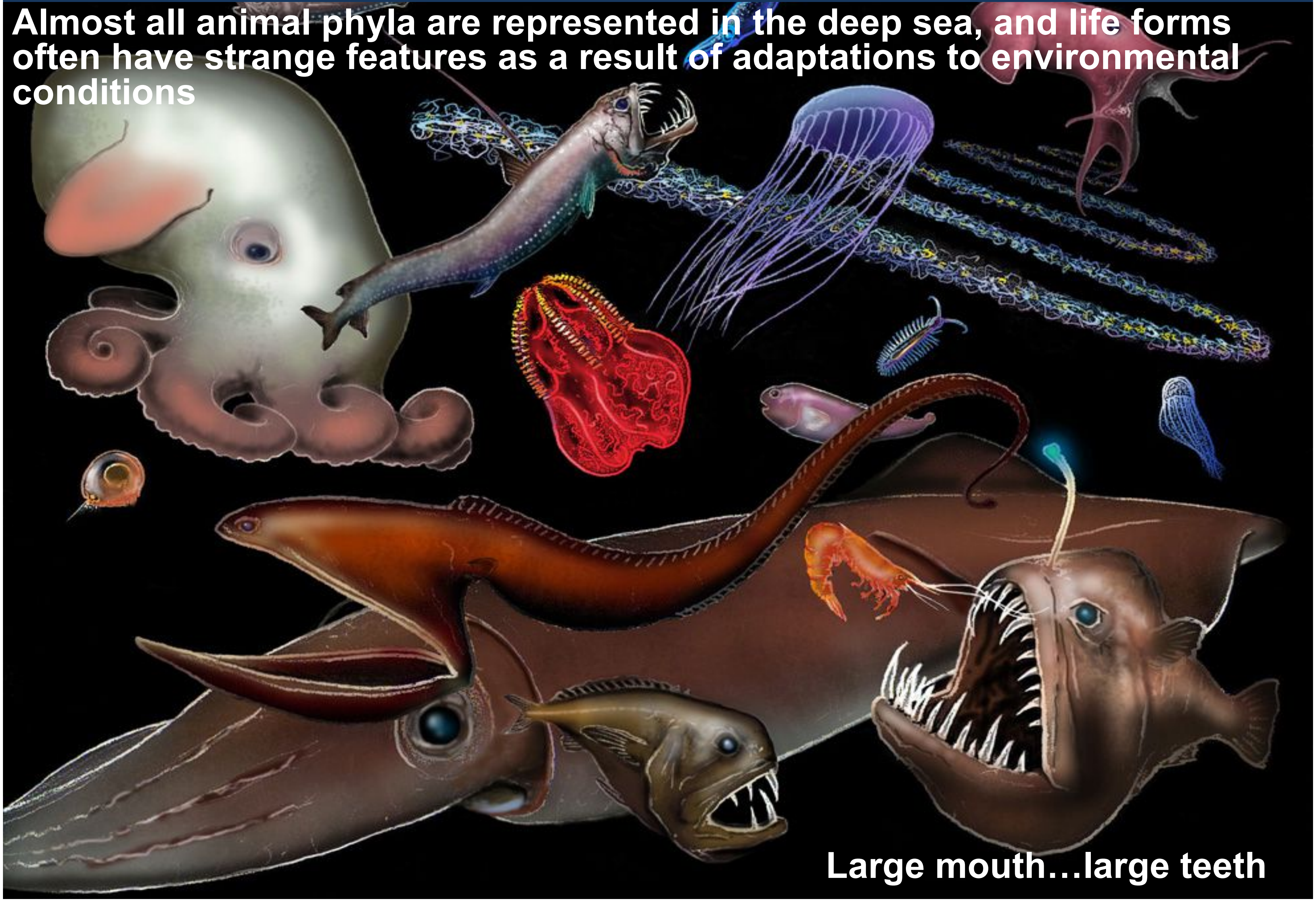
Species richness decline from the surface to the deeper areas. However, information is geographically restricted to some areas of the Atlantic, Pacific and Southern Ocean.
Very few studies in the Mediterranean

Dominant macrobenthic taxa:
polychaetes, cumaceans, tanaidacea, amphipods, isopods, gastropods, bivalves, scaphopods, oligochaetes, pogonophora, chitons, aplacophora

Dominant meiofauna:
nematods, harpacticoid copepods, ostracods

Strange guys

Almost all animal phyla are represented in the deep sea, and life forms often have strange features as a result of adaptations to environmental conditions

