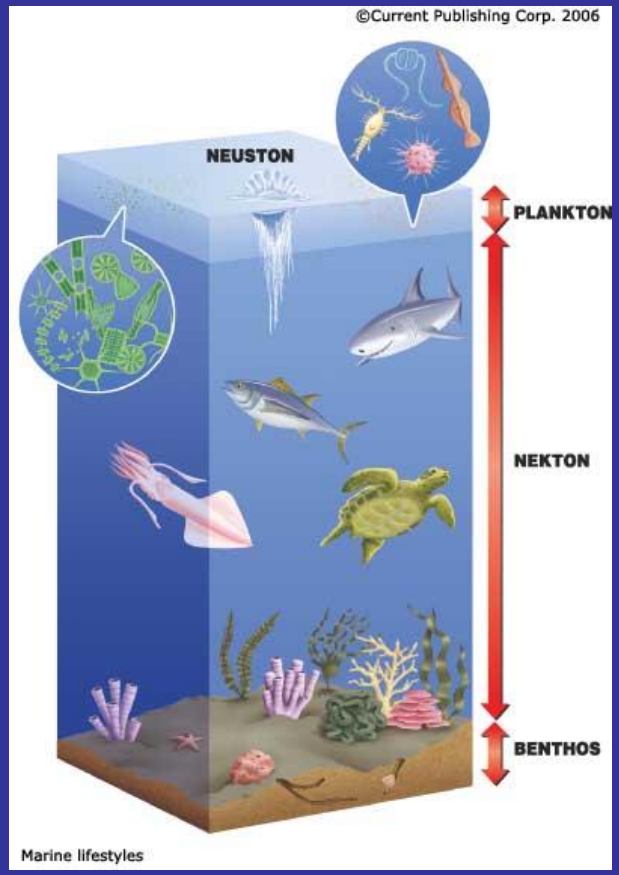
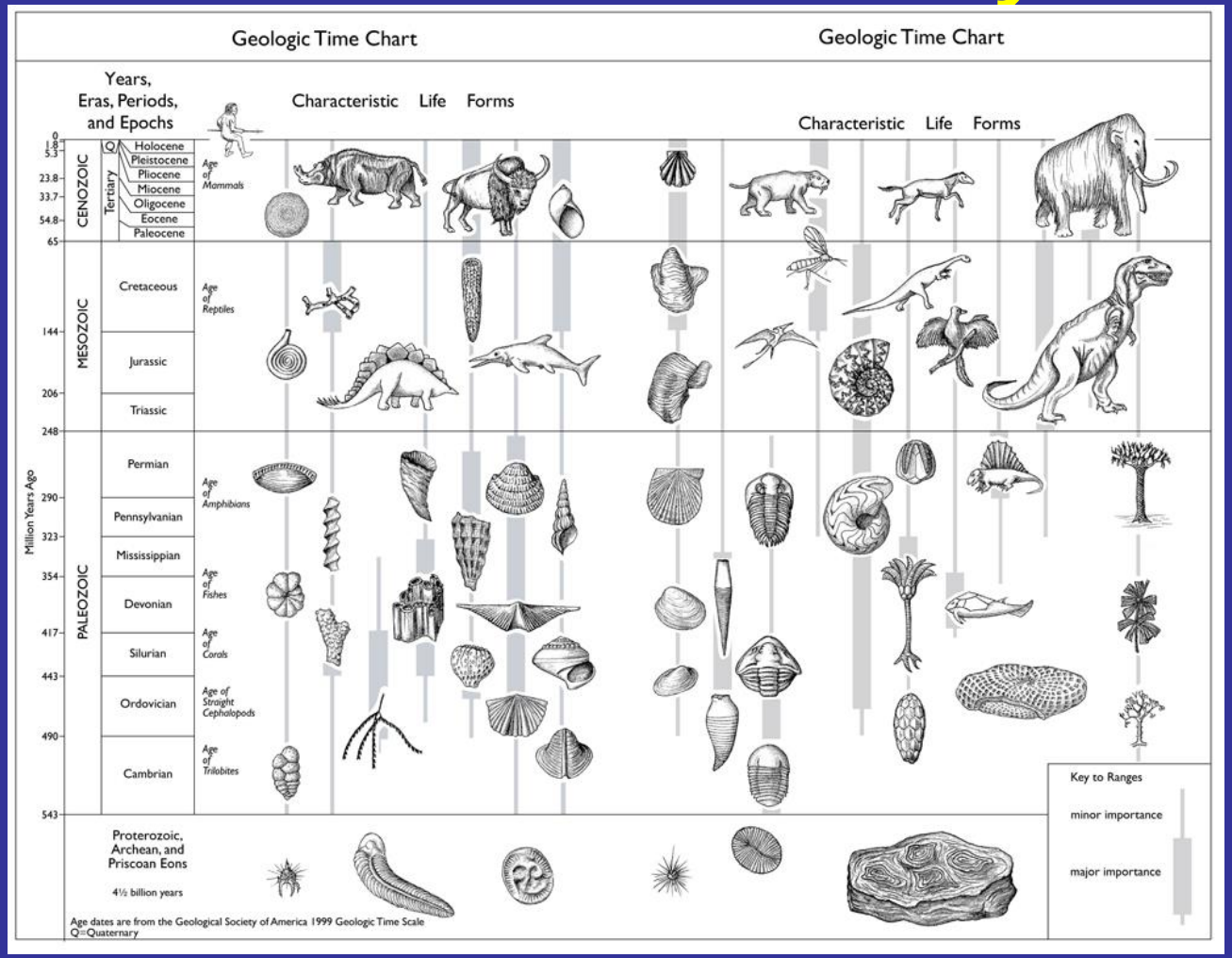
Life in the Ocean

Energy and Biogeochemical Cycles
The Physical Environment
Ocean Zones
Lifestyles by Zone



Life on Earth had Unity and Diversity



All of Earth's life forms are related and function universally the same way.

All species evolved from a single common ancestor at life's origination 3.5 bya.

>200 million living species on Earth

Life requires energy

The first law of thermodynamics states that **energy** cannot be created or destroyed.

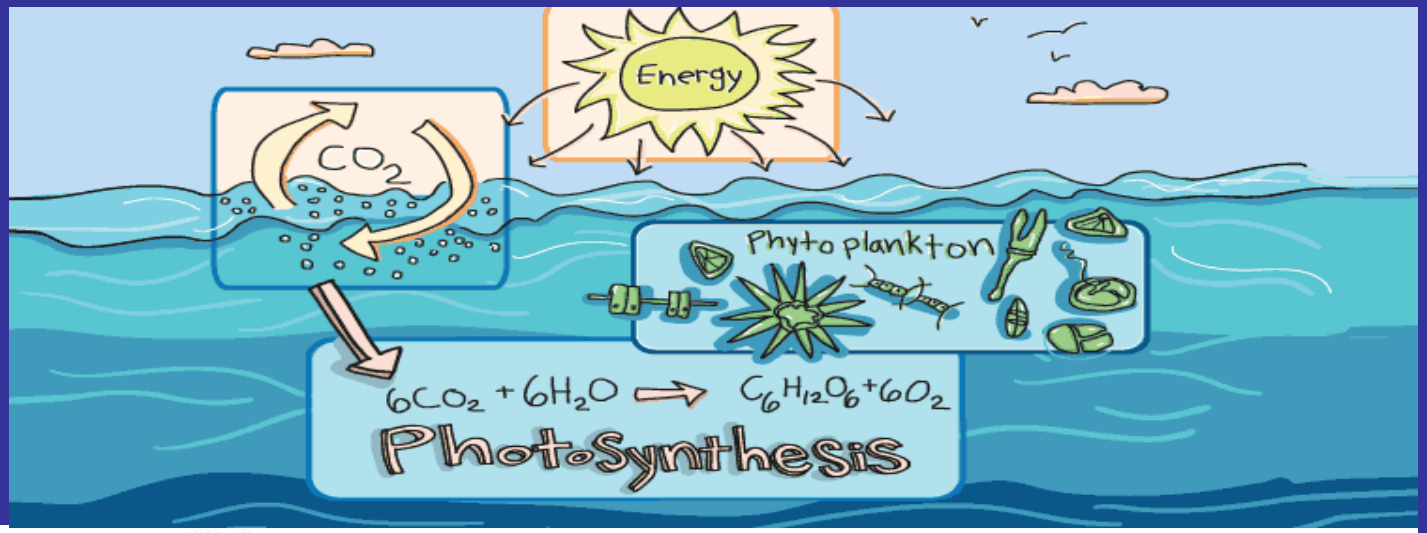
Energy is defined as the capacity to do work.

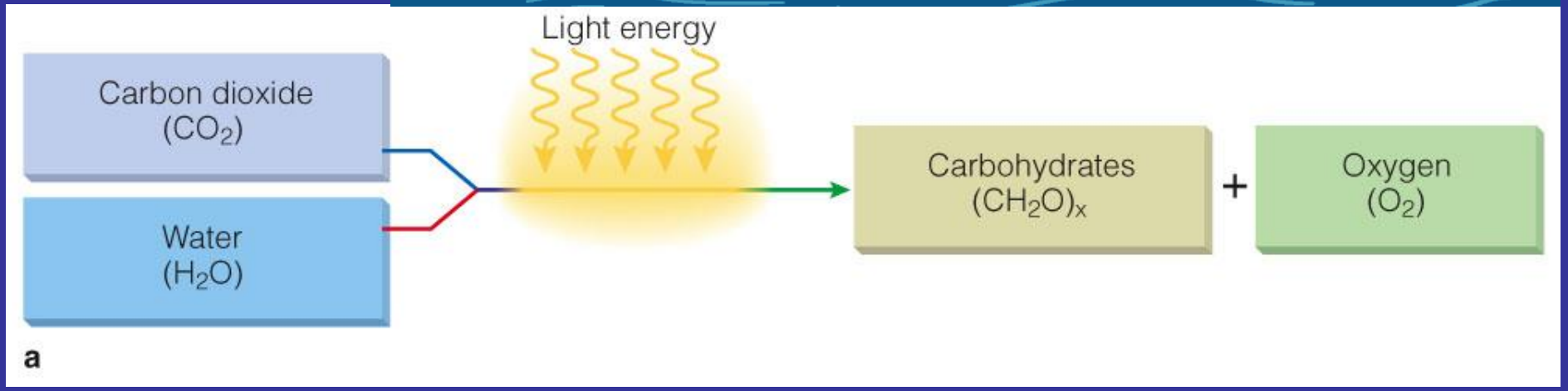
Energy is necessary for life because living systems use energy for processes of life including reproduction, growth, movement, eating and cellular respiration.

What is the primary source of **energy** for living organisms?.....

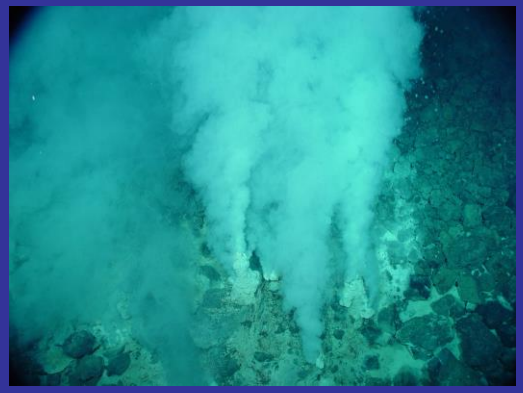
Sunlight -> Photosynthesis

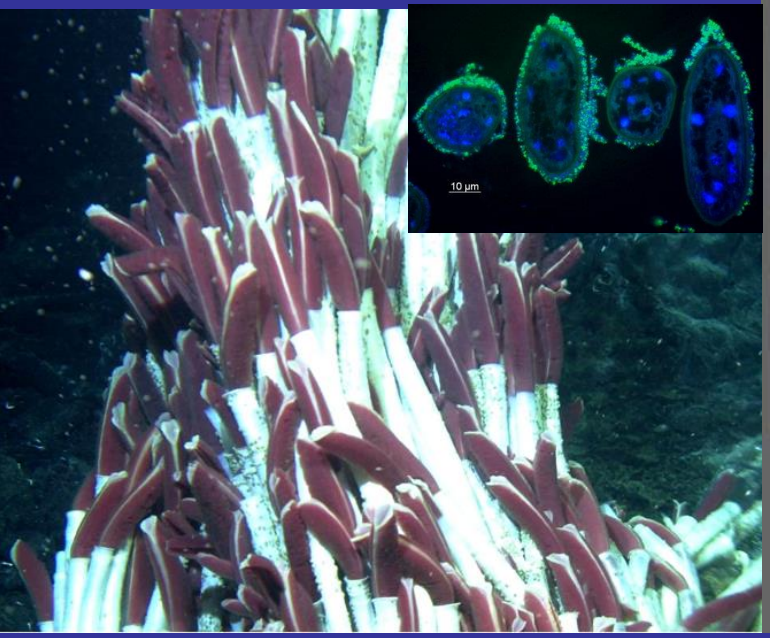
Using chlorophyll, primary producers capture energy from the sun to make food (carbohydrates), absorbing CO_2 and releasing oxygen in the process…

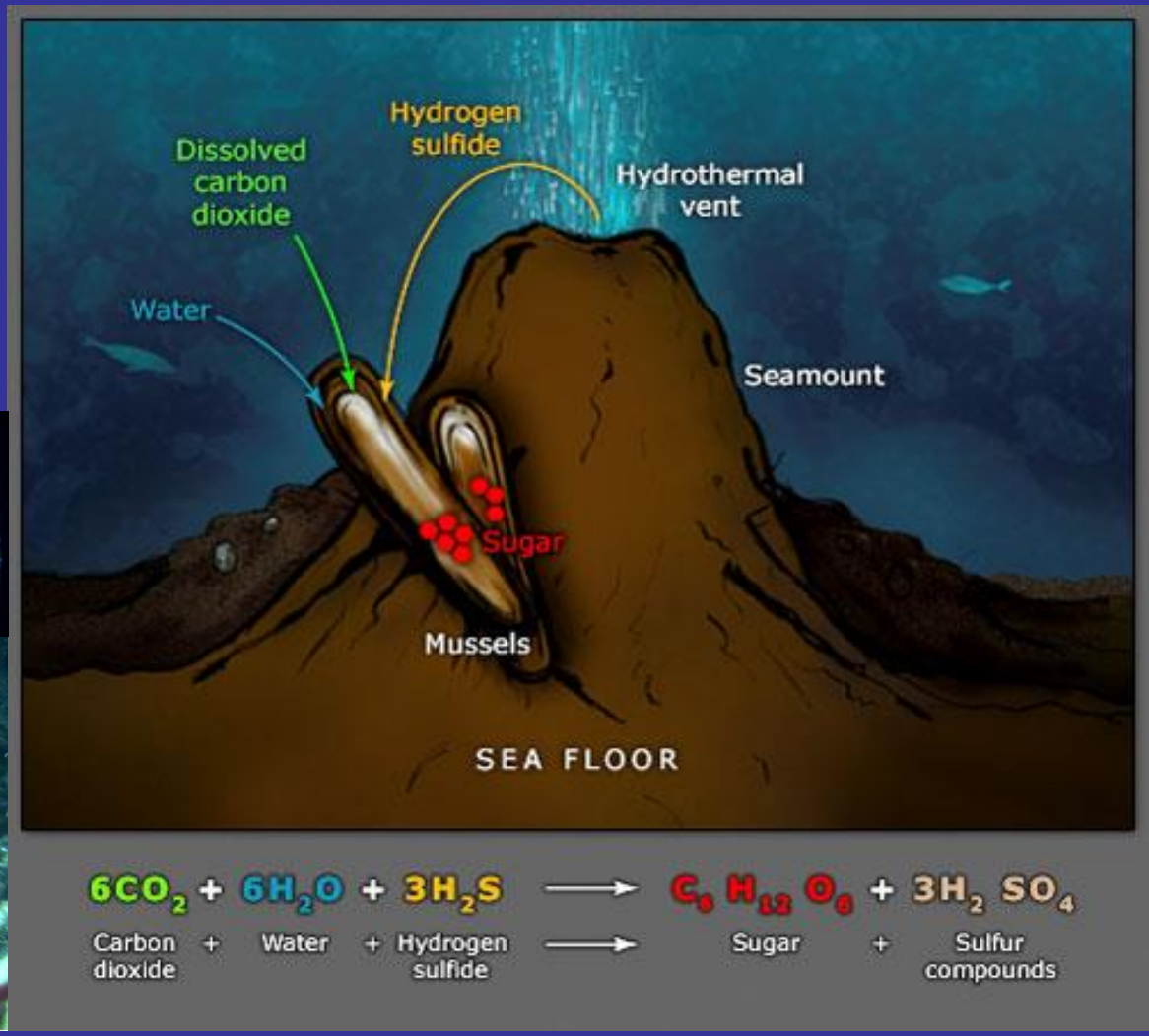




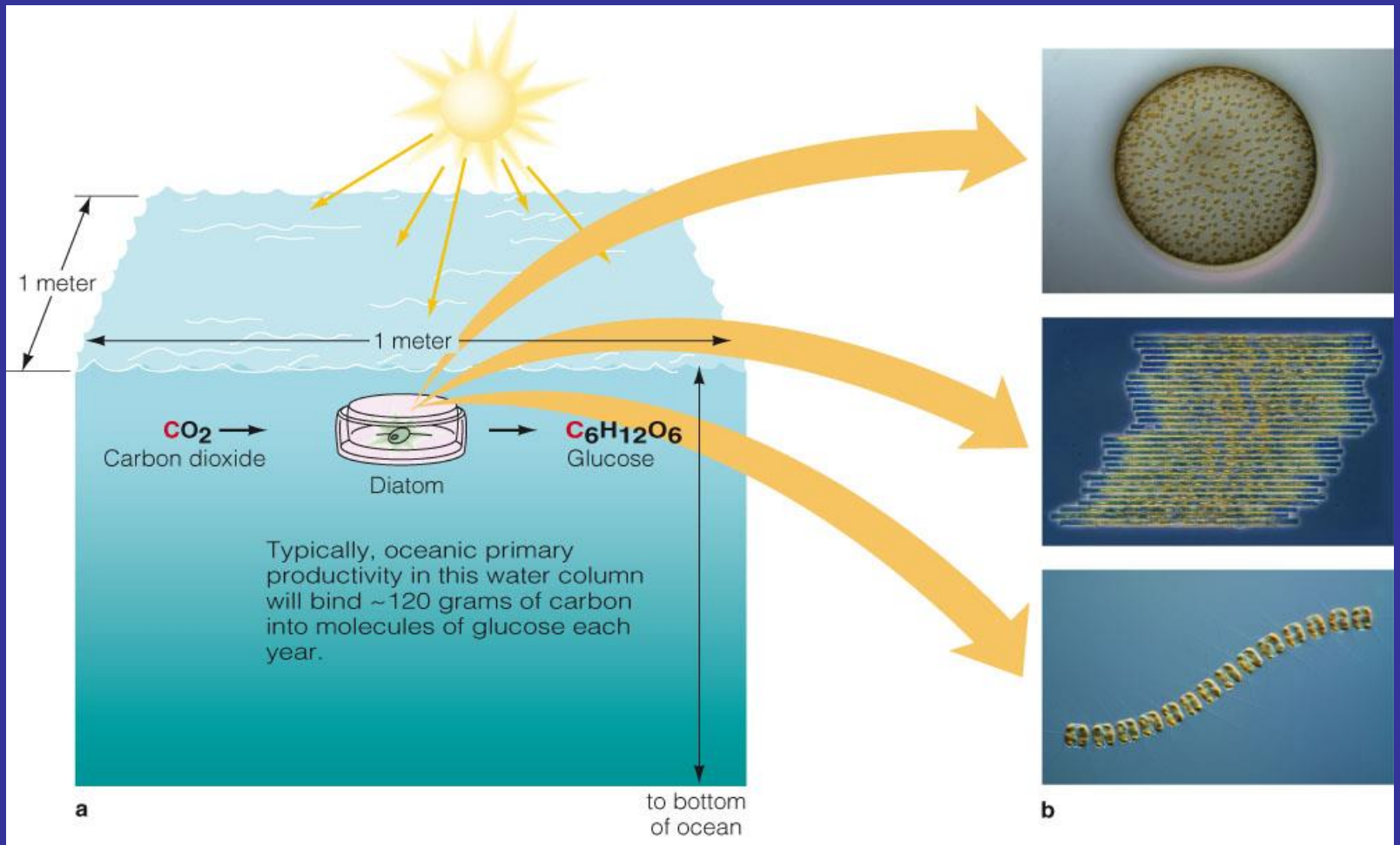
Hydrogen Sulfide -> **Chemosynthesis** is the production of energy from inorganic molecules in the environment. Occur at deep sea hydrothermal vents (seamounts).



