An underwater photograph showing a large school of small, silvery fish swimming in clear blue water above a rocky reef. Sunlight rays penetrate the water from the top, creating a bright, shimmering effect. The fish are densely packed in some areas and more sparse in others, moving in various directions. The reef below is covered in green algae and other marine life.

**GLOBAL CHANGE ECOLOGY AND SUSTAINABILITY**  
**a.a. 2022-2023**

**Conservation and Management of Marine Ecosystems**  
**Prof. Stanislao Bevilacqua ([sbevilacqua@units.it](mailto:sbevilacqua@units.it))**

**Adaptations**

# Size



10<sup>-8</sup> metri



10 metri

Marine organisms range from virus (<100 nm) to whales (>30 m), and from <1 fg (= 10<sup>-15</sup> g) to >100 tons

3.5 m  
7 tons

*Loxodonta africana*



33 m

150 tons

*Balaenoptera musculus*



18 m

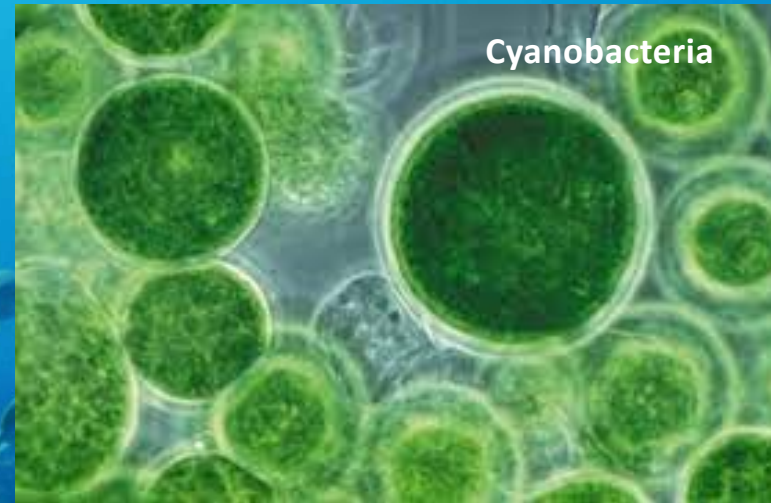
20 tons

*Rhincodon typus*

This has many reasons, such as the higher efficiency in energy transfer through the trophic levels and buoyancy.

# Size

Primary producers in the ocean are smaller than on land. Most of them are small phytoplanktonic species, whereas macroalgae and seagrass are only a small component of primary producers.



Small size in marine organisms allows increasing the surface/volume ratio of their bodies, increasing the resistance to sink and the efficiency of exchanges of gases, metabolites, and/or nutrients with the environment

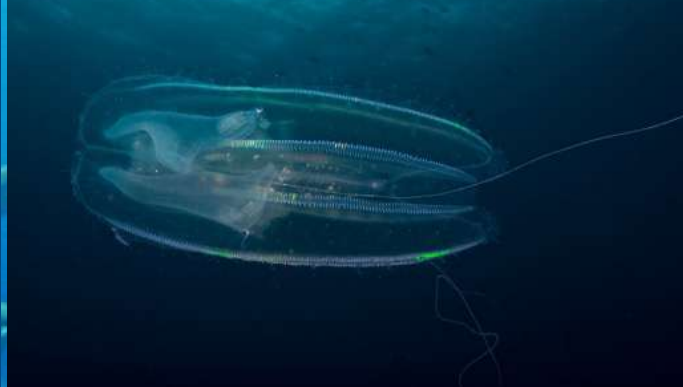
# Tissue density

Sea water density generally ranges between  $1.020$  and  $1.040$   $\text{g cm}^{-3}$ , with lower values at the surface (generally warmer) and near the coast (freshwater inputs) and higher at higher depth.

Thaliacea (~90%)



Ctenophores (~96%)



Medusae (~98%)



Cytoplasmatic density in animals ranges between  $1.03$  and  $1.10$   $\text{g cm}^{-3}$ .

Many marine organisms have low density of their biomass, close to that of sea water, to facilitate bouyancy.

Fish tissues  $1.07$   $\text{g cm}^{-3}$

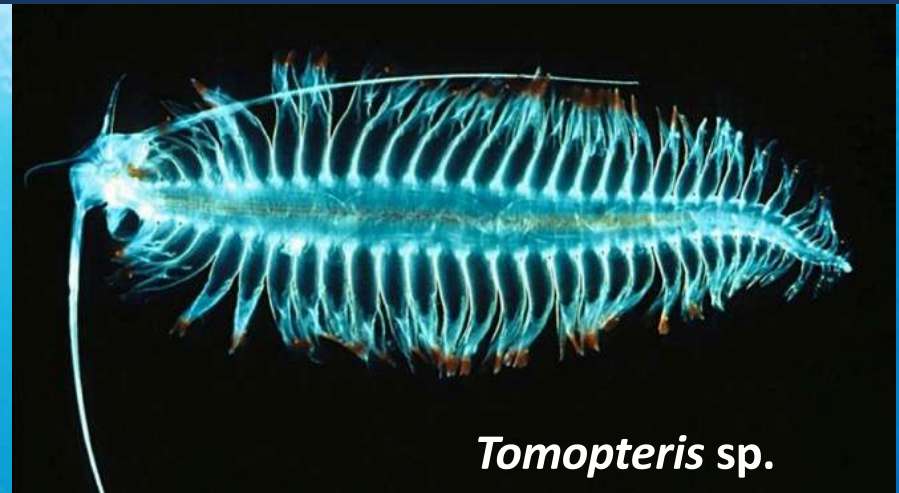
Zooplankton  $1.05$ - $1.15$   $\text{g cm}^{-3}$

# Body shape

Most of planktonic species, but also fish, have body appendices or other structures that increase buoyancy



*Glaucus atlanticus*



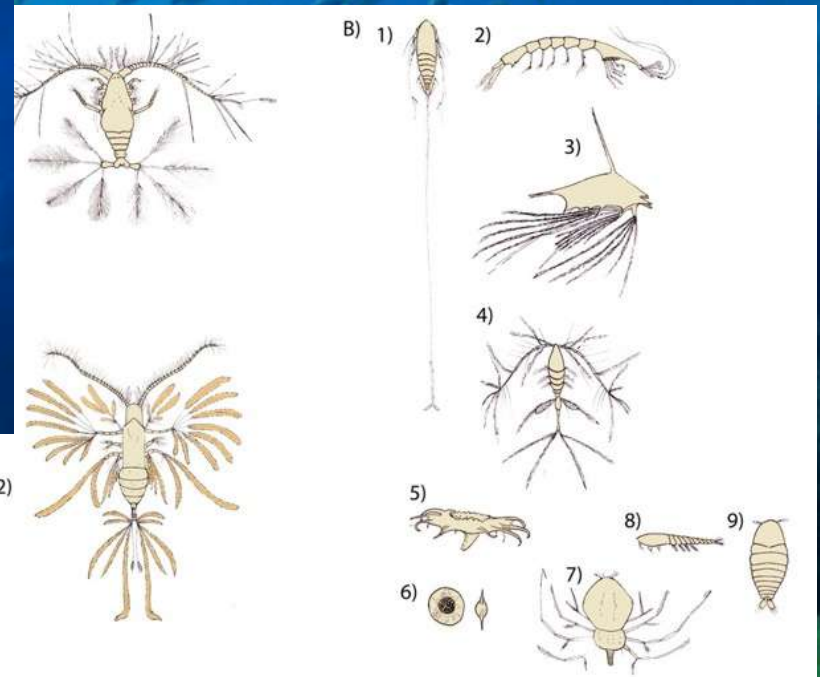
*Tomopteris* sp.



