Zoogeography

Lesson 6

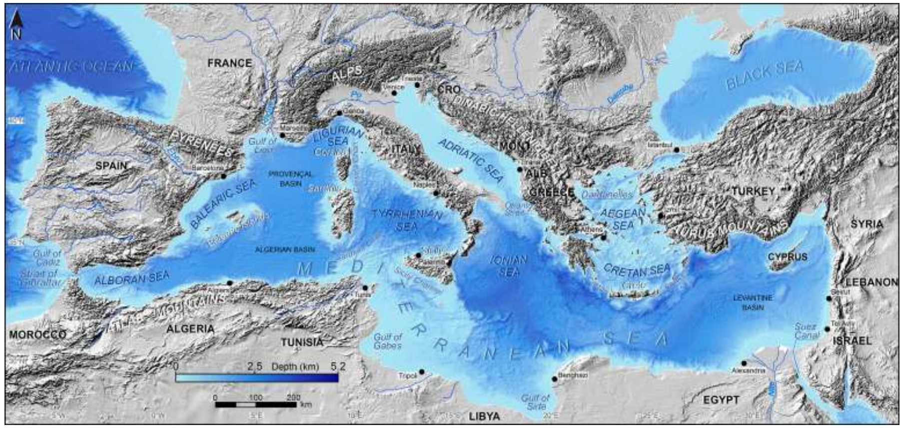
Intro and Recup

- ➢ the current distribution of landmasses and seas is the result of the movements of the continental masses (movements that originated in the Palaeozoic Era), which continue to this day.

- ➢ the consequences of these movements are especially evident along the coasts where, under the pressure of ‘clods’, very steep mountain ranges and abyssal trenches have formed at the edges of the continents.

- ➢the waters of the oceans penetrate more or less deeply into the continental masses with inland seas and Mediterranean seas

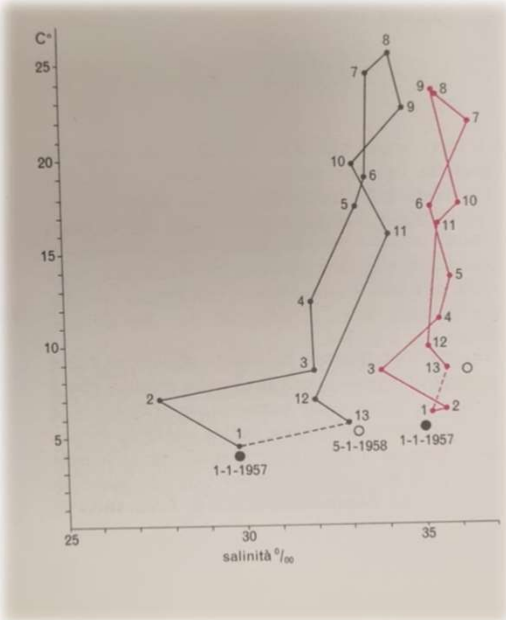
- e.g. Mediterranean sea and Carribean sea (American Mediterranean sea)

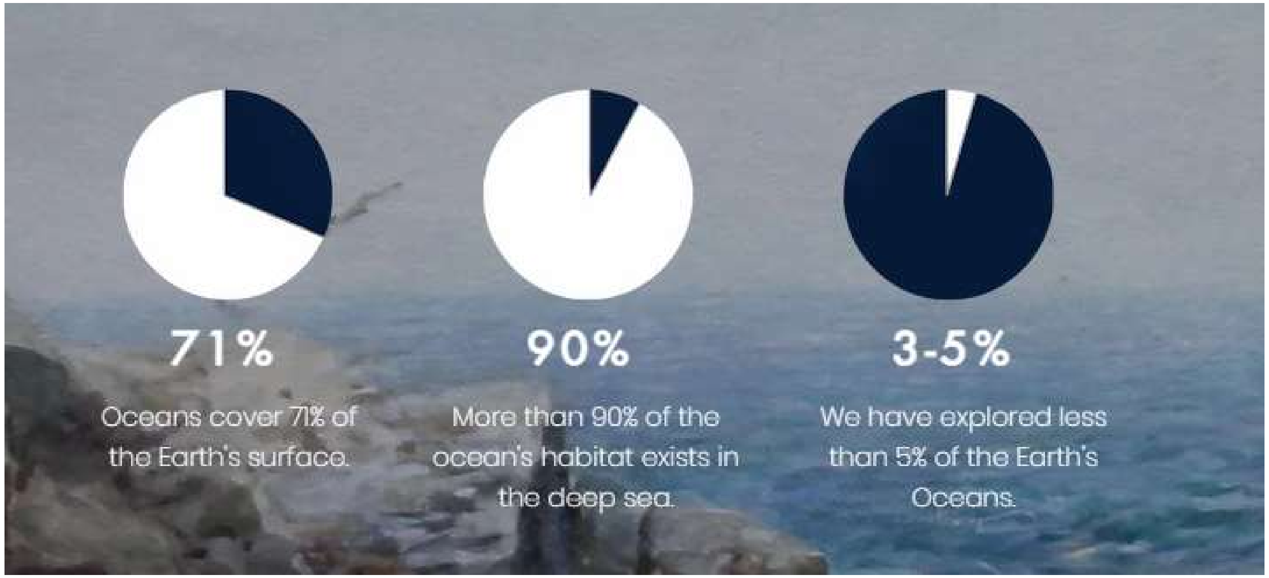


- other seas are those located on the continental shelf, and therefore have a limited depth, such as the Adriatic sea

Salinity and temperature have a considerable influence on the distribution of marine organisms.

Species that are able to tolerate wide variations in temperature are called **eurytherms**, while those adapted to live within narrow temperature ranges are called **stenotherms**. Similarly for salinity, we speak of **euryhaline** or **stenohaline** species.





