

# Ecology and Sustainable Development.

## 2. Ecology and Ecosystems:

2.1 Biology and Environment: hierarchy of matter, Earth's ecological systems.

2.2 Biosphere: lithosphere, atmosphere, hydrosphere, biogeochemical cycles.

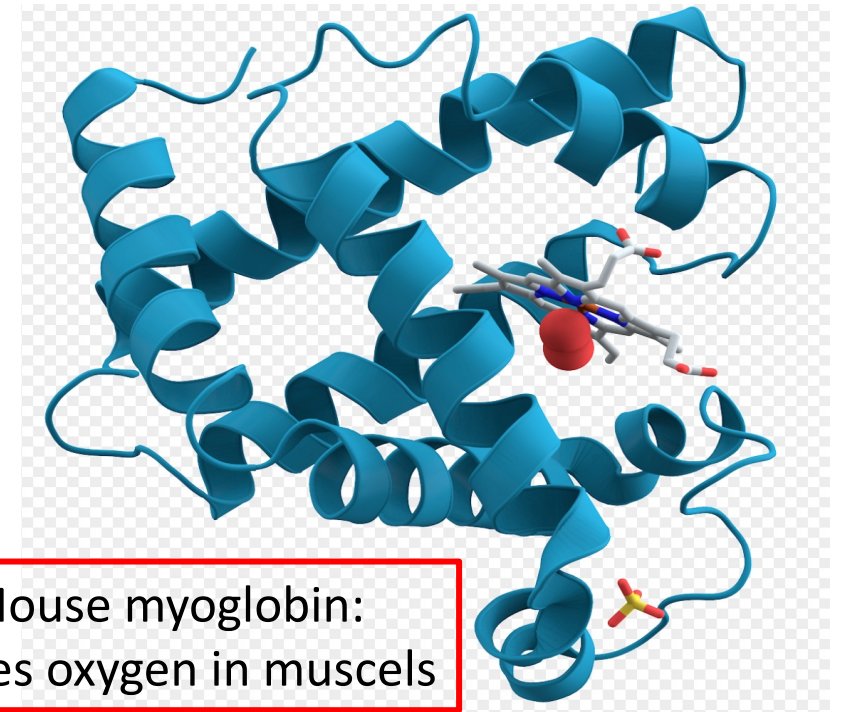
2.3 Ecosystem Dynamics: productivity, stability/vulnerability, ecological crisis.







Vincent van Gogh: Auvers. 1890




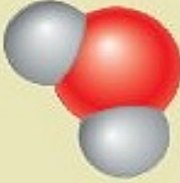
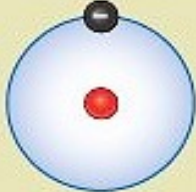
## 2.1 Biology and the Environment.

- **Ecology:**
  - Multi-disciplinary science focusing on the relationship of organisms – usually of higher level - with the environment.
- **Environment of an organism:**
  - (local) abiotic factors such as insolation (sunlight), climate, and geology,
  - biotic factors, which are other organisms that share its habitat.
- **Organisms can be studied at many different levels, from**
  - **proteins** and **nucleic acids** (in biochemistry and molecular biology), to
  - **cells** (in cellular biology), to
  - **individuals** (in botany, zoology, and other similar disciplines), and finally at the level of
  - **populations, communities**, and
  - **ecosystems**, to the
  - **biosphere as a whole.**



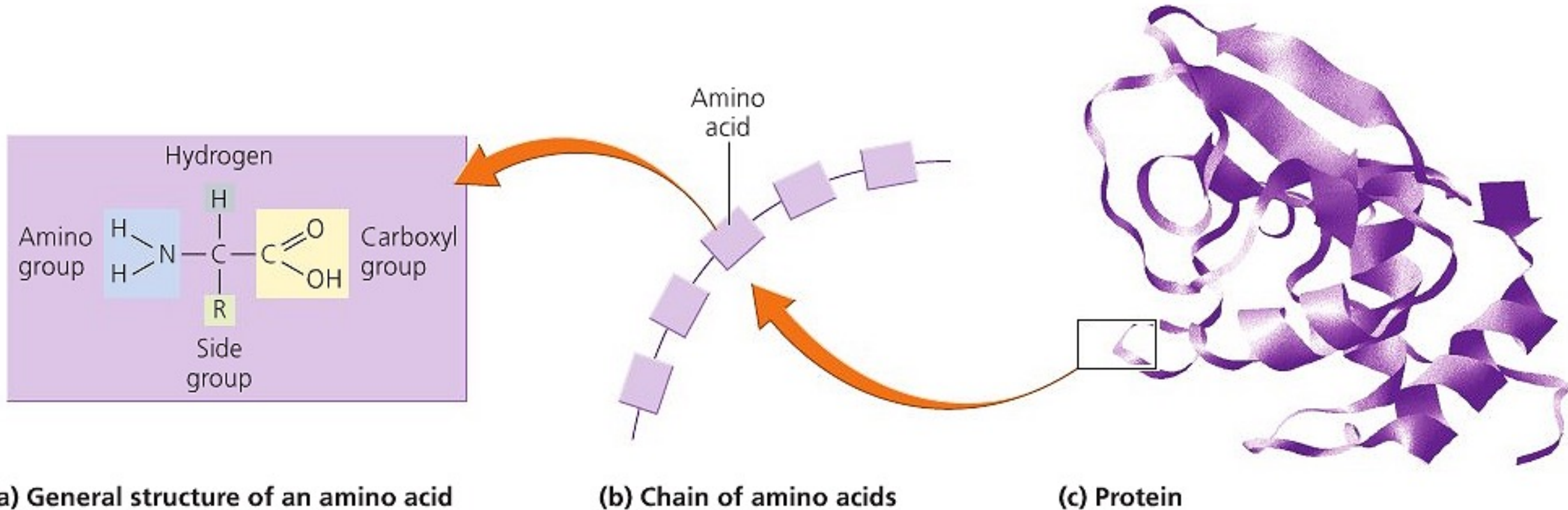
# Hierarchy of Matter.

	Organism	An individual living thing
	Organ system	An integrated system of organs whose action is coordinated for a particular function
	Organ	A structure in an organism composed of several types of tissues and specialized for some particular function
	Tissue	A group of cells with common structure and function

	Cell	The smallest unit of living matter able to function independently, enclosed in a semi-permeable membrane
	Organelle	A structure inside a eukaryotic cell that performs a particular function
	Macro-molecule	A large organic molecule (includes proteins, nucleic acids, carbohydrates, and lipids)
	Molecule	A combination of two or more atoms chemically bonded together
	Atom	The smallest component of an element that maintains the element's chemical properties

# From Molecules to Living Cells.

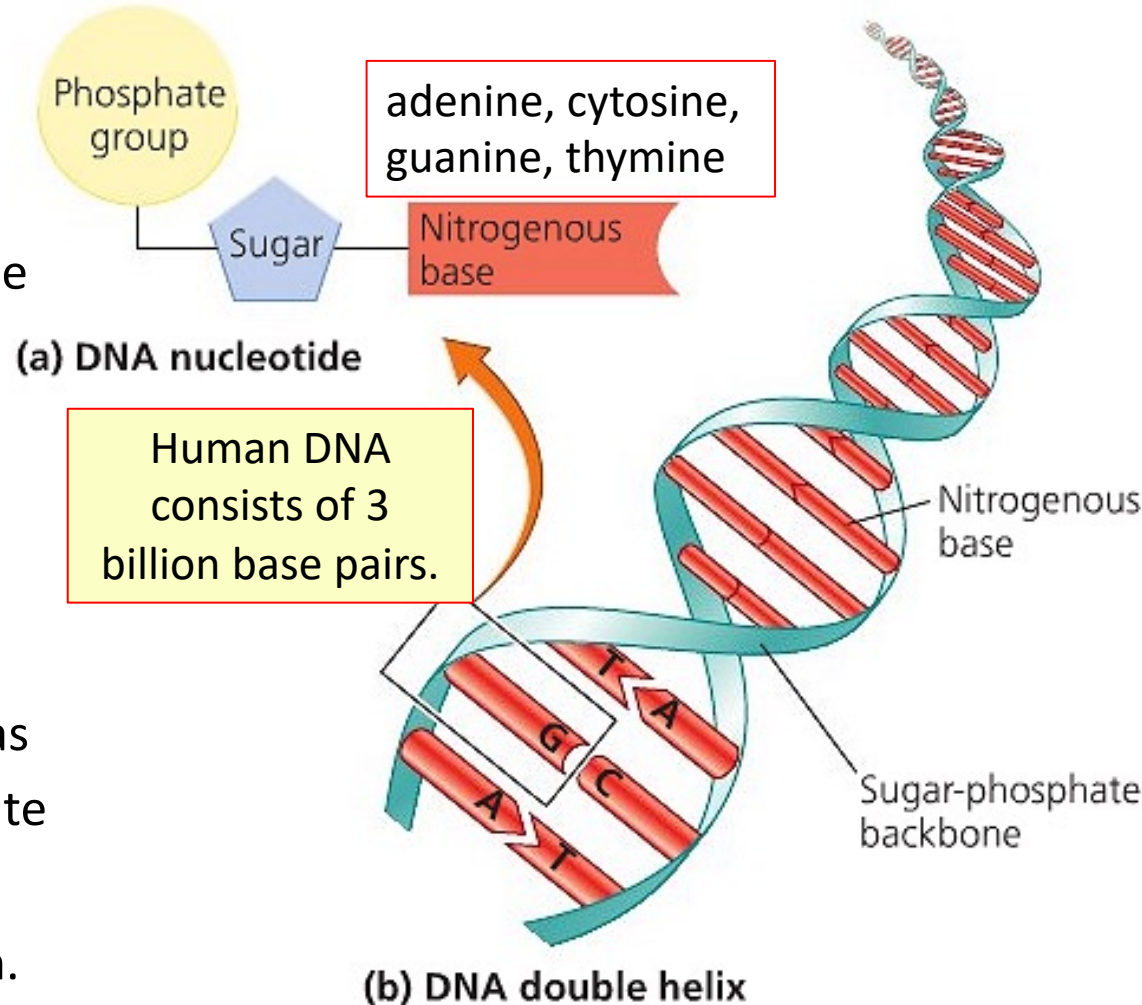
**Makromolecules are the building blocks of life: proteins**