*Manta bisostris*



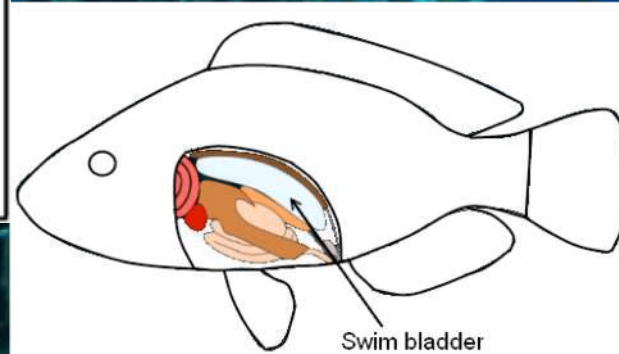
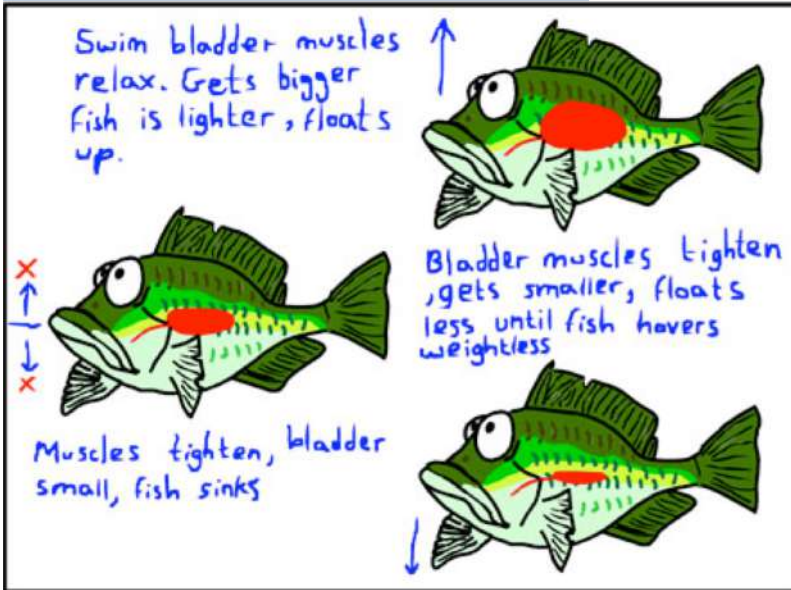
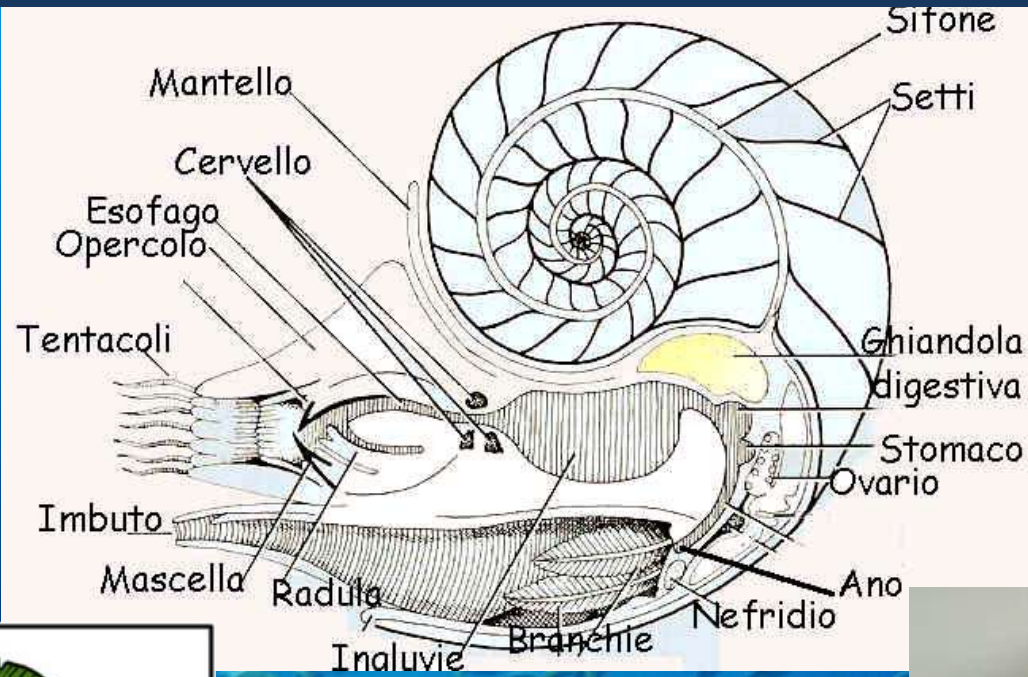
*Rhyzostoma pulmo*