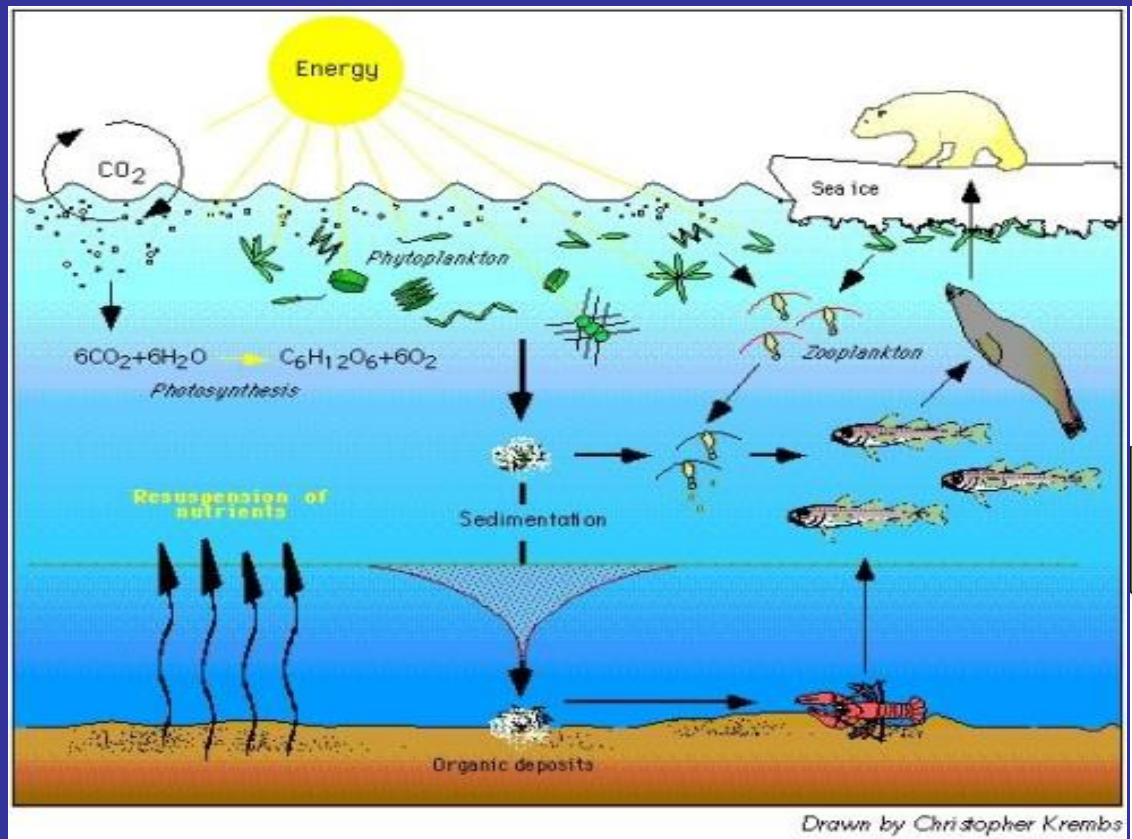


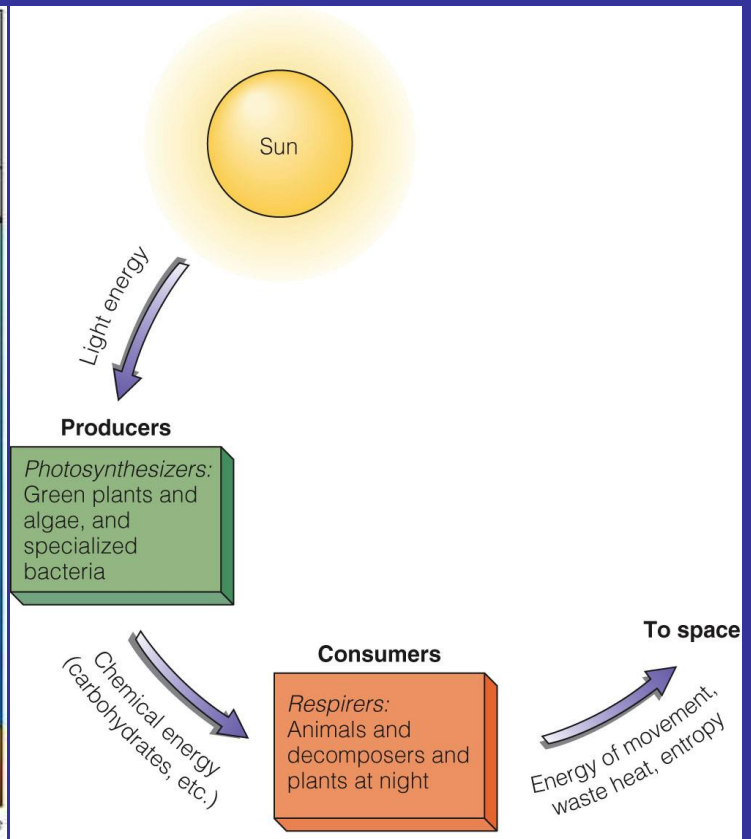


Primary productivity is the synthesis of organic matter from inorganic materials (remember the carbon cycle). Glucose is the carbohydrate formed for energy.



Energy flows through living systems. At each step, energy is used and transferred into lesser forms.



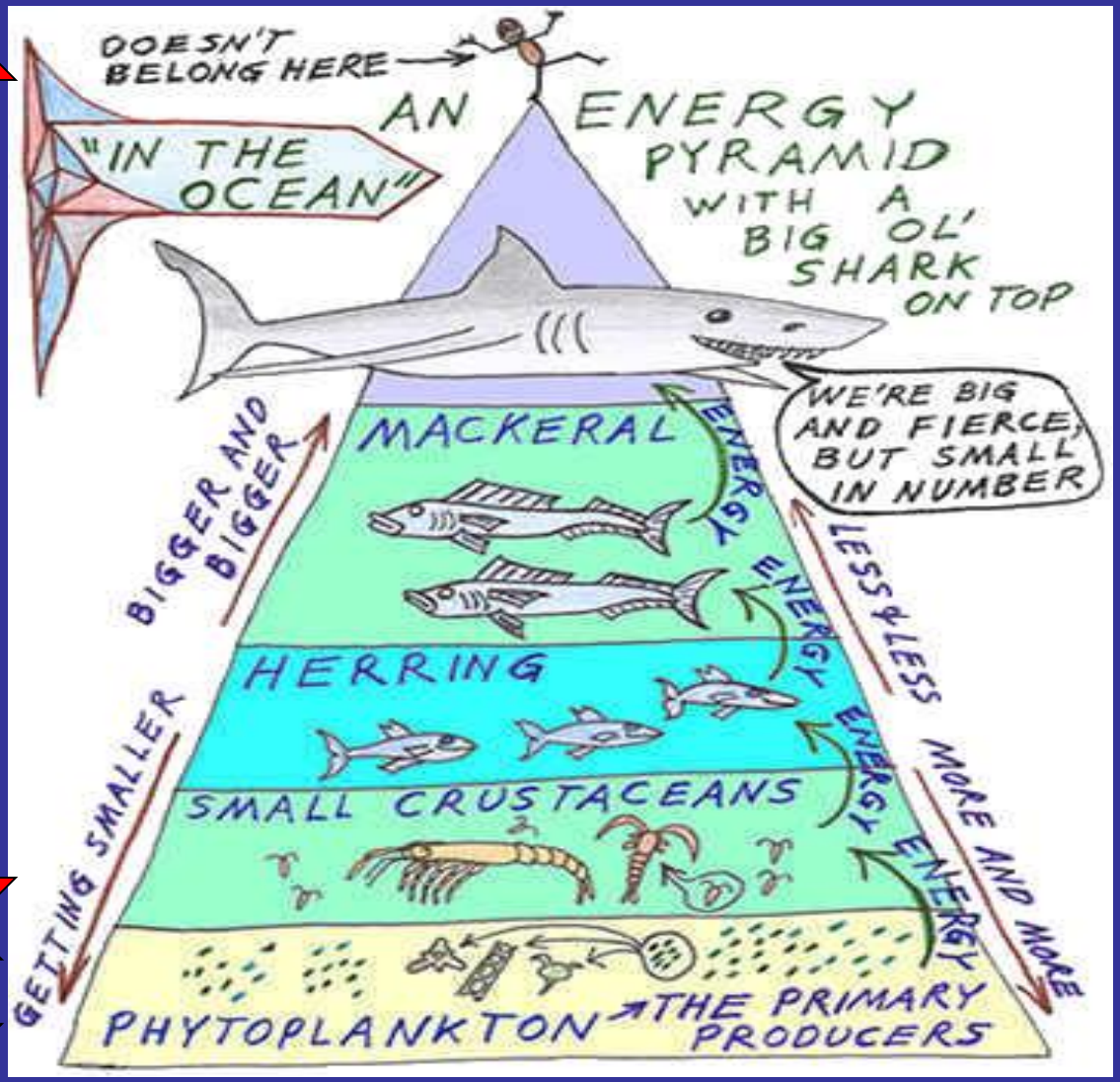


Food Webs Disperse Energy through Communities

- Terminology used to describe feeding relationships
- **Autotrophs –** organisms that make their own food, also called *producers*.
- **Heterotrophs –** organisms that must consume other organisms for energy
- **Trophic pyramid –** a model that describes who eats whom
- **Primary consumers –** these organisms eat producers
- **Secondary Consumers –** these organisms eat primary consumers
- **Top consumers –** the top of the trophic pyramid

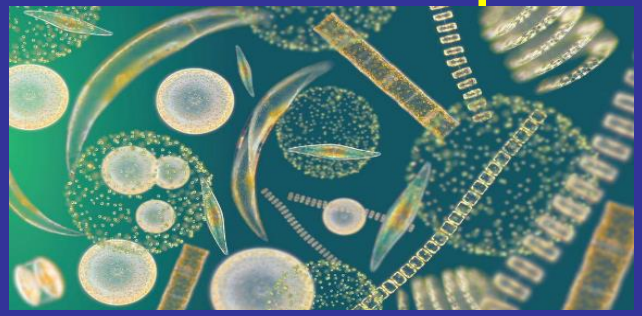
Energy Flow Through the Biosphere: Trophic pyramid

A trophic pyramid represents energy transfer from one level of organisms to the next as they consume each other.



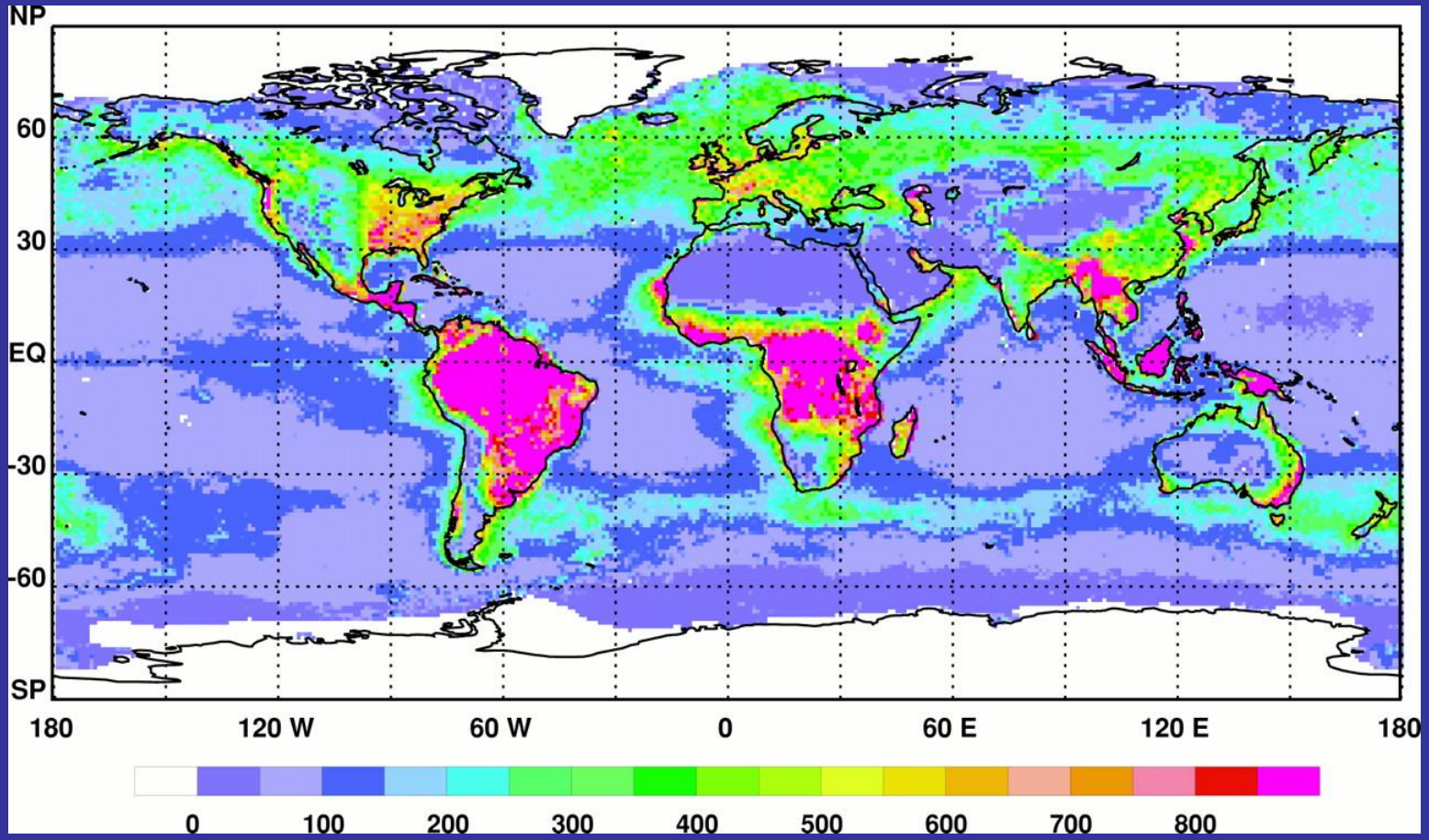
Phytoplankton are **primary producers**

Phytoplankton (algae) in the ocean absorb carbon dioxide during photosynthesis, converting inorganic carbon to organic carbon, producing food for the bottom of the ocean food chain. 90 to 95% of carbohydrates in ocean surface water is produced.



Phytoplankton need sunlight and nutrients (e.g., Nitrate, Silicate, Iron)

Global distribution of net primary production:
Most oceanic primary production occurs in high latitude regions or coastal regions.



(gC m^{-2} yr^{-1})

Zooplankton are **heterotrophic** and comprise most of the primary **consumers** in the oceans

Zooplankton

Where do **zooplankton** 'fit' in food chains?

Review:
a simple
food chain:

↑

Carnivore = maybe you (or maybe some of you) (probably an omnivore, but still a **heterotroph**)

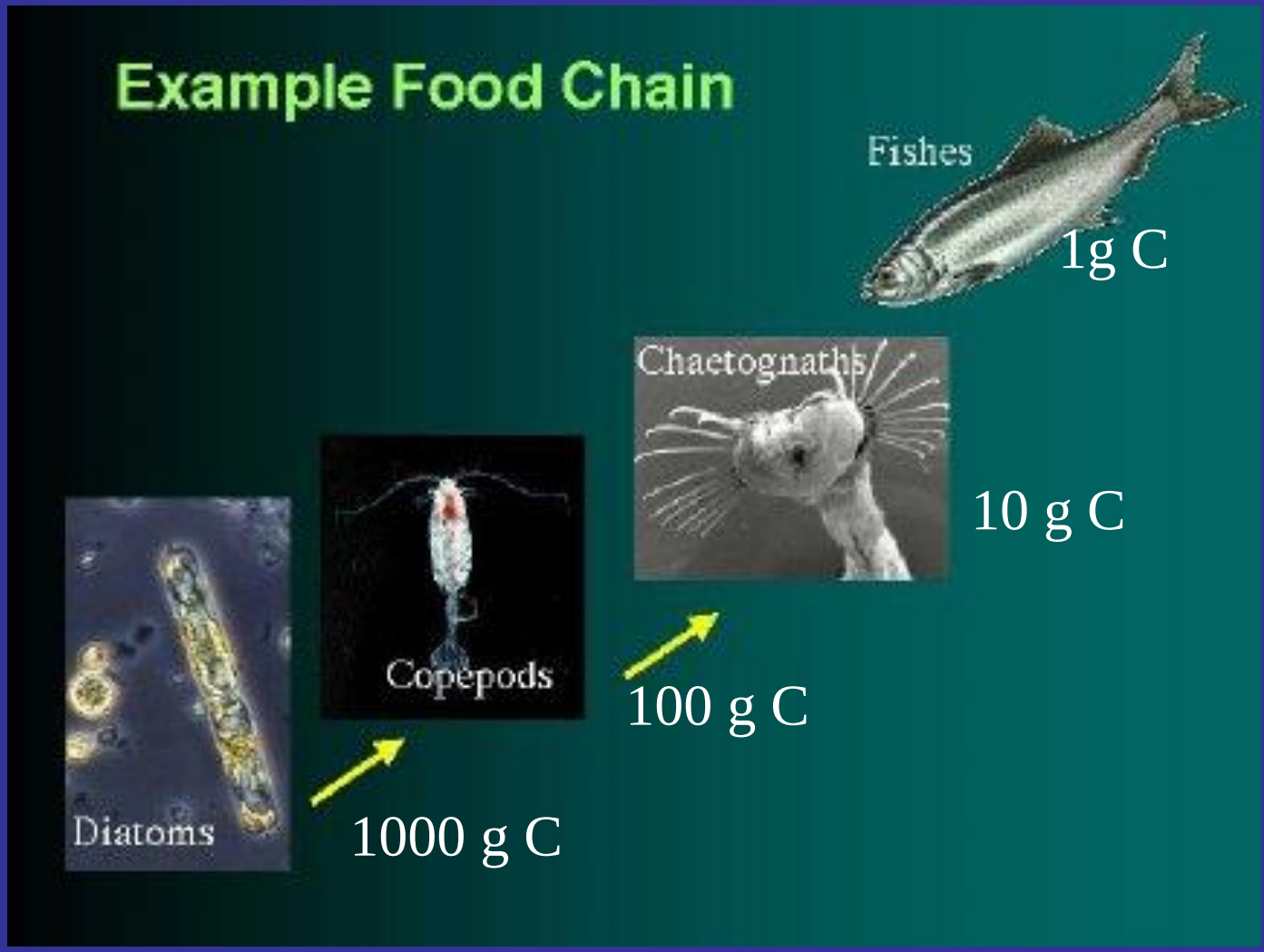
↑

Herbivore = cow
(a **heterotroph**)