# From Molecules to Living Cells.

**Protein production is directed by the nucleic acids deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).**

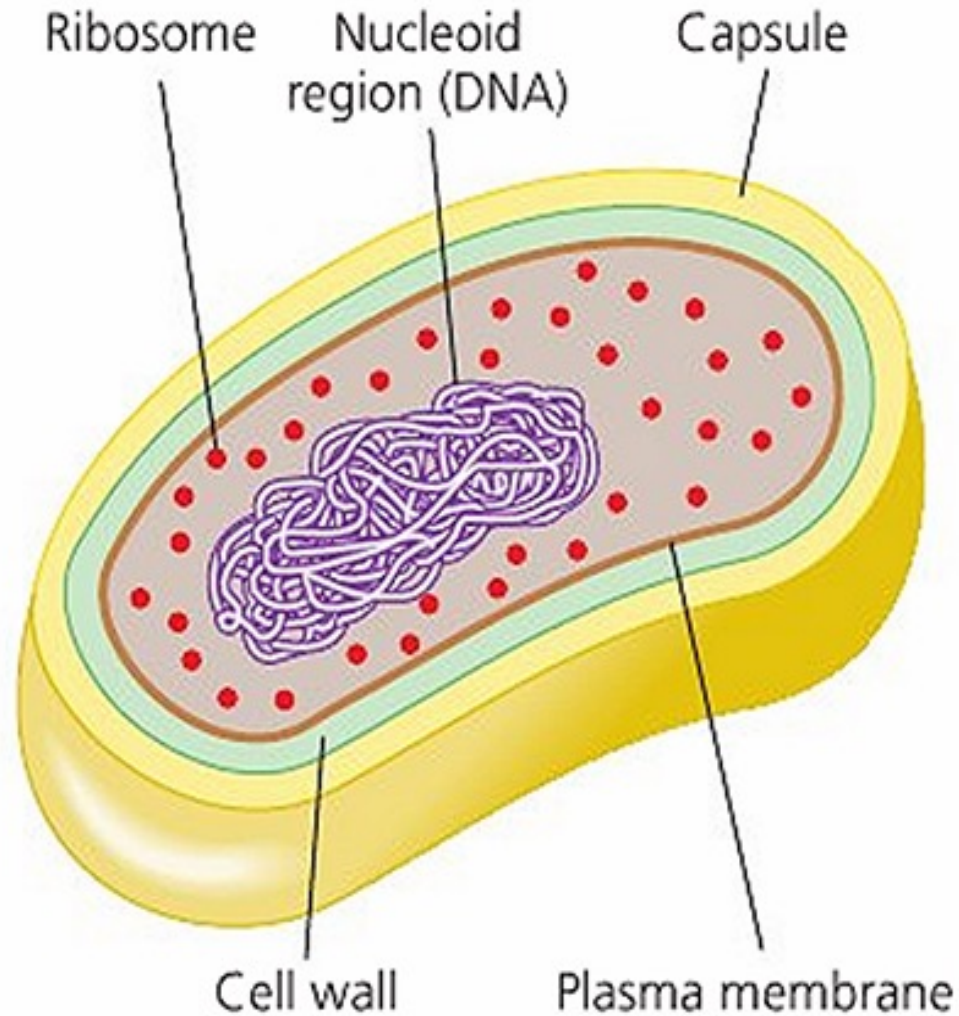
- The DNA contains all the hereditary information.
- This information is rewritten to a molecule of RNA which directs the order of amino acids in building a protein.
- Genetic information contained in the DNA is passed on from one generation to another as the DNA strands replicate during cell division and egg or sperm formation.



- Length of a human DNA-strand: 2m
- Genes: Regions of the DNA which perform the particular coding functions.
- Humans have 23.000 genes.
- The genome is the whole set of genes of an organism and is divided into chromosomes.
- 99,9% of DNA of all persons are identical.
- Hereditary influence determined by individual human genome: size 90%, weight 70%, diabetes 70%, age 25%, eye color.

# From Molecules to Living Cells: Prokaryotes.

**Cells are the smallest unit of life that can function independently.**



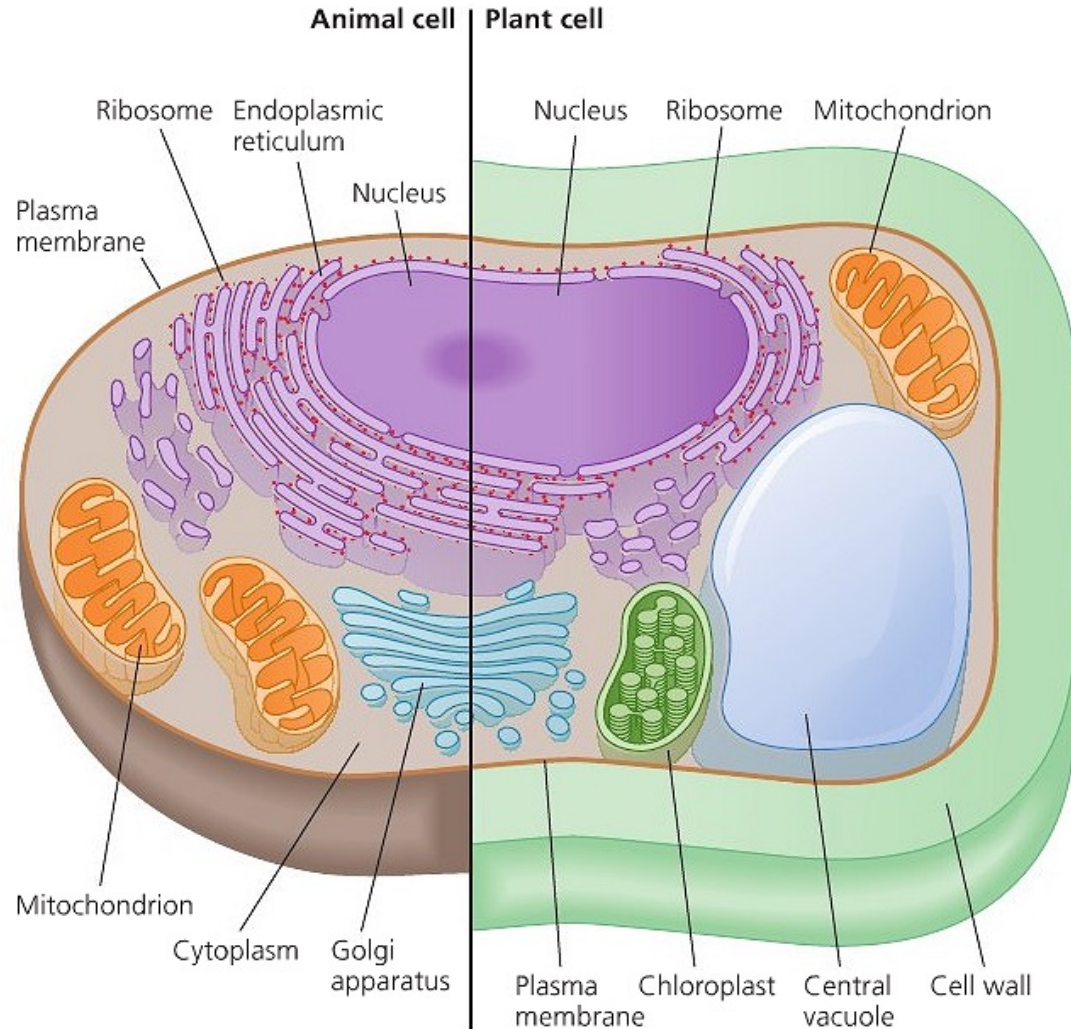
**Prokaryotic cell.**

- Prokaryotes are single cell organisms like bacteria.
- Prokaryotic cells have a simple structure:
  - cell wall of peptidoglycan (polysaccharide chains cross-linked with peptides),
  - membrane of lipids,
  - cytoplasm (cell fluid),
  - ribosomes for the synthesis of proteins,
  - a nucleoid region with the DNA.
- Bacteria are diverse and ubiquitous in the environment, vital for life, and often form colonies and live in symbiosis with other organisms.

The first living things on Earth were prokaryotes.  
The oldest ancient fossil microbe-like objects  
are dated to be 3.5 billion years old.

# From Molecules to Living Cells: Eukaryotes.

Animals, plants, fungi have eukaryotic cells.

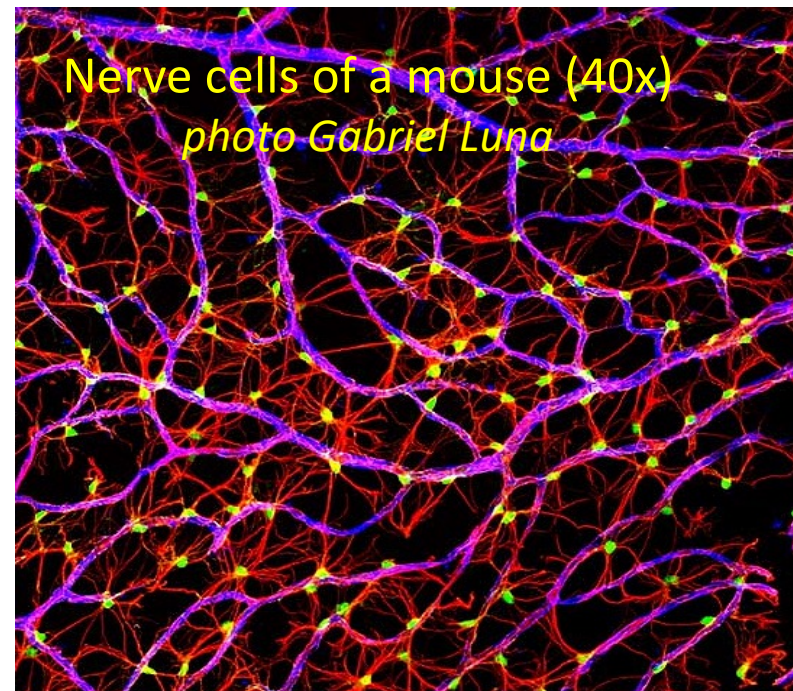


**Eukaryotic cell.**

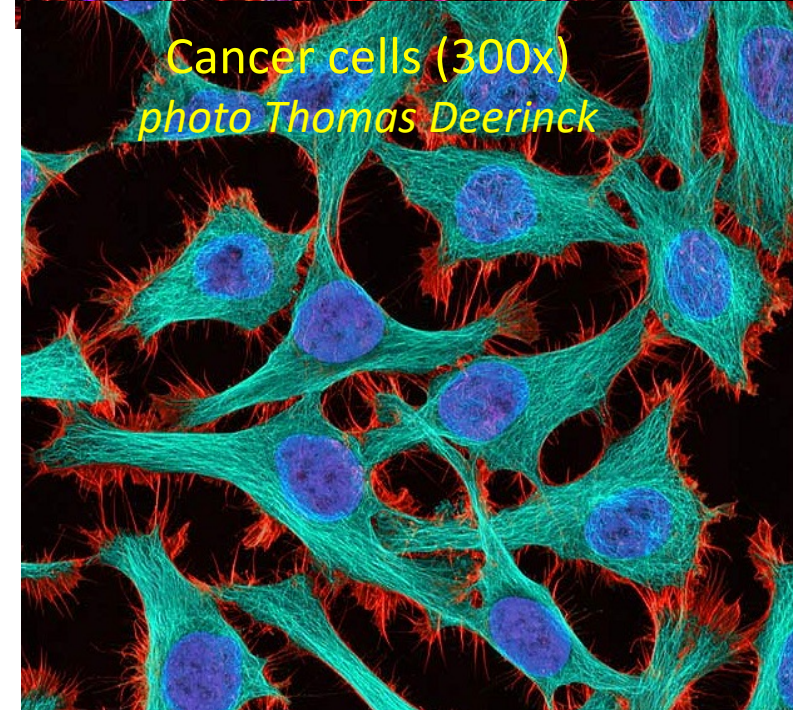
- Eukaryotic cells have a more complex structure.
- Cell wall (peptides and/or carbohydrates) and an outer membrane of lipids.
- Cytoplasm containing organelles and an enclosed membrane-bound nucleus with the DNA.
- Specific functions of organelles:
  - mitochondria extract energy from sugar and fat,
  - ribosomes synthesise proteins,
  - chloroplasts of plants with chlorophyll for photosynthesis.
- Eukaryotes: many and different cells.