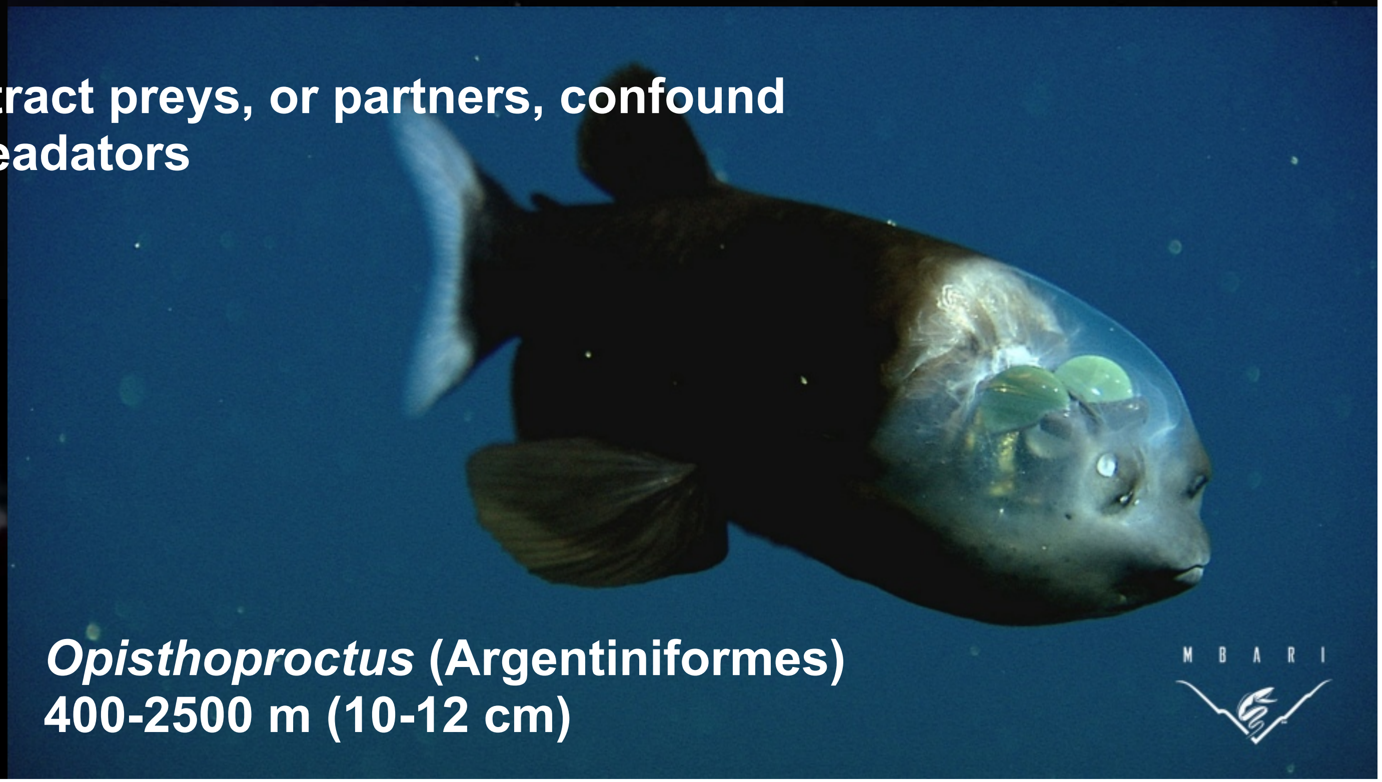


Further adaptations

Melanocetus (Lophiiformes)
100-4500 m (18 cm)

Cyclothone (Stomiiformes)
1000-4000 m (6-7 cm)