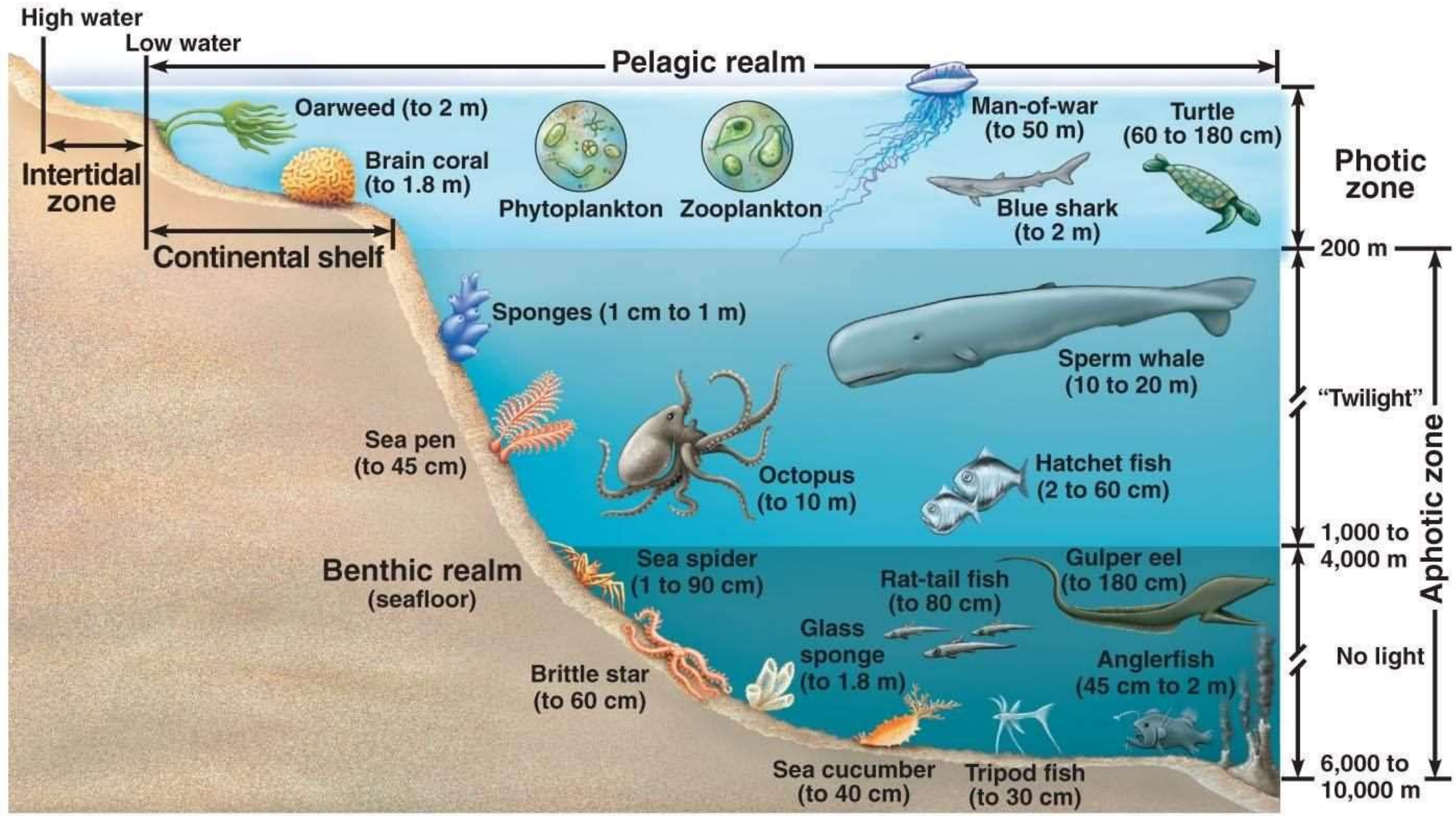
https://www.youtube.com/watch?v=9FqwhW0B3tY

Marine ecosystems – ocean zones

Several broad categories (although there is some disagreement)

Marine ecosystems

1- estuaries ✓
2- salt marshes ✓
3- mangrove forests ✓
4- coral reefs,
5- the open ocean, and
6- the deep-sea ocean



The sunlight zone - Epipelagic Zone 0 - 200m

- The sunlight zone is the only zone in the ocean where photosynthesis is able to provide sufficient energy to support communities of life.

Below 200m, we will find no plant life at all.

Coral reef

• Coral reefs are natural underwater limestone structures made by small creatures called polyps.

• A bit farther out into the tropical sea are coral reefs, euphotic-zone ecosystems built from the exoskeleton secreted by coral polyps. These exoskeletons form complex structures that shelter many different organisms.

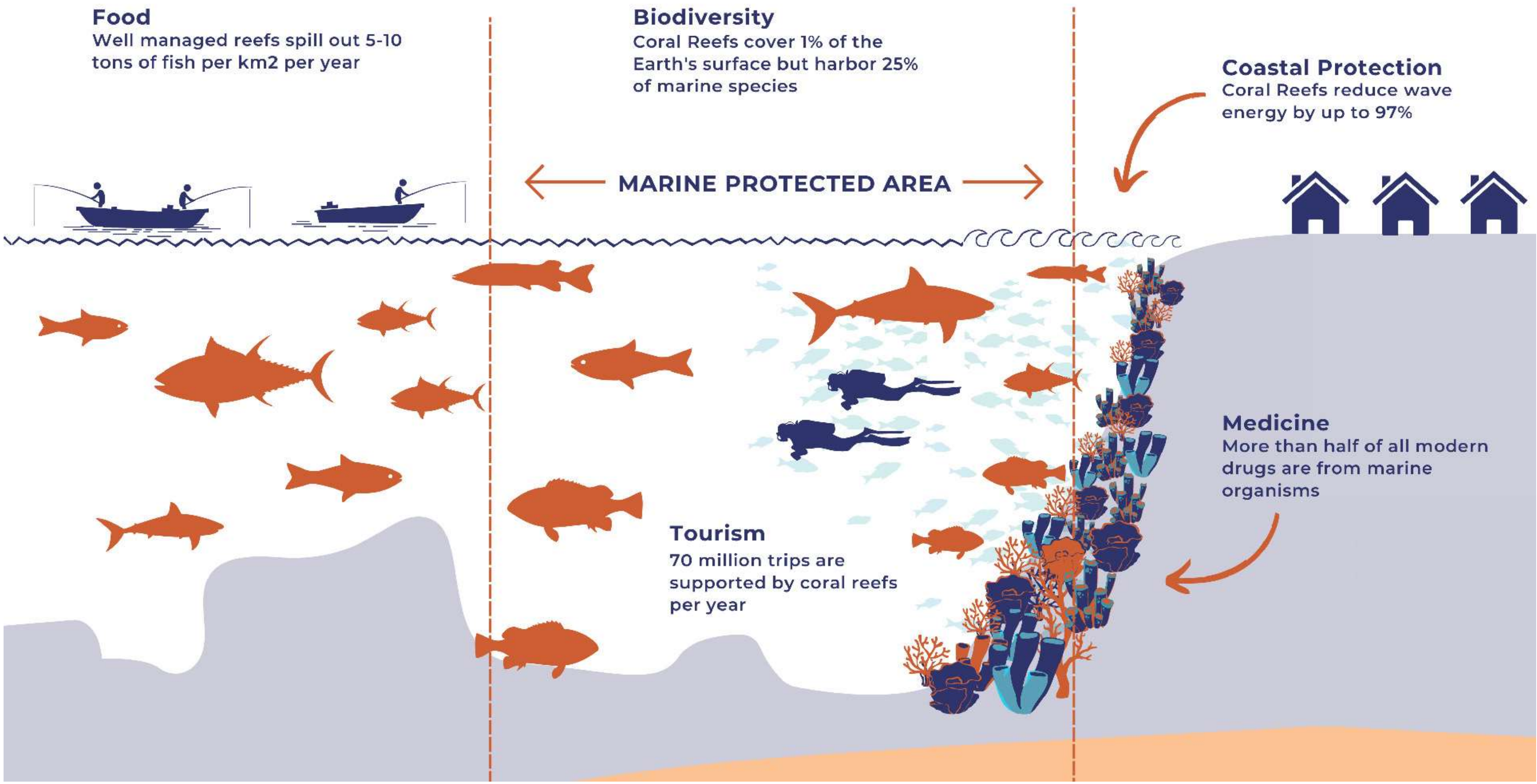
Coral reef

- Coral reefs are extremely diverse ecosystems that host sponges, crustaceans, mollusks, fish, turtles, sharks, dolphins, and many more creatures. By some counts, **coral reefs can account for a quarter of all ocean species**.