Different cells perform different functions.  
Cells of the same function form tissues and  
tissues make up organs.

Nerve cells of a mouse (40x)  
photo Gabriel Luna



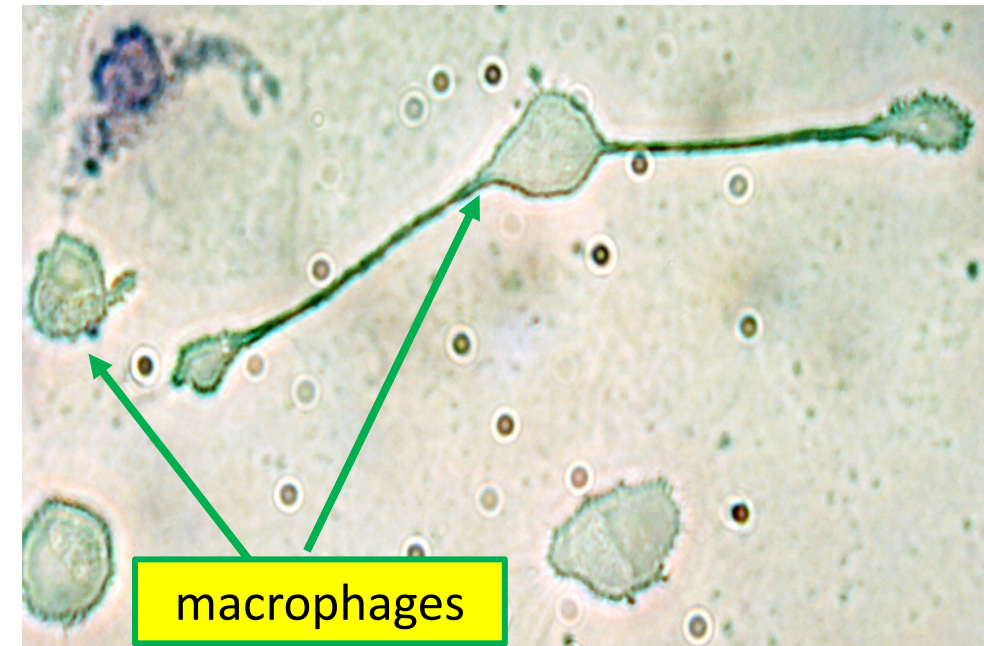
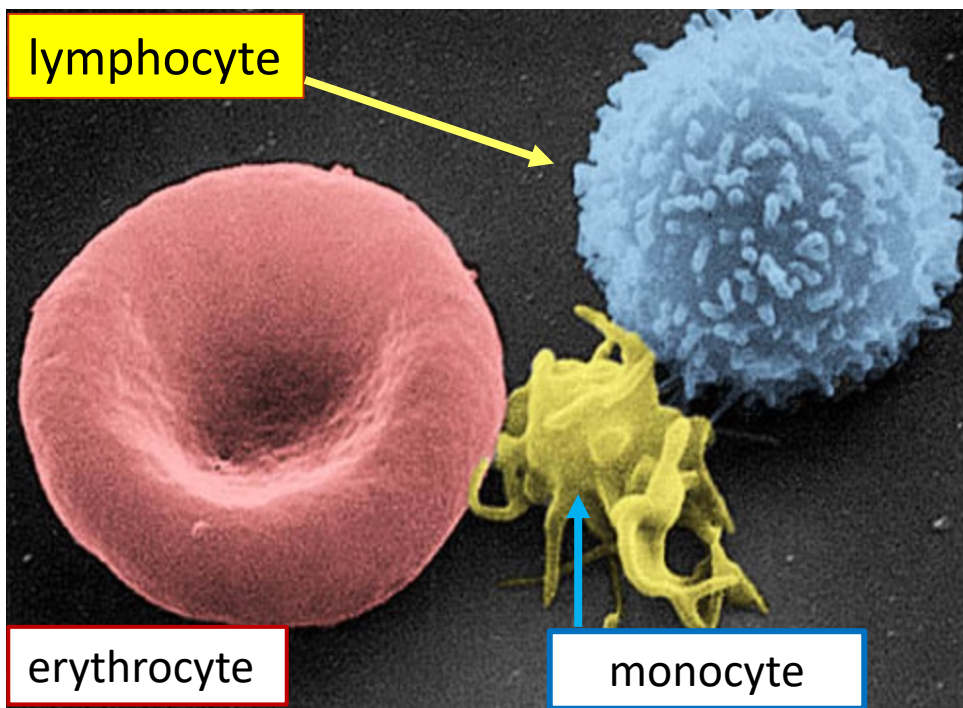
Cancer cells (300x)  
photo Thomas Deerinck



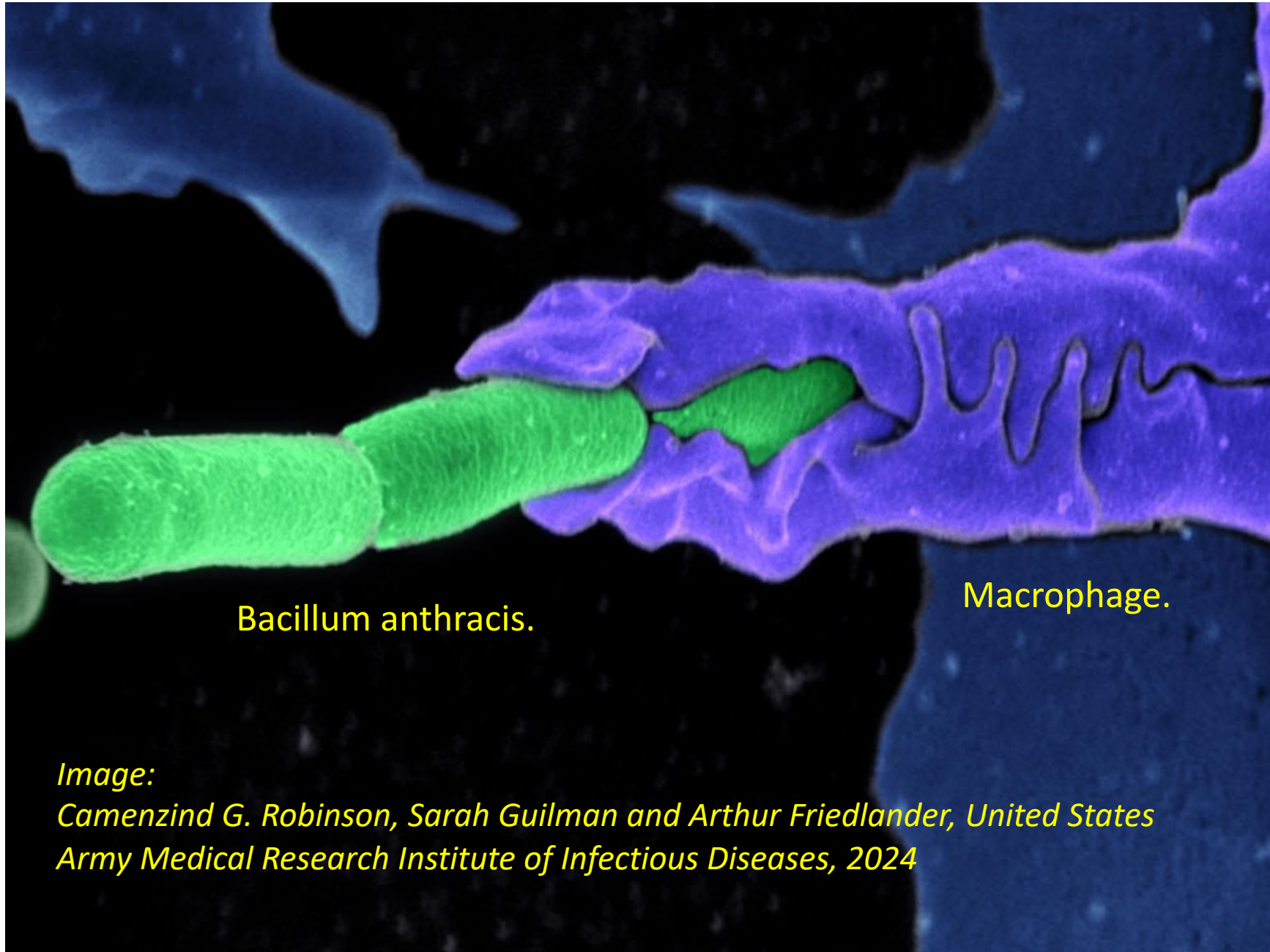
## Different Cells Types.

- **Human body:**

- 25.000 billion blood cells (erythrocytes, monocytes, passive cells without nucleus)
- 750 billion cells of immune system (macrophages, lymphocytes - highly specialized)
- 240 billion liver cells for metabolism
- 180 billion brain cells
- 180 billion nerve cells
- 30 billion skin cells
- 300 million muscle cells



# Functioning of Immune Cells.



Bacillum anthracis.

Macrophage.