Attract preys, or partners, confound preadators



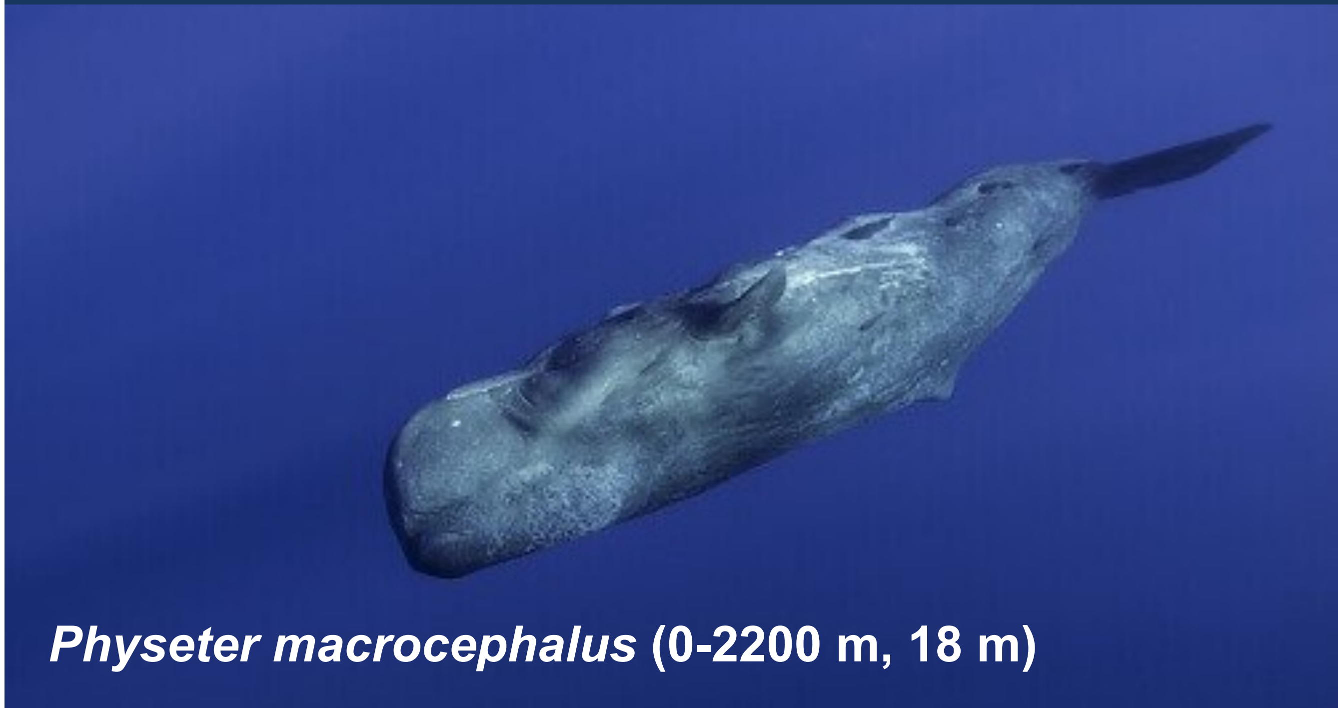
Opisthoproctus (Argentiniformes)
400-2500 m (10-12 cm)

Living fossils

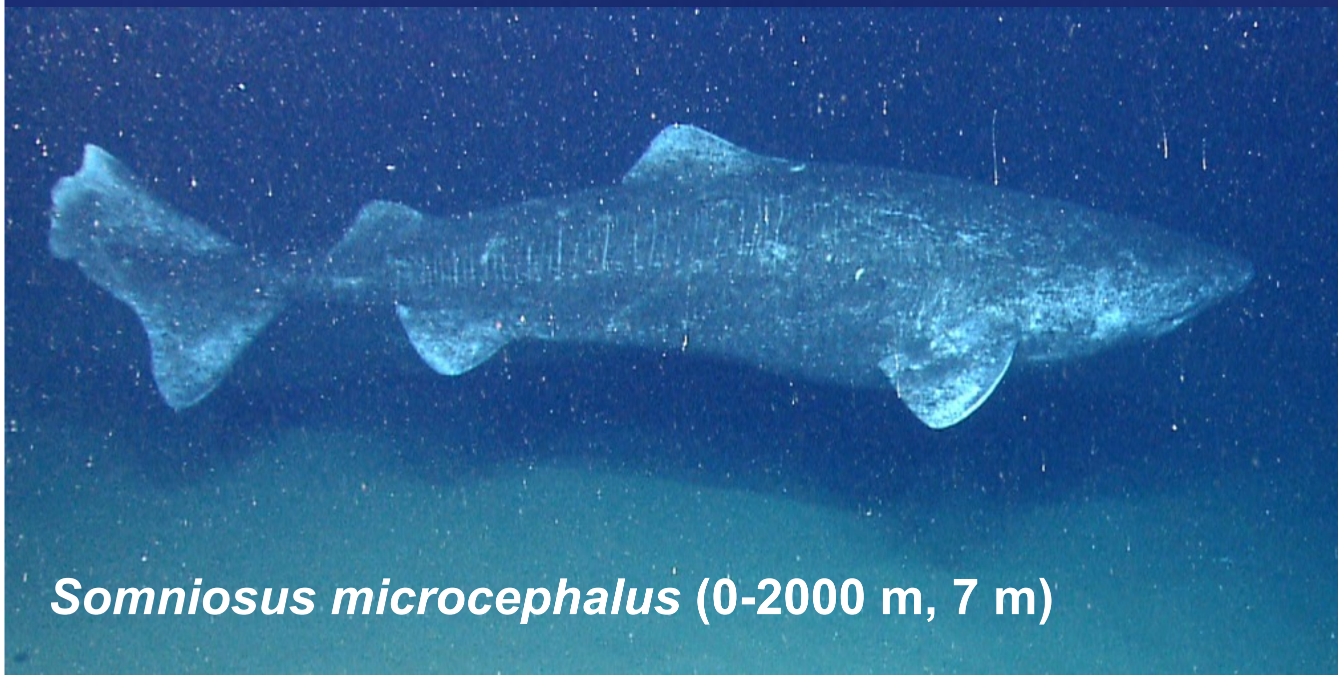
Latimeria chalumnae (Coelacanthiformes)
150-700m (140-165 cm)