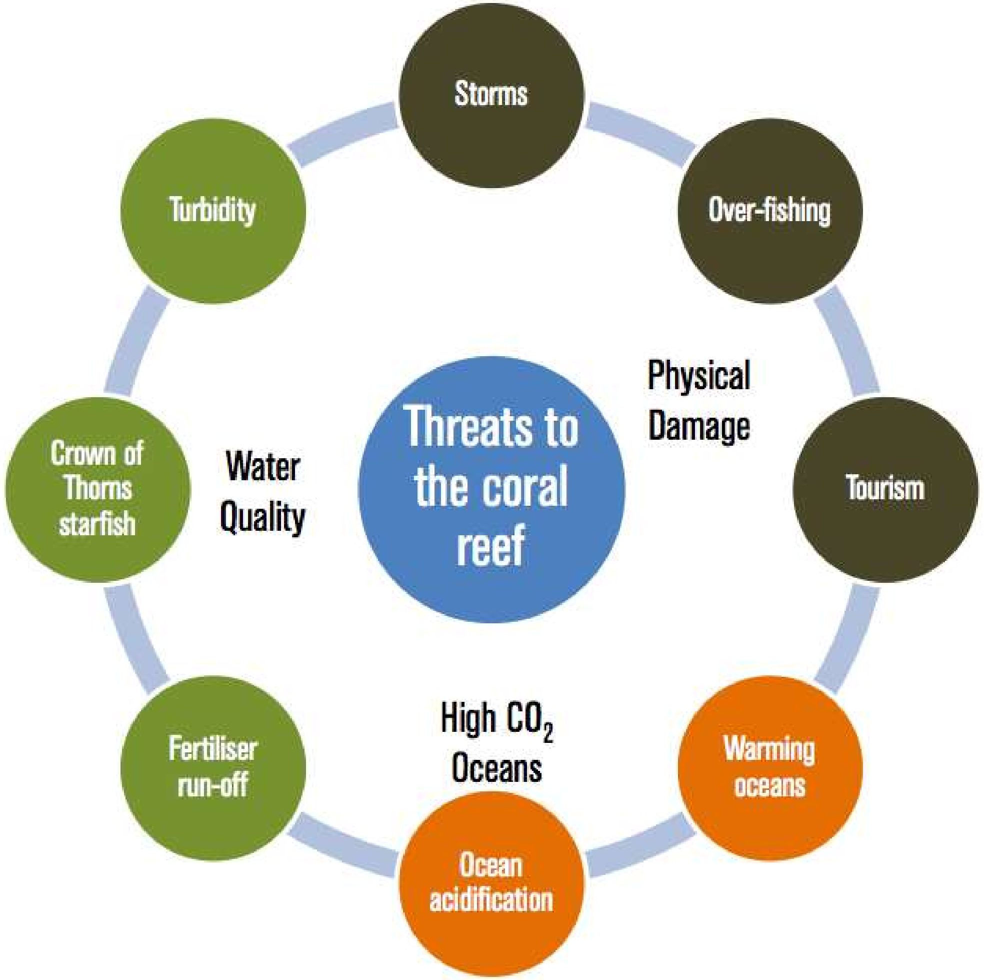
- They're the ocean version of an apartment block – they provide homes for many different living things.

They have been compared to rainforests because of their biodiversity, importance to humans and the role they play in helping to limit the damage caused by climate change.

The importance of coral reef ecosystems

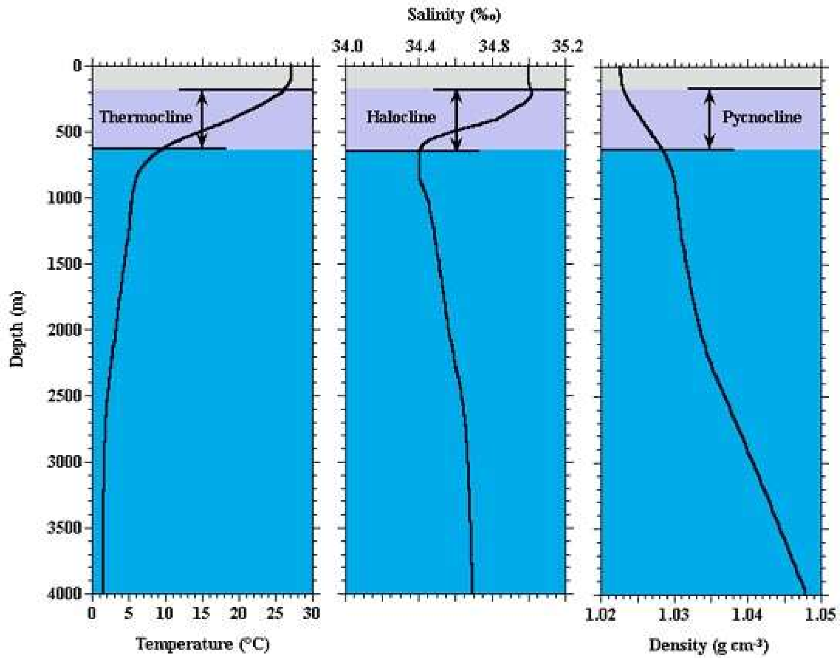


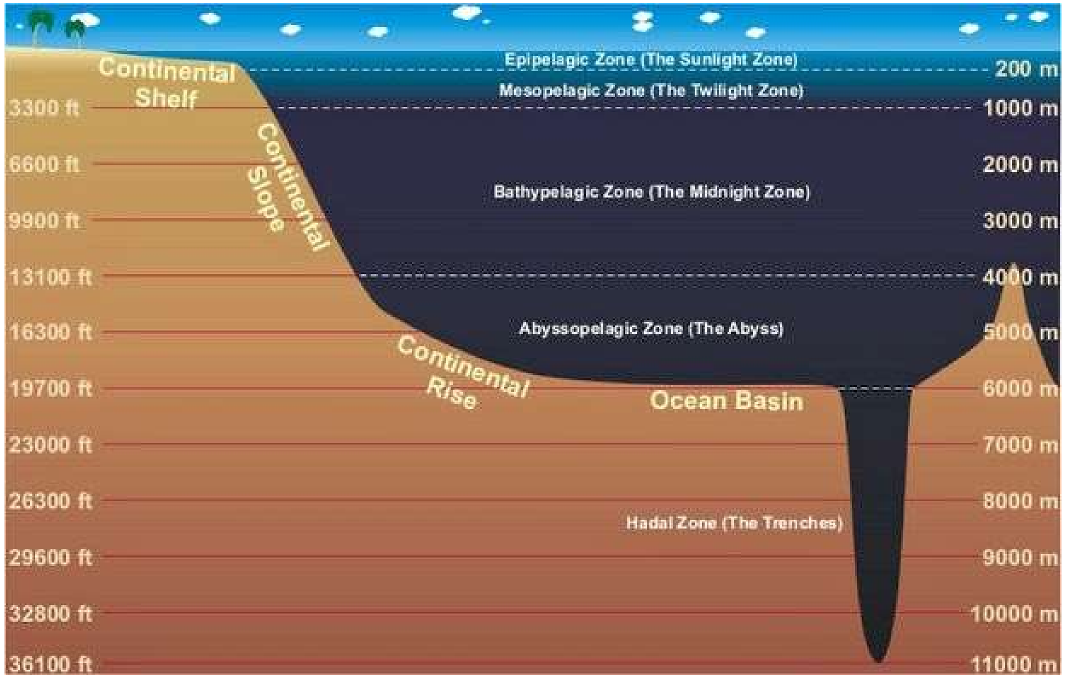
Coral reef threats



The open ocean

- Beyond the coral reefs lies the open ocean.
- At the surface of the ocean, the **euphotic zone**, the ecosystem receives plenty of light and oxygen, is fairly warm, and supports many photosynthetic organisms. Many of the organisms that we associate with marine ecosystems, such as whales, dolphins, octopi, and sharks, live in the open ocean.