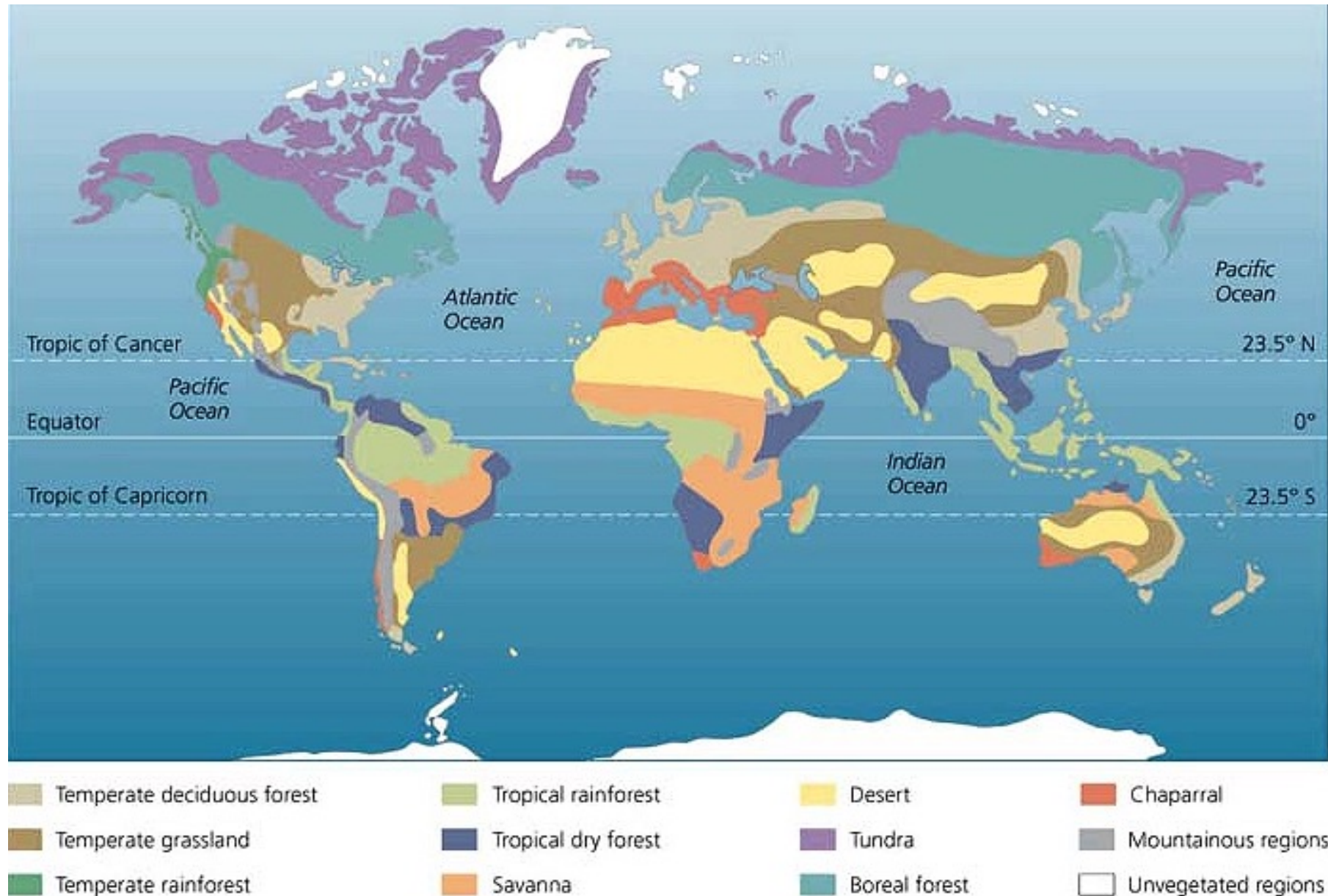
## Macrophage eating bacillum anthracis.

- Anthrax can cause severe illness in both people and animals.
- The bacteria that causes anthrax occurs naturally in soil worldwide.
- Anthrax is also a potential biological weapon.

*Image:*

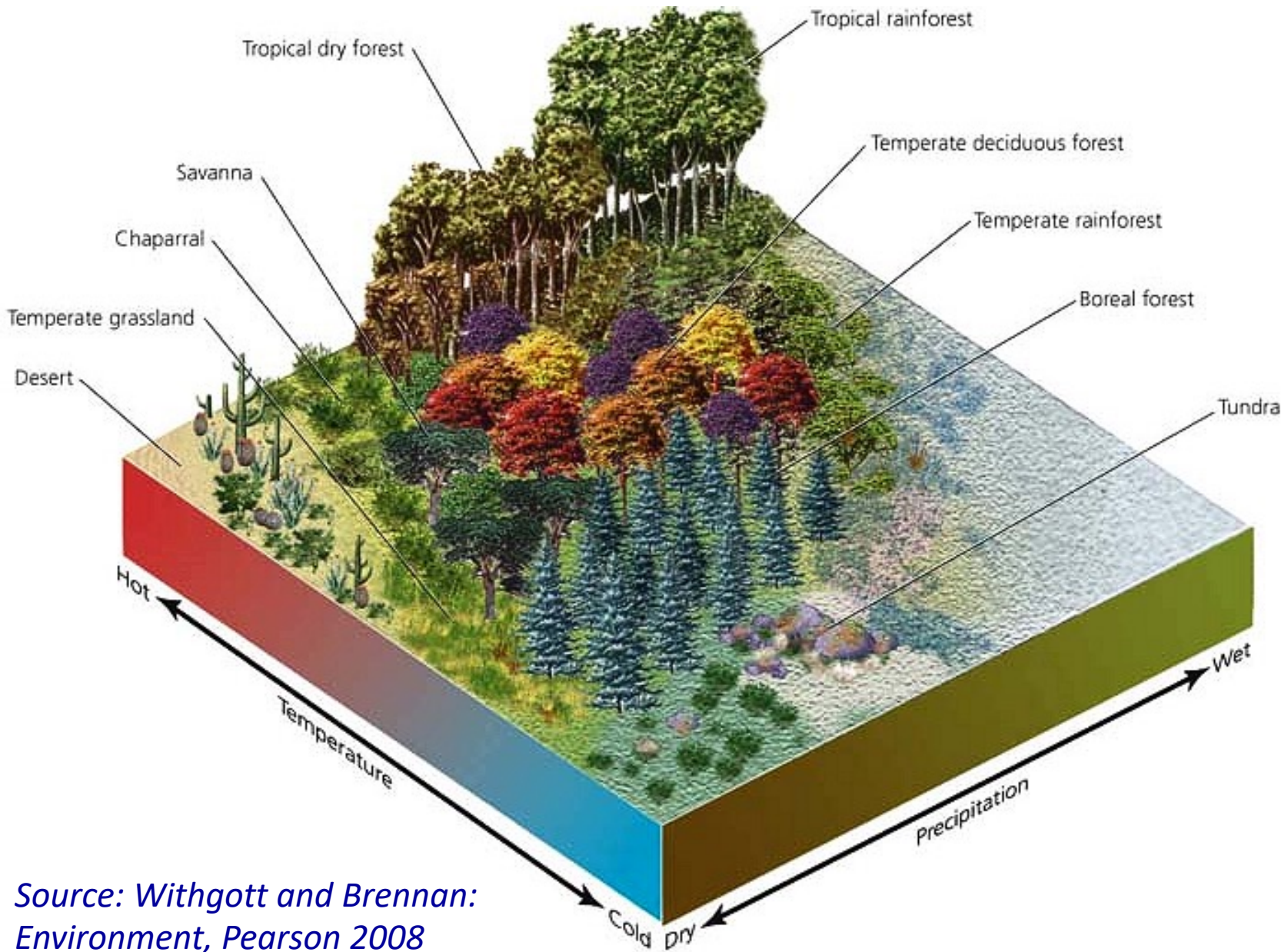
*Camenzind G. Robinson, Sarah Guilman and Arthur Friedlander, United States Army Medical Research Institute of Infectious Diseases, 2024*

# Spatial Classification of Earth's Ecological System: Biomes.



- **Biome:** climatically and geographically defined area of ecologically similar communities of plants, animals, and soil organisms.
- **Terrestrial biomes:**
  - Indicated on global map.
- **Aquatic biomes:**
  - river deltas, polar freshwaters, mountain freshwaters, tropical and subtropical rivers.....
  - polar seas, temperate seas, tropical coral regions....

# Biomes: Typical Vegetation.



**Determining factors:  
Temperature and precipitation.**

- The biodiversity characteristic of a biome is a function of abiotic factors and the biomass productivity of the dominant vegetation.
- Tropical rain forest: apes, orchids
- Savanna: antilopes
- Desert: snakes, thorn bushes
- Temperate forest: deer
- Tundra: reindeer

*Source: Withgott and Brennan:  
Environment, Pearson 2008*

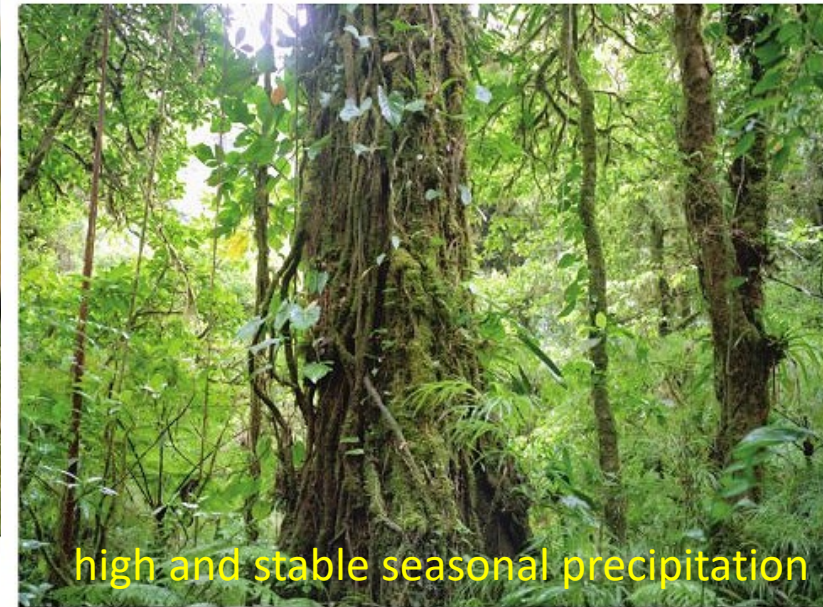
# Influence of Temperature and Precipitation on the Formation of Biomes.