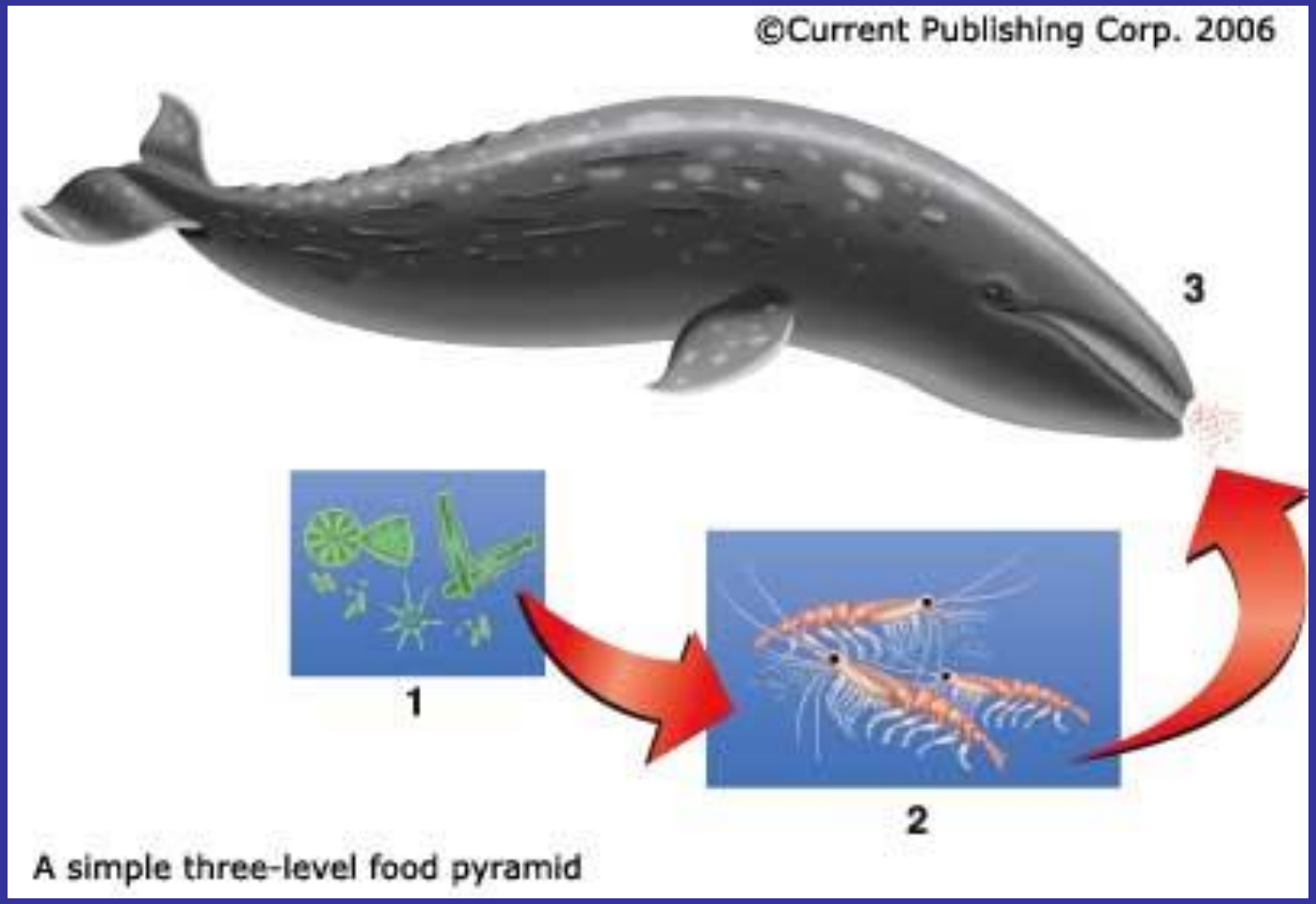
↑

Primary producer = grass
(**autotroph**)

Plankton are the basis for all fish life in the oceans and it takes a lot of plankton at the bottom of the food chain to feed a fish at the top.



A simple three-level food pyramid



Simple marine food **chain**…

Large fish (fourth order consumer, e.g., tuna)

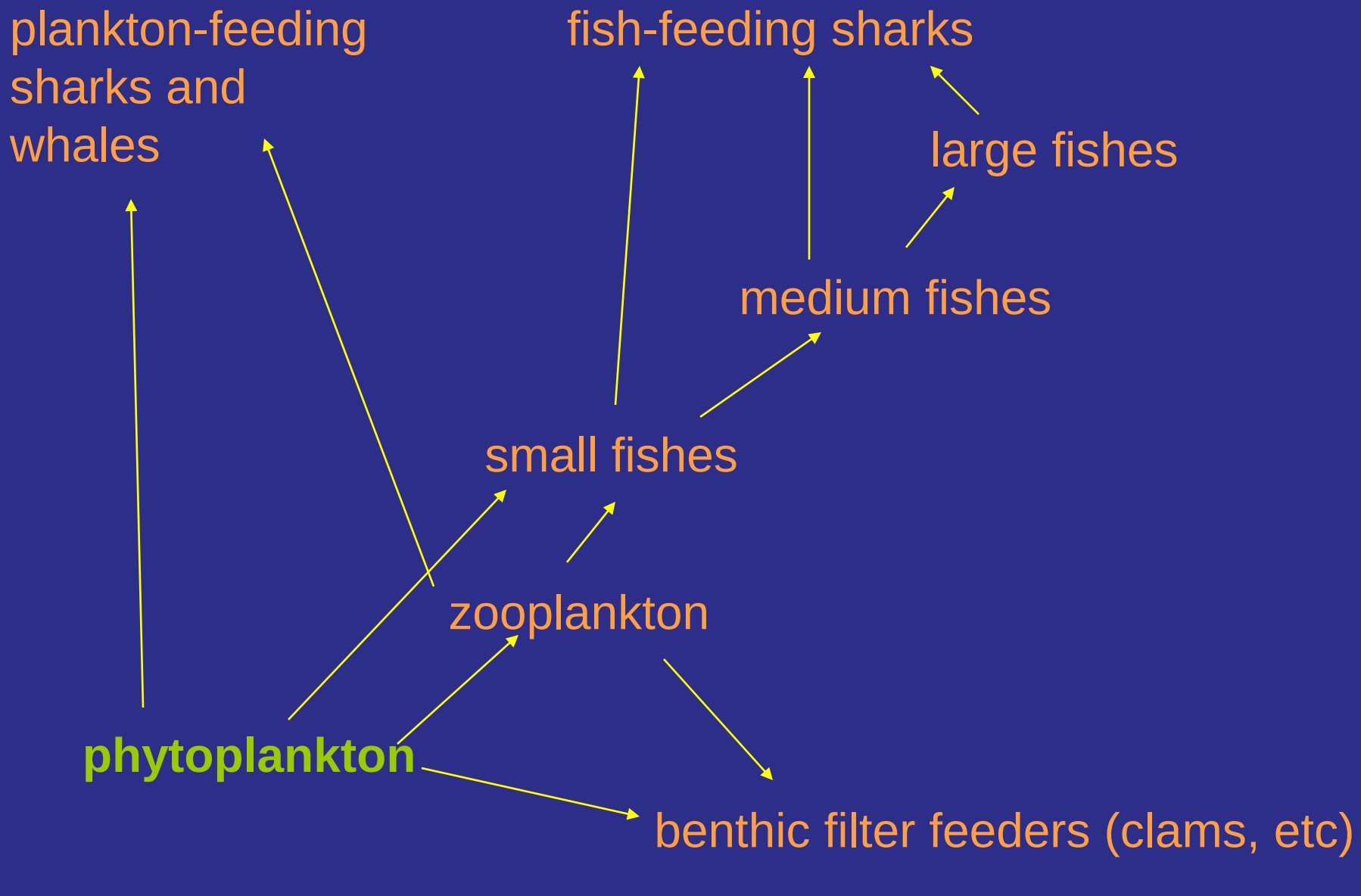
Medium fish (third order consumer)

Fish larvae, carnivorous zooplankton (second order consumers)

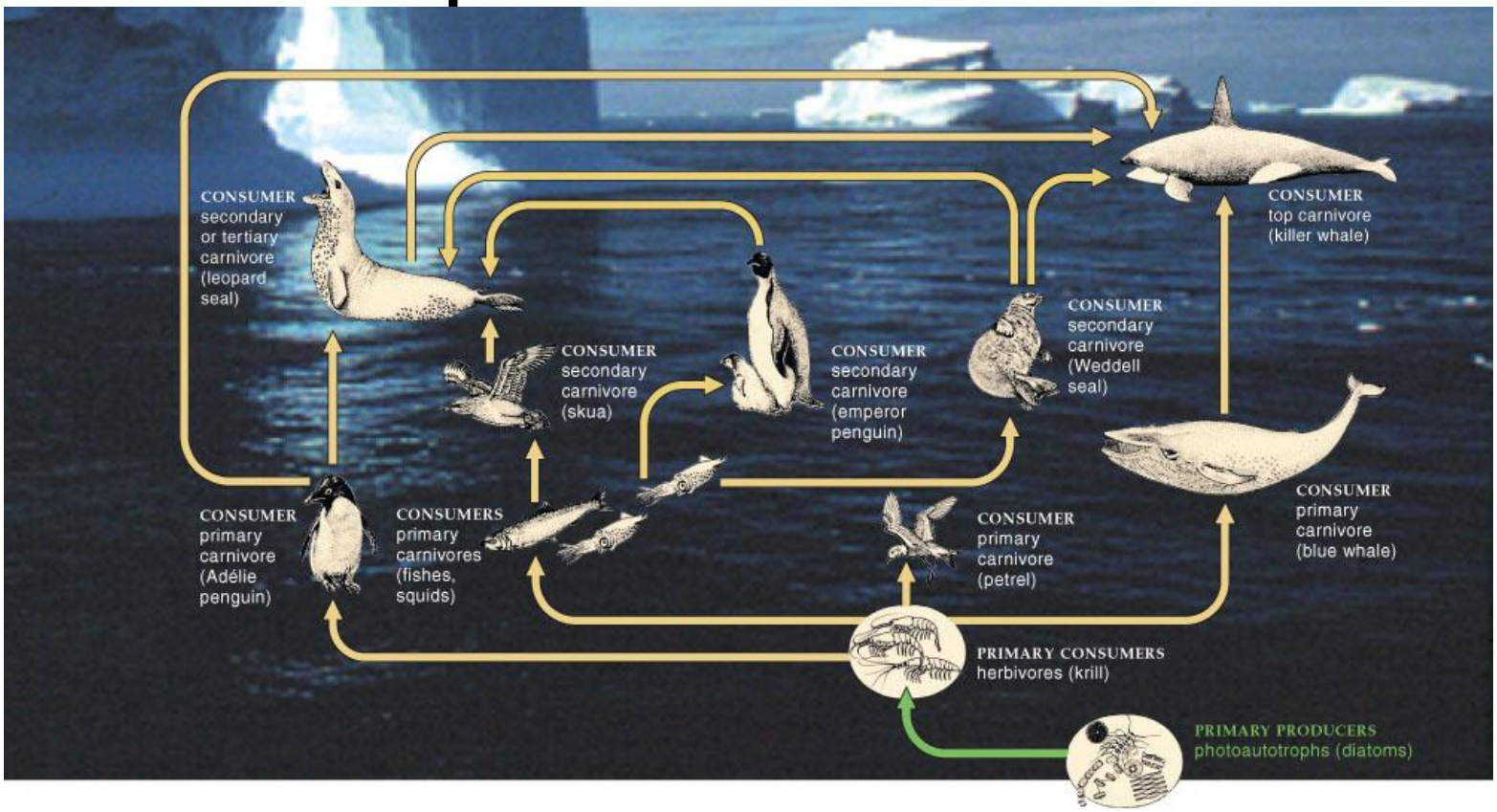
Zooplankton (first order consumers)

Phytoplankton (autotrophs, producers)

… and food **web**


plankton-feeding sharks and whales
fish-feeding sharks
large fishes
medium fishes
small fishes
zooplankton
phytoplankton
benthic filter feeders (clams, etc)

A simple marine food web

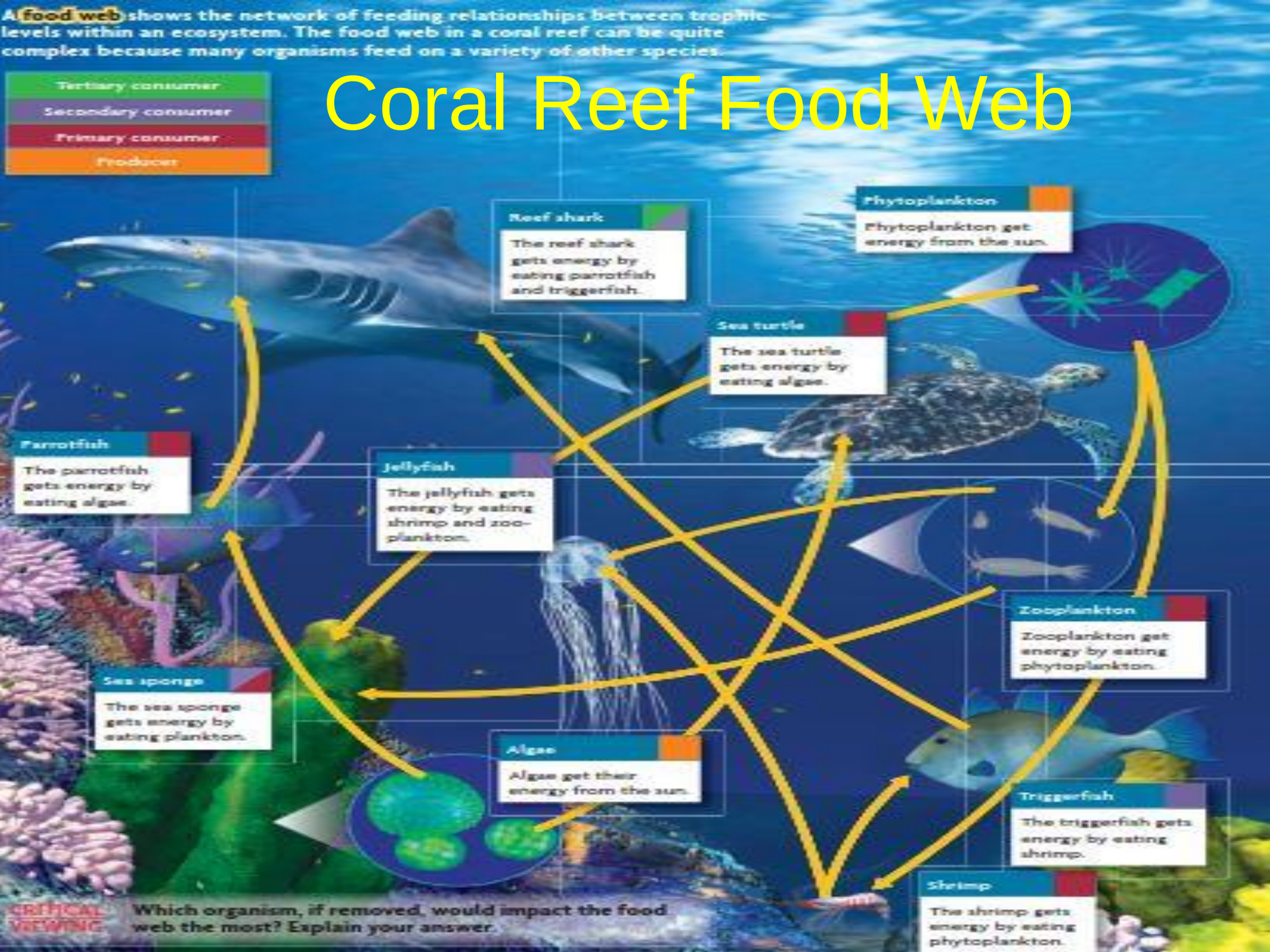


Diatoms, and other primary producers, convert the energy from the sun into food used by the rest of the oceanic community.

This simplified food web illustrates the major trophic relationships leading to an adult blue whale.

The arrows show the direction of energy flow; the numbers on each area represent the trophic level at which the organism is feeding.

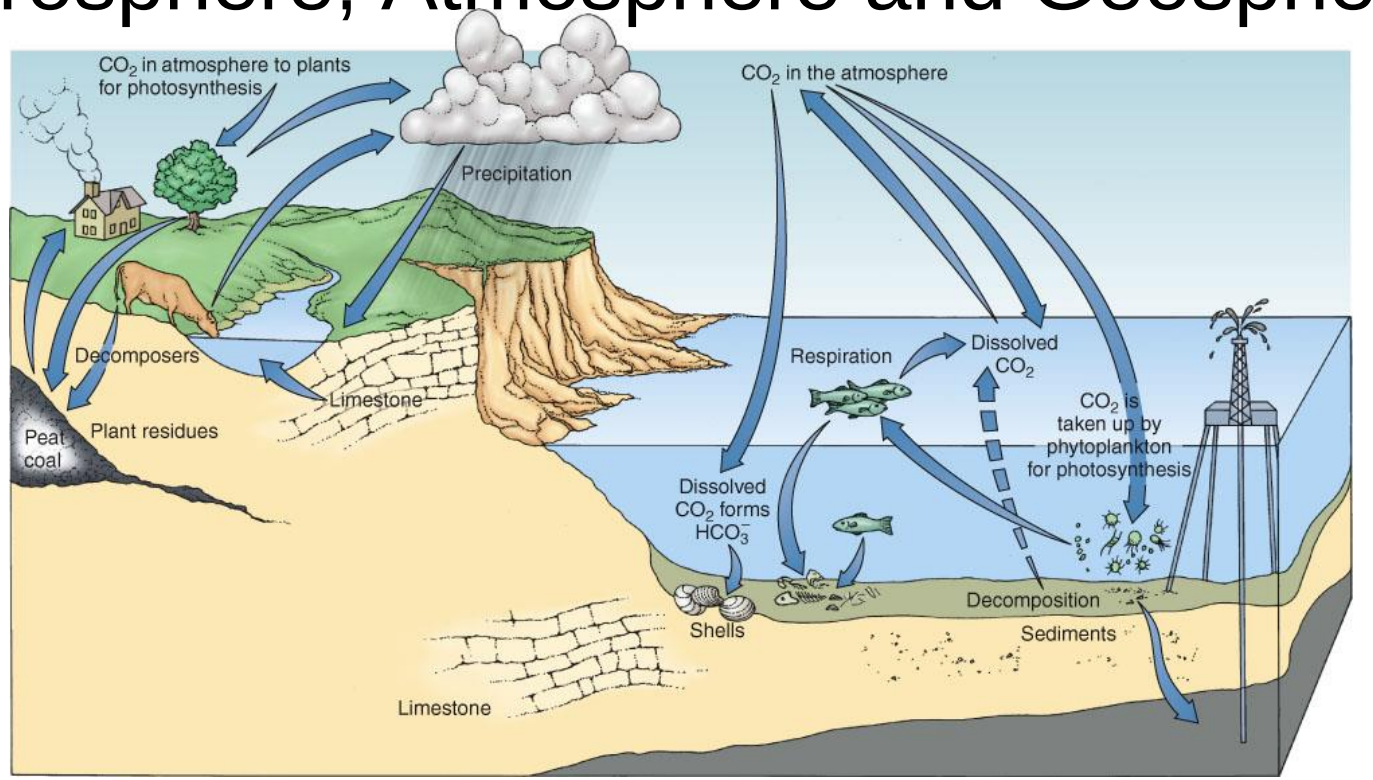
Coral Reef Food Web



Elements Cycle between Living Organisms and Their Surroundings

- What are some atoms and molecules that cycle in **biogeochemical cycles**?
- **Carbon** - present in all organic molecules
- **Nitrogen** - found in proteins and nucleic acids (RNA, DNA)
- **Phosphorus and silicon –** found in rigid parts of organisms
- **Iron and trace metals -** used for electron transport