- https://www.bioexplorer.net/ocean-animal-adaptations.html/
- **Camouflage:** To survive in the well-lit, exposed habitat of the open ocean, many types of animals have evolved a form of camouflage called countershading (e.g. sharks, rays, dolphins, and whales). These animals are darker on their top side and lighter on their under side (e.g. great white shark, Fig. 7). This makes them more difficult to spot from above (they blend in with the darker deep water below them), or from below (they blend in with the clearer shallow water above them).
- https://manoa.hawaii.edu/sealearning/survival-of-the-fittest#:~:text=To%20survive%20in%20the%20well,7).

- But amidst the productive frenzy of the shallow open ocean, animals excrete, and die, and moult, creating a trickle of organic material that begins to sink downwards. A nutrient-rich supply of food, known as marine snow. And so, we enter the isolated deep.

- With no sunlight, photosynthesis cannot occur below 200 metres in the Twilight Zone. There are no plants here to fulfil the role of nutrient producers. There is only marine snow, bringing down the leftovers from above. It might be enough to sustain an abundance of detrivores, or small filter feeders like sponges, but this alone is not enough to support a complex biological community.

- And yet, the deep sea is complex in its biodiversity. So if the energy is not coming from the sun, where is it coming from?

The deep sea (below 200 m)

- As the depth of the ocean increases, it gets darker, colder, and with less available oxygen. Organisms living in deep-sea ecosystems within the **dysphotic and aphotic zones** have unusual adaptations that help them survive in these challenging environments. Some organisms have extremely **large mouths** that allow them to catch whatever nutrients fall from shallower ocean depths. Others have adapted to get their **energy via chemosynthesis** of chemicals from hydrothermal vents.

The Food Web of the Deep Sea

At first look, the depths of the ocean may appear barren, lifeless, and silent. The lonely expanse rolls out into a long horizon, while the great abyss plummets ever-downwards into darkness. Communities of life are solitary. They seem isolated from other habitats in the deep. But there is more going on here…

- At the bottom of every food web, whether it is terrestrial or marine, there must be a source of nutrients. There must be organisms capable of synthesising organic molecules from energy.

- Photosynthesising organisms that use energy from sunlight to convert carbon dioxide into oxygen and chemical energy stored as glucose (Photoautotrophs)

- Herbivores, or primary consumers, such as zooplankton or turtles and manatees, feed primarily on the plants and phytoplankton.

- The herbivores become food themselves for secondary consumers, which make up the top two levels of the food web. Carnivores, and top predators.

Chemosynthesis

PRIMARY PRODUCTION IN THE DEPTHS

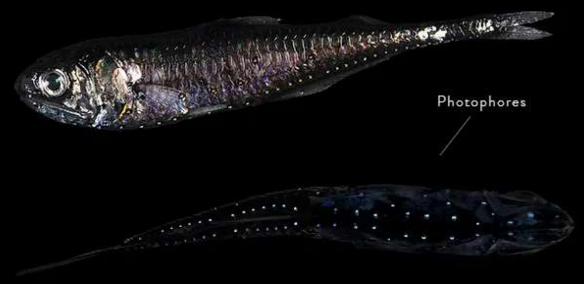
- there are **hot upwellings** of dissolved chemicals and minerals that form towering chimney structures on the sea-floor, and release heated minerals from deep within Earth into the ocean. The chemicals expelled within the superheated vent fluid would be toxic to us humans. But to the life here, they are vital, containing nutrients that bacteria are able to convert to energy in a process that mirrors the conversion of sunlight during photosynthesis.

- In place of Photoautotrophs, we find Chemoautotrophs. In place of plants and plankton, there is bacteria. In place of photosynthesis, chemosynthesis. The bacteria are the primary producers, a major source of nutrients for the deep sea ecosystem.

The Mesopelagic zone (200-1000 m)

COUNTER-ILLUMINATION

Many organisms in the Twilight Zone, including this lanternfish, use counter-illumination to blend in with the ambient light in order to avoid predators.



COELACANTH

700m (2,300ft)

The coelacanth was thought to have gone extinct 65 million years ago, during the great extinction that wiped out the dinosaurs. They were rediscovered in 1939.

- The light from the sun diminishes to a faint glow. There is not enough sunlight here to support photosynthesis in plants or microorganisms.

SUNFISH

580m (1,900ft)

The wonderfully weird Mola mola is the world's largest bony fish. To move its large, cumbersome body, it wiggles its large fins and steers with the crest-like clavus at its back.

https://www.naturalworldfacts.com/the-deep-sea-zones

ATOLLA JELLYFISH

The vivid colours of the Atolla jellyfish are actually protective. because most deep sea creatures see blue light, the deep red hue makes them practically invisible.

https://www.naturalworldfacts.com/the-deep-sea-zones

The midnight zone
Bathypelagic Zone 1000 - 4,000m

With no light, there is no growth of plants or phytoplankton - all animals are thus predators or scavengers.