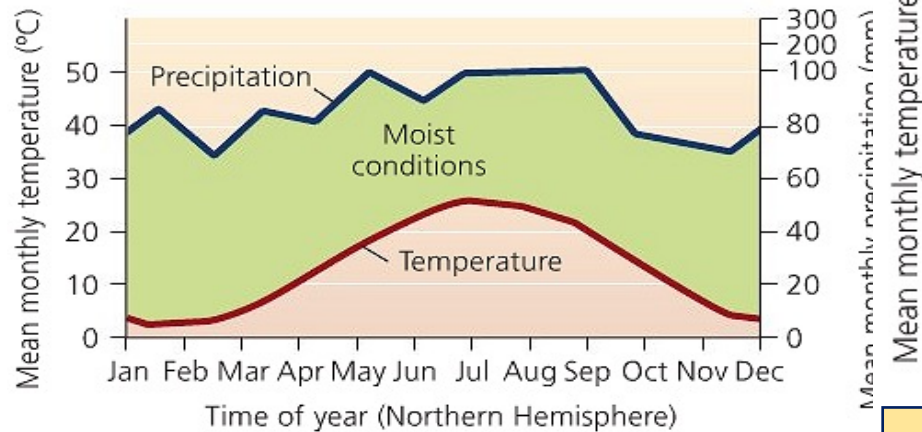
**Temperate deciduous forest.**



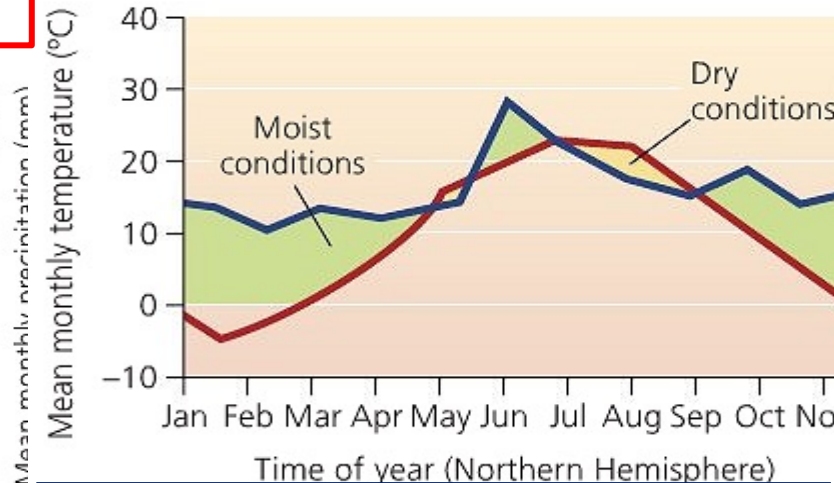
**Temperate grassland.**



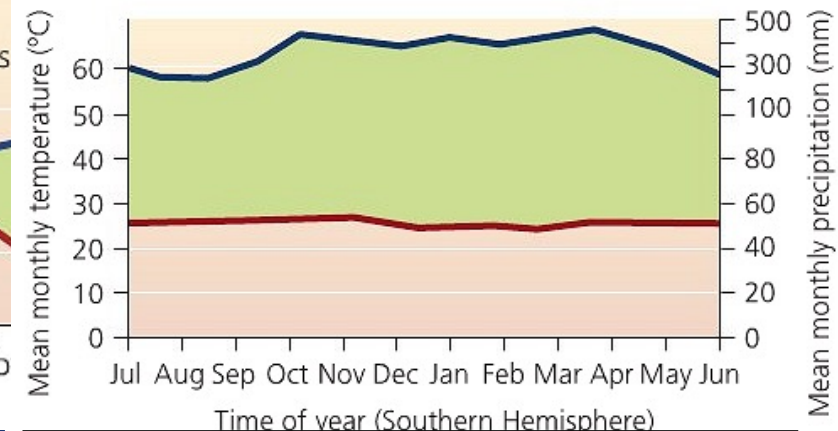
**Tropical rain forest.**



**Varied seasonal temperatures.**



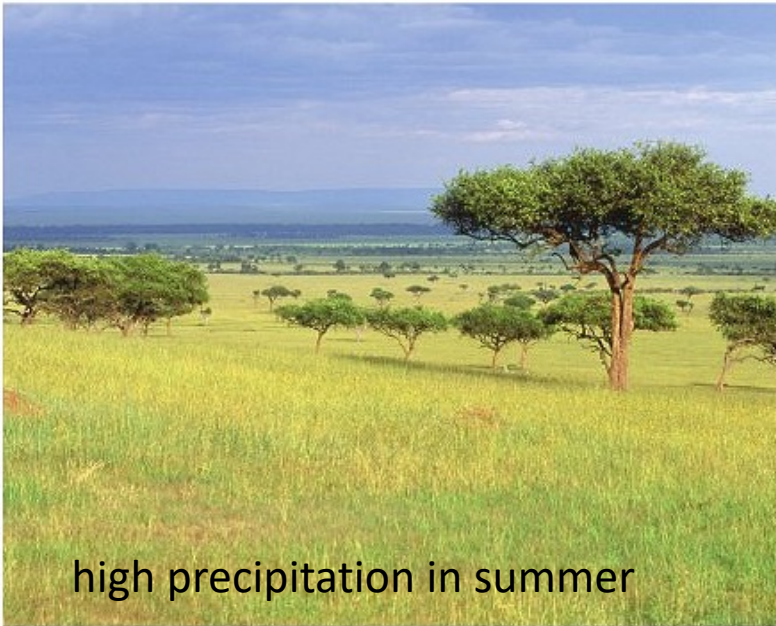
**Large temperature variations.**



**Stable high temperatures.**

Source: Withgott and Brennan: Environment, Pearson 2008

# Influence of Temperature and Precipitation on the Formation of Biomes.



high precipitation in summer

**Savanna**



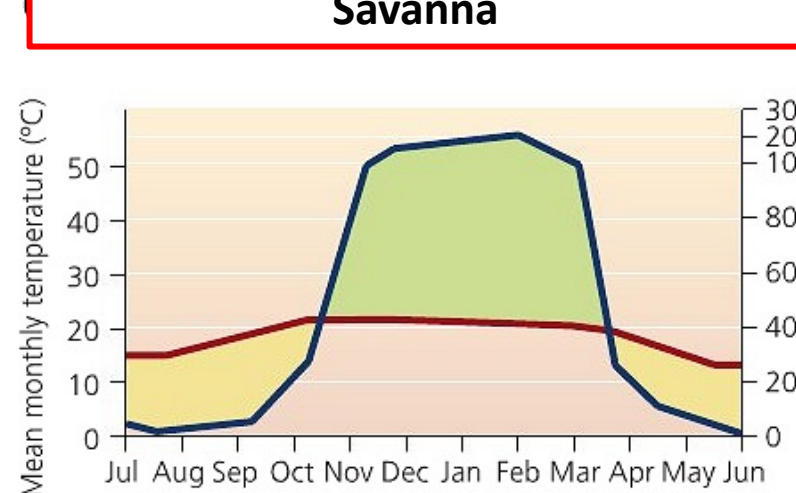
very little precipitation over the year

**Desert**

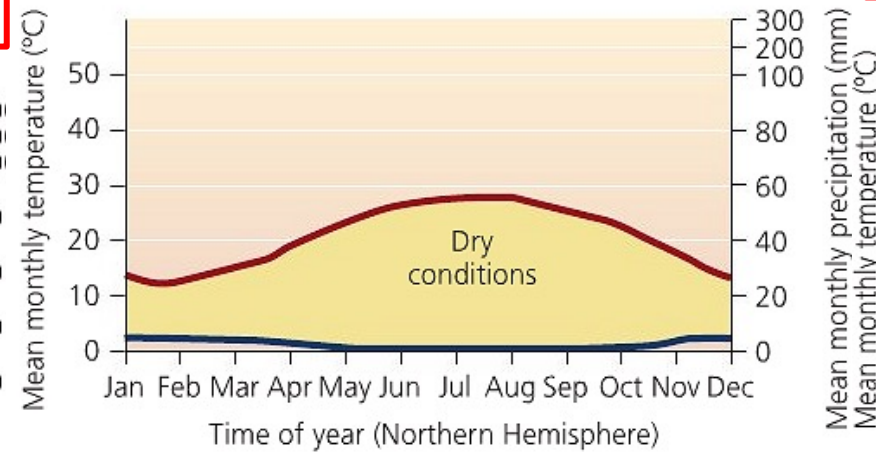


high winter precipitation

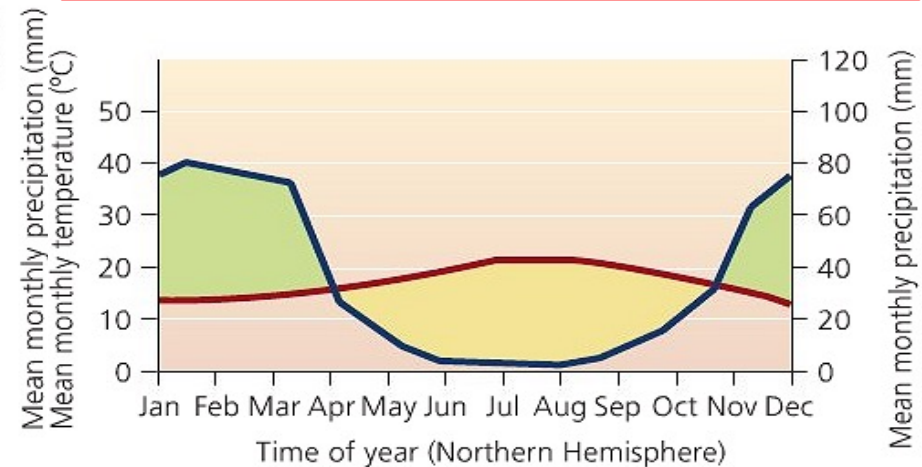
**Chapparral**



Stable lower temperatures.



Varied seasonal temperatures.



Stable temperatures.

Source: Withgott and Brennan: Environment, Pearson 2008

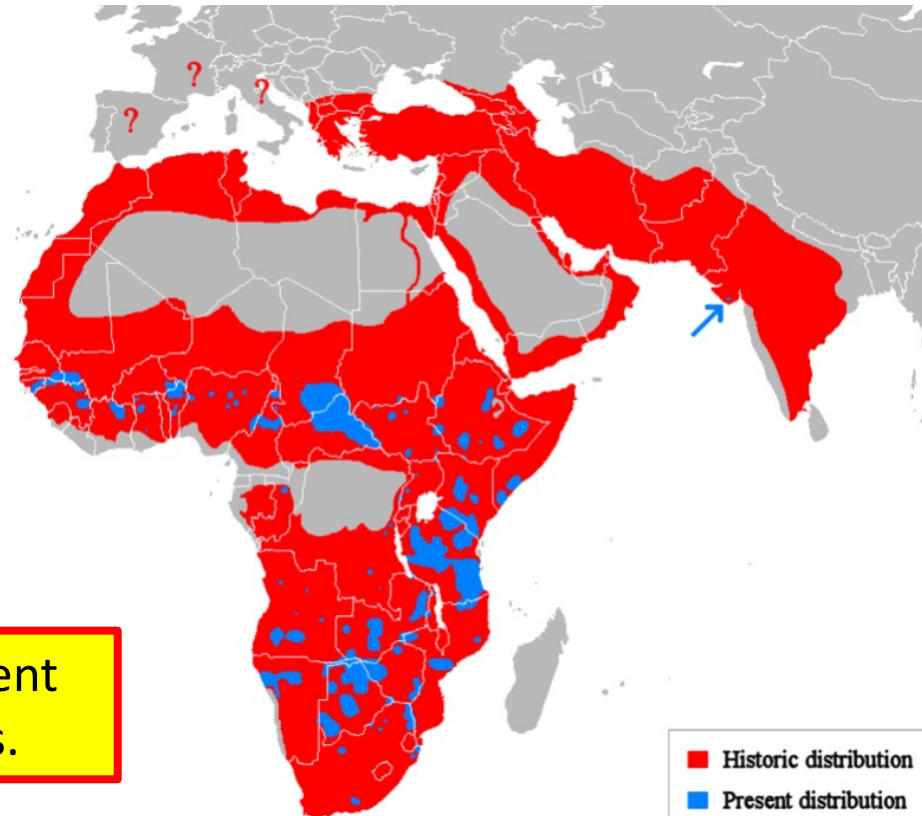
# Spatial Classification of Earth's Ecological System: Ecoregions and Habitats.

- **Ecoregion (bioregion/biogeographic region):**
  - ecologically and geographically defined area containing a characteristic, geographically distinct assemblage of species.
  - WWF identified 825 terrestrial ecoregions and approximately 450 freshwater ecoregions (like Himalaya, Sahara, Australian coral reef, mangrove swamps).