Believed extinct since 65 millions years ago
(Madascar 1938)

Visitors from the surface



Physeter macrocephalus (0-2200 m, 18 m)



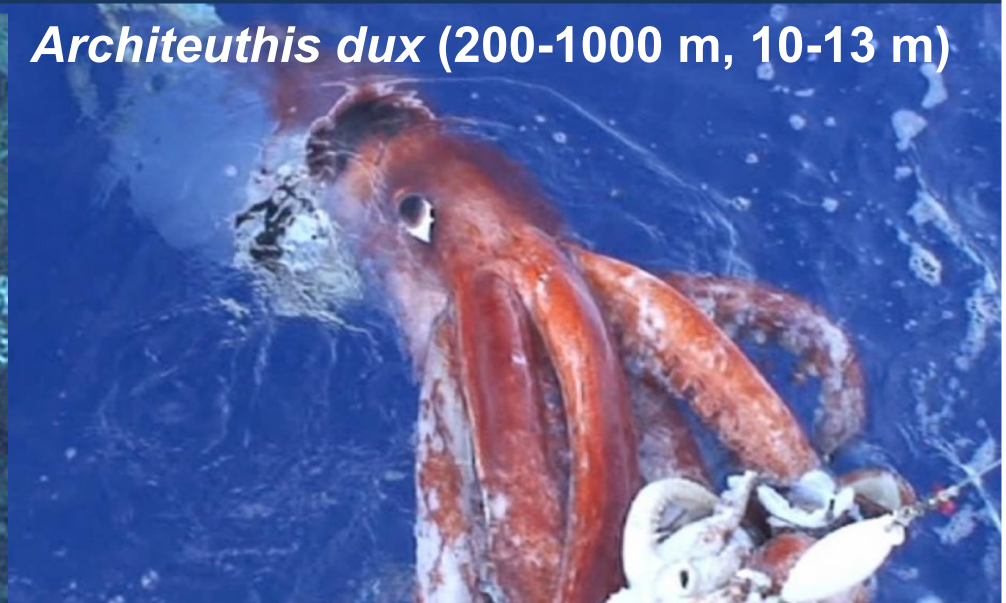
Somniosus microcephalus (0-2000 m, 7 m)

In some cases, animal living in shallow waters may visit deep sea for feeding

Others prefer conditions of deeper waters, but could occasionally frequent the surface or going more deeper

Big…strange guys

Xenophyophores (>6 km, 10 cm)



Architeuthis dux (200-1000 m, 10-13 m)

Macrocheira (150-300 m, 5 m)

Bathynomus (300-2500 m, 15 cm)

Regalecus glesne (20-1000 m, 11 m)