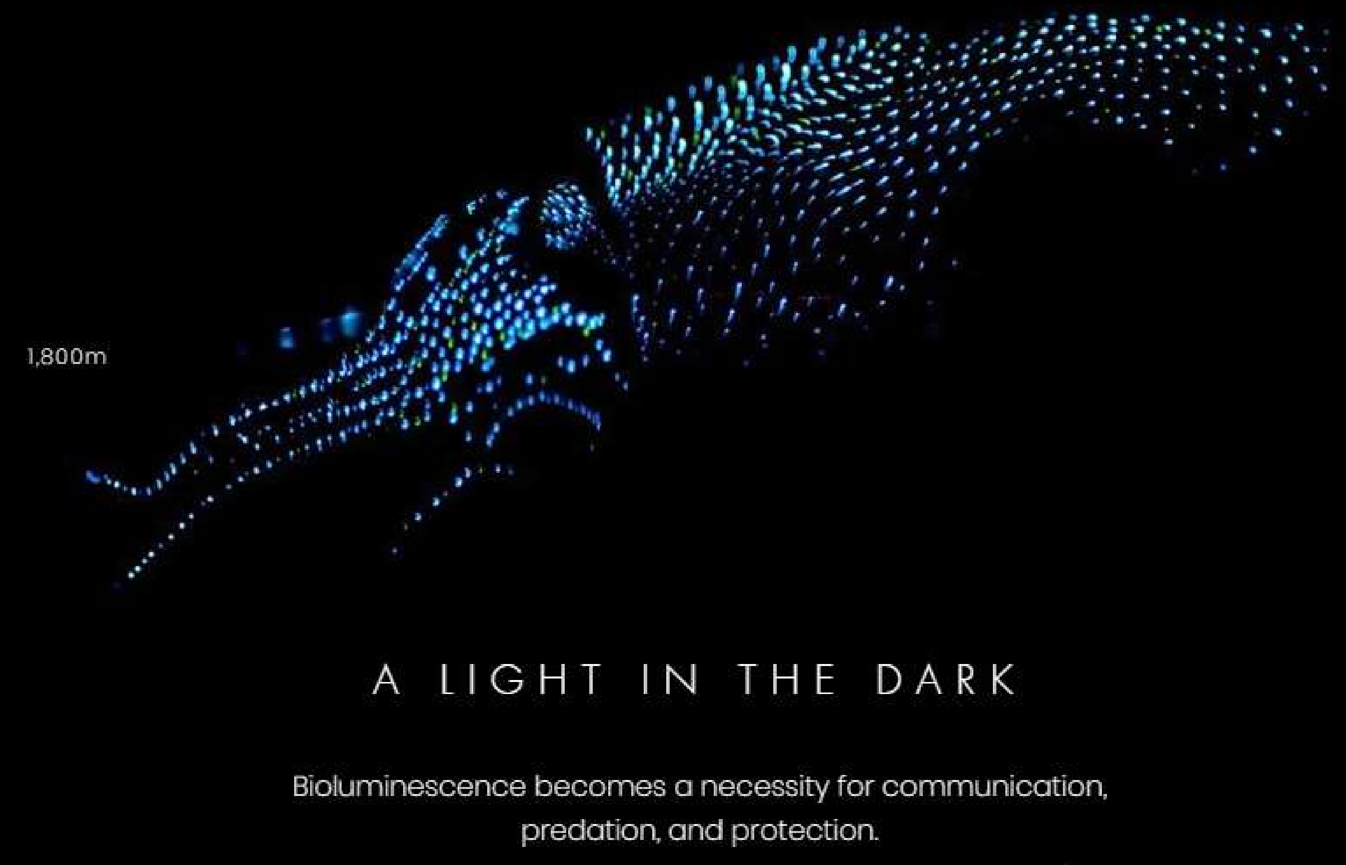
https://www.naturalworldfacts.com/the-deep-sea-zones

1,500m

The Deep Sea Anglerfish attracts prey using a bioluminescent lure.

1,600m

https://www.naturalworldfacts.com/the-deep-sea-zones



An organism itself will contain the chemicals needed to luminesce.

In order for bioluminescence to occur, a species must contain a molecule called luciferin. When luciferin undergoes a chemical reaction with oxygen, it produces light. Organisms are able to regulate their chemistry in order to control when they light up, as well as how bright and what colour. This is useful as different situations will benefit from differences in the way the light is expressed.

1,900m

SIPHONOPHORES

7,550 feet (2,300m)

Though they may look like single organisms, these drifting translucent blobs are actually colonies made up of thousands of tiny zooids. The zooids specialise to fulfil a specific role in the colony, meaning each kind of zooid relies on the others in order to survive. It is a bioluminescent vessel of life, drifting in the deep sea.

2,000m

Pelagic scavengers that obtain energy from Whale-fall communities

Occasionally, amidst the constant trickle of marine snow from above, something larger will sink to the deep sea. A sunken whale carcass - known as a ‘whale-fall’ - that can support a complex biological community for up to 50 years.

2,300m

SLEEPER SHARK

2,400m

7,200 feet (2,200m)

The Greenland or sleeper shark is the most eery-looking deep sea wonder. With blind white eyes, and rough dark skin, they truly look like living fossils. They outlive all other vertebrates on Earth, with lifespans close to 500 years.

2,500m

THE CHIMAERA

2,600m

8,500 feet (2,600m)

Also known as ghost sharks, these deep sea fish demonstrate that the deeper you go, the weirder life becomes. With fins like bird wings, a large head, and dead-looking eyes, they exhibit a truly unique morphology that dates back 300 million years.

https://www.naturalworldfacts.com/the-deep-sea-zones

A sperm whale can dive down more than 2,000 meters and can stay submerged for up to an hour.

It is a skill that they must acquire in order to hunt their prey, deep-dwelling squid.

https://www.naturalworldfacts.com/the-deep-sea-zones

3,200m

3,300m

Ctenophores beat their shimmering hair-like cilia to move around.

https://www.naturalworldfacts.com/the-deep-sea-zones

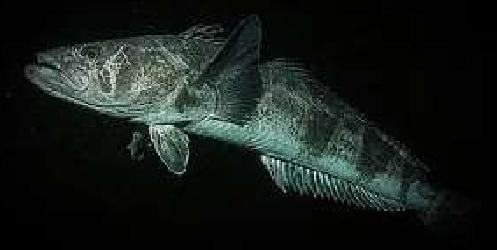
This is the average depth of the oceans. But in some places, it goes deeper.

3,700m

3,800m

THE 'UNSINKABLE'

On the 14th April, 1912, the Titanic sank to its final resting place at a depth of 3,800 meters.



Patagonian Toothfish have antifreeze proteins in their tissues.

3,900m

Beneath the Midnight Zone lies an even stranger realm of darkness and silence.

The Abyss

4,100m

Abyssopelagic Zone (4000-6000 m)

Temperatures are near freezing, and very few animals can survive the extreme pressure here.

4,200m

ATOLLA JELLYFISH

Look familiar? This jellyfish swims in a range from 1,000m deep at the bottom of the Twilight Zone, to up to 4,000 metres in the Abyss.

4,400m

THE SEA PIG

4,500m

Sea pigs have five to seven pairs of enlarged tube feet. These "walking legs" are hydraulically operated appendages that can be inflated and deflated to move around.

4,600m

MEGAMOUTH

15,000 feet (4,600m)

4,700m

Megamouths spend most of their lives in the dark of the Abyss, only returning to the surface at night to feed. They are filter feeders, and in order to survive in the deep where food is scarce, they grow to enormous sizes in order to become more efficient. This is known as deep sea gigantism.

5,000m

The aptly named Fangtooth has been found as deep as 5,000m.

https://www.naturalworldfacts.com/the-deep-sea-zones

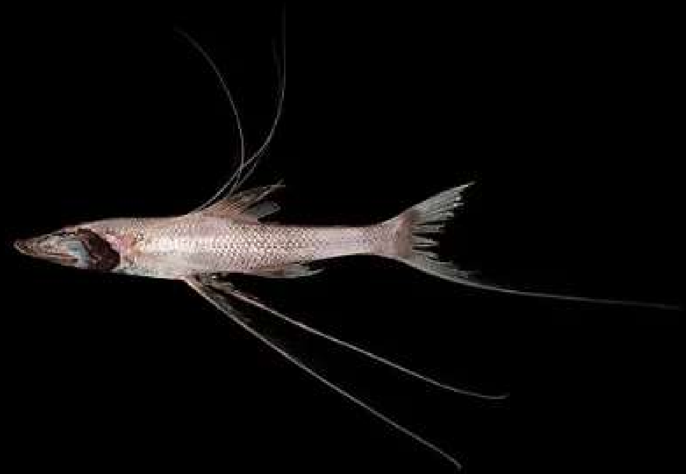
Much of the life that dwells in the Abyss is Benthic or Demersal, meaning they live on or near the sea-floor. Many are well-adapted for such a lifestyle.