- **Habitat:**

- ecological or environmental area inhabited by a particular species.

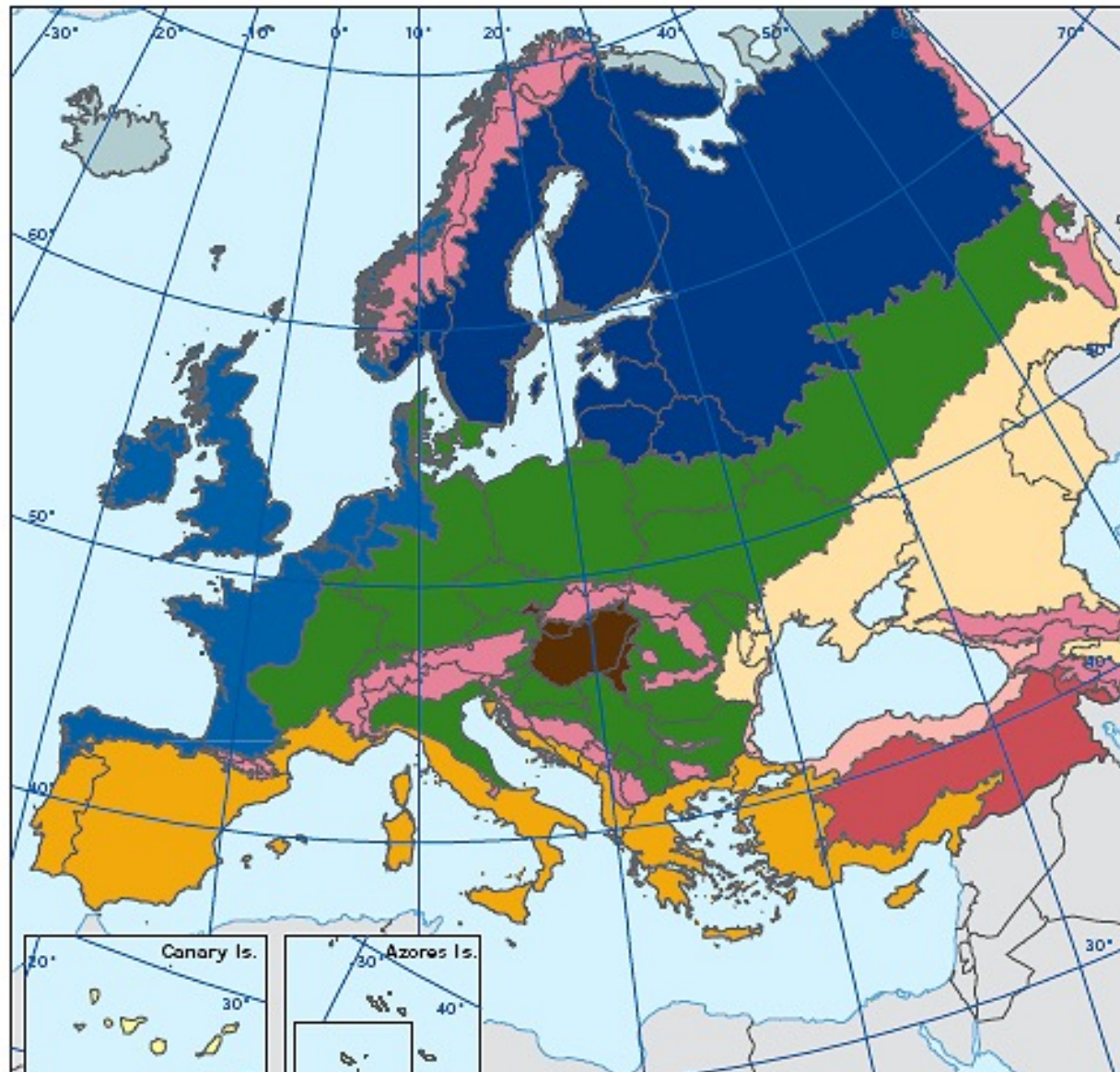
Historic and present habitats of lions.



Shrinking habitats of wild animals pose a massive threat towards these species.

Source: Facebook 2024

# Biogeographic Regions of Europe.



Biogeographic regions  
in Europe, 2011

- Alpine
- Anatolian
- Arctic
- Atlantic
- Black Sea
- Boreal
- Continental
- Macaronesia
- Mediterranean
- Pannonian
- Steppic
- Outside data coverage

**Boreal region:**

0,6 million km<sup>2</sup>

**Continental**

**region:**

2,7 million km<sup>2</sup>

**Mediterranean**

**region:**

1,2 million km<sup>2</sup>



Iceland



Austria



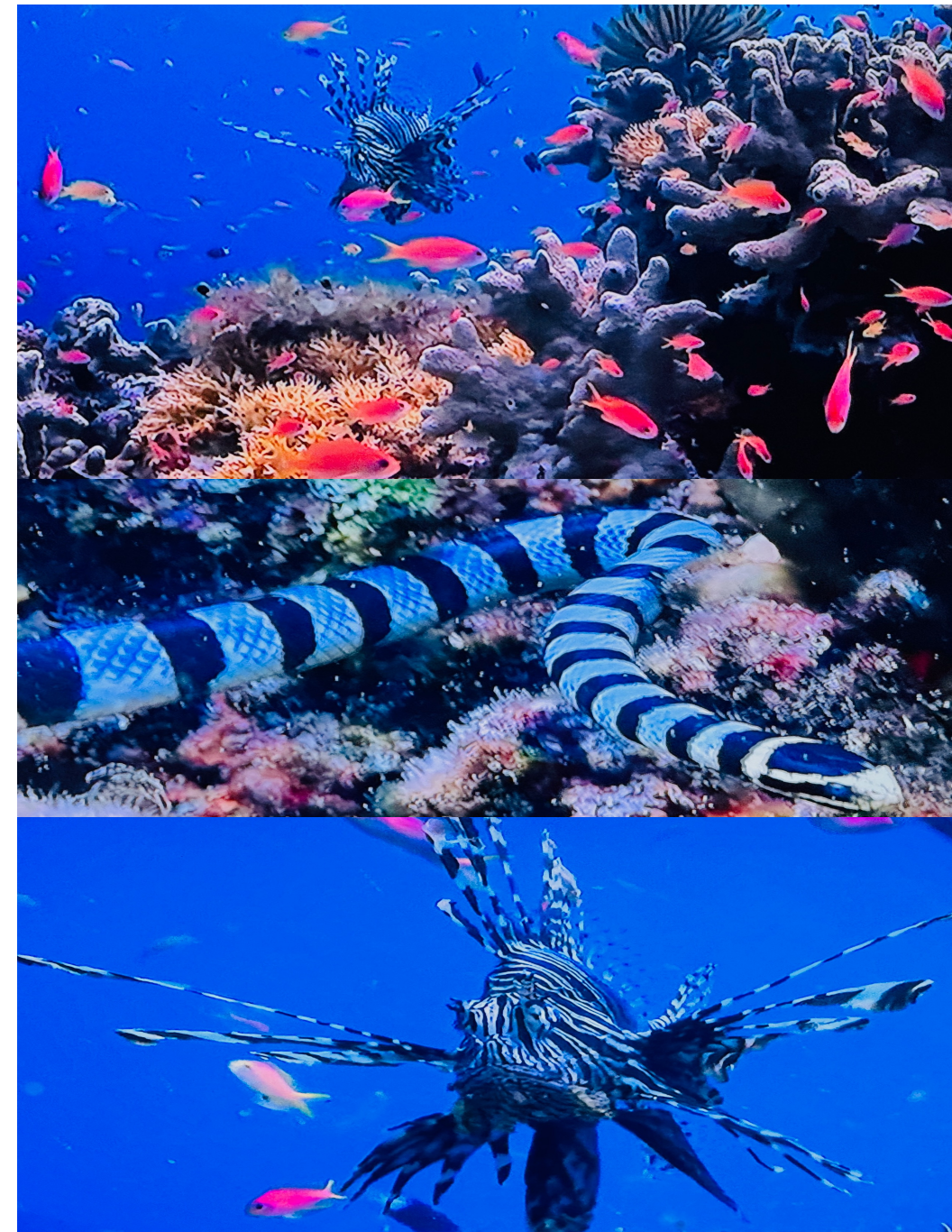
Spain

# Dynamics of Ecosystems.

- **Ecosystem:** Natural unit consisting of all plants, animals and micro-organisms (biotic factors) in an area functioning together with all of the non-living physical (abiotic) factors of the environment.
- **Ecosystem dynamics:**
  - Primarily stochastic (chance) events.
  - Introduction of new elements: possible disruptive effects, which in some cases, can lead to ecological collapse.
  - Ecosystems have the (limited) ability to rebound from a disruptive agent.
  - Difference between collapse or rebound determined by the toxicity of the introduced element and the resilience of the original ecosystem.

## Example of stressed ecosystem: Coral reefs

- **Massive damages:**
  - Bleaching of corals.
  - Reduction of species.
- **Possible causes:**
  - Increase of ocean temperature.
  - Increase of acidity of water.
  - Unknown diseases.