# Gas tanks

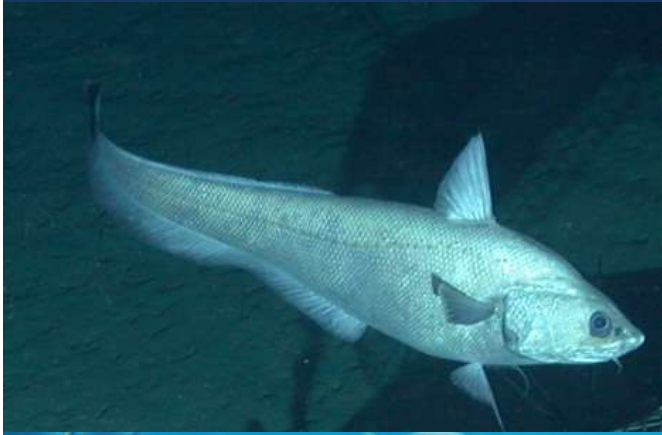


*Nautilus spp.*



*Physalia physalis*

# Other adaptations



**Macrurids**



**Scorpeniformes**



***Sepia officinalis***



# Fats and oils

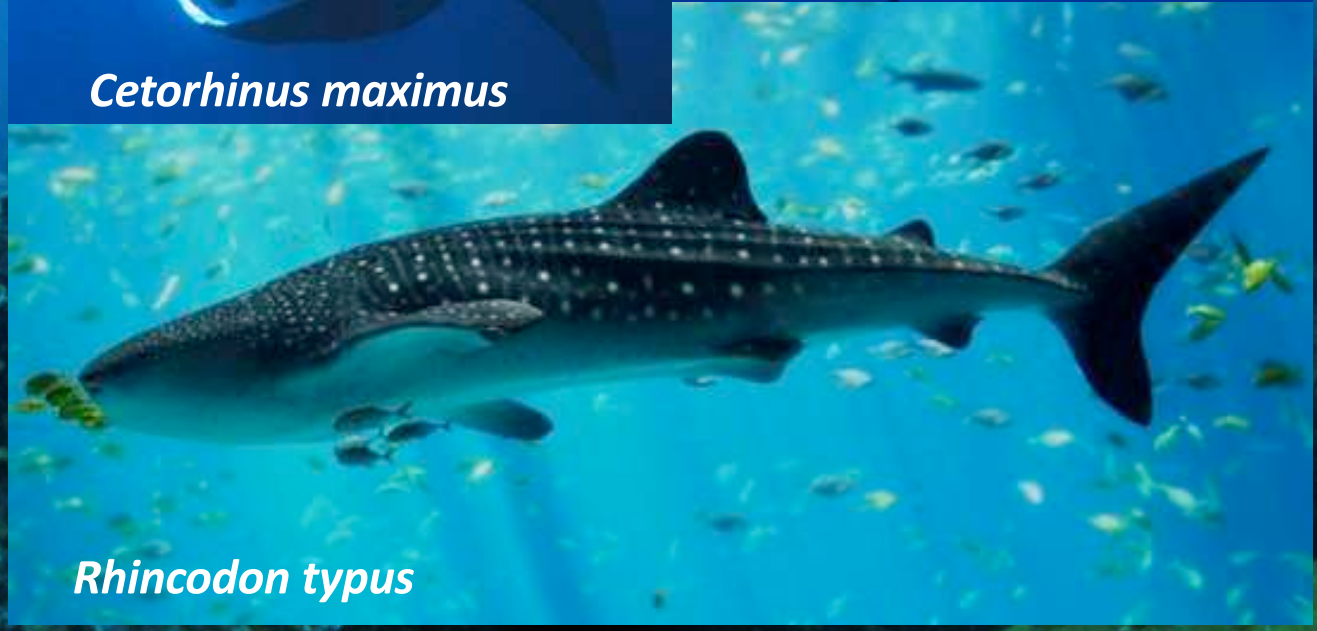
In many marine organisms, buoyancy is ensured by lipids, which have lower density than sea water, and are accumulated in their body (cytoplasm, tissues) to decrease density (and as energy reserves). Sharks do not have a swimming bladder, and use the liver for buoyancy. This organ in sharks has a high content of lipids and could account for the 20-30% of the total body weight.



*Cetorhinus maximus*



*Carcharodon carcharias*



*Rhincodon typus*





# Movement and body shape

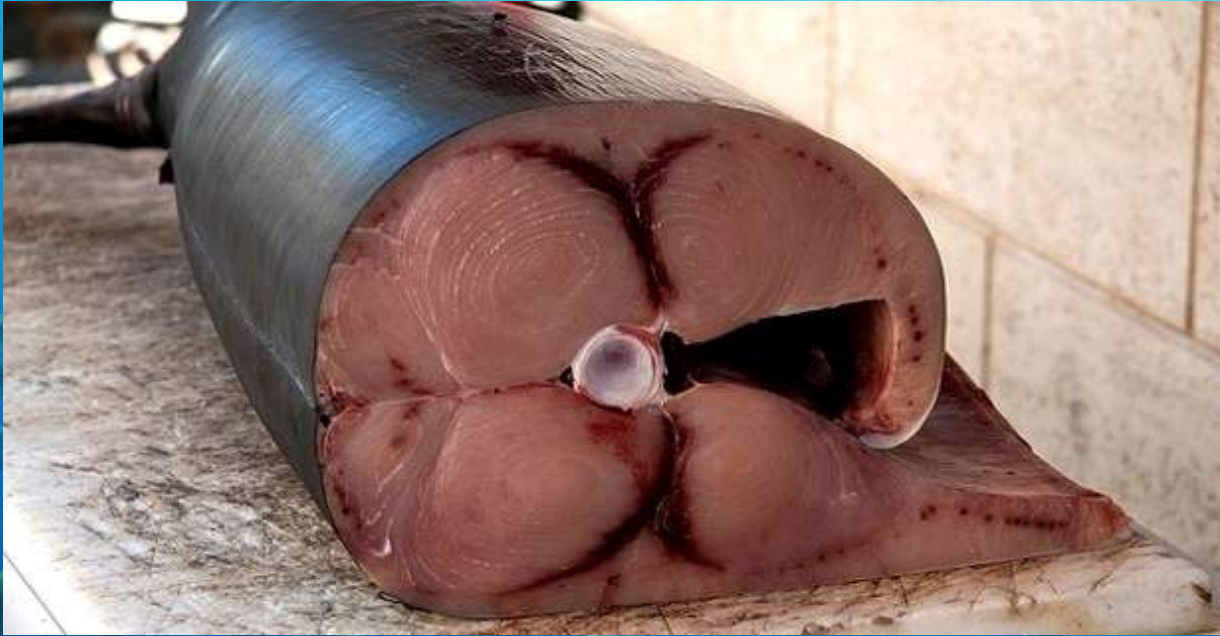


Pelagic fish have streamlined shapes, adapted for cruise swimming. Arrow-like for predators that need strong acceleration.

Demersal fish have compressed/flat shapes, adapted to move near the bottom and/or within crevices



# Movement and muscles



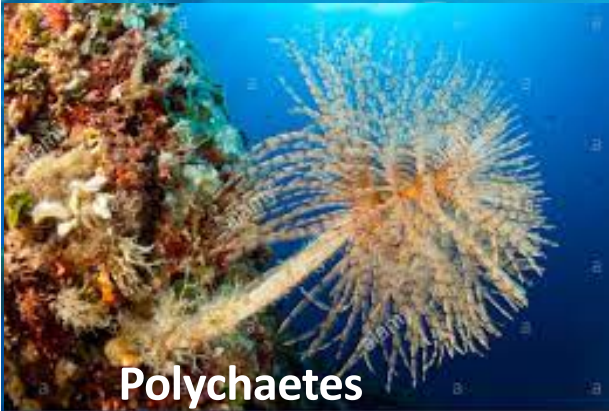
The body shape is related to the movement pattern. This also has implications for the muscle type. In animals adapted to prolonged swimming patterns (like tuna), muscle mass is mostly red (high content of myoglobin, with high blood supply, and high mitochondrial volume). In contrast, in animals specialized to rapid attack or to move in complex seascapes, white muscle is dominant (low content of myoglobin, with low blood supply, and low mitochondrial volume). This last muscle type is particularly efficient in anaerobic conditions, thus for quick and short movements.