Abyssal gigantism

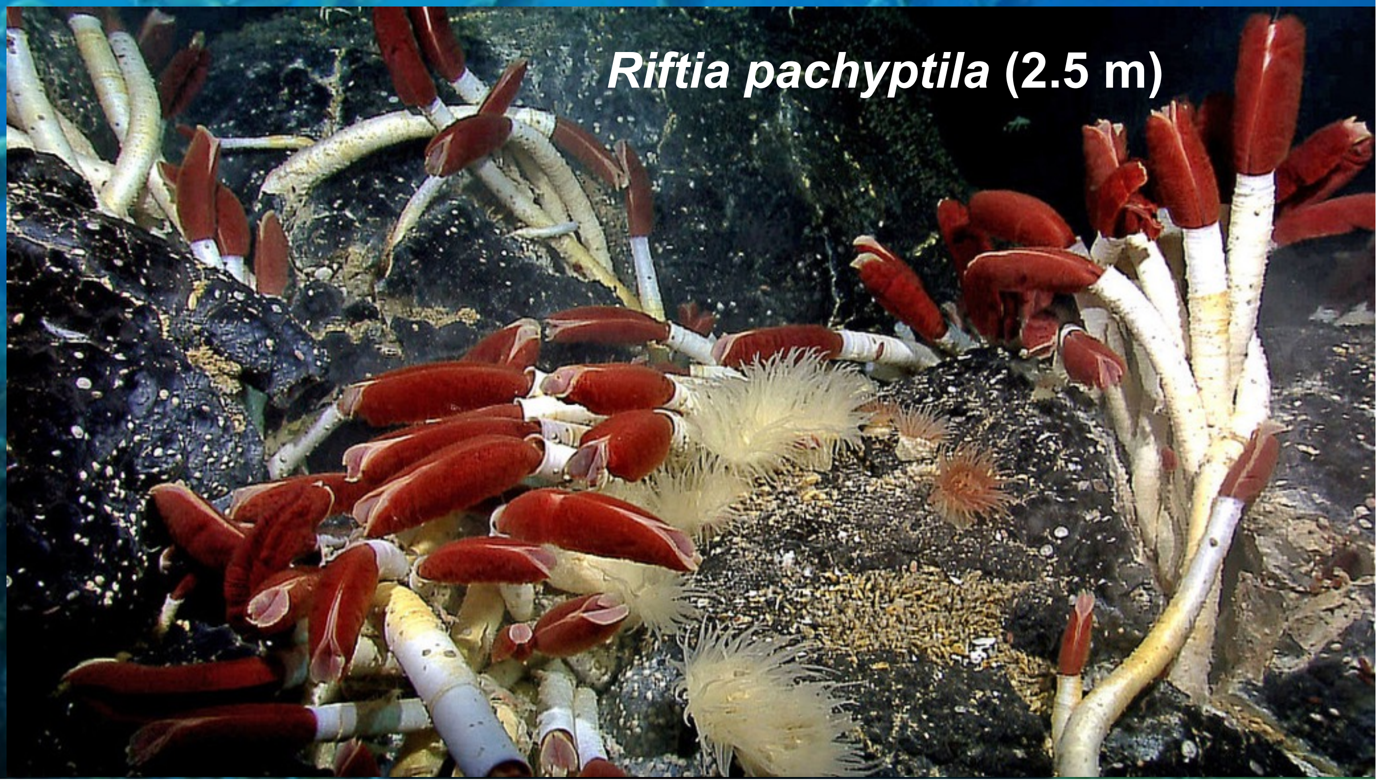
Late sexual development and continuous growth

Escaping predation through increasing size

Kleiber's rule: basal metabolism is proportional to body mass. Metabolism (and therefore energy consumption) slows down as body mass increase. So large organisms are more energetically efficient. This depends on heat dissipation, circulation, and proportion of structural and reserve mass.

Bergmann's rule: species of larger size are found in colder environments, and species of smaller size are found in warmer regions. This due to low surface area-to-volume ratio, which decrease heat dissipation.

Trophic reasons (optimal foraging, higher productivity of endosymbionts)