# Sensitive Ecosystems: Coral Reefs.

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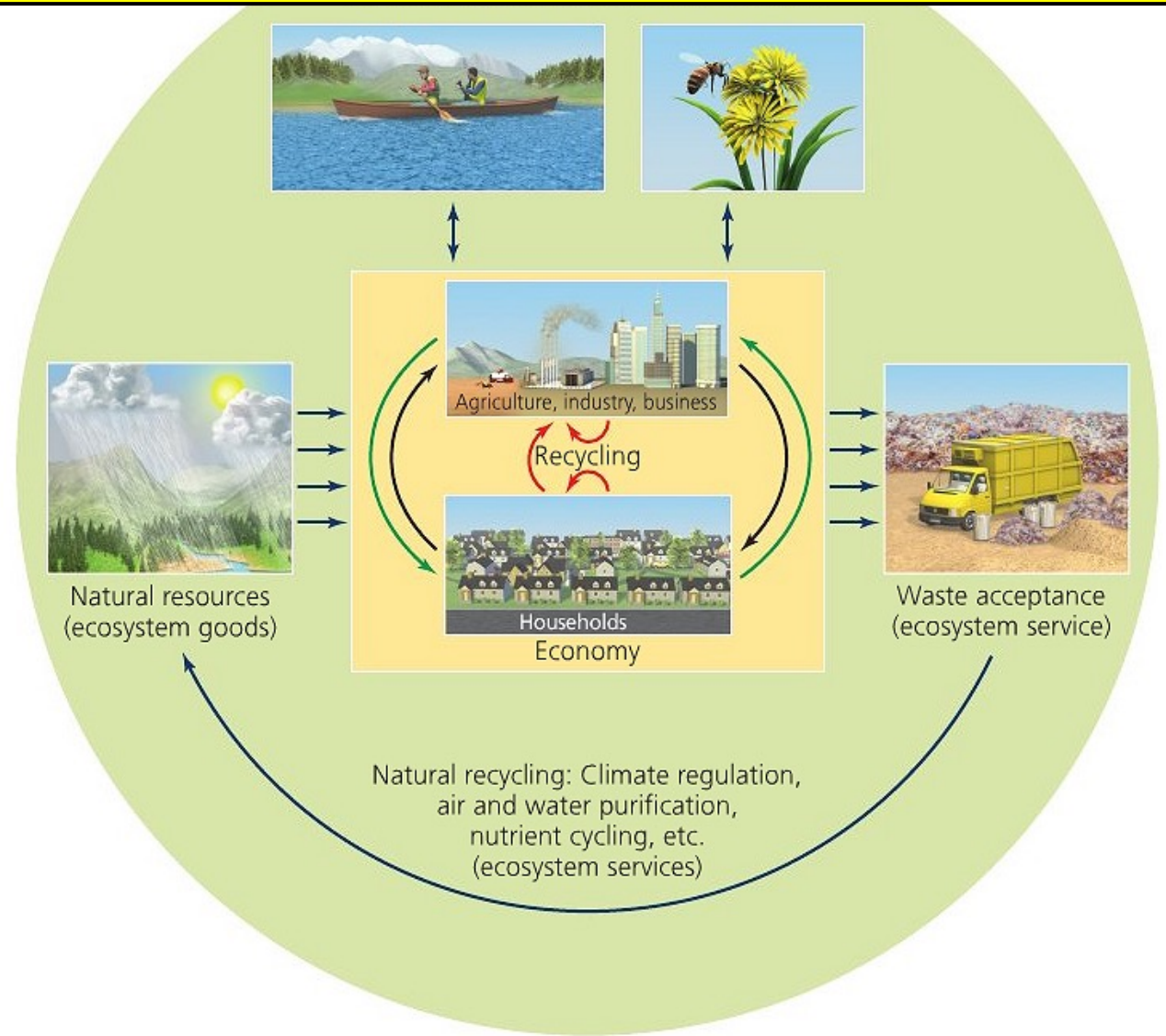
Source: Phoenix 2024

## 2.2 Biosphere.

- **Biosphere:**

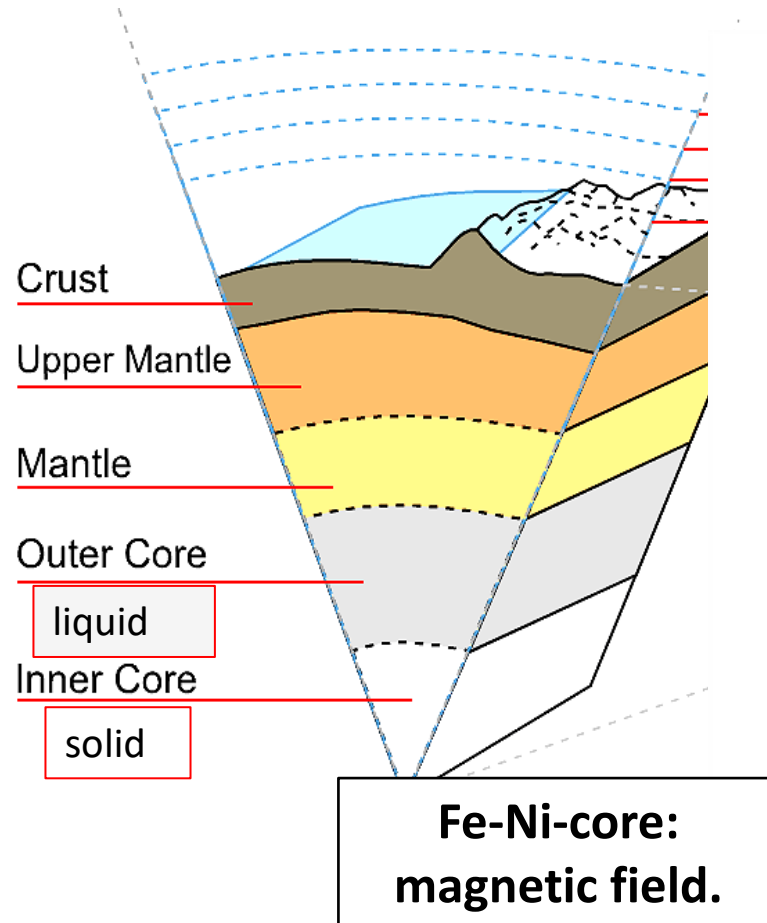
- Global ecological system integrating all living beings and their relationships, including their interaction with the elements of the lithosphere, hydrosphere, and atmosphere.
- Evolution of our biosphere began through a process of biogenesis 3.5 billion years ago.
- Biosphere comprises all of the Earth's biomes.
- Biosphere is a very thin surface layer which extends from 11,000 meters below sea level to 15,000 meters above.
- Life can be found in the deep seas and highest altitudes.

The biosphere provides “fundamental life-support services upon which human civilization depends”.



- **Crust (lithosphere) :**  
solid, 30–50 km thick, consisting mainly of magnesium-iron-silicates, on top thin layer of soil.
- **Upper mantle:**  
up to 200 km.
- **Lower mantle:**  
up to 2.800 km below the surface, minerals viscous.  
( $T = 1000 - 4000^{\circ}\text{C}$ ).
- **Core:**  
outer and inner core mainly iron and nickel.  
( $T = 4.000 - 6.100^{\circ}\text{C}$ ).

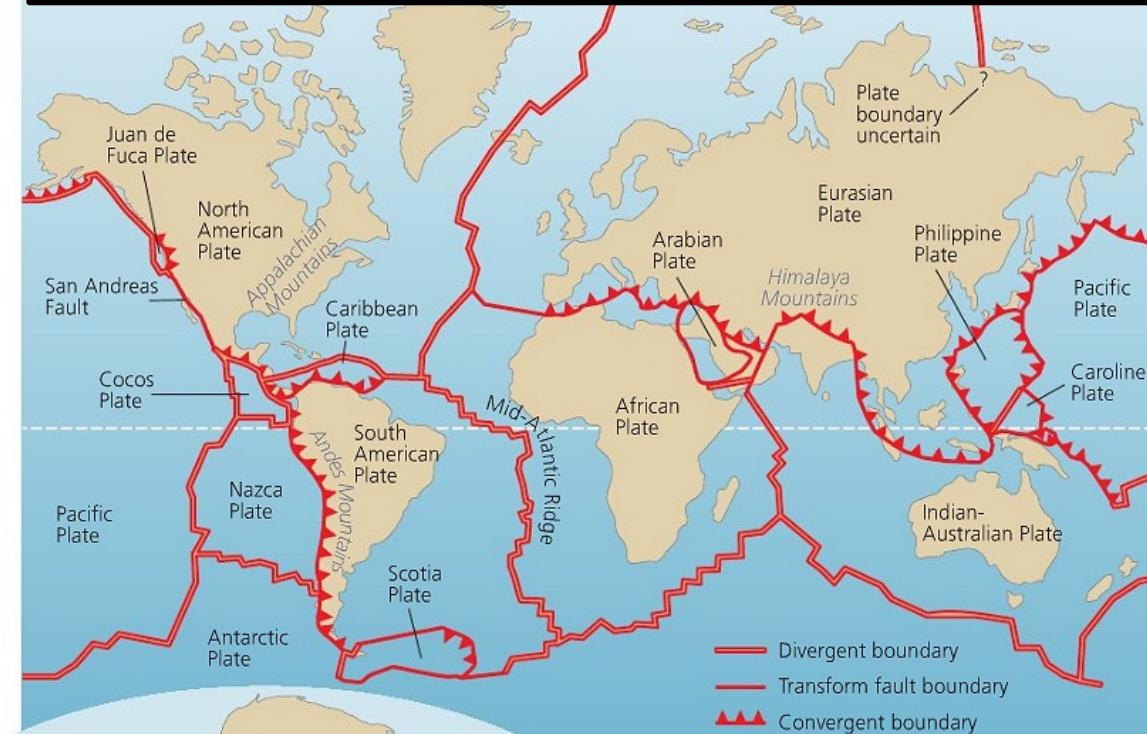
## Structure of the Earth.



Mass of earth:  
 $6 \times 10^{21}$  tons  
gravitational field.

## Earth's crust:

15 major plates moving at rates of 2–15 cm/yr

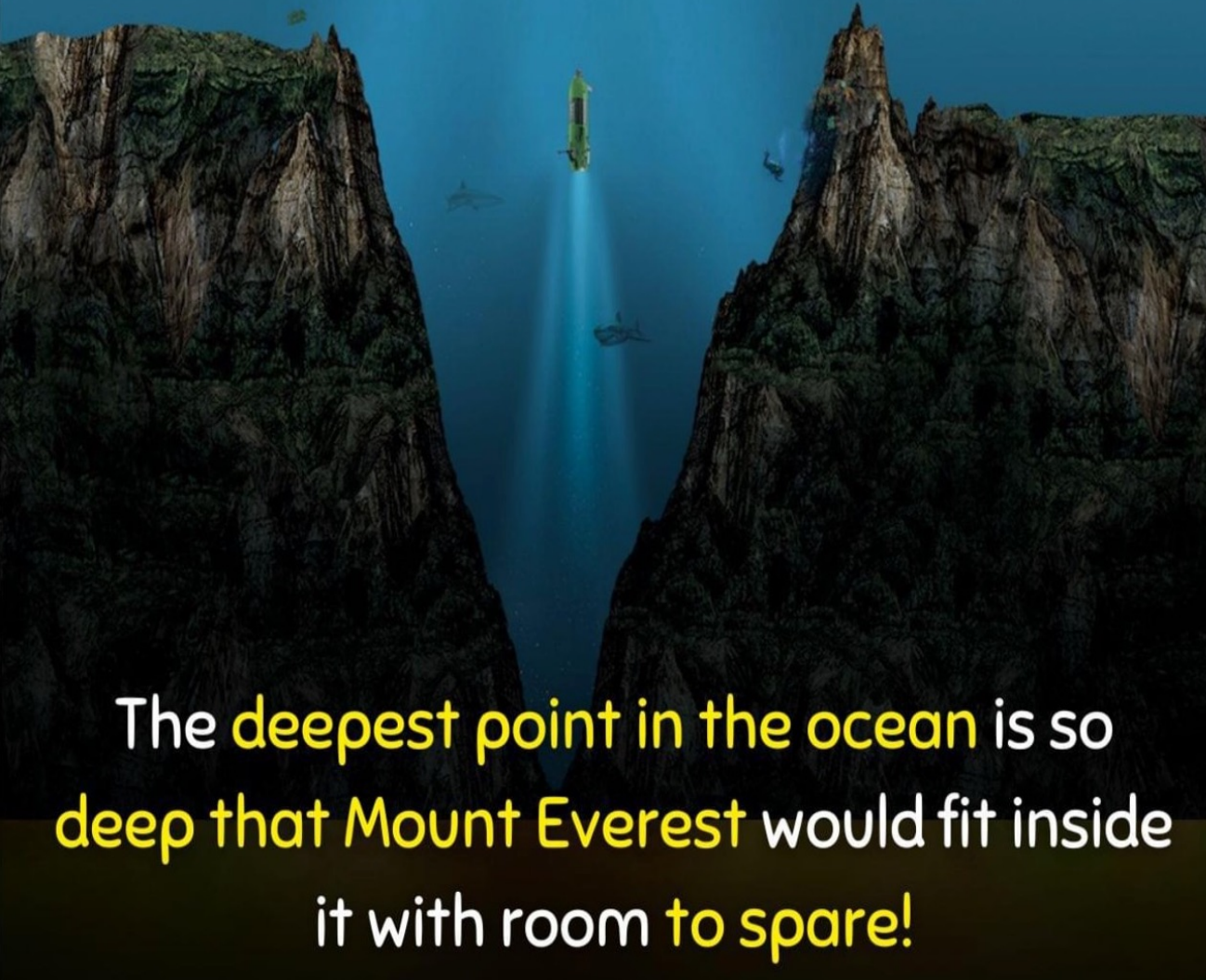


- Movements have greatly influenced the evolution of climate and life.
- Plate movement leads to volcanic activity, earthquakes and tsunamis.