# Sessile animals

Many marine animals are sessile, and live attached to the substrates, like plants. They feed on suspended particles or plankton. This is possible due to the transport of organic matter in the sea water



Crustaceans



Polychaetes



Anthozoans and hydrozoans



Bivalves



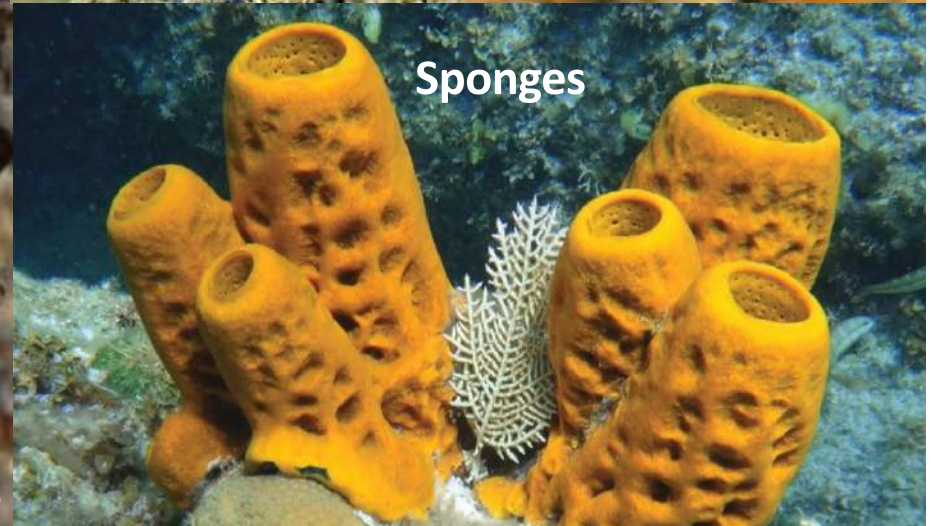
Gastropods



Ascidians



Bryozoans



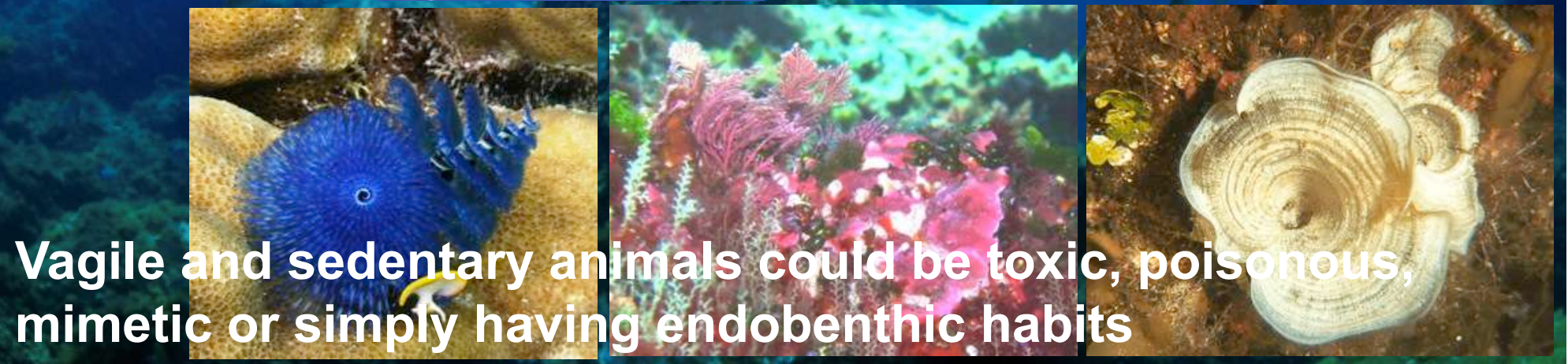
Sponges

# Defense

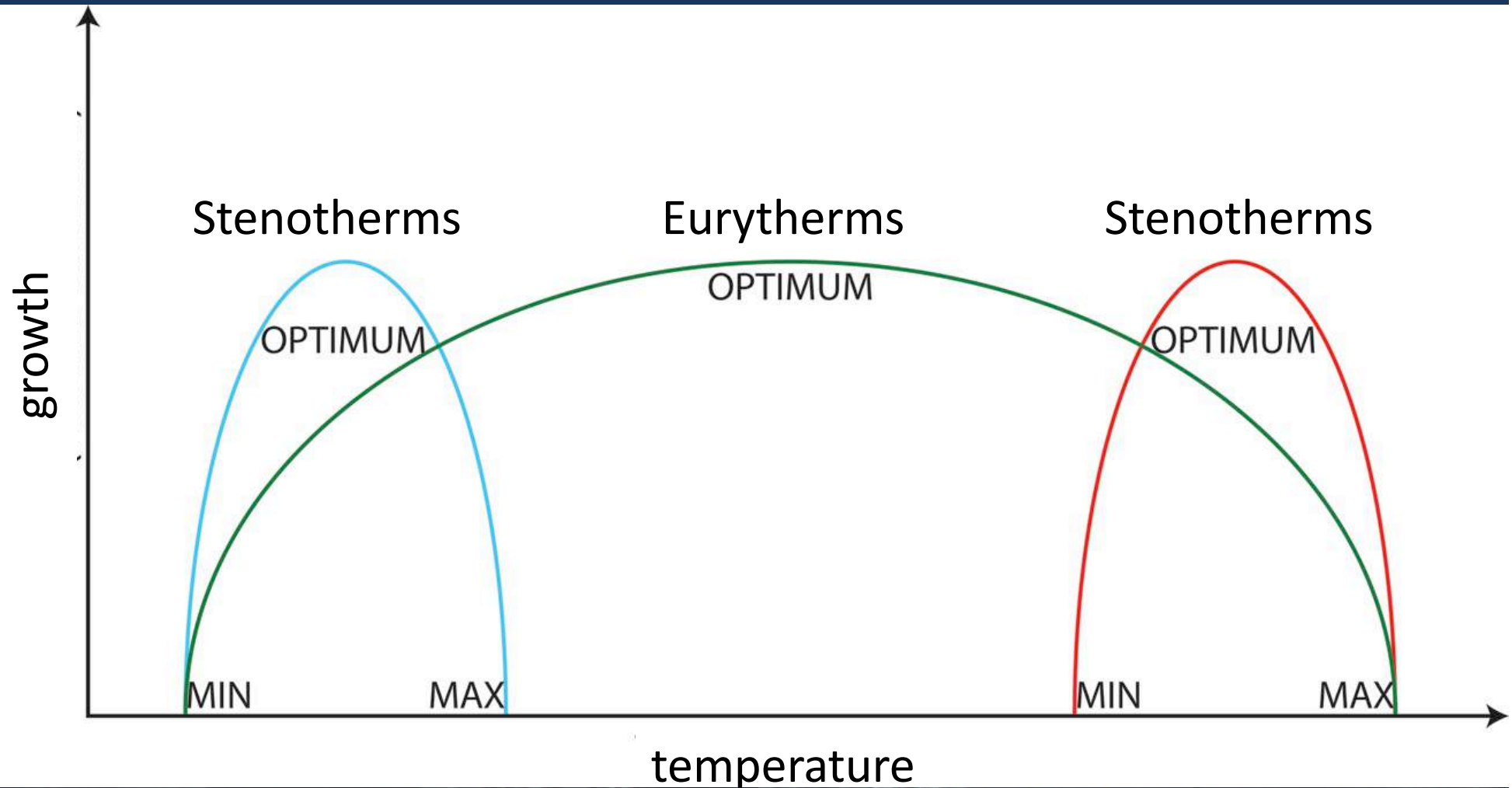
Hard structures are developed to protect against predators, physical disturbance, and to sustain the soft bodies. Structures could be external, or within the bodies. Silicates and carbonates are the most widespread inorganic compounds building these structures.