The Carbon Cycle Is Earth's Largest Cycle
Carbon cycles through the Biosphere, Hydrosphere, Atmosphere and Geosphere



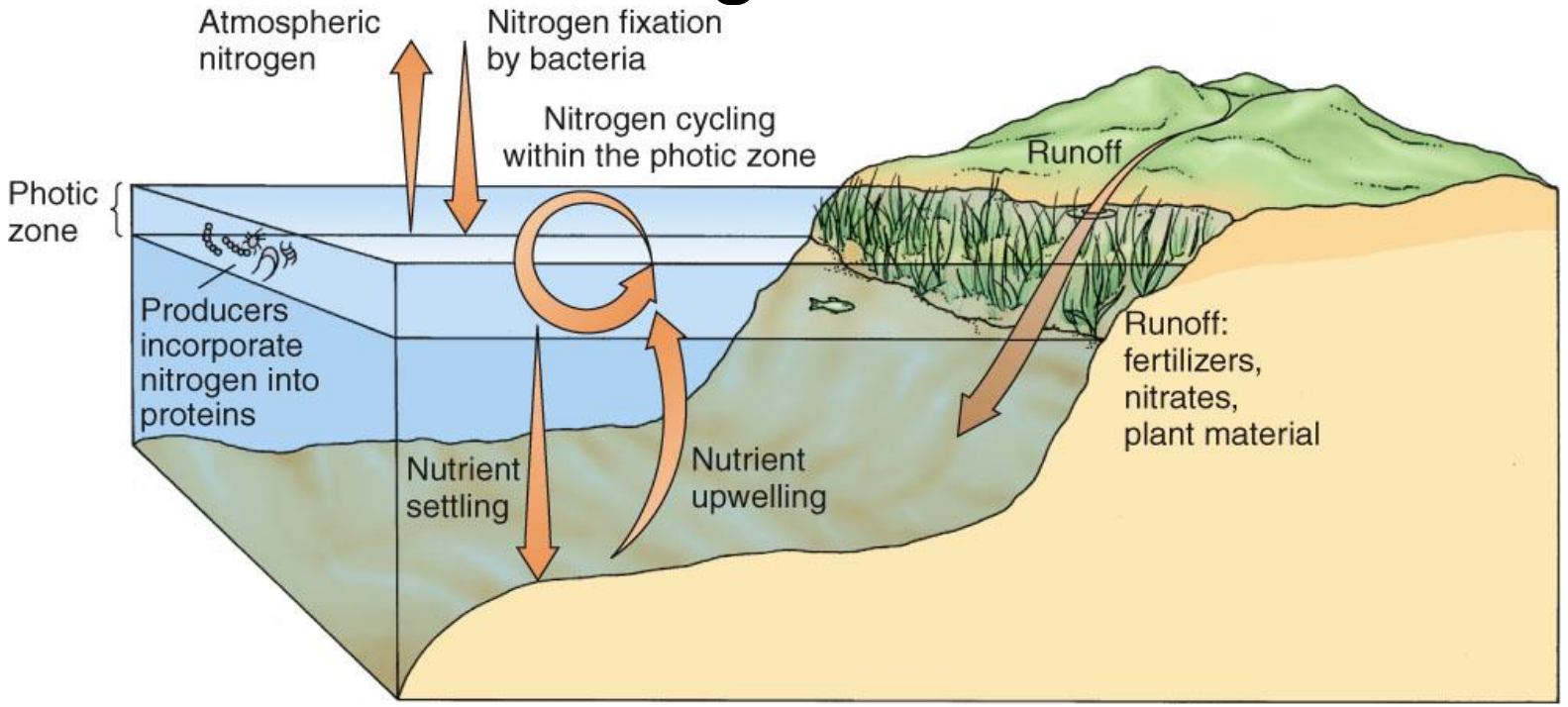
The Carbon Cycle in the Ocean.

Carbon dioxide dissolved in seawater is the source of the carbon atoms assembled into food (initially glucose) by photosynthesizers. When this food is metabolized (respiration), the carbon dioxide is returned to the environment.

Nitrogen Cycles through the Biosphere, Atmosphere, Hydrosphere and Geosphere

- Nitrogen fixed (combined with hydrogen)
  - Lightning
  - Nitrogen-fixing bacteria
- Nitrification (N combined with oxygen)
- Denitrification (N returned to atmosphere)

Nitrogen Must Be “Fixed” to Be Available to Organisms



The Nitrogen Cycle in the Ocean.

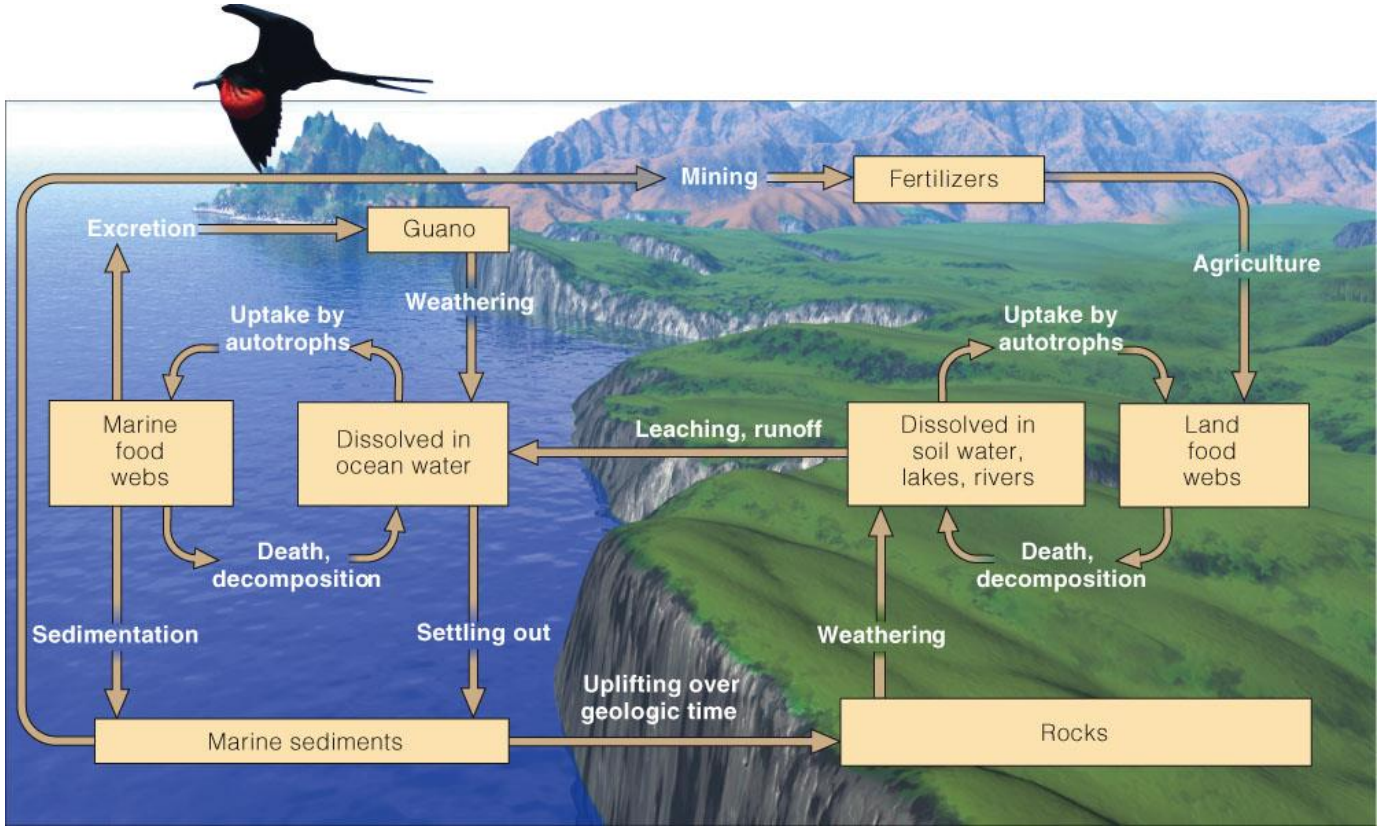
Nitrogen is an essential element in the construction of proteins and nucleic acids (RNA, DNA). Upwelling and runoff from the land bring useful nitrogen into the euphotic zone, where primary producers can incorporate it into essential molecules.

Phosphorus Cycles through the Biosphere, Hydrosphere and Geosphere

- Cycles through water, the earth's crust, and living organisms

- May be limiting factor for plant growth

Phosphorus Cycle in Three Distinct Loops



The Phosphorus Cycle.

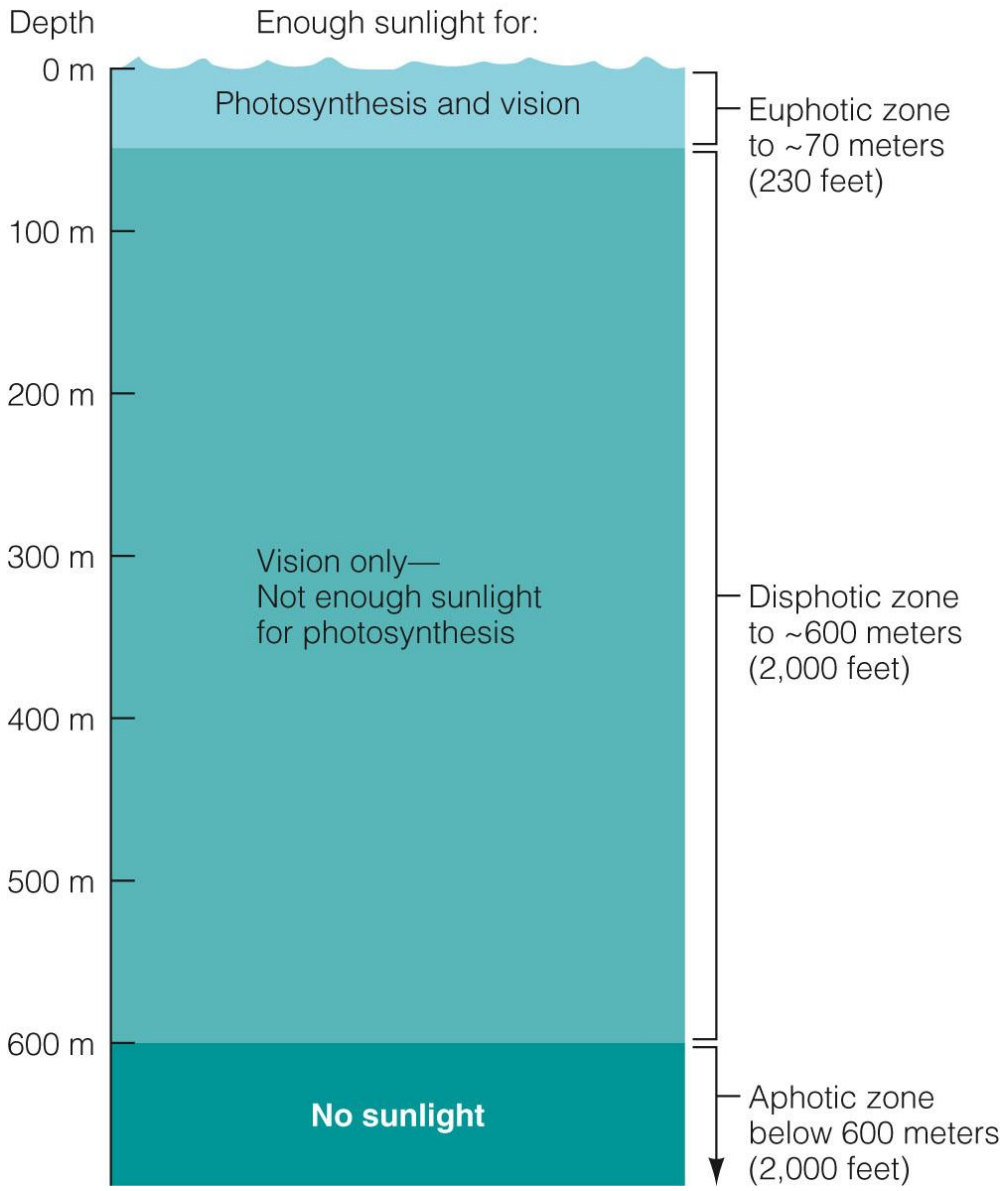
Phosphorus is an essential part of the energy-transporting compounds used by all of Earth's life-forms (e.g., ADP, ATP). Note that it does not cycle through the atmosphere.

Physical and **Biological Factors** Affect the Functions of an Organism

- A **limiting factor** is a factor that can be harmful if present in quantities that are too large or too small.
  - Any factor required for life can become a **limiting factor** (ex: light, nitrogen, phosphorus).
- Any aspect of the **physical environment** that affects living organisms is a **physical factor.**
- What are the most important physical factors for marine organisms?
  - Light, dissolved gases, temperature, salinity
  - Acid-base balance, **hydrostatic pressure**, nutrients

- **Biological factors** also affect living organisms in the ocean.
- Some **biological factors** that affect ocean organisms:
  - Feeding relationships (and symbiotic relationships)
  - Crowding (competition for space)
  - Metabolic wastes
  - Defense of territory

Photosynthesis Depends on Light

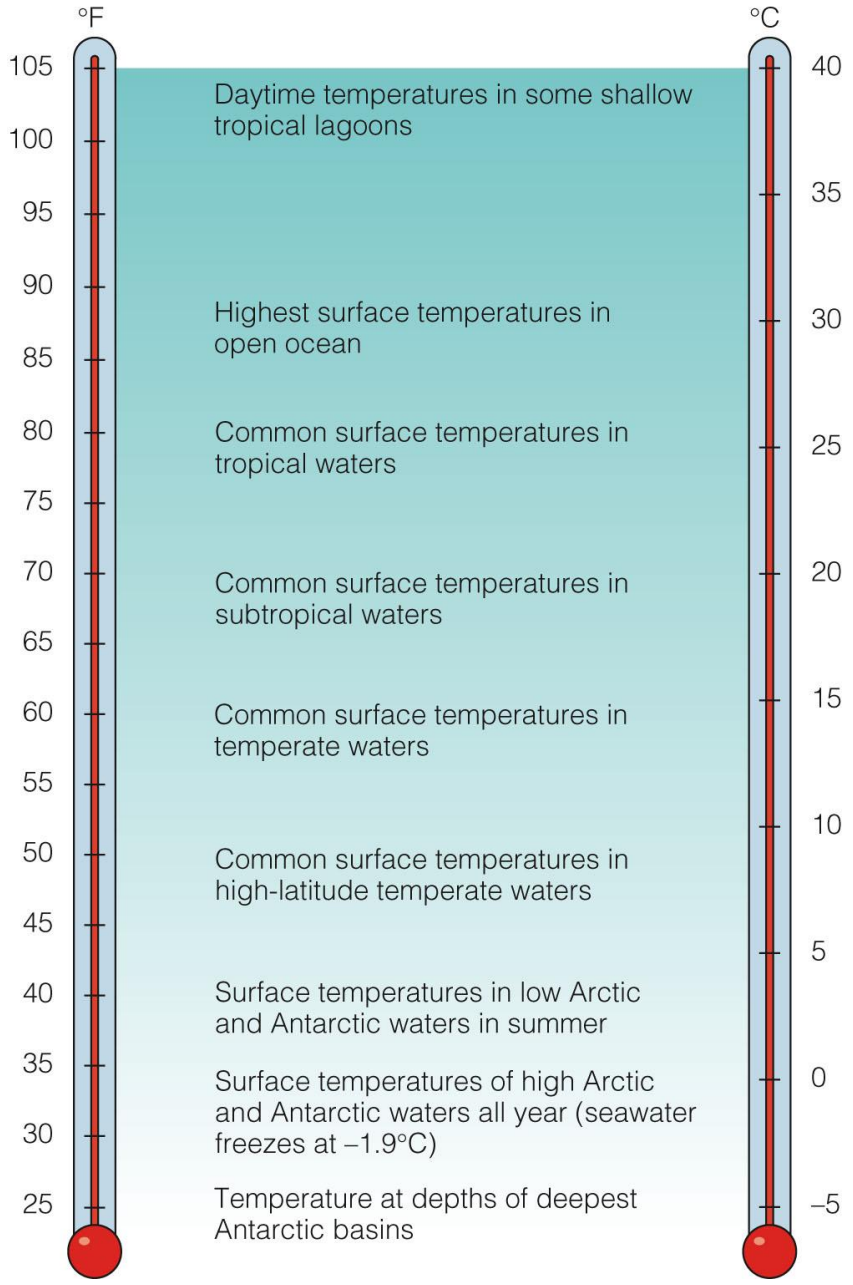


Most of the biological productivity of the ocean occurs in an area near the surface called the ***euphotic zone.***

Below the euphotic zone lies the ***disphotic zone***.

Below the disphotic zone lies the dark ***aphotic zone*** (where sunlight never reaches).

Temperature Influences Metabolic Rate



<- Temperatures of marine waters capable of supporting life.

Some isolated areas of the ocean, notably within and beneath hydrothermal vents, may support living organisms at temperatures of up to 400°C (750°F)!

Temperature and Metabolic Rate

- **Metabolic rate** (the rate at which energy releasing reactions occur) increases with temperature.
- **Ectothermic animals**:

  internal temperature = environment (most fish).
- **Endothermic animals**:

  “warm blooded” with a stable, high internal temperature (marine mammals, few fish).