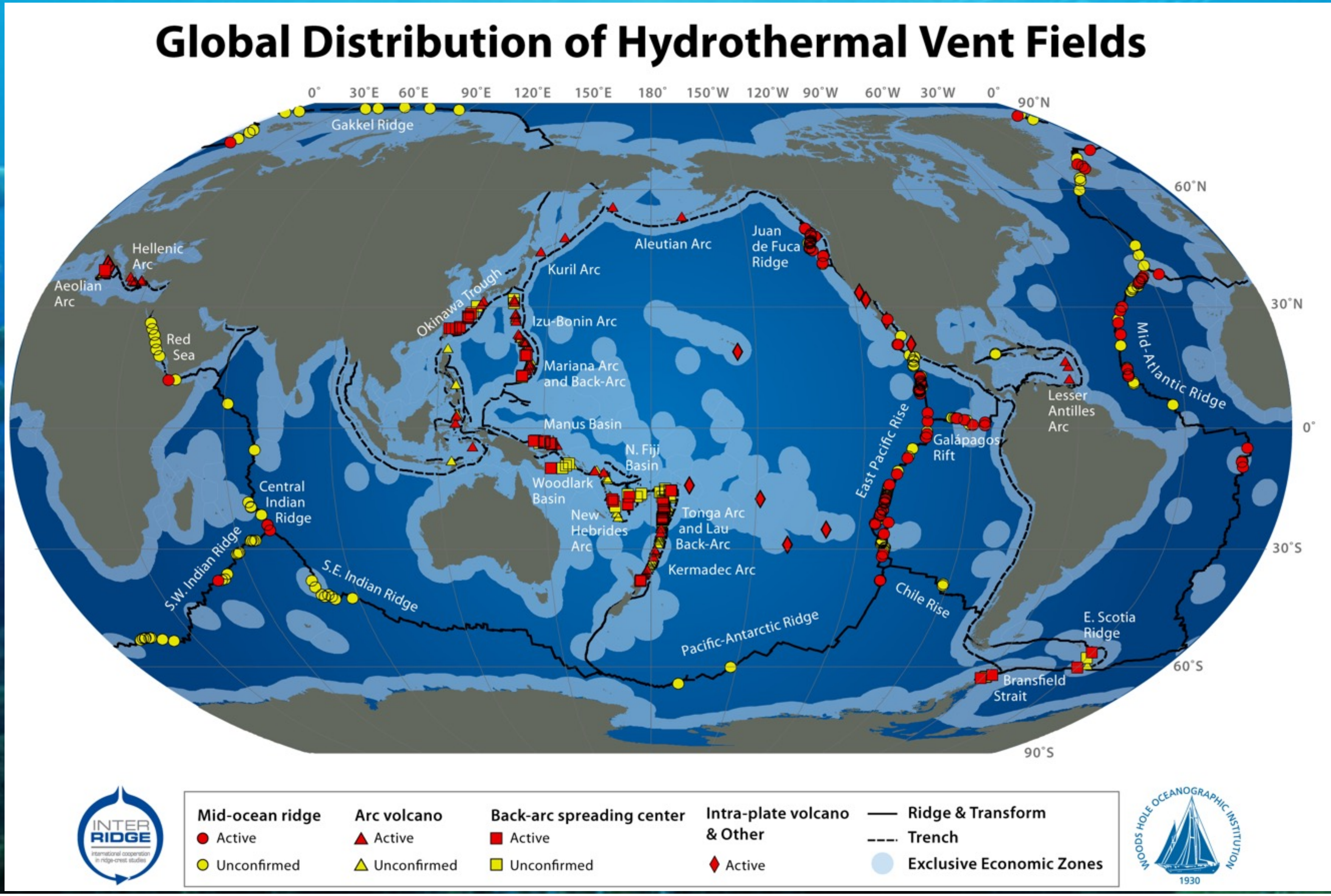
Riftia pachyptila (2.5 m)