Vagile and sedentary animals could be toxic, poisonous, mimetic or simply having endobenthic habits



# Temperature range



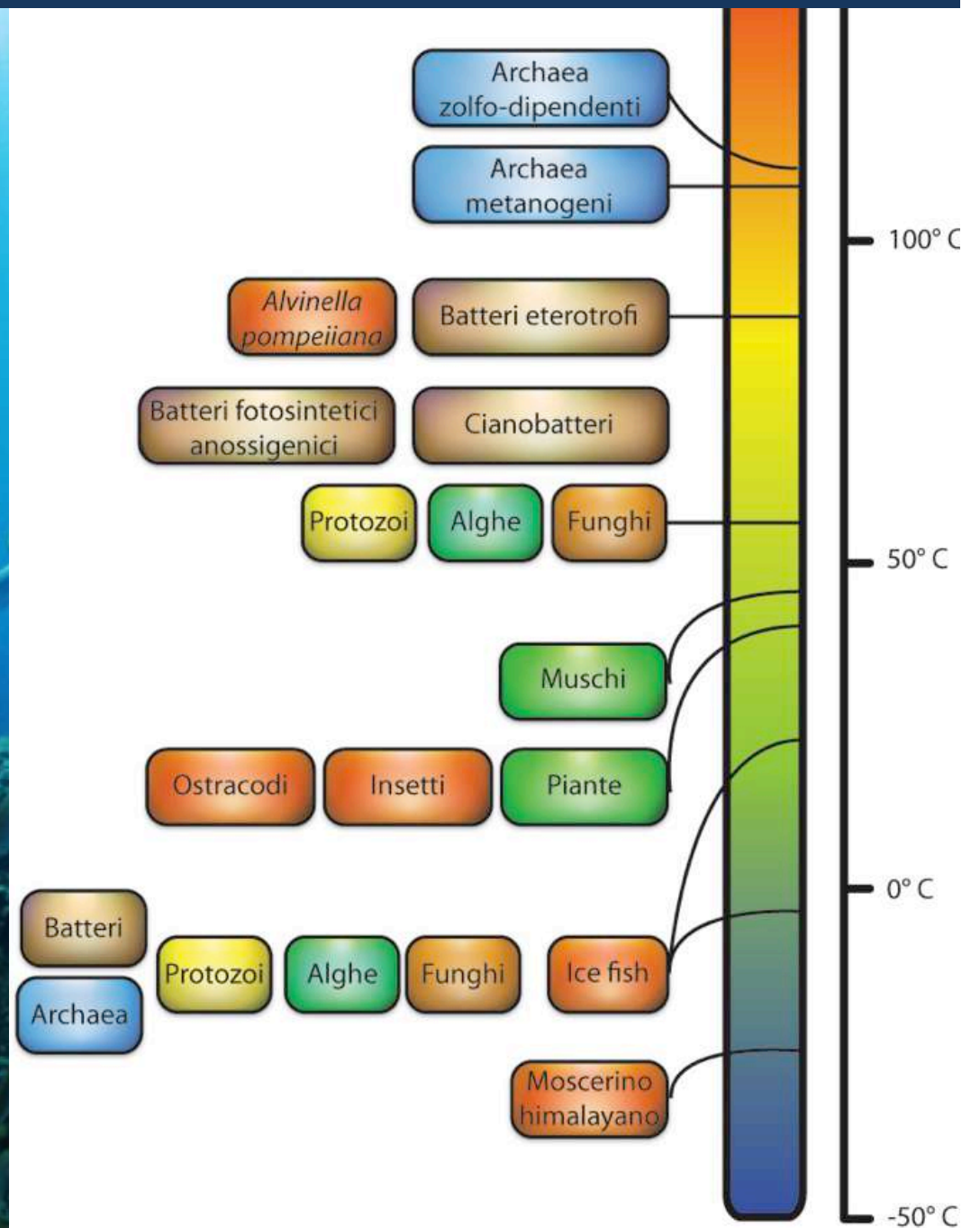
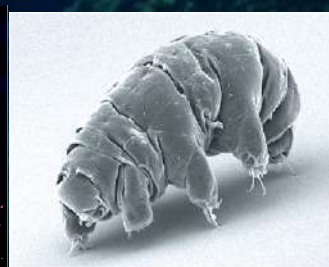
Species have a range of tolerance as far as environmental conditions (and even resources). This range is comprised between two extremes, a minimum and a maximum value which include the optimal interval (*optimum*) where the species can survive and thrive.

# Temperature range

Above 60° C and below -20° C, temperature conditions are prohibitive for the the continuity of life. For high temperatures, problems depends on proteins denaturation, metabolic disruption and dehydration. At very low temperatures, instead, metabolism could be too slow to allow the normal functioning of organisms. Also, water within cells and tissues represents a problem due to the formation of ice crystals.

Some organisms have adaptations to resist to very low or very high temperatures. some bacteria could resist to temperature >100° C near hydrothermal vents, some fungi instead could live at -50° C in antarctic ice.

Also particular animals could live at high temperature, like the polychaetes *Alvinella pompeiana*, whereas tardigrads could survive at temeperature close to 0° K.



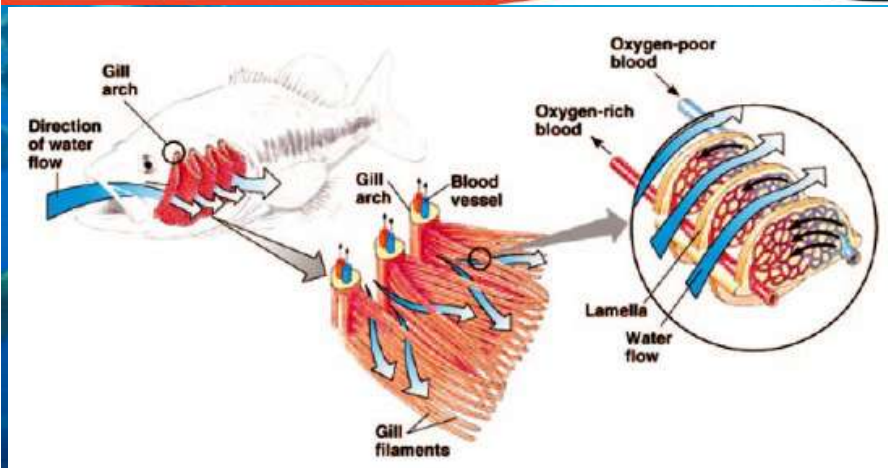
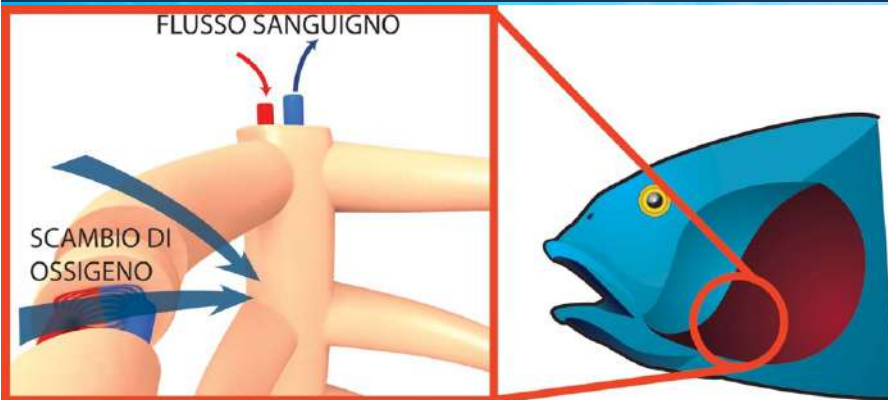
# Adaptation to extremely low temperature



Fish of the order Notothenioidae dominate in the Antarctic waters. They have low hemoglobin and limited erythrocytes to increase the blood flow, increased heart size and diameter of veins, and increased vascularization of the skin. In some species, both hemoglobin and blood cells are absent.