Chemical Factors That Affect Marine Life

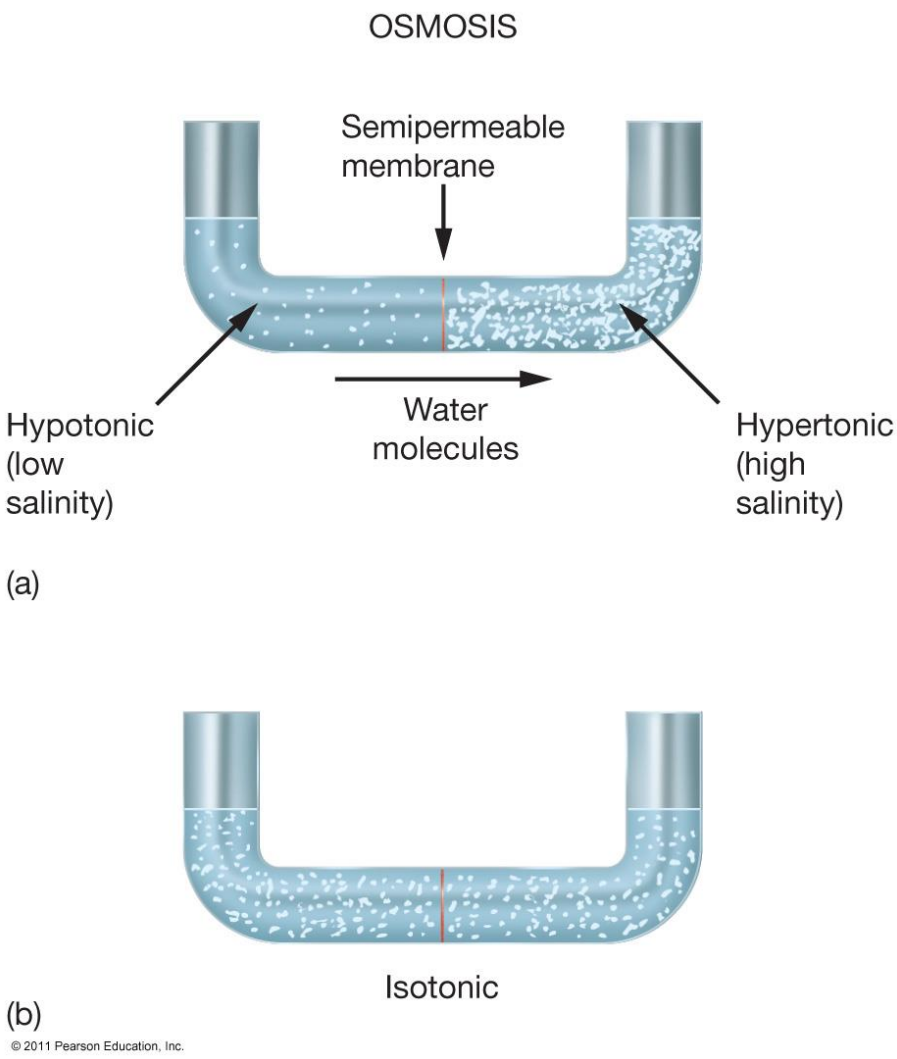
Diffusion and Osmosis

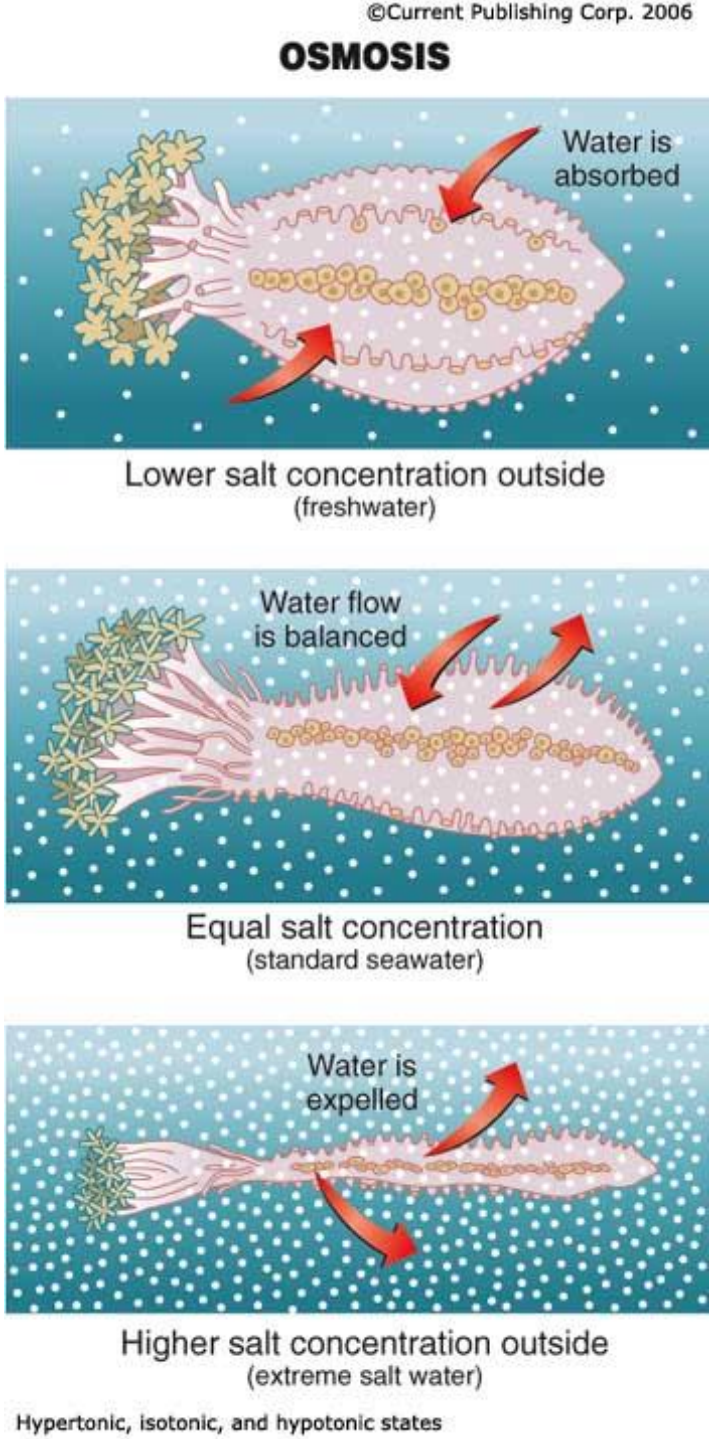
Diffusion is the tendency for a liquid, gas, or solute to flow from an area of high concentration to an area of low concentration.

Osmosis is diffusion through a semipermeable cell membrane.

Osmosis

- Water molecules move from less concentrated to more concentrated solutions
- Osmotic pressure
  - In more concentrated solutions
  - Prevents passage of water molecules
- Isotonic
- Hypertonic
- Hypotonic





In freshwater, aquatic animals are **hypertonic** to their environment and water is absorbed.

Isotonic is when aquatic animals have same salt concentration as their environment

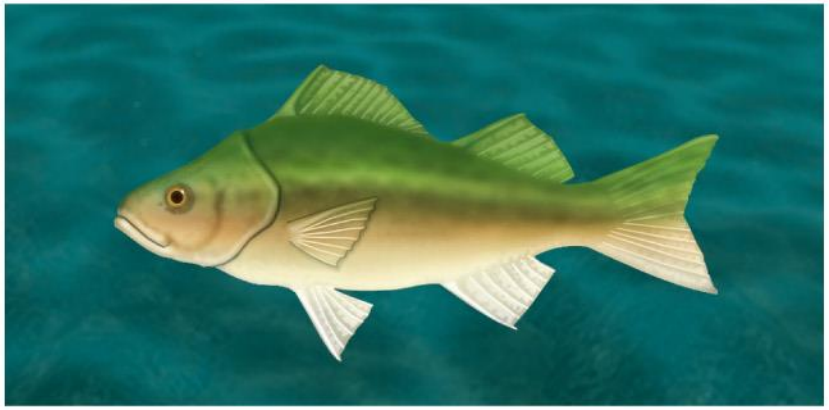
In highly saline water, animals are **hypotonic** to their environment and water is lost, resulting in dehydration.

Marine vs. Freshwater Fish

(a) MARINE FISH
(Hypotonic)

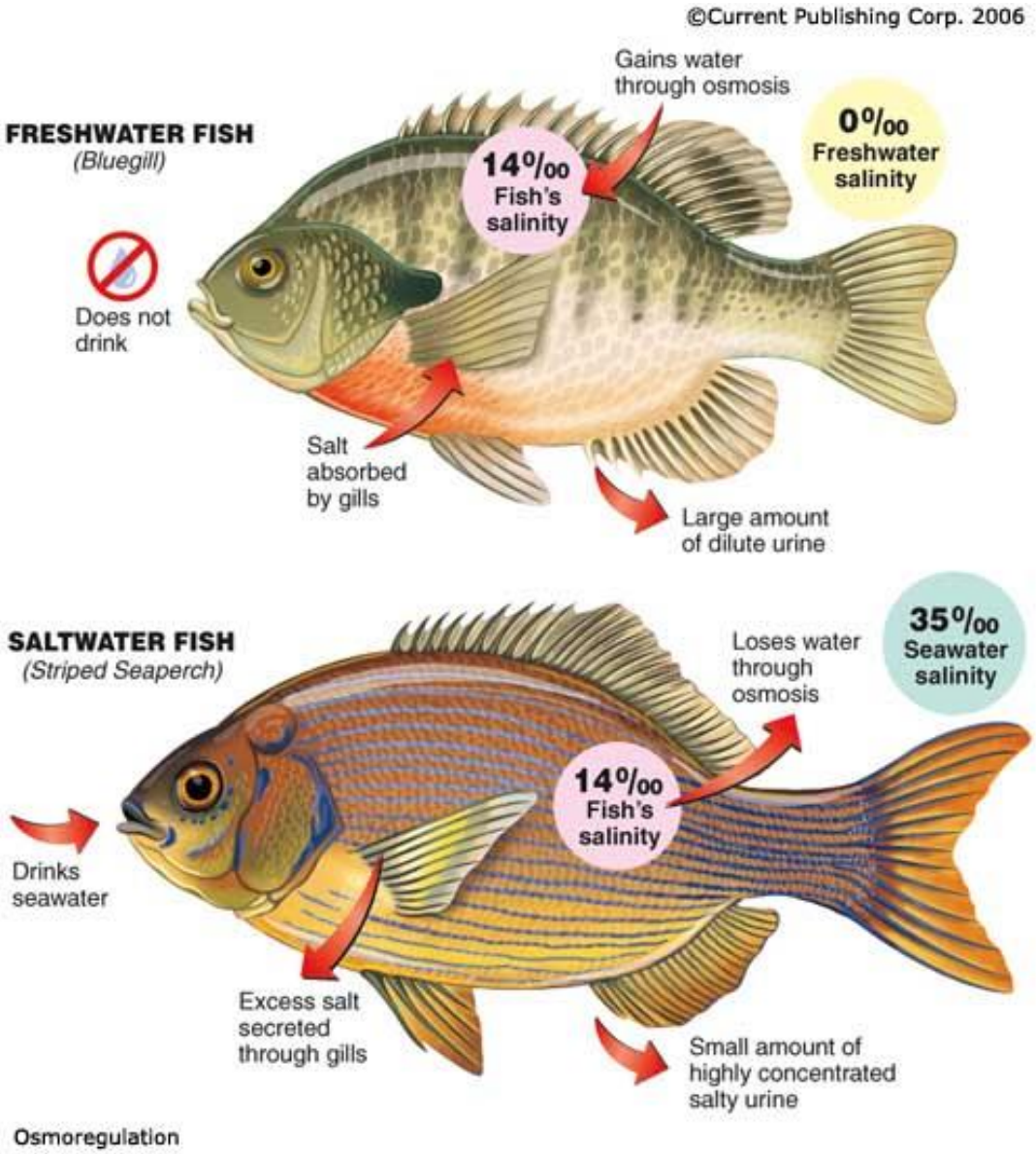
- Drink large quantities of water
- Secrete salt through special cells
- Small volume of highly concentrated urine

(b) FRESHWATER FISH
(Hypertonic)



- Do not drink
- Cells absorb salt
- Large volume of dilute urine

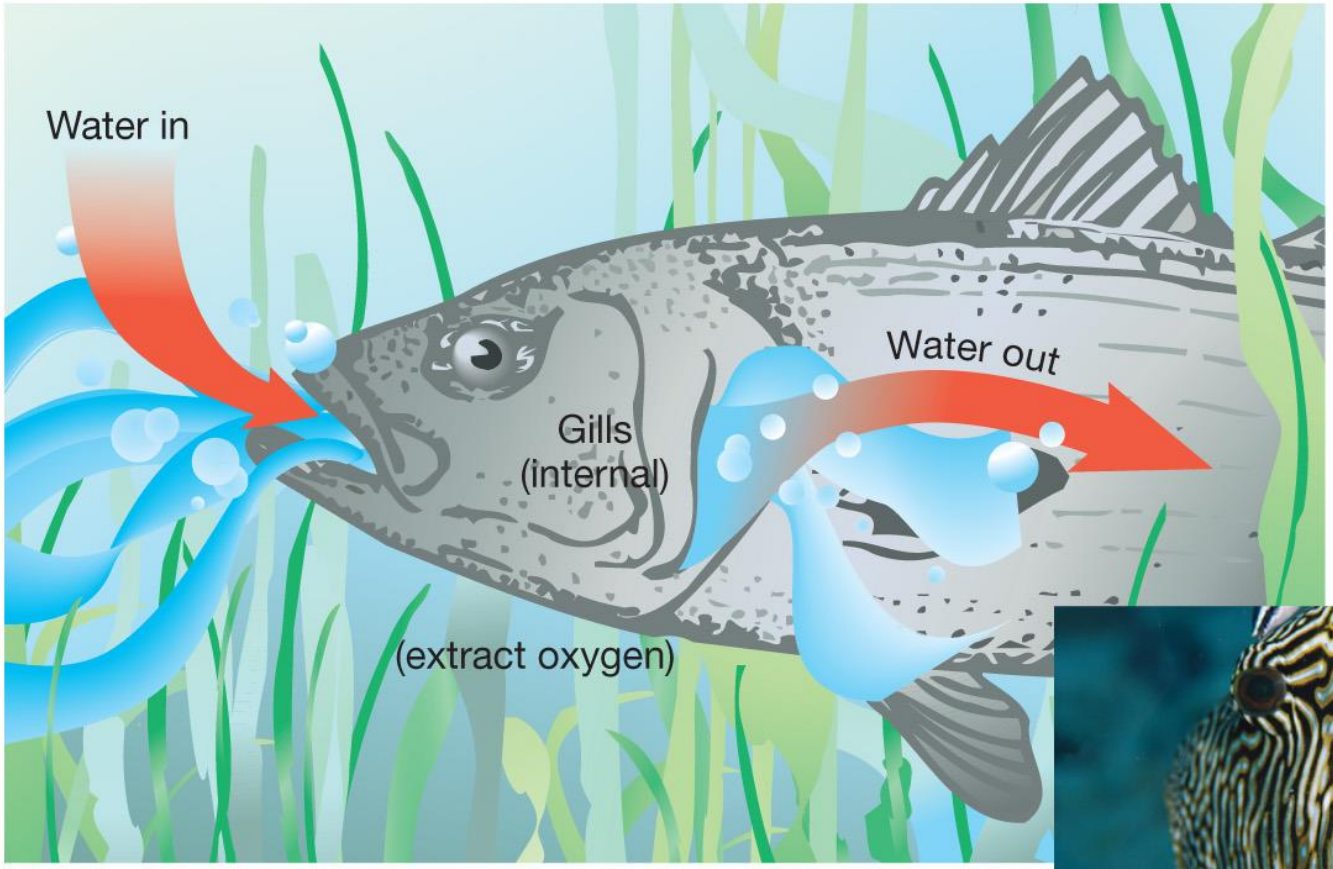
Do fish drink water?



Freshwater fish absorb water from their environment and do not need to drink water.

Saltwater fish lose water to their environment and must drink seawater and secrete salt through their gills.

Gills on Fish



Oxygen diffuses in gills through osmosis down a concentration gradient

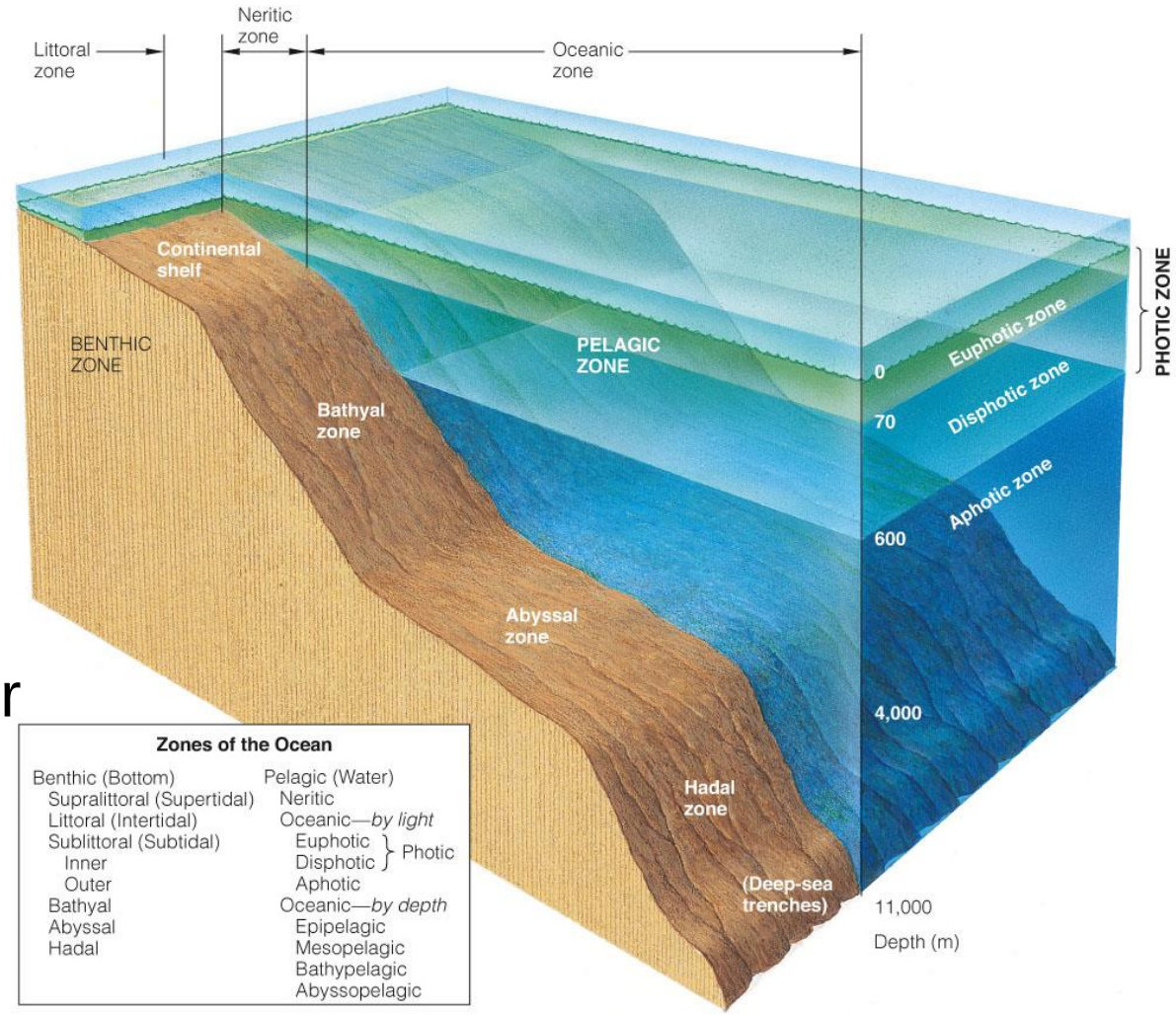
Ocean Zones and Lifestyles

- Two most basic subdivisions:
- Pelagic zone = water column between the bottom and the surface
- Benthic zone = ocean bottom