Scavengers

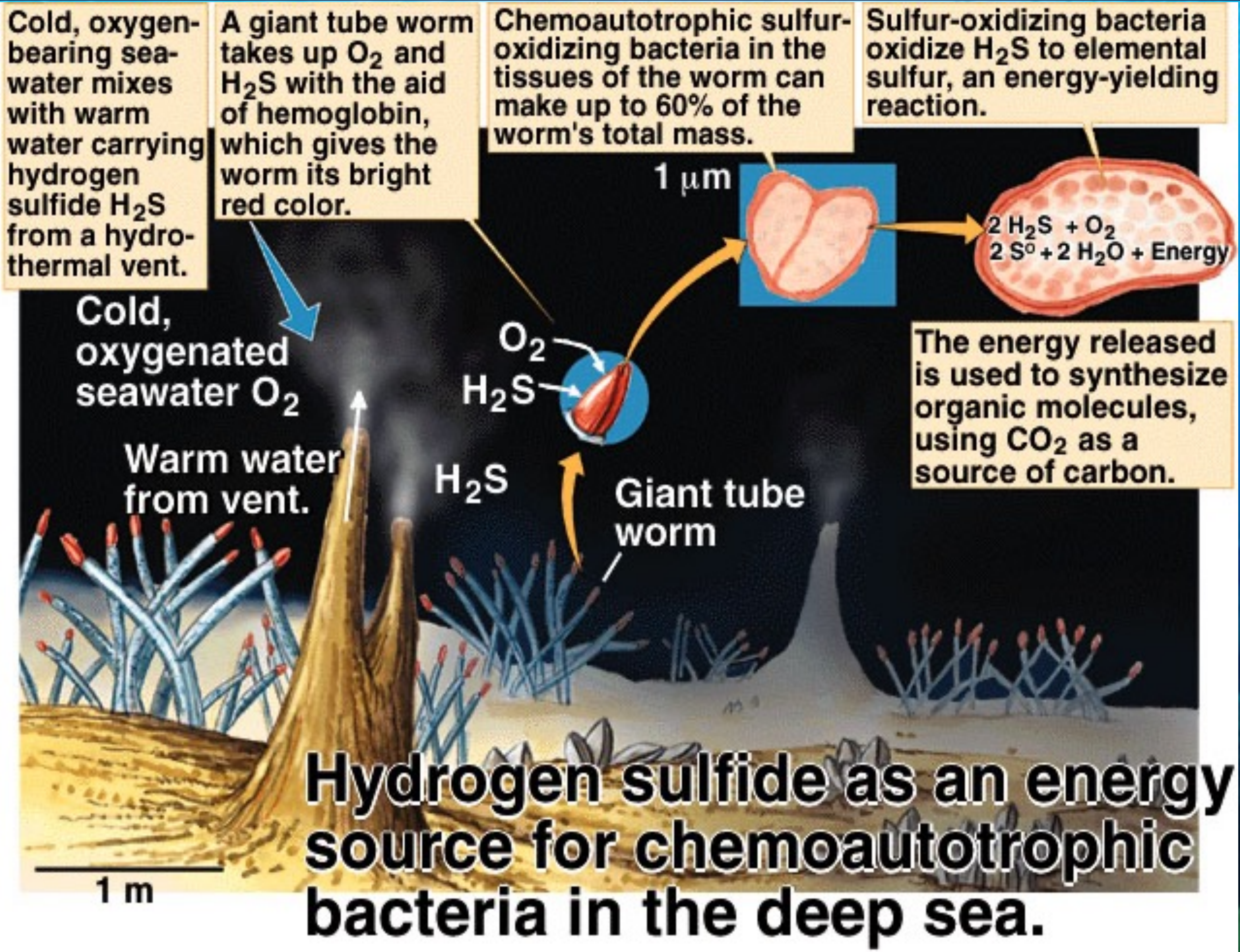
Deposit feeders, Filter-feeders, Predators

Hydrothermal vents

First discovered at Galapagos in 1977
Typical of areas of intense tectonic activity. High temperature (100-350° C), often at 2500 m depth

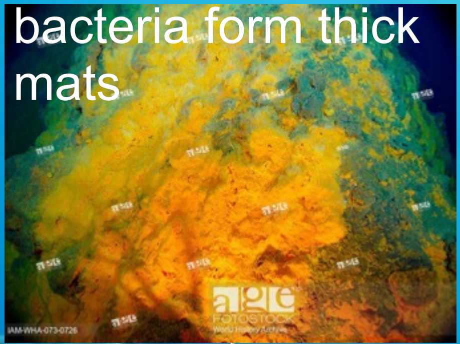


How they work



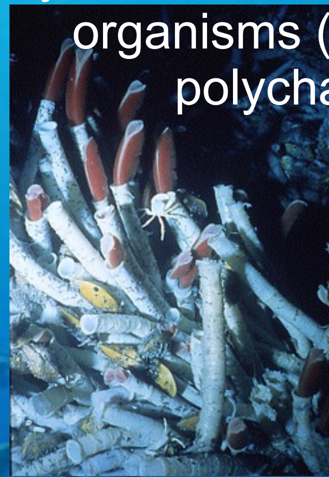
Mesocosm ecosystems

Chemosynthetic bacteria form thick mats



Snails, crabs, fish, cephalopods prey on vent organisms

Chemosynthetic bacteria are also symbionts of many organisms (e.g., polychates)



Grazers feed on these mats (e.g., amphipods, copepods)