These characteristics, coupled with low metabolism, contrast the tendency of higher blood viscosity due to low temperature, and compensate the low number of erythrocytes and low content of hemoglobin facilitating oxygen exchange from the environment and transport to tissues. They also have Anti Freezing Glicoproteins that prevent body fluid to freezing.

# Oxygen

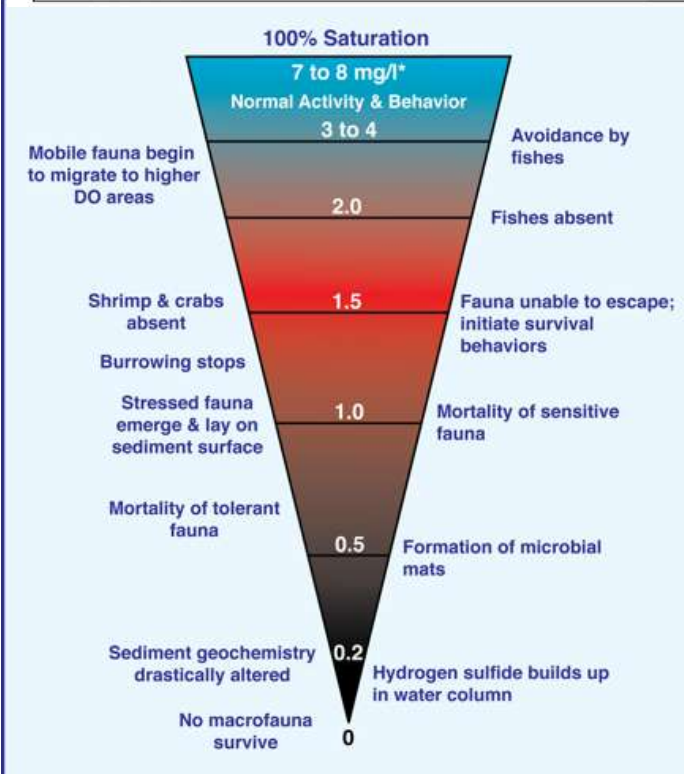
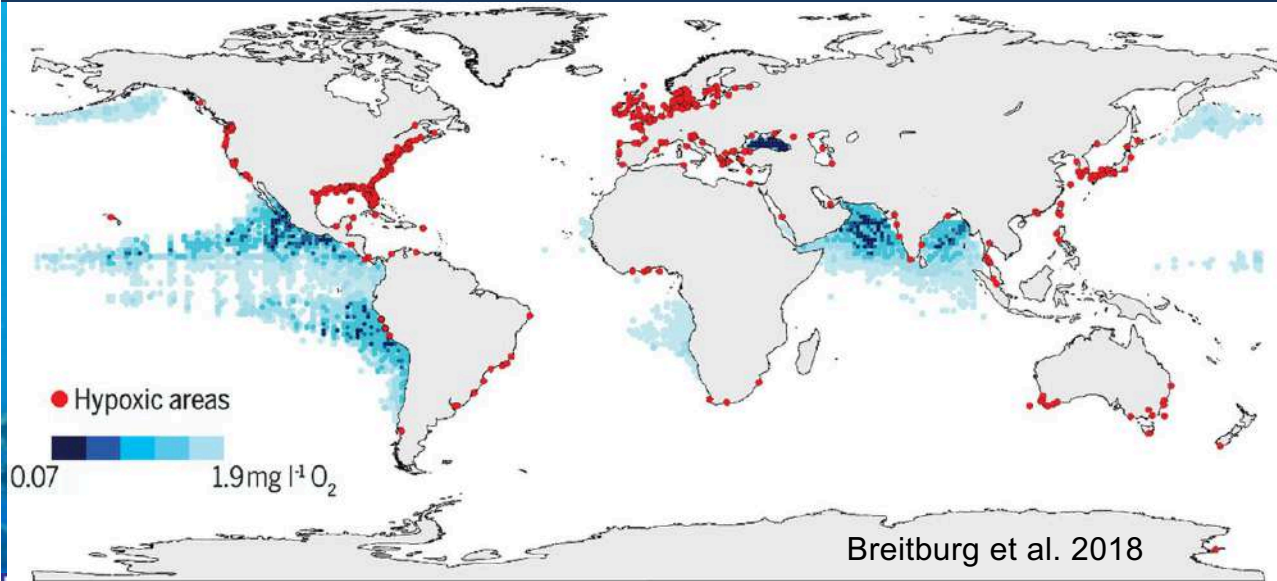


Dissolved oxygen in sea water (normally between 5-10 ml/l) comes from photosynthetic activities and diffusion from the atmosphere. Its concentration depends on temperature and salinity (higher T and salinity, lower oxygen). Marine organisms absorb oxygen in different ways, through skin and external tissues, digestive organs or have specific structures (e.g. gills)





# Oxygen



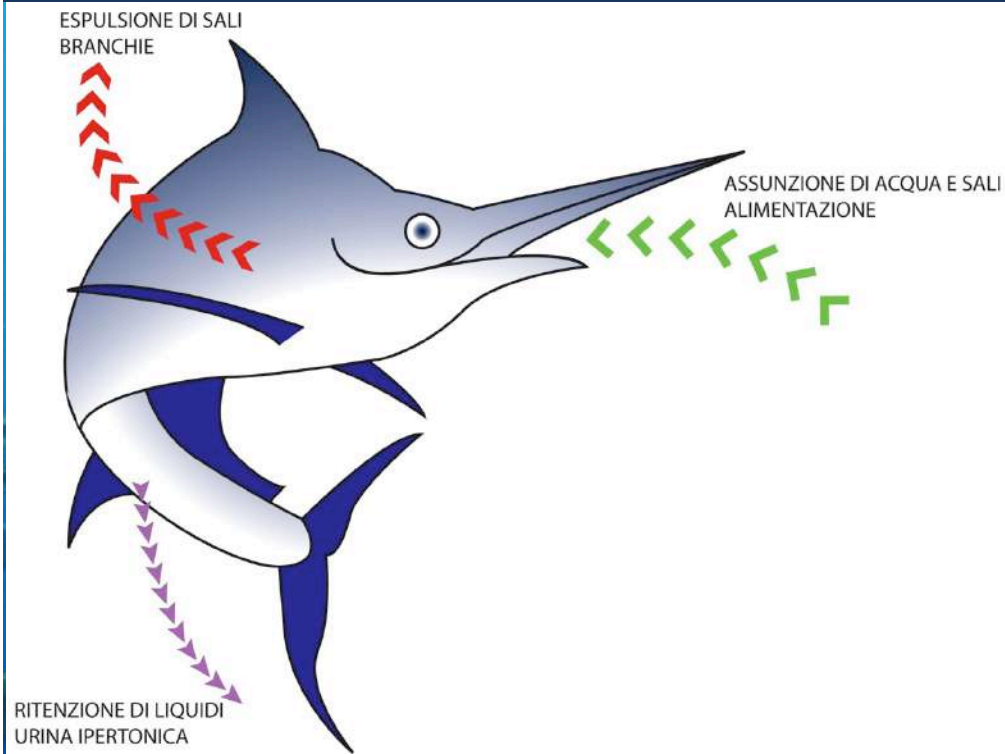
Levels of DO below 2 mg/l could cause drastic changes to marine environments and, consequently, to marine life.