The Marine Environment Is Classified into Distinct Zones

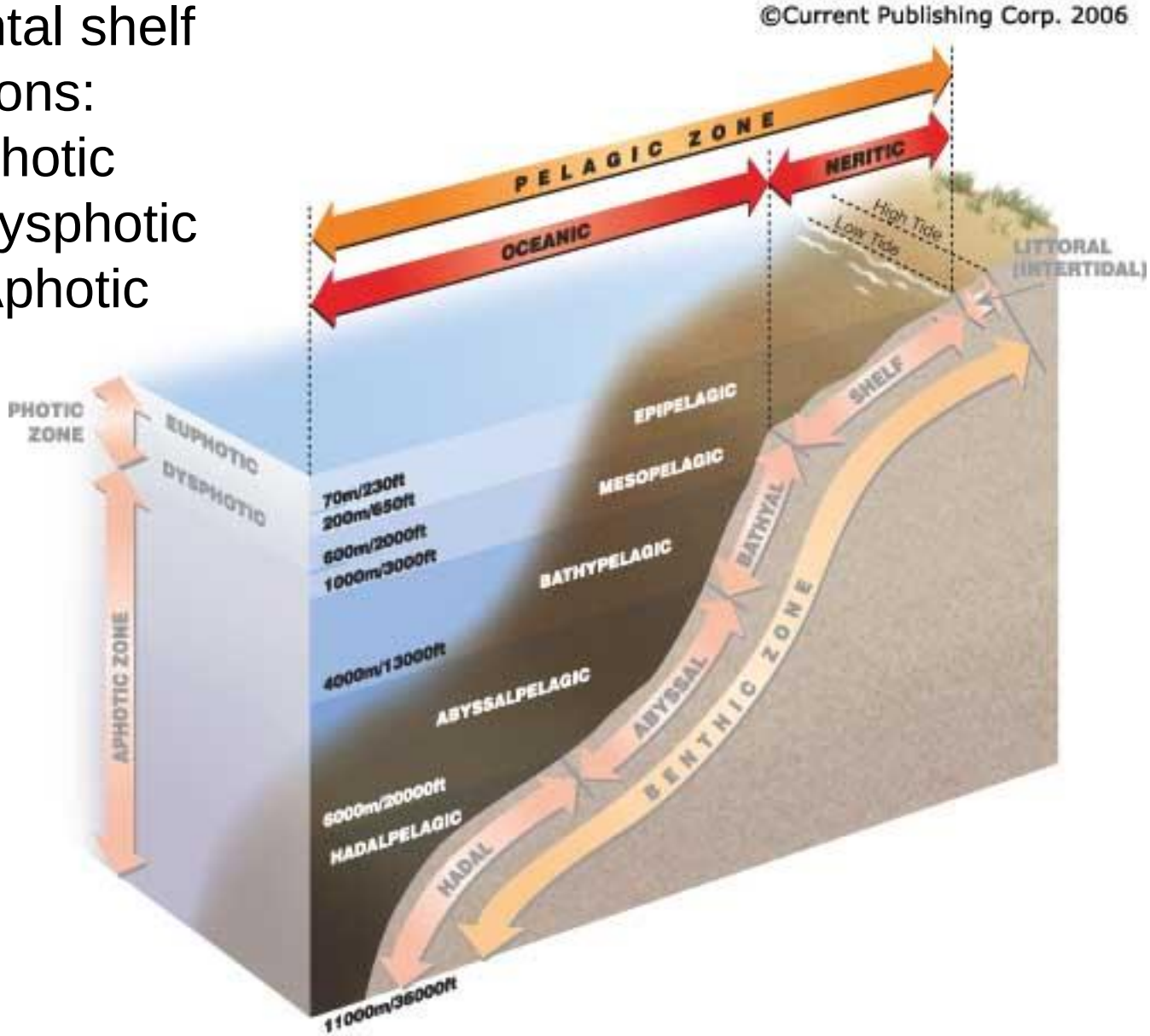
Scientists divide the marine environment into **zones**, areas with homogeneous physical features.

Zones are classified by location and the behavior of the organisms found there.



The Pelagic Zone

Neritic = continental shelf
Oceanic subdivisions:
Epipelagic ~ Euphotic
Mesopelagic ~ Dysphotic
Bathypelagic ~ Aphotic
(see next slide for definitions)



The pelagic zone

Epipelagic zone: upper, lighted (photic) region of the ocean; usually ca. 100-200 meters deep.

Mesopelagic zone: region of low light (dysphotic), usually ca. 200-1000 meters deep.

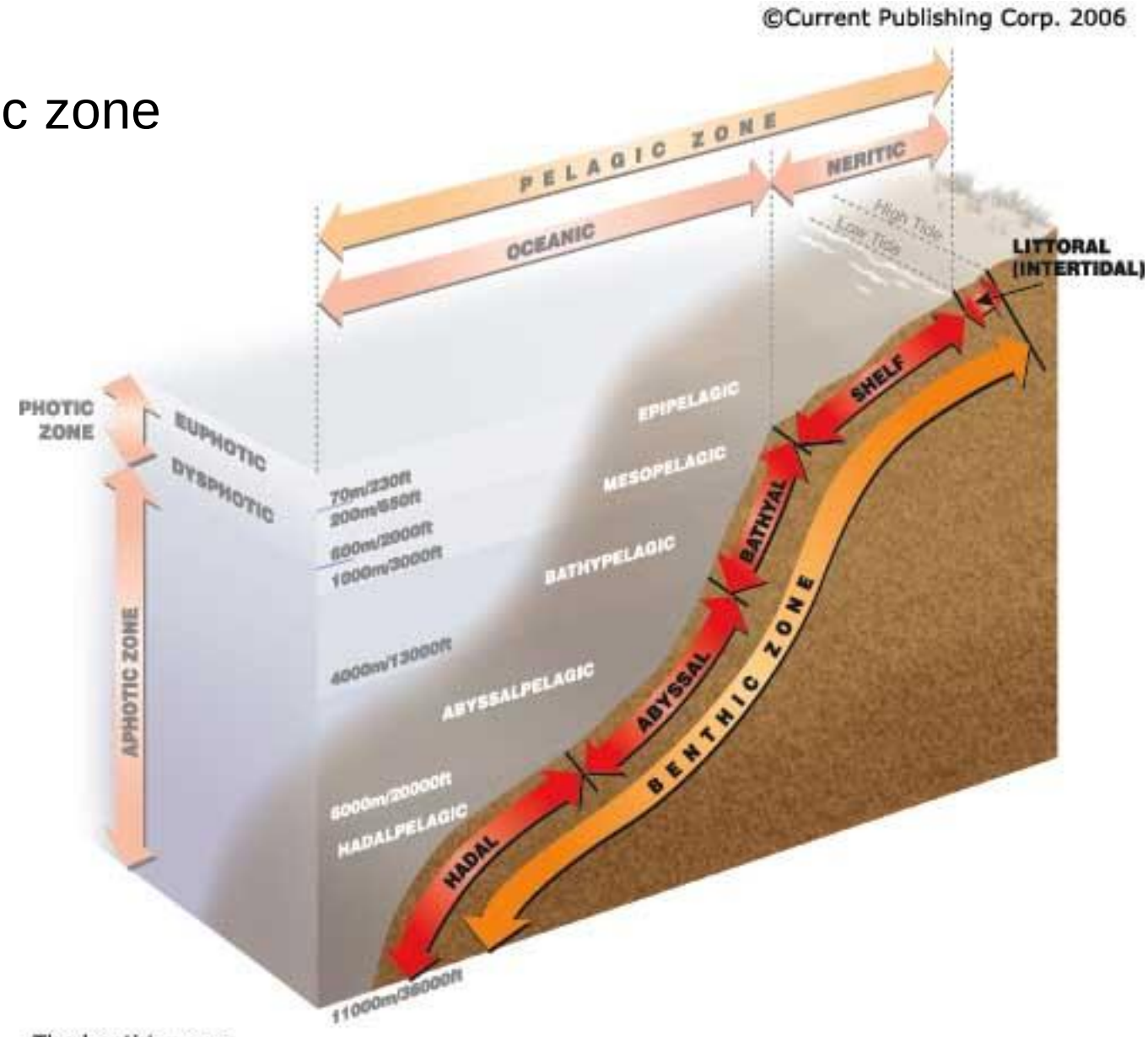
Bathypelagic zone: dark (aphotic), ca. 1000-4000 meters deep

Abyssopelagic: very deep, near bottom zone, ca. 4000-6000 meters deep

Where is the benthic zone?

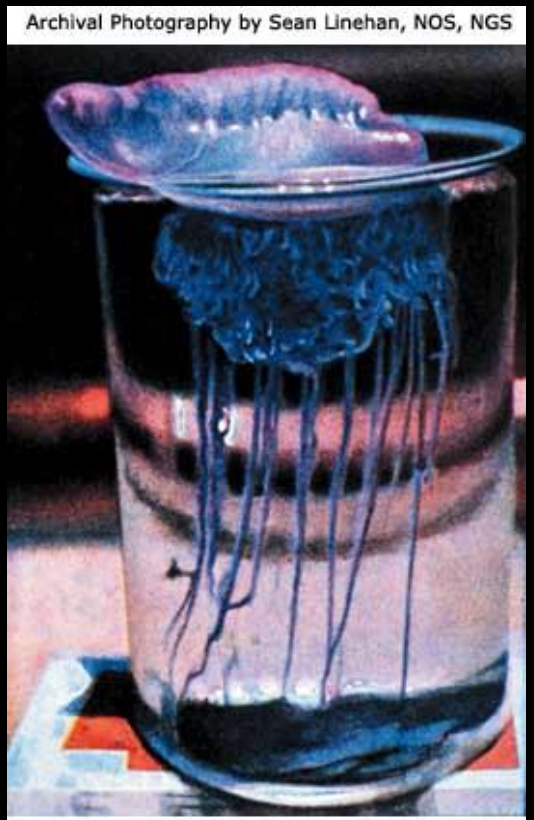
Under the pelagic zone

Littoral zone=
Intertidal zone

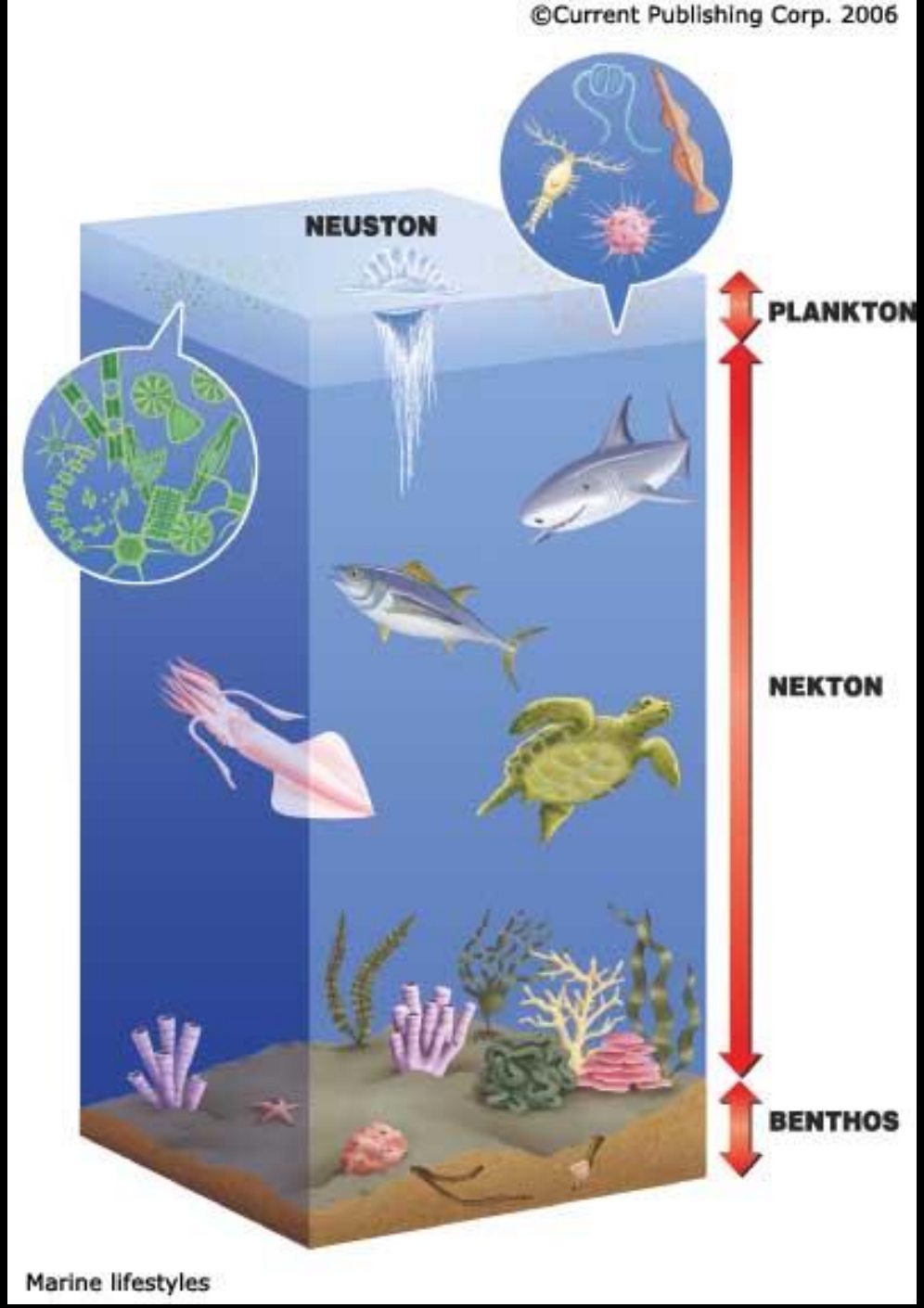


The benthic zone

Who lives where?



The neuston

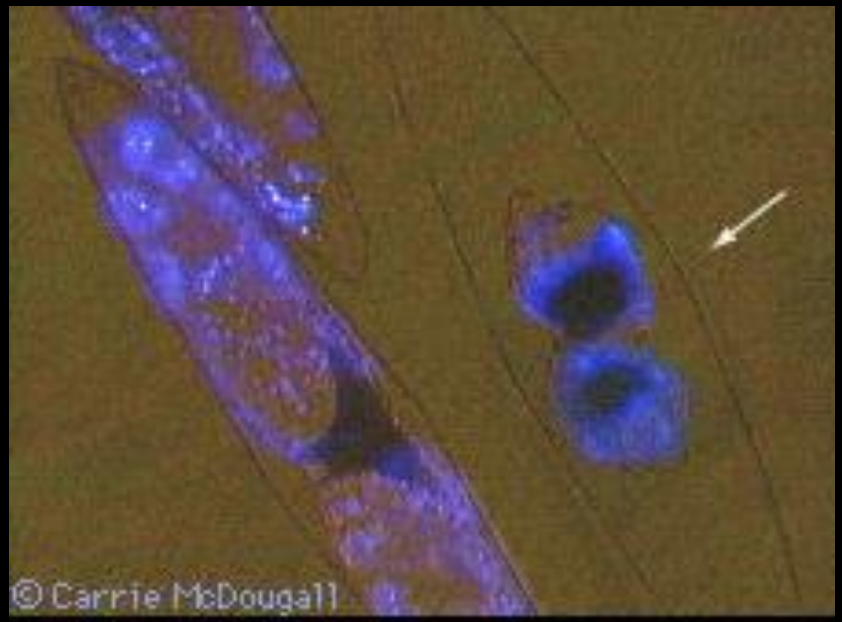


Marine lifestyles

What are plankton, nekton and benthos?

- Plankton (Greek *planktos* = wanderer) is a group of plant-like algae (phytoplankton) and animals (zooplankton) that exist adrift in the ocean currents.

Pyrocystis fusiformis



Actual color of bioluminescence from 3 *Pyrocystis fusiformis* cells. One (arrow) has just reproduced and both new "baby" cells still occupy the same cell wall.

More on biolumiscence later…

Examples of zooplankton…

- Nekton (Greek *nekton* meaning *swimming)* are swimmers from shrimps to whales, usually predators.

Anchovies

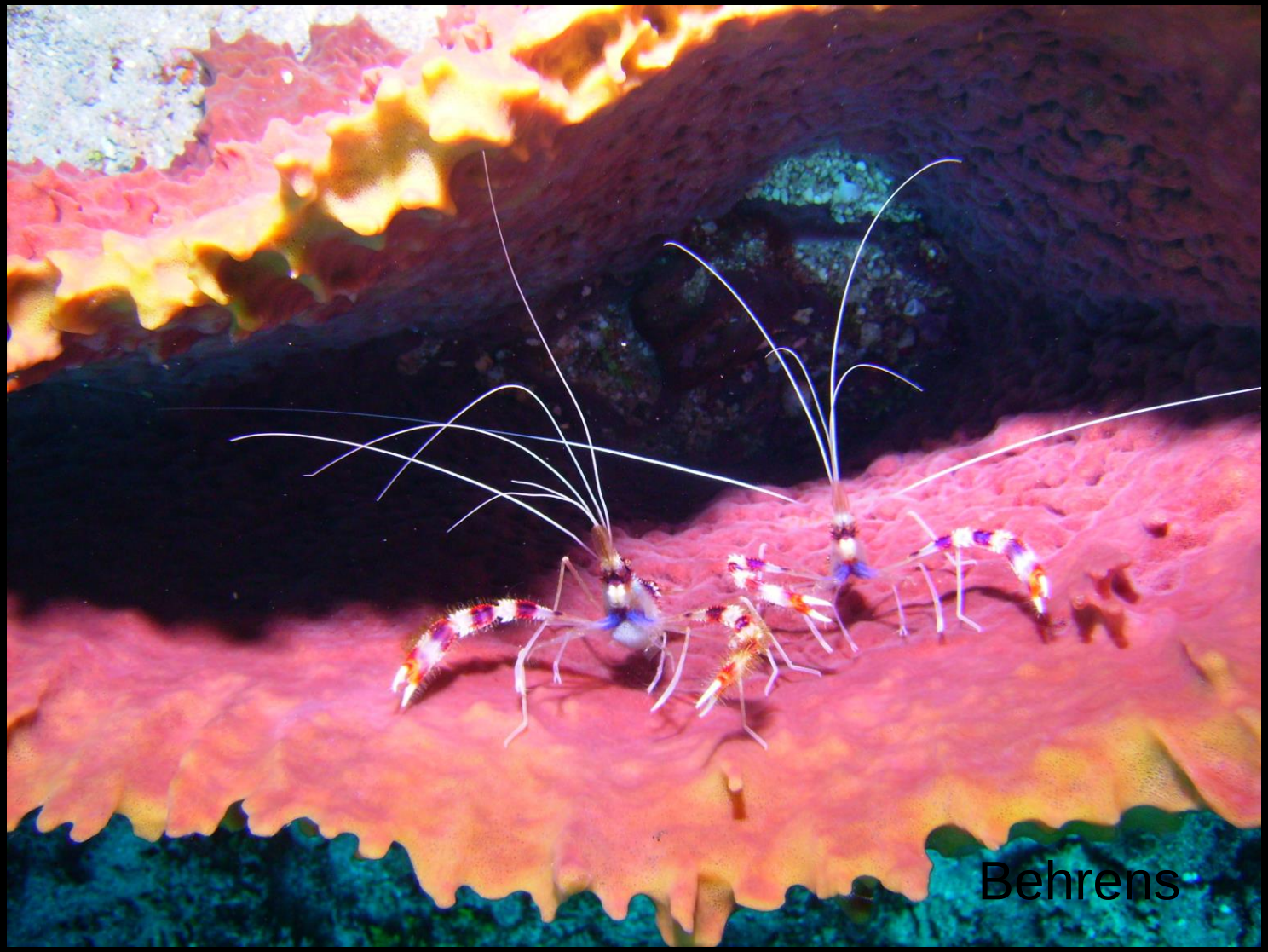
- Benthic organisms live on the bottom (or in sediments and mud). For example starfish, sea urchins, clams…

http://www.smbaykeeper.org/images/site_images/Purple-sea-urchin.jpg

What am I?

What am I?

What am I?