5,400m

FACELESS FISH

5,500m

This species of cusk eel has made evolutionary sacrifices in order to survive the Abyss. Its face is buried deep beneath the skin, making its eyes virtually useless.



TRIPOD FISH

The Tripod fish uses elongated pelvic and lower caudal fin rays to stand on the sea floor like a tripod. It waits motionless until it detects potential prey with its extended pectoral fins.

These fins then direct the food towards its huge mouth. This method of hunting uses very little energy and is ideal for a predator on the desert of the deep ocean.

https://www.naturalworldfacts.com/the-deep-sea-zones

The Trenches

Hadalpelagic Zone (6000-11000m)

More people have been to the Moon than the Hadal Zone of the deep.

Most of the Hadal Zone lies in deep sea trenches.

These form by 'subduction' where the Earth's tectonic plates meet and push together.

6,700m

The extreme conditions make survival difficult. Thus, life here is sparse.

So little is known about life in the Abyss. Almost every expedition uncovers new species.

6,800m

8,200m

HADAL SNAILFISH

9,400m

This flabby, translucent creature is the deepest dwelling fish on Planet Earth.

HADAL AMPHIPOD

10,500m

Amphipods can and do consume just about anything that falls to the seafloor, filling an important ecological function by recycling nutrients from even hard-to-digest material back into the environment. The hadal amphipod even has microbes in its gut that can digest wood.

On January 23rd, 1960, about 9 years before the moon landing, humans went where they never had before.

Two men, Jacques Piccard and Don Walsh, onboard the submarine Trieste slowly descended into the Mariana Trench.

And even at these depths, they could see creatures in the dark beyond.

Following 4 hours and 47 minutes of fear, anxiety and claustrophobia, they reached
Ocean's deepest point 11,000m

10,900m

Yeti crabs, *Kiwa hirsuta*, were discovered relatively recently, in 2015, during the expedition to the deep-sea hydrothermal vents

- These crabs can be found at the bottom of the sea, around hydrothermal vents in the Pacific, and close to Antarctica. Yeti crabs are yellowish-white in color, with prominent front pincers.
- All of their appendages are covered in long hair called setae, and the hair layer is incredibly thick on the front pincers.
- The scientists have observed that the crabs occasionally sit at the vents' openings, waving their hairy pincers above them.
- It was also established that the **hair contains a large number of bacteria**. It is supposed that the crabs support these bacterial colonies, providing them with nutrients emitted by the vents, and these bacteria are used as a supplemental food source.

The Pacific blackdragon is a deep-water fish. It has an elongated body with a long fin along the upper part of the body.

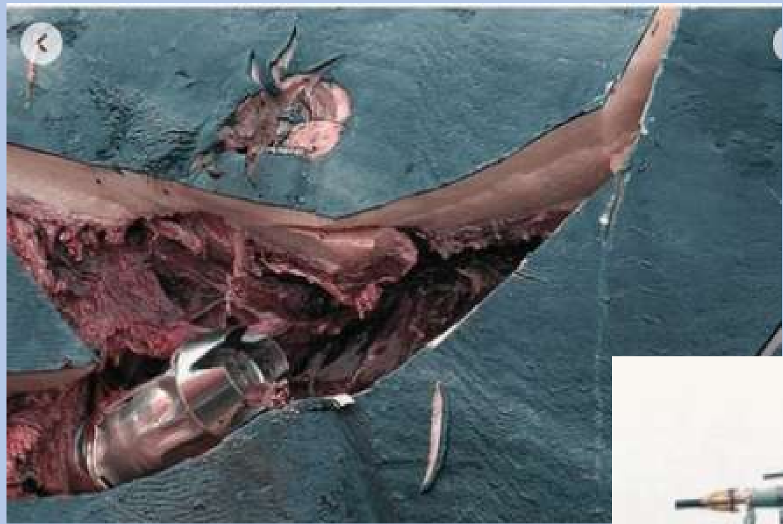
- It has a large head with prominent, sharp, and curved teeth.
- This fish is a predator.
- Unlike anglerfish that bait the potential prey, the blackdragon prefers to wait in an ambush. Unfortunately, this strategy can be problematic even in the deep sea.
- Though this species lives on the levels where there is no natural light, multiple species have bioluminescence.
- This means that there is enough light for potential prey to see their predators. The black dragons have an ingenious solution to this problem.
- Like many sea species, these fish have the black pigment-melanin. Melanin is stored in unique structures called melanosomes.
- In Pacific blackdragons, these melanosomes are very tightly packed, which is usually quite rare.
- Due to this melanosomes organization, the Pacific Blackdragons can absorb bioluminescent light almost wholly, dissolving into the darkness – and attacking their prey entirely unexpectedly.

Agony of a whale

Biologicamente

Smith, C. R., Glover, A. G., Treude, T., Higgs, N. D., & Amon, D. J. (2015). Whale-fall ecosystems: recent insights into ecology, paleoecology, and evolution. Annual review of marine science, 7, 571–596. https://doi.org/10.1146/annurev-marine-010213-135144

unexploded explosive harpoon



26 mt for 77-81 tons

launched from a Japanese whaler

After three days it's gone

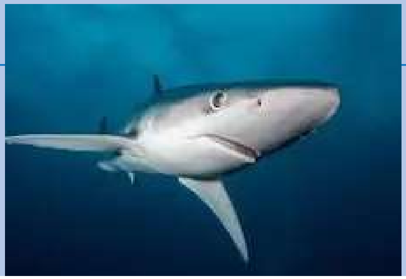
The whale sinks, taking with it all the carbon stored in its body

The carcass swells due to the gases released by decomposition

The carcass sinks towards the abyss, along with **billions of organic particles** falling from the other like snowflakes. Kilometre after kilometre, it reaches the dark, almost inhospitable depths, seemingly devoid of life

The carcass floats on the surface of the water and becomes a hearty meal for seagulls and other sea birds for a while.

A blue shark then arrives and takes off a large piece and the whale begins its descent into the depths of the sea.



The carcass crosses the bathypelagic zone (between 1,000 and 4,000 m), lies on the seabed and raises a new layer of sediments.

Thanks to her in this cold and dark place, **spring has come**

Missinae dig tunnels in the carcass, octopuses (*Muusoctopus spp*) consume the soft tissues of the whale, together with fish of the Macrouridae family

giant isopods, crabs and holothurians, colonise sediments enriched with new organic matter

polychaete worms (*Osedax* genus) penetrate the skeleton and through root-like extroversions form small white tubes from which tufts of red fringes emerge. They feed on collagen and lipids thanks to the presence of symbiotic bacteria that are able to metabolise these highly nutritious and precious substances.