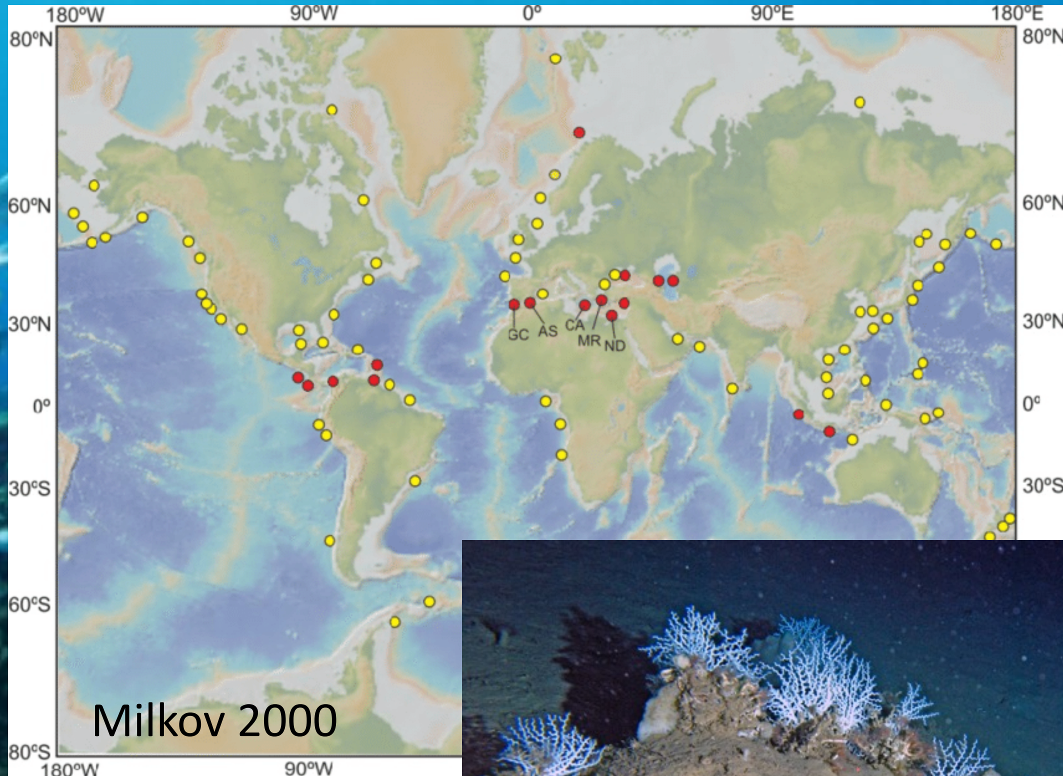
Filter-feeders exploit plankton and POM (some have also symbionts)

Hotspots of biodiversity, with population densities >>> higher than neighbouring areas, high primary productivity from chemosynthesis and secondary productivity from associated fauna

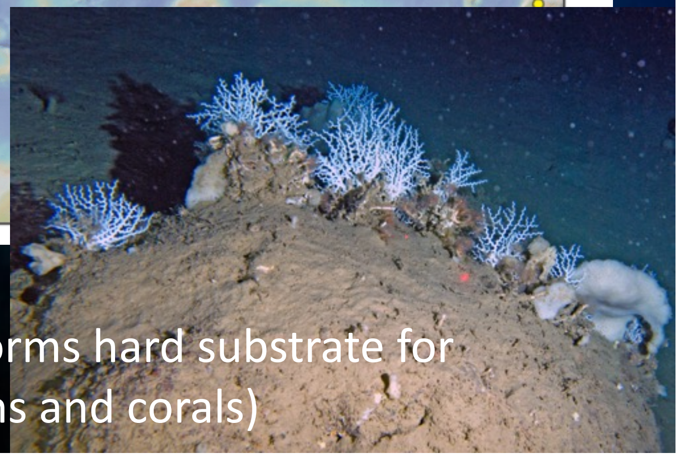
Cold seeps

They are places where hydrocarbons – mostly methane but also ethane, propane, or even oil – seep from the sediment. From few to 1000s m, often near continental margins. In contrast to vents, fluids are not at a high temperature (so "cold"). Methanotrophic bacteria oxidise CH_4 and sulphate-reducing bacteria produce H_2S. A community could develop. Also, H_2S sustain chemosynthetic bacteria and further increase colonization of seeps.

Brine pools



Milkov 2000



Carbonate deposition forms hard substrate for sessile organisms (worms and corals)

CO_2 seeps