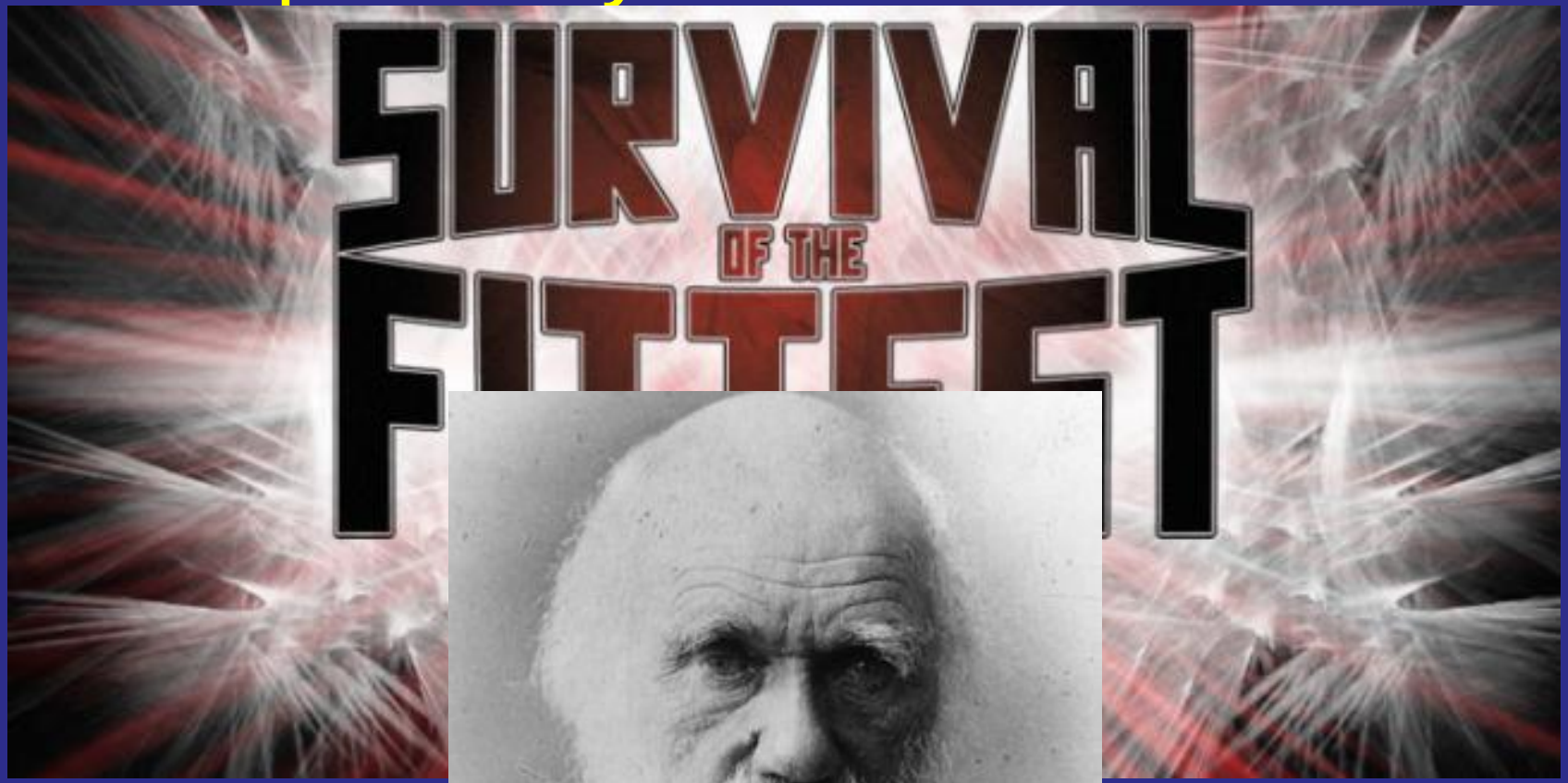


What am I?

What am I?

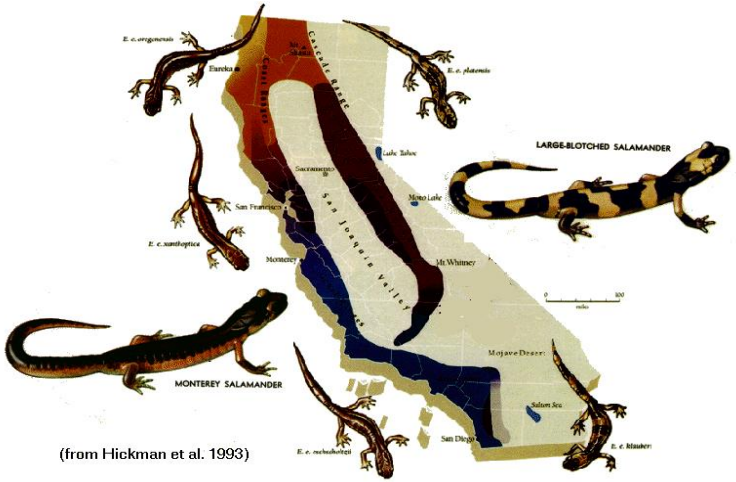
More plankton coming soon!

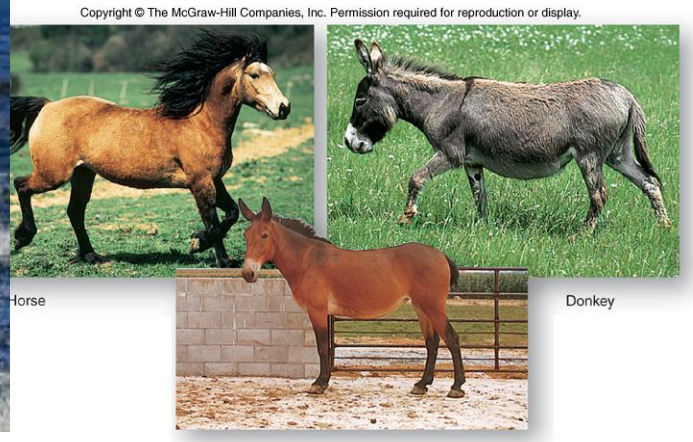
Variety of Life: Evolution Appears to Operate by Natural Selection



Biological Species Concept

- A species are members of populations that actually or potentially **interbreed** in nature, not according to similarity of appearance.
- Although appearance is helpful in identifying species, it does not define species.
- Reproduce fertile, viable offspring
- Overlapping or interconnected population





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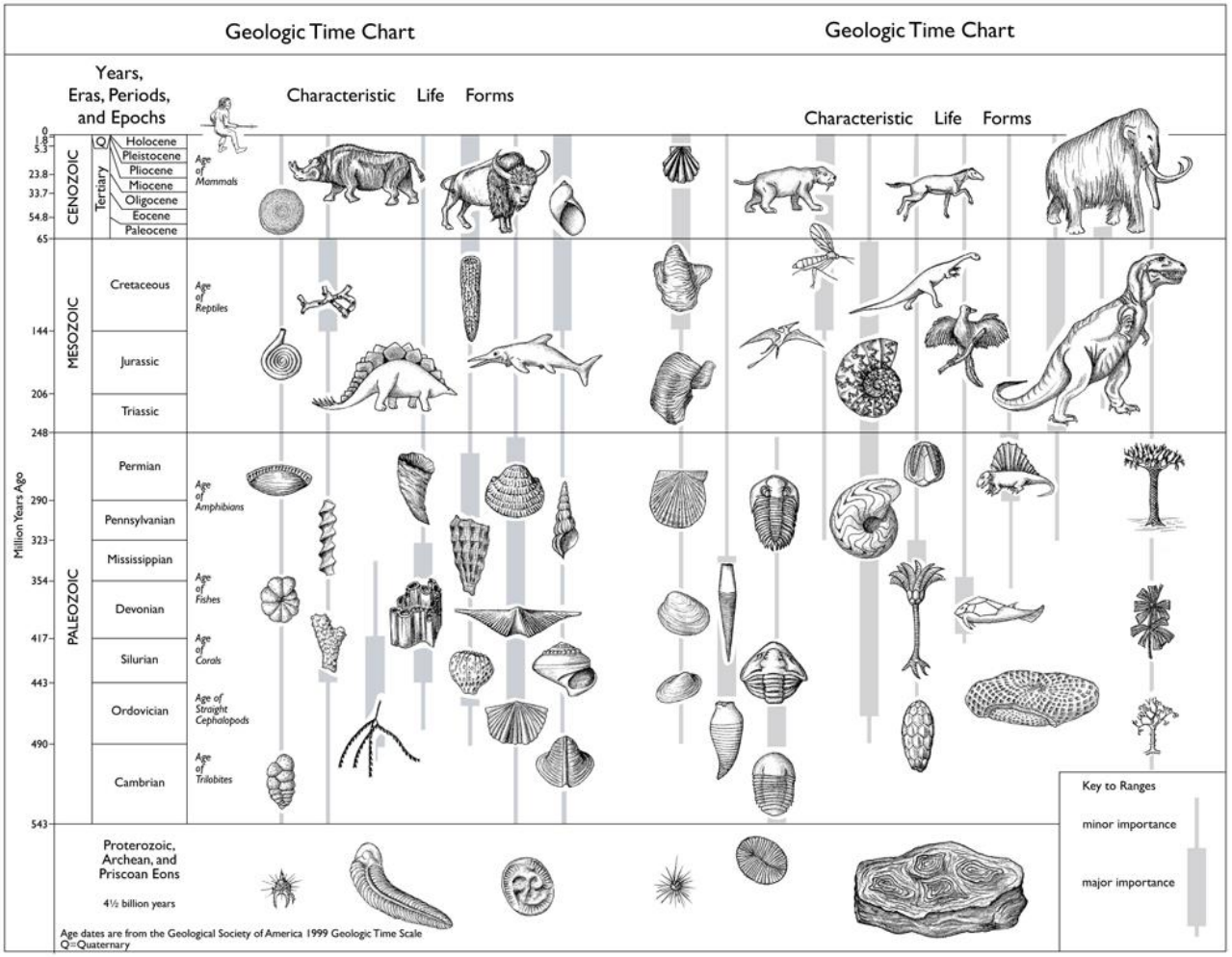

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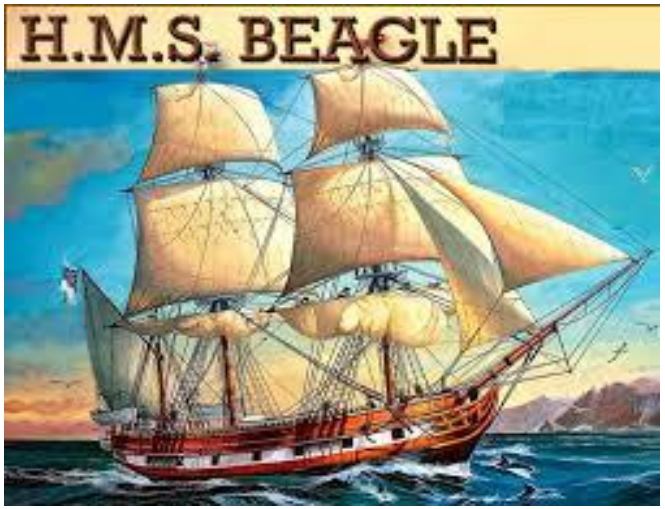
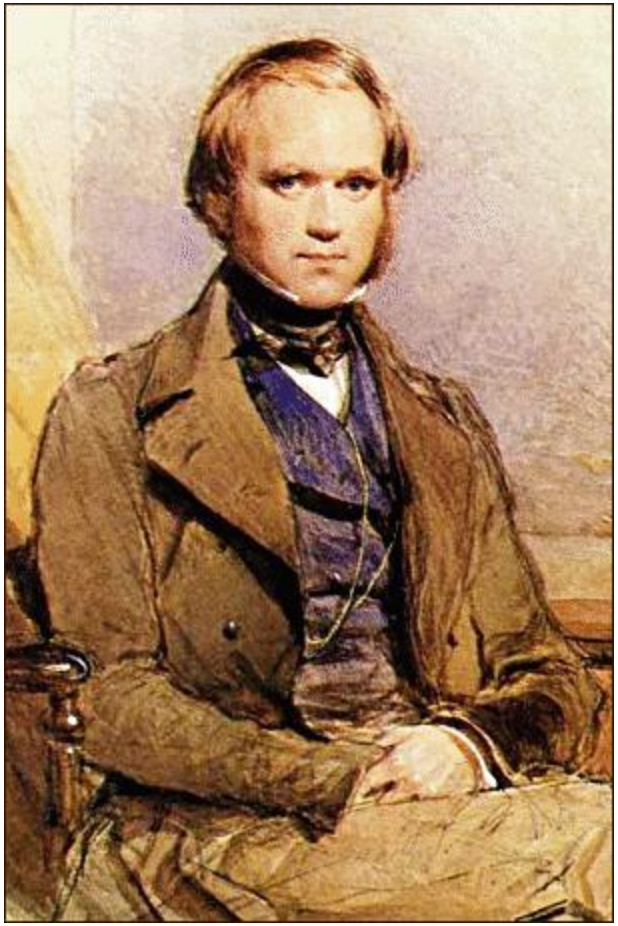
All species evolved from a single common ancestor at life's origination 3.5 bya.

>200 million living species on Earth

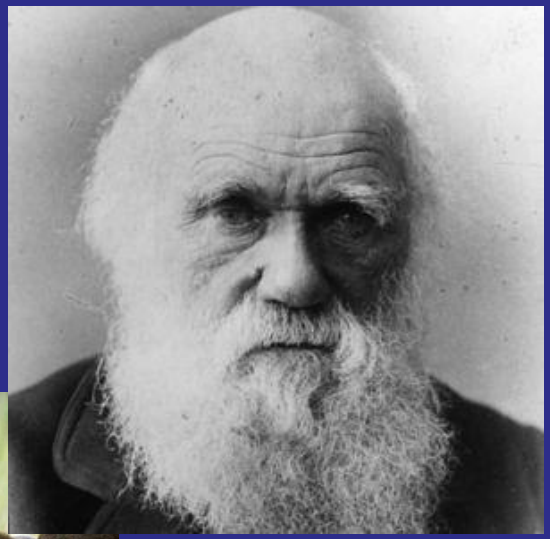
Voyage of The Beagle 1835: Darwin describes species of the Galapagos Islands



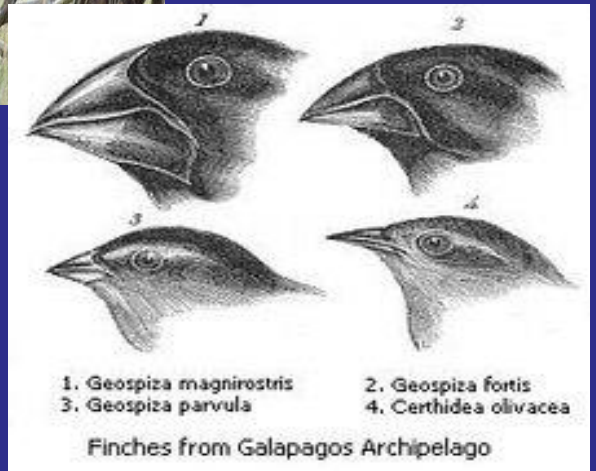


Variety of Life: Evolution Appears to Operate by Natural Selection

- Earth's organisms have changed, or evolved, over 3.5 billion years.
- Evolution occurs through the process of **natural selection.**
- The environment favors individuals that are well adapted. Their favorable traits are retained because they contribute to the organism's reproductive success.



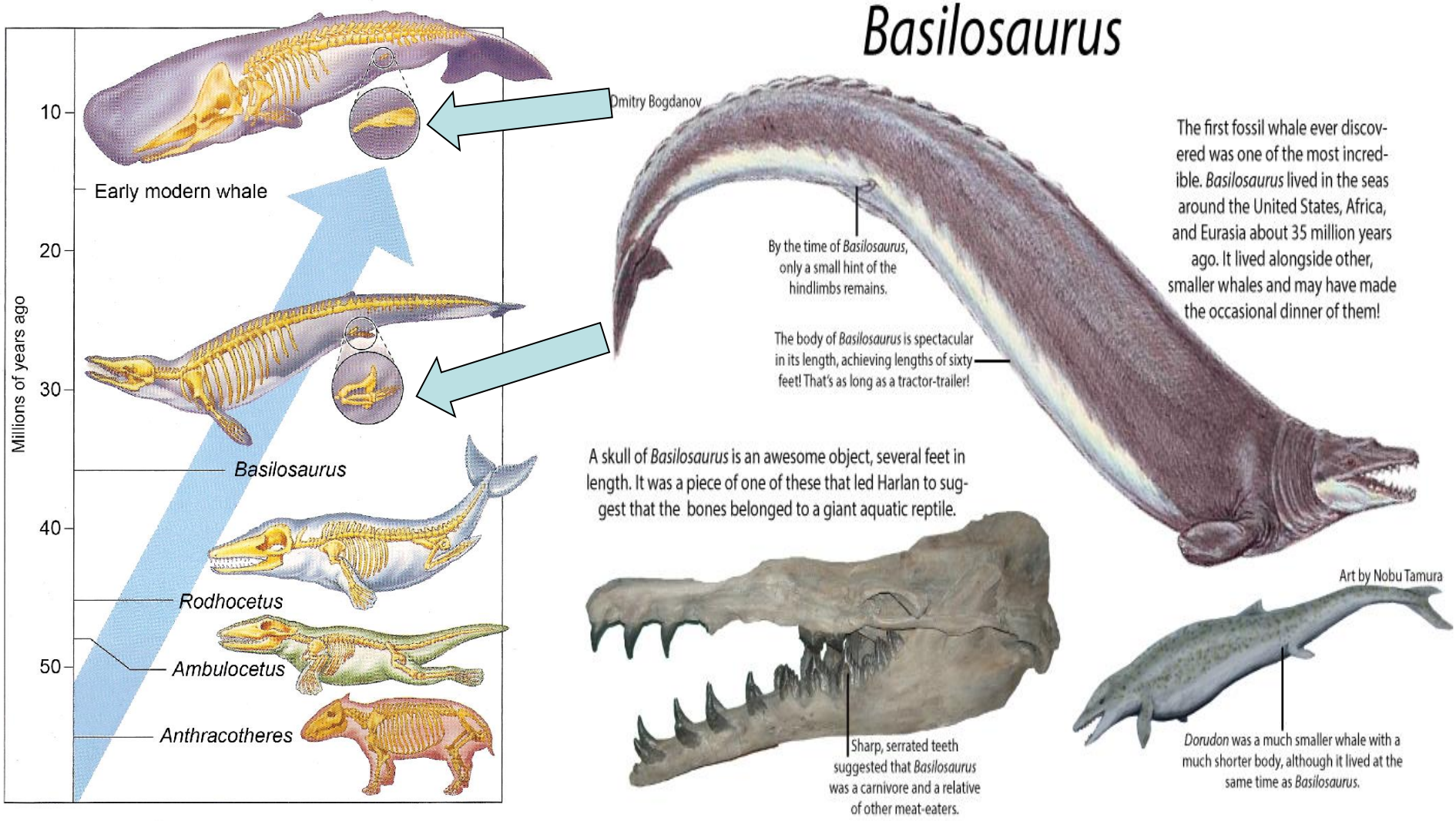
New Species evolve from new adaptive traits