50 years later…

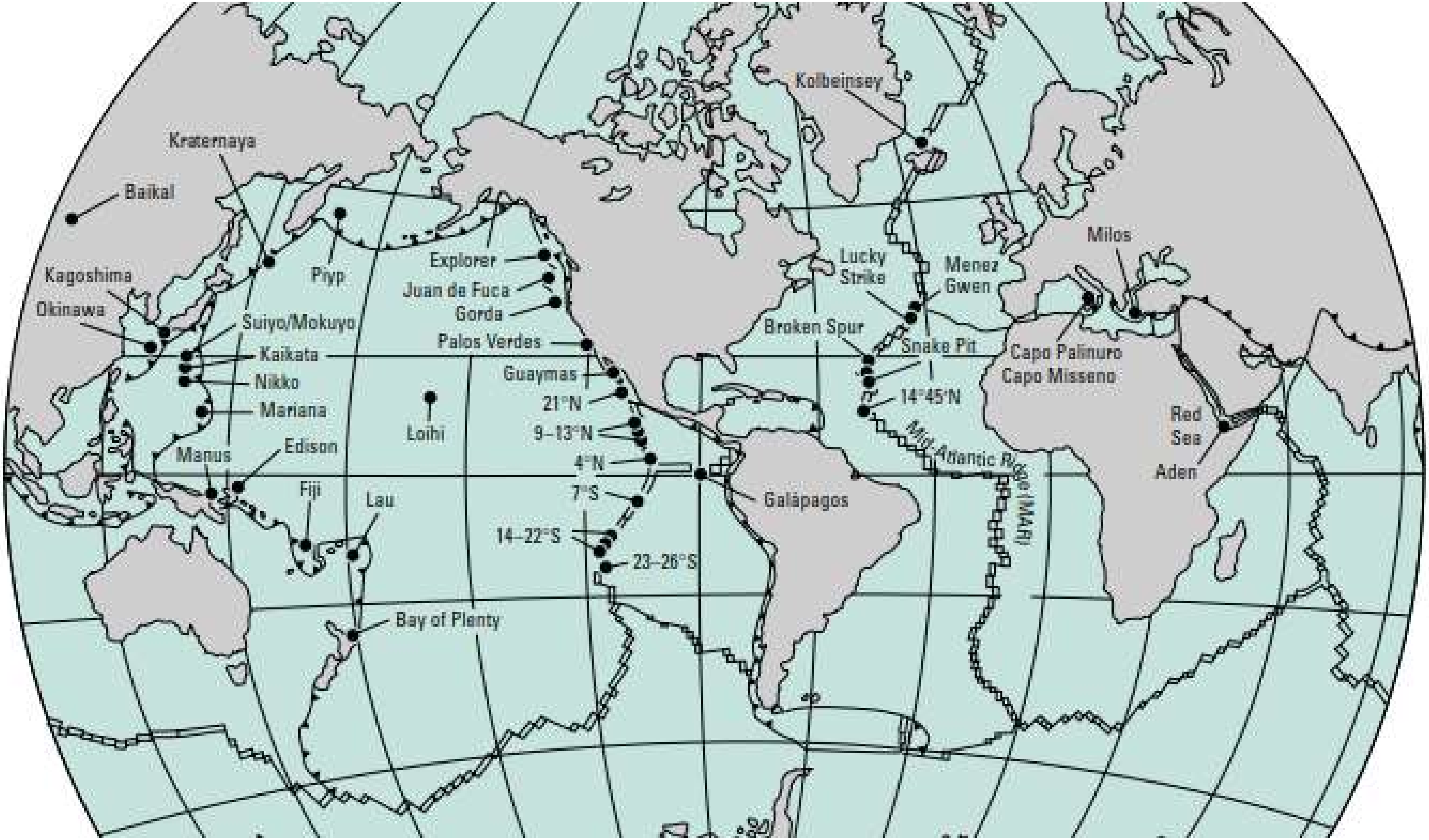
Sulphur-depleting and sulphide-oxidising bacteria, along with methanogenic and methanotrophic archaea, fish, crustaceans, molluscs, and echinoderms, have ravaged the whale's carcass, breaking down its bones and consuming the organic compounds embedded in the surrounding sediment.

The whale is not just yet another victim of ruthless and senseless hunting, it is not just a whale shot with **defective weapons**; instruments that in no way guarantee a quick and dignified death

The whale become a new and temporary ecosystem!

Saltwater in the deep sea

- Concentrations of ‘saltwater’ often occur at deepwater and cold water sites.
- They accumulate above submarine oil deposits. In some cases they are surrounded by vast mussel beds,
- probably dependent on methane released from hydrocarbons, which is fixed by bacteria within the tissues of the bivalves themselves.



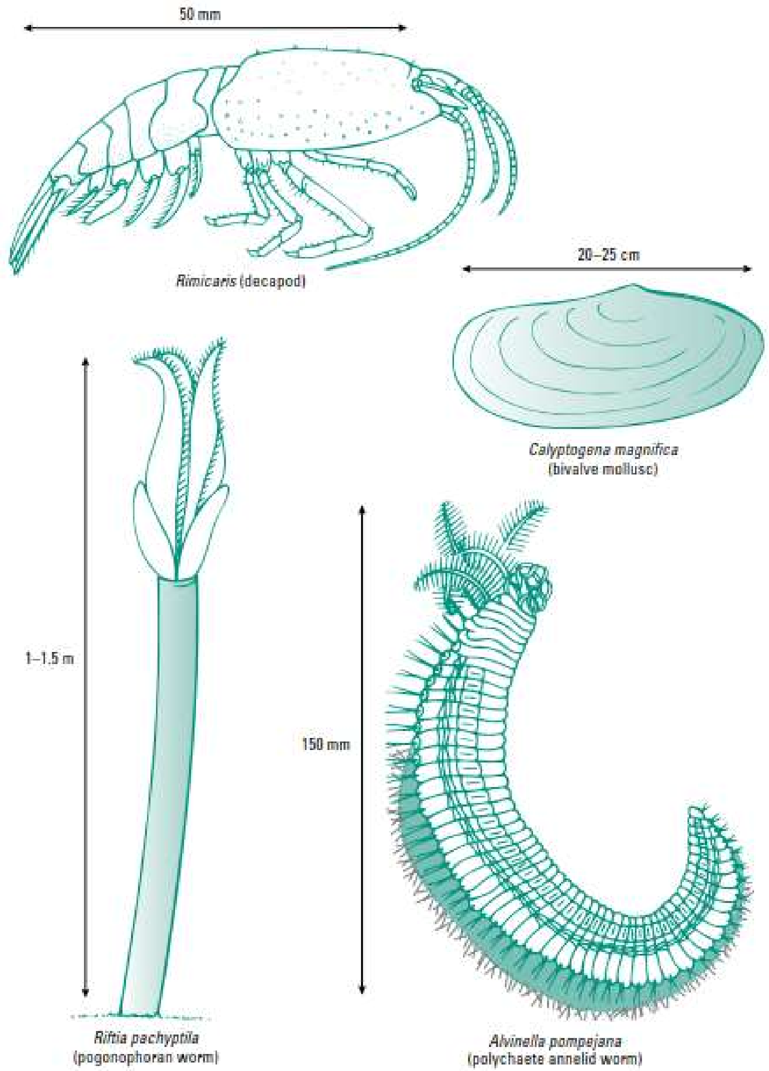
Kolbeinsey
Kraternaya
Baikal
Piyp
Explorer
Juan de Fuca
Gorda
Kagoshima
Okinawa
Suiyo/Mokuyo
Kaikata
Nikko
Mariana
Palos Verdes
Guaymas
21°N
9–13°N
4°N
7°S
14–22°S
23–26°S
Loihi
Manus
Edison
Fiji
Lau
Bay of Plenty
Galápagos
Lucky
Strike
Menez
Gwen
Broken Spur
Snake Pit
14°45'N
Mid-Atlantic Ridge (MAR)
Milos
Capo Palinuro
Capo Misseno
Red
Sea
Aden