Due to increasing temperature, altered circulation, increasing nutrient load, coastal but also pelagic areas all over the world's oceans are becoming hypoxic or completely anoxic (dead zones)

# Air exposure



# Osmoregulation



Teleosts have hypotonic blood. To maintain osmosis ingest water and salts (also from food) and excrete salts from gills and hypertonic urine.

Sharks increase urea concentration in their blood to approximate isotonic conditions.

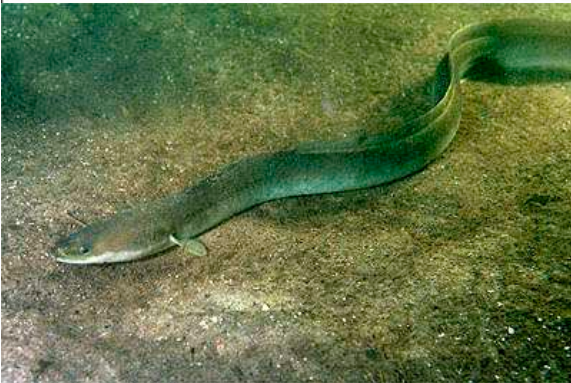
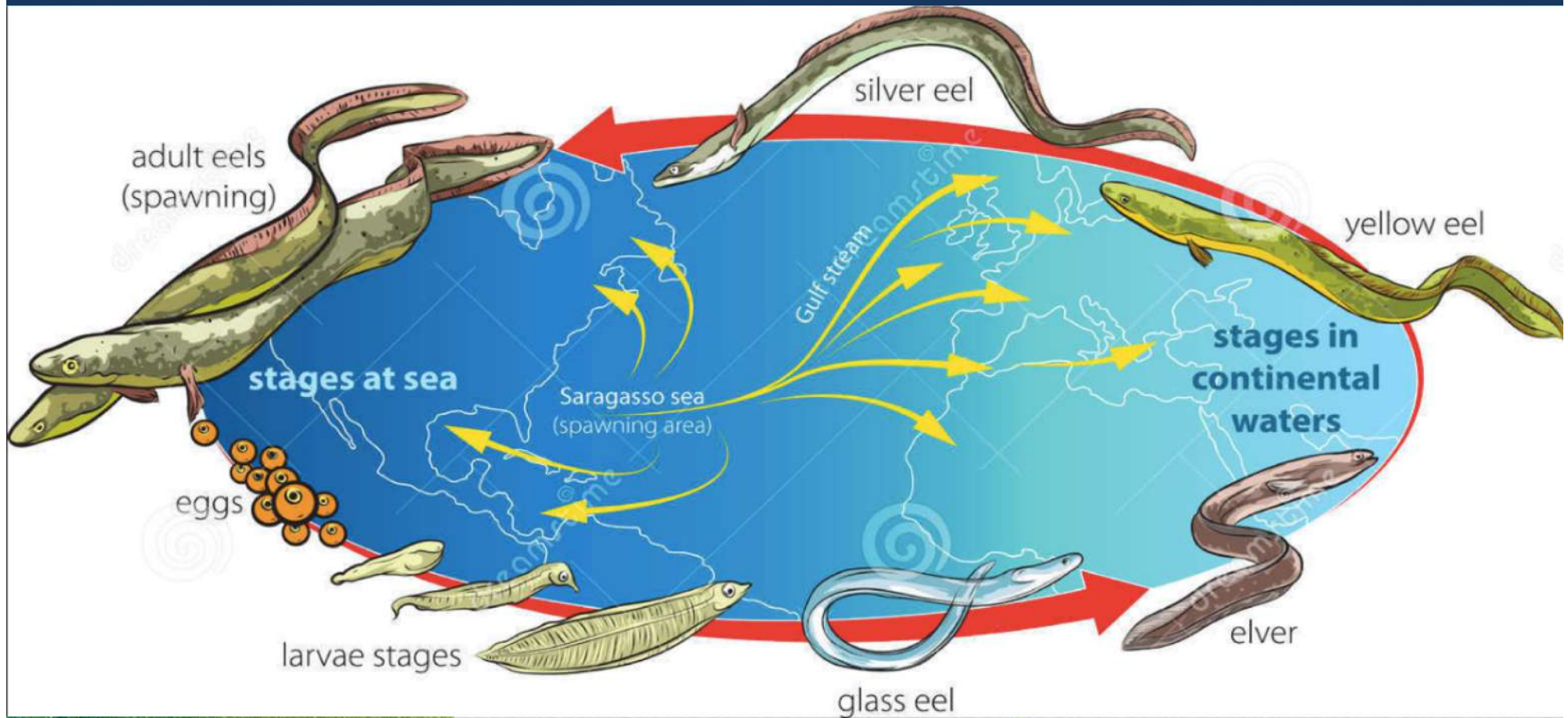
Marine mammals avoid sea water ingestion (water is taken with food), and excrete hypertonic urine.

Other marine vertebrates also excrete salts through specific glands near the eyes (reptiles) or the nose cavity (seabirds)



Many marine organisms are isotonic or hypertonic with respect to sea water, and maintain salt concentration in their fluids through active transport of salts, low permeability of teguments to water, osmolite production (e.g., urea, glycerol).