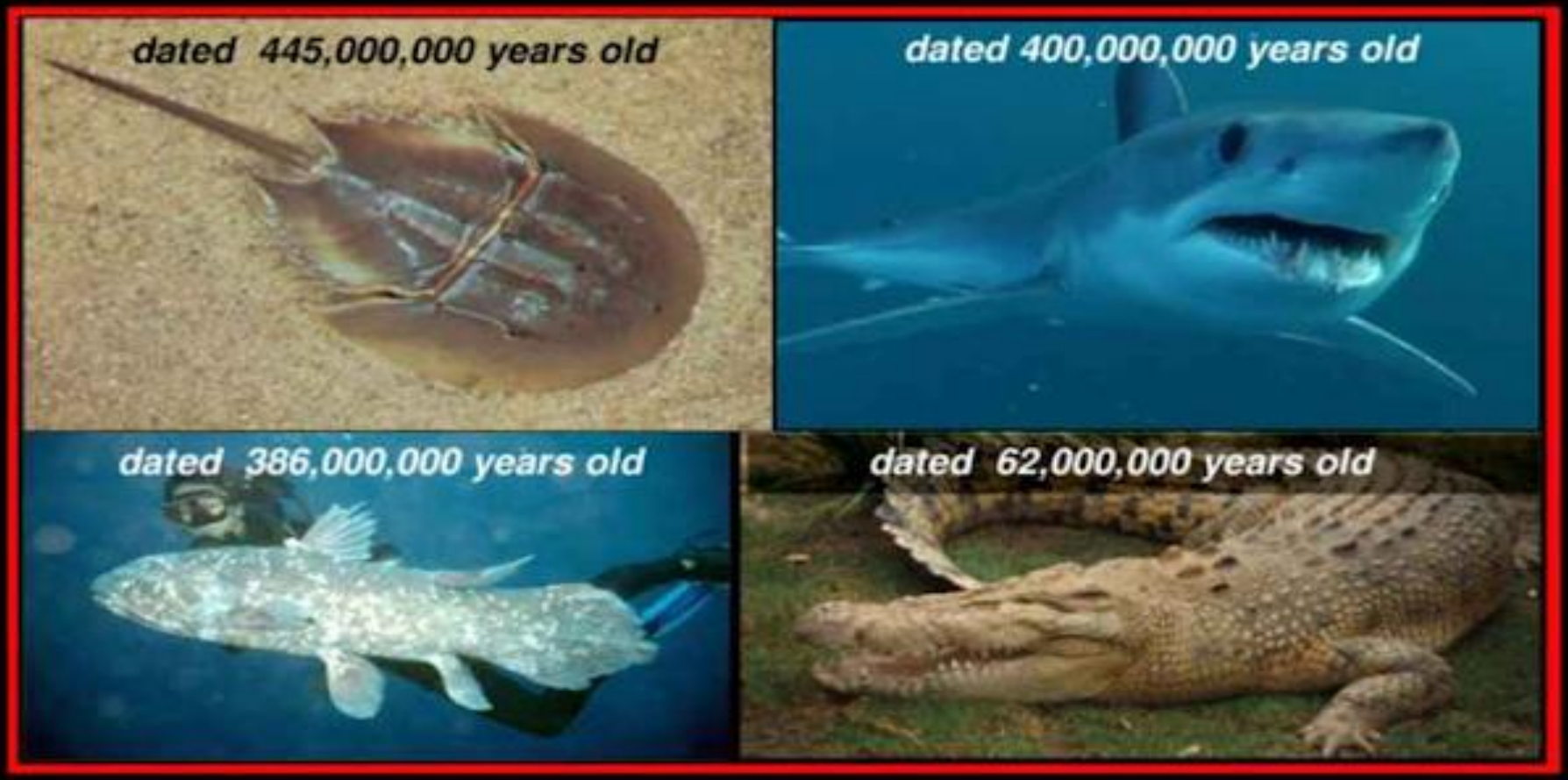


- Natural selection is a mechanism by which individuals that have inherited beneficial adaptations produce more offspring on average than do other individuals.

- Heritability is the ability of a trait to be passed down.
- There is a struggle for survival due to overpopulation and limited resources.
- Darwin proposed that adaptations arose over many generations.

Evolution of the Modern Whale (Odonticetes) from transitional species with vestigial structures





Evolution: not for everybody

because when all you can prove is the exception to the rule, its time to switch to a game you can win.

"Living Fossils"

Types of Adaptations in the Marine Environment

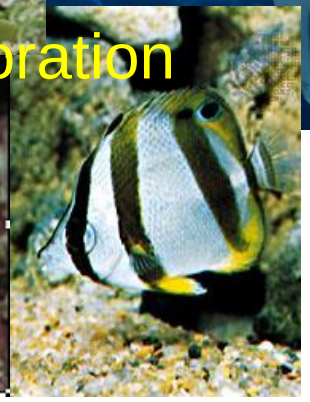
Camouflage

Camouflage: organisms use body patterns, colors or body parts for concealment. Why adaptive?

Countershading

Countershading: Organisms are dark on top, light on the bottom. Why adaptive?

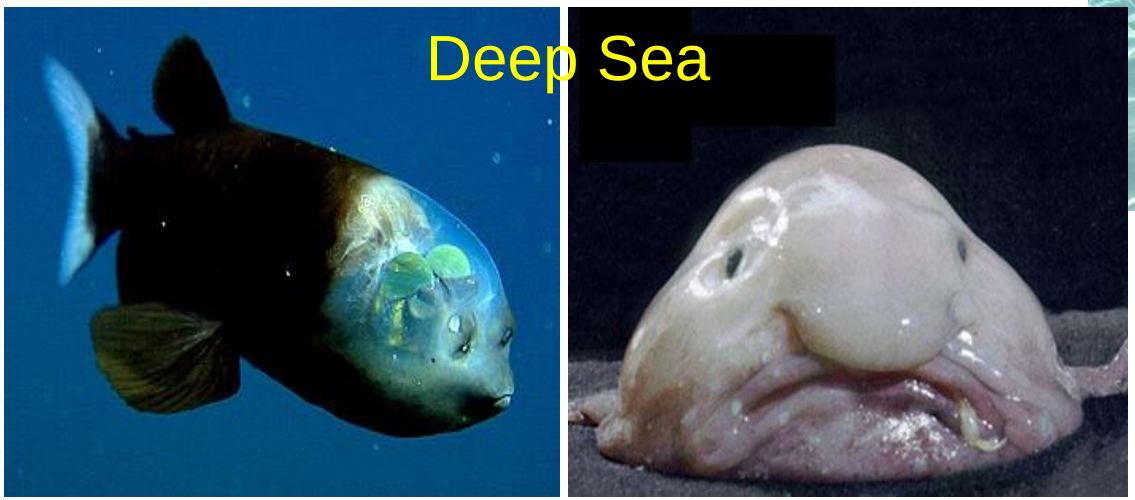
Disruptive Coloration



Disruptive Coloration: large bold patterns, contrasting colors make animal blend into background. Why adaptive?

Types of Adaptations in the Marine Environment

How has **Body Plan** adapted to the living space or Environment?



Barrelfish

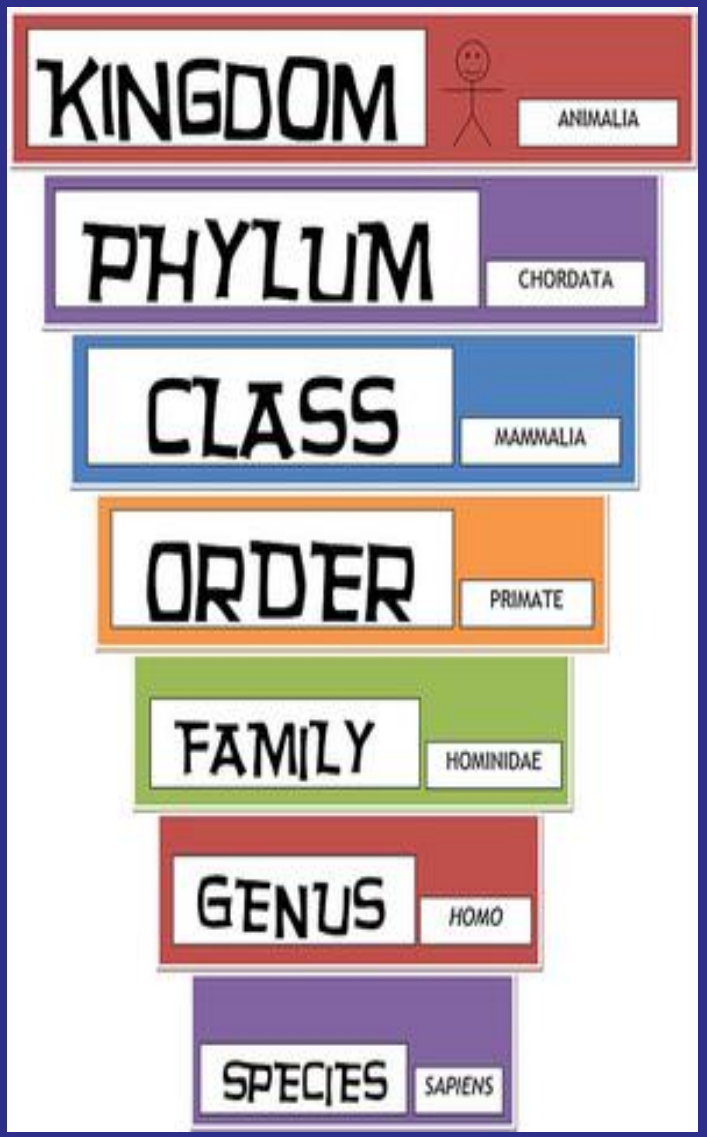
Blobfish

Types of Adaptations in the Marine Environment

- **Aposematic Warning Colors**: Advertise the organism as noxious or harmful to predators
- **Chemical** and **structural *defenses***
  - *Venom*
  - *Spines*

Classification of Organisms

- What were the contributions of Carolus Linnaeus?
- He was one of the first to use a system of **natural classification**
- He developed a classification system based on **hierarchy**
- He developed a system of **scientific names** for organisms



Review of Classification

- Why do we need classification?
  - Identify relationships between organisms
  - Identify key characteristics of organisms
  - Avoid confusion

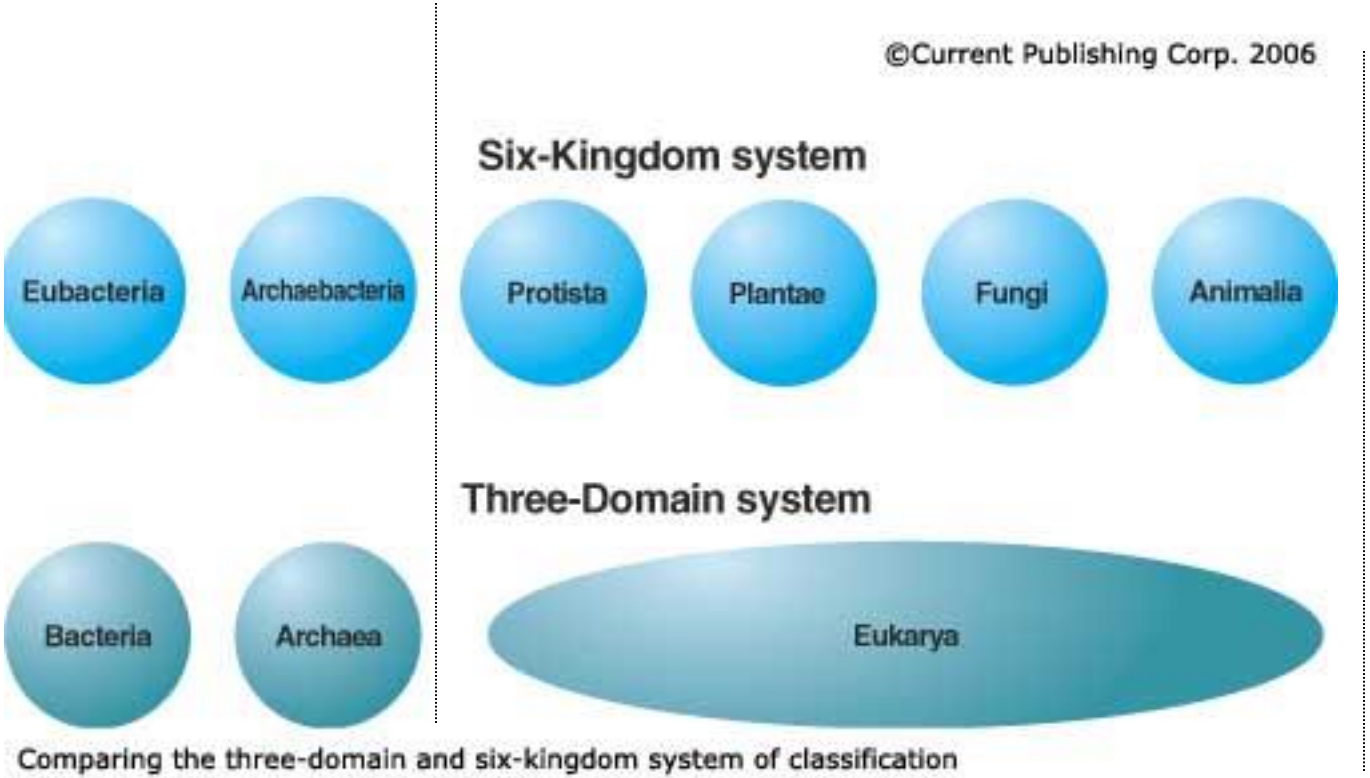
Budd Christman NOAA

Dolphin mammal

Bob Brown - fishdeco.com

Dolphin fish

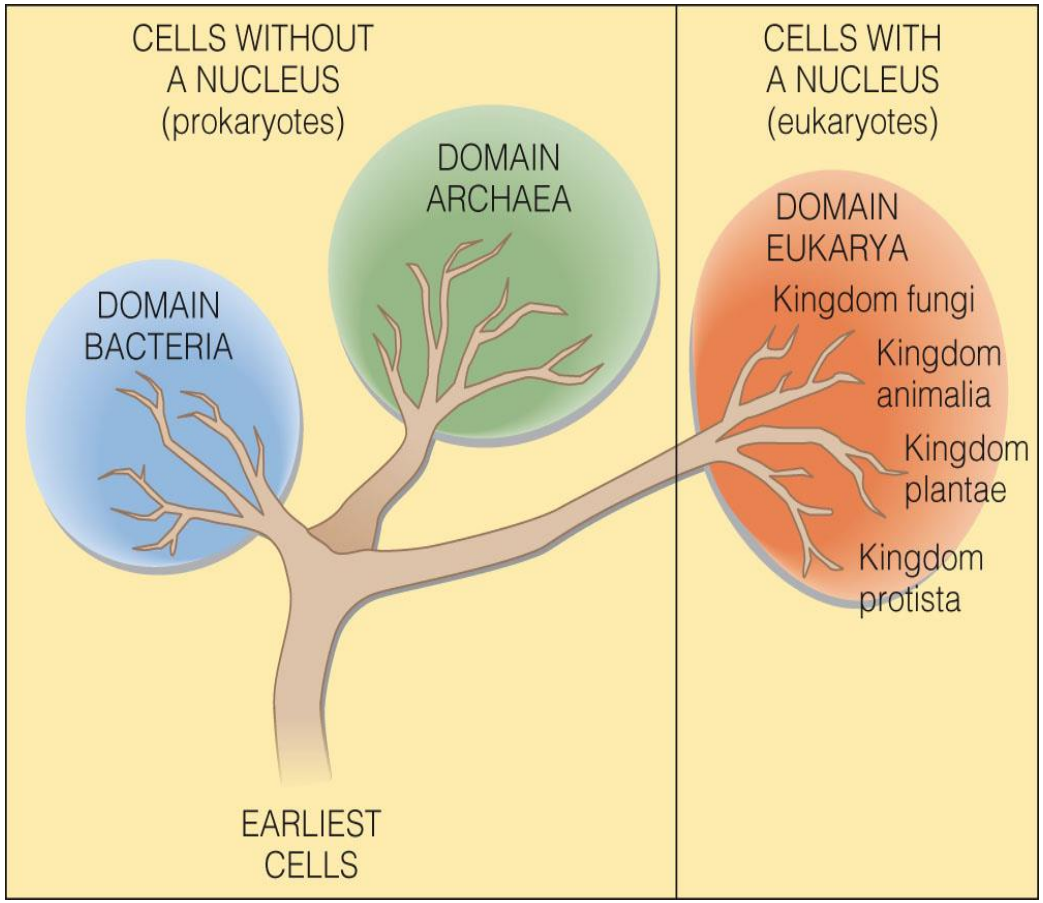
Six Kingdoms and Three Domain Systems



Comparing the three-domain and six-kingdom system of classification

Systems of Classification May Be Artificial or Natural

Three Domain System

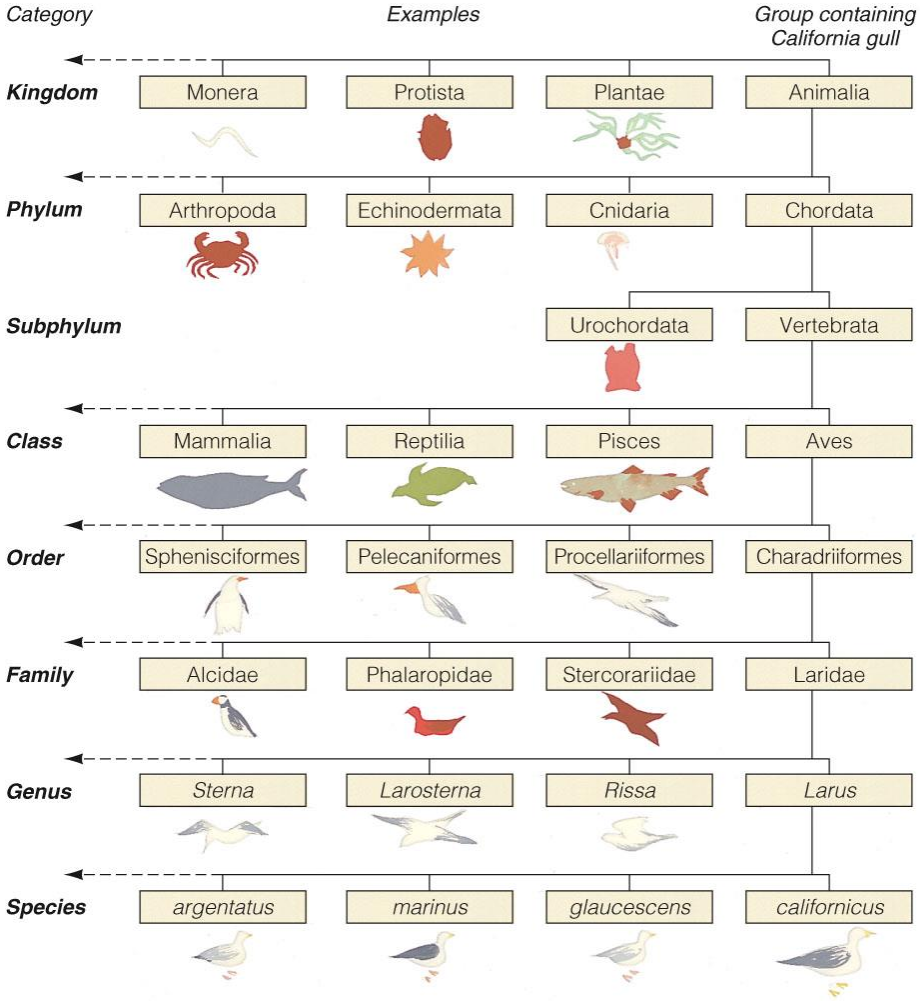


A family tree showing the relationship of **6 kingdoms** presumably evolved from a distant **common ancestor**.

Prokaryotes: The Bacteria and Archaea contain single-celled organisms without nuclei or organelles.

Eukaryotes: The fungi, protists, animals, and plants contain organisms with cells having nuclei and organelles; collectively, they are called eukaryotes.

Systems of Classification May Be Artificial or Natural



Hierarchy Classification of Six Kingdoms