Hydrothermal Vents

Superheated pressurized water (**up to 350°C**) then forces up through the crust to emerge as “hydrothermal Vents»

Fauna of hydrothermal vents

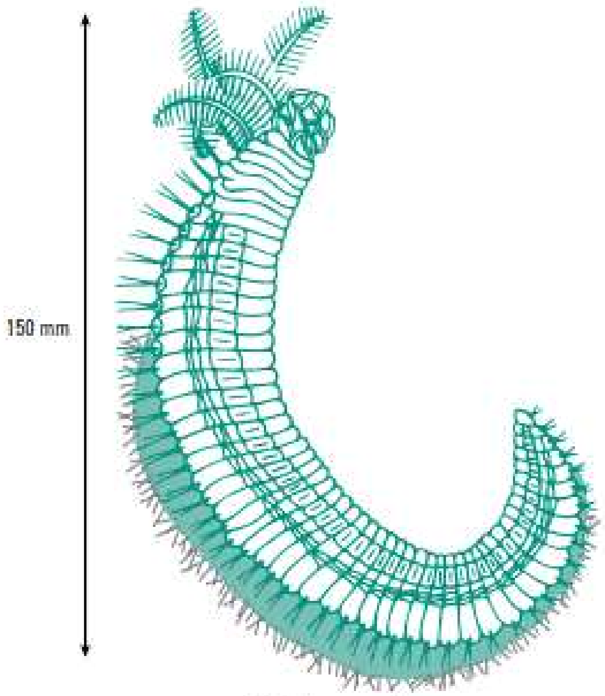
- Procaryotes present at the boiling T°C of H_2O. The enzymes of these 'extremophile' organisms are rich in disulphide bridges
- In the vicinity of the chimneys, the air interacts with the surrounding water and produces an environment around 30°C with hydrogen sulphide concentrations of less than 400 µm
- Fauna associated with hydrothermal chimneys have been discovered since 1977



- 250-300 discovered species of macrofauna

- Of these 200 were new spp never before identified

- The composition of fauna associated with hydrothermal vents is variable, but can be predictably dictated by their age and site in relation to larval recruitment and dispersal.



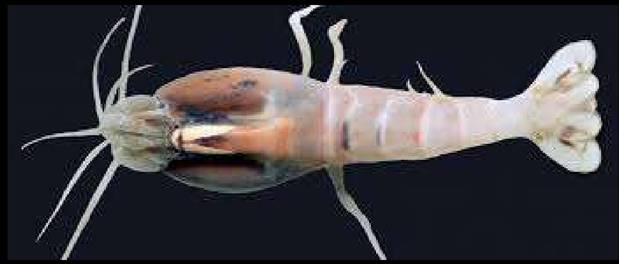
Alvinella pompejana
(polychaete annelid worm)

This polychaete lives in a range of Temp 68-81°C.

Around the mouth the temperature is 22°C with a gradient up to 60°C along the length of the body.

To date, the functioning mechanisms of the proteins and membranes of these worms are unknown.

- *Rimicaris exoculata* (Decapoda) does not have eyes except for a ‘thoracic eye’ adapted to low-light vision. It is probably used to detect the low radiation emitted by the very warm water of the mouths.



- Studies conducted on crabs inhabiting these environments reveal that high pressures accompanied by high temperatures cause less structural damage (pressure: reduces membrane fluidity, but temperature: increases membrane fluidity)

Living in the Oil

In some parts of the world, bodies of water become contaminated by spills from nearby oil deposits, and hydrocarbon spills support various metazoans.

These fluids contain (H_2S, HS^- and S^2) and toxic hydrocarbons (C_xH_x) as well as C and N

Nutrition and respiration in the presence of sulphuric acid

- Sulphur compounds are potentially toxic

1. They bind the Heme group of Cyt c by inhibiting cell resp.

2. They can reduce the S-S of proteins (structural instability)

DETOXIFICATION MECHANISMS

Haemoglobin

Riftia pachyptila

Plasma proteins

Calyptogena magnifica

These proteins transport free sulphide into the general circulatory system where it is strongly bound, and thus achieve three important functions:

1 The preservation of aerobic respiration.

2 The prevention of sulphide precipitation in the blood (could impede circulation).

3 The transport of sulphide to internal centres where the symbionts exploit it for energy production

Symbiotic relationships

- The nematode, *Eubostrichys dianeie*, houses sulfur-oxidizing bacteria in a mucus web over the exterior of its body.
- The worm, *A. pompejana*, maintains an epithelial “fur” of fine projections densely packed with sulfur-containing filamentous bacteria.
- Bivalves have specific intracellular (endosymbiotic) strains of sulfur bacteria housed in their gills in modified cells called bacteriocytes; gastropods also have bacteriocytes in their gills
- In pogonophoran worms, sulfide oxidation occurs in the “trophosome”, an internal organ that fills much of the coelomic cavity and contains extremely high concentrations of sulfide-oxidizing bacteria.

Bivalves

Calyptogena magnifica possesses a mouth and intestine although the digestive system is very small.

- The enlarged gills contain sulphur-oxidising chemolithoautotrophic bacteria that provide the clams‘ main source of energy and weigh on average 17% of the bivalves’ wet weight.
- Sulphates appear to be taken up by the foot and transported by a serum factor that binds sulphate and is present in the blood to the gills. Clam serum can reversibly bind to sulphates [8 mM], with a significantly higher concentration than in the seawater environment

Phogonophora

- Most sulphate oxidative processes occur in the ‘trophosome’. Worms lack a mouth and intestine, and the tentacle plume serves as the primary site of gas and solute exchange with ambient seawater.
- abundant haemoglobin (up to 26% of the worm's wet mass) present in the vascular and coelomic spaces carries both oxygen and sulphate to the trophosome
- Bacteria are therefore able to fix CO2 by involving the ribulose enzyme 1,5-biphosphate carboxylase, providing reduced carbon compounds that in Riftia sp. account for almost 100% of the worm's C demand

Crustaceans

- The crab *Bythograea thermydron* shows a high tolerance for sulphuric acid and high temperatures
- Like molluscs, it has been shown to oxidise H2S to thiosulphate, this time in the hepatopancreas.
- In this species, thiosulphate has an additional adaptive function that increases the affinity of the respiratory pigment (haemocyanin) for oxygen (present at low concentrations)