# Catadromous and anadromous species



Life cycle of the European eel (*Anguilla anguilla*): from fertilized eggs to the zygote, who through several larval stages becomes a small transparent eel (glass eel). Then, the individual grows and start to produce pigments until the juvenile stage. It migrate in continental freshwaters or brackish waters and increase in size until the adult stage (yellow eel). It becomes a silver eel to return to the sea for reproduction. **(catadromous species)**

# Anadromous species

Salmons do exactly the opposite (anadromous species)



*Salmo salar*



# Diadromous species



*Megalops*



*Carcharinus leuca*

# Summary of main land-sea differences

Biodiversity and evolutionary history

Space dimensionality, connectivity and environmental variability

Organisms do not invest much of their biomass to form structures (skeletal and cellulose) to oppose the force of gravity

Important biochemical differences:

Carbohydrates for terrestrial organisms (structural molecules for support and protection) - Proteins from marine organisms (complex organic molecules, muscles) – buoyancy

Amount of organic matter produced is higher in terrestrial environment

Transfer efficiency is higher in the marine environment -> more trophic levels:

active biomass in producers – reduced energy loss for movement and temperature regulation

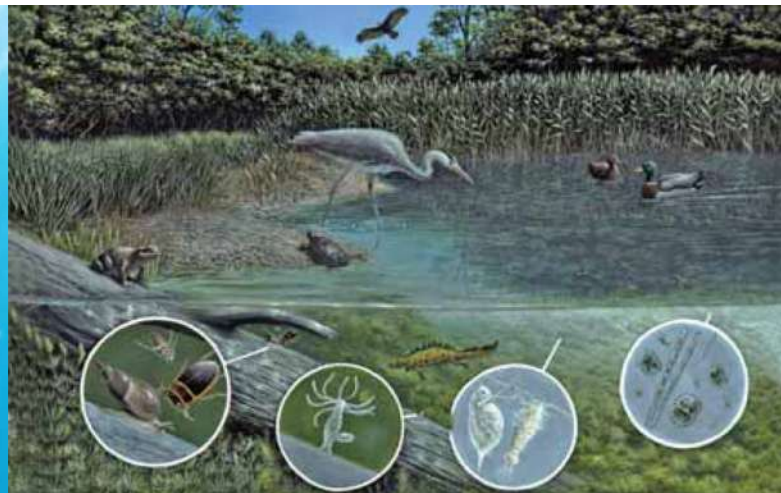
Difficulty of framing trophic groups in the marine environment:  
switching to different trophic levels during the life cycle

# On land

the landscape is made of plants (necromass)

plants are the structural backbone of ecosystems

animals are functional

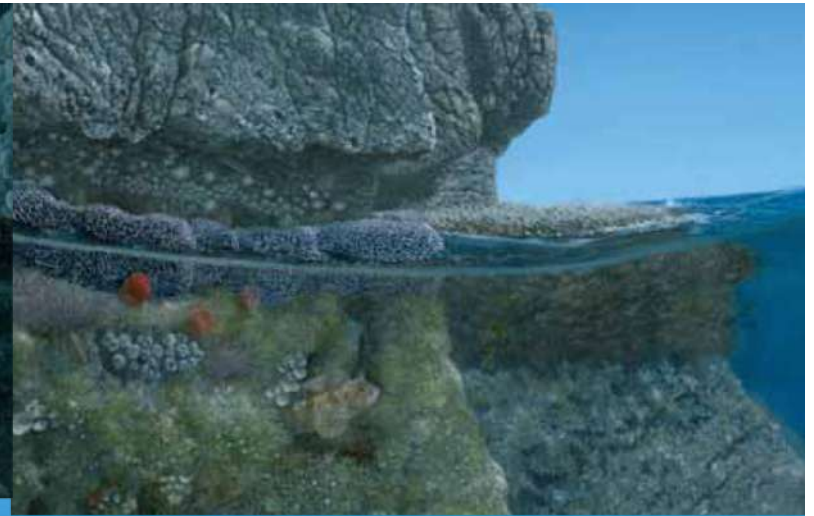


# In the sea

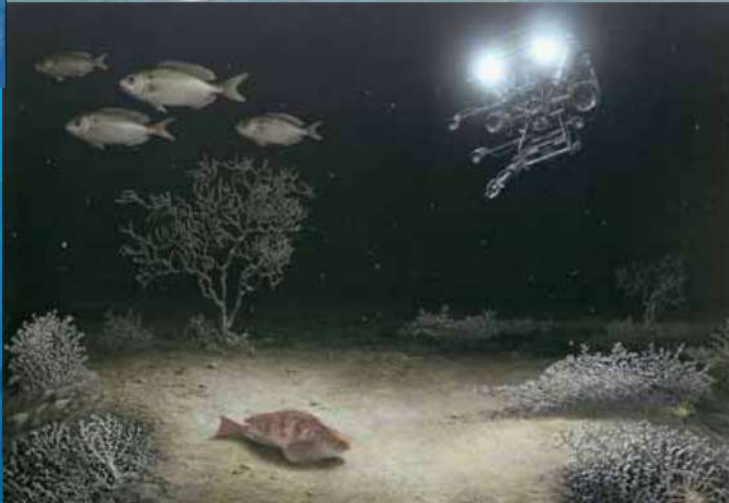
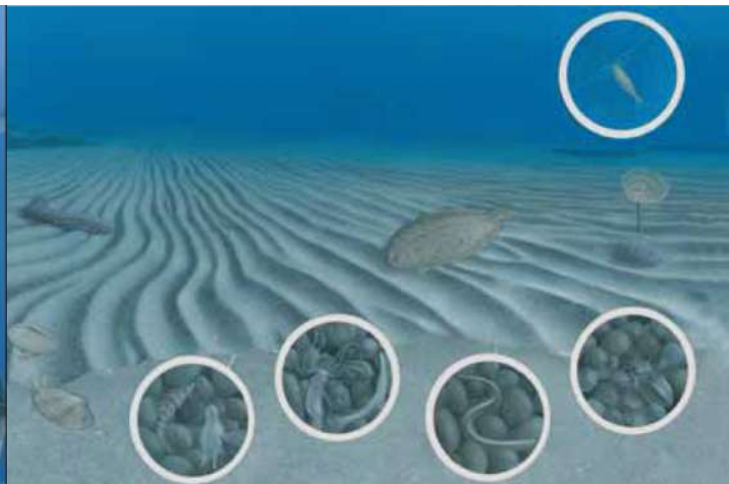
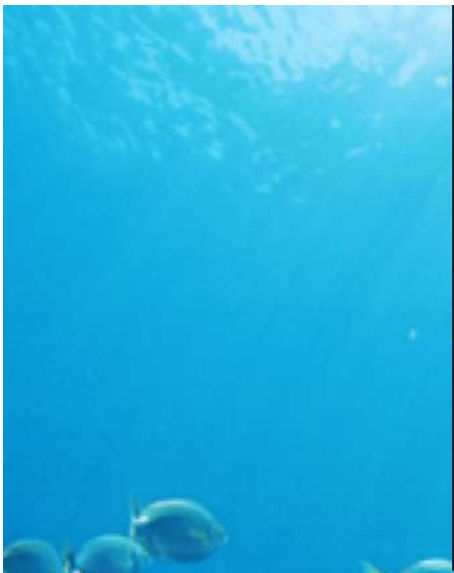
plants make  
the landscape  
near the  
surface

but, below the  
euphotic zone,  
habitats are  
dominated by  
animals

the land is for  
botanists  
the sea is for  
zoologists







**In certain marine habitats**  
plants are invisible or  
are absent

## **On land**

**all products derive from  
agriculture**

**we are not hunters and  
gatherers any more**

**landscapes are radically  
altered**



## **In the sea**

**seascapes are  
much less altered**

**we can still be  
hunters and  
gatherers**