• Originally one supercontinent „pangea“.



Mariana Trench, located in the Pacific Ocean  
12.000 m deep!

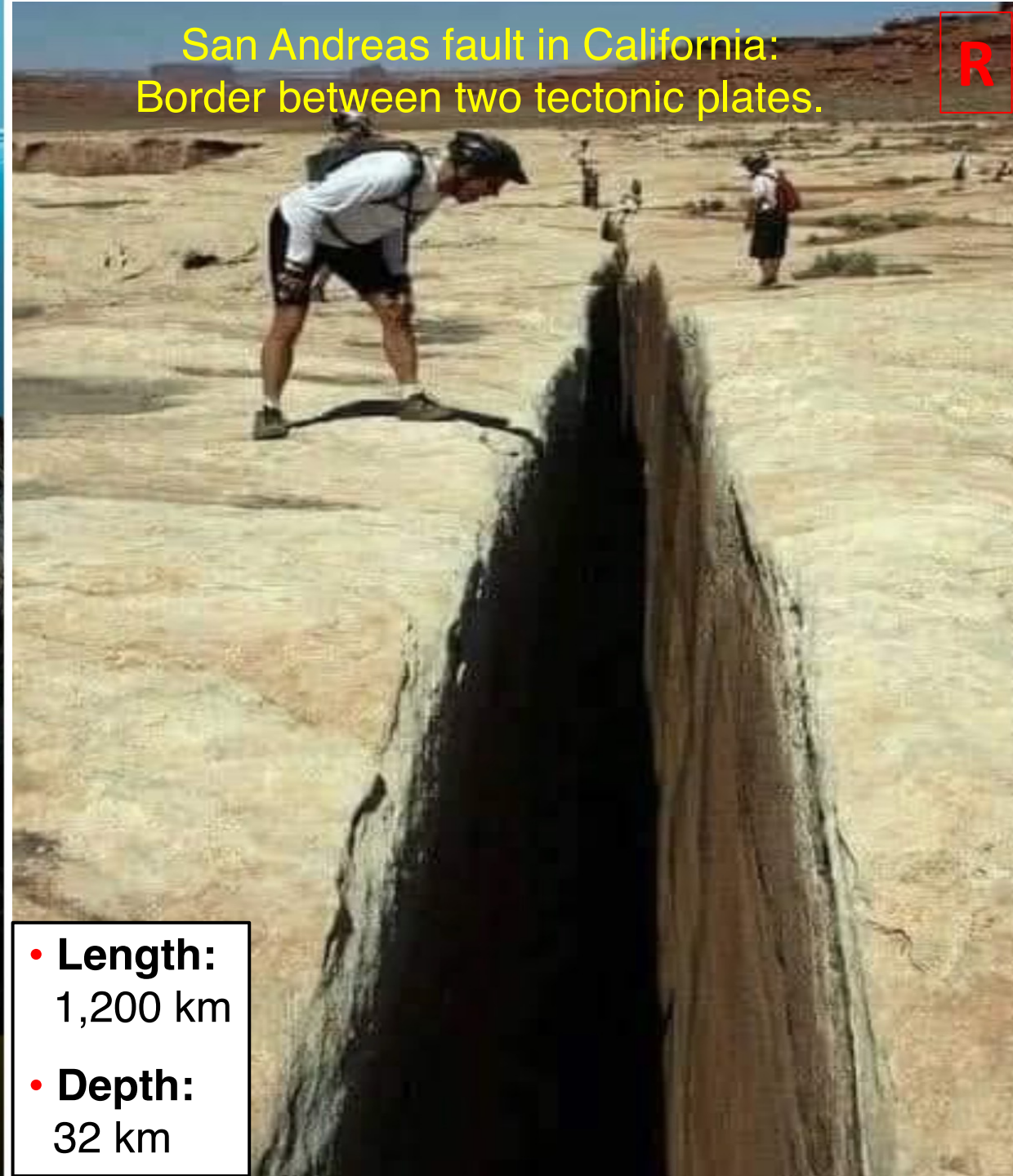


The **deepest point in the ocean** is so  
**deep that Mount Everest** would fit inside  
it with room **to spare!**

San Andreas fault in California:  
Border between two tectonic plates.

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- **Length:**  
1,200 km
- **Depth:**  
32 km





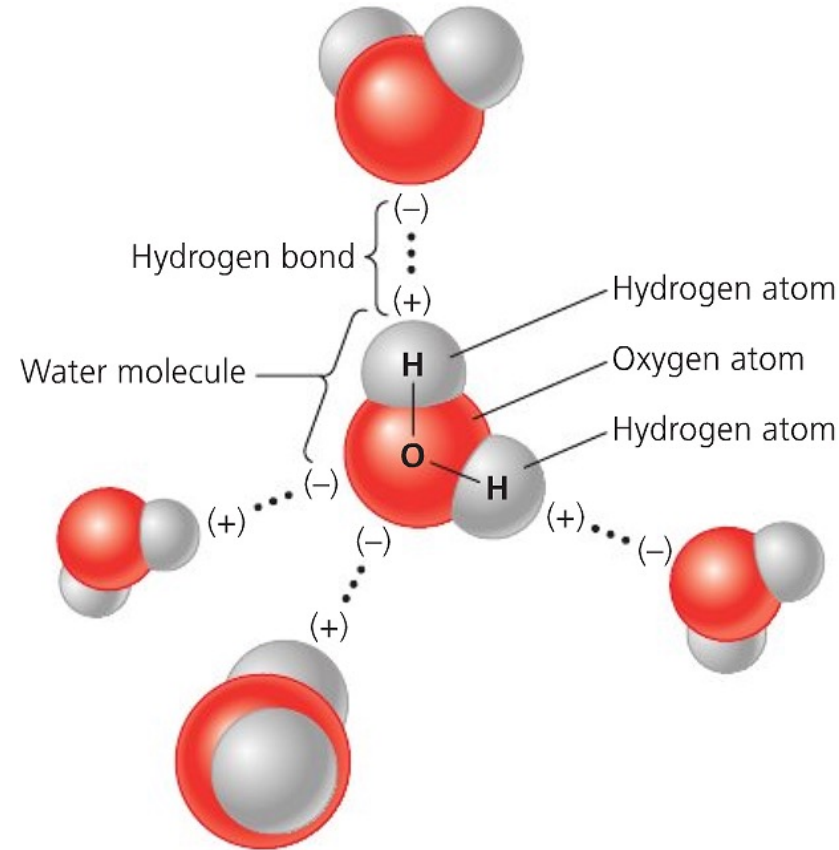
Water in three states: Liquid, solid (ice), and vapor in air. Clouds are droplets of liquid, condensed from water vapor.

- **Maximum density of water at 4°C:**

- Cold water sinks to the bottom of water bodies and creates circulation and supply of nutrients and oxygen for living species.
- Ice floats on water protecting lower layers from freezing.

# Hydrosphere.

## The Structure and Properties of Water.



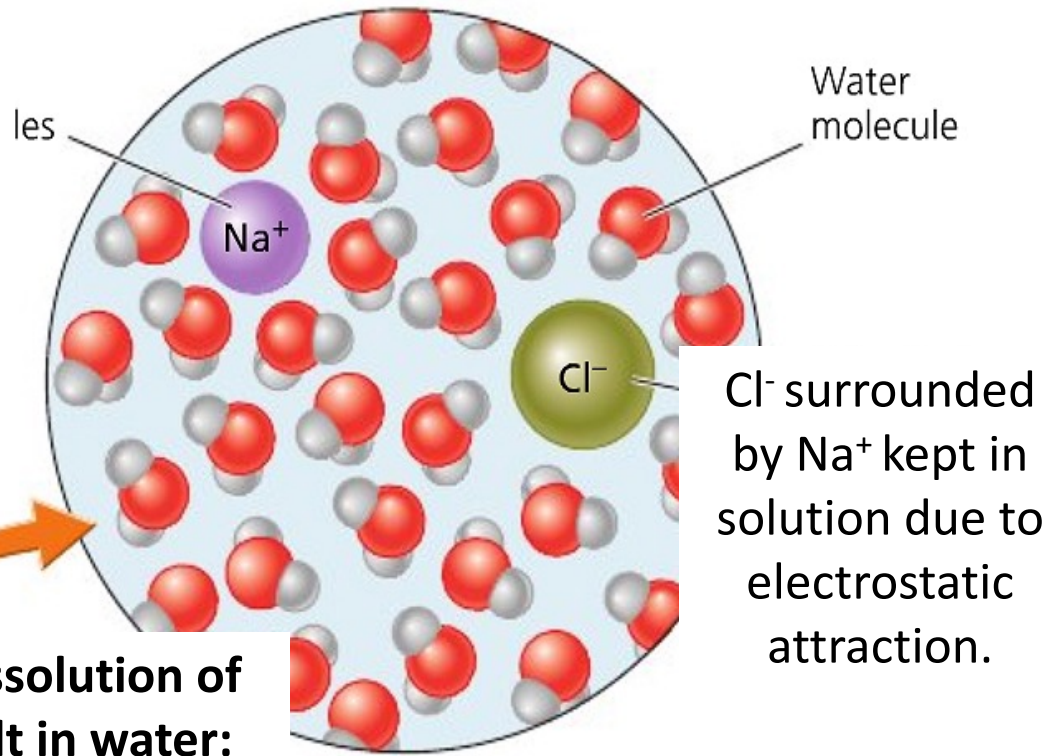
- **Water molecule: very high dipole moment giving water special properties:**

- liquid state at normal environmental temperatures due to high cohesive forces,
- high solubility for nutrients and gases like oxygen due to strong interaction with other polar molecules,
- reduction of temperature extremes on earth due to high heat capacity allowing water bodies to absorb huge amounts of heat.

*Source: Withgott and Brennan: Environment, Pearson 2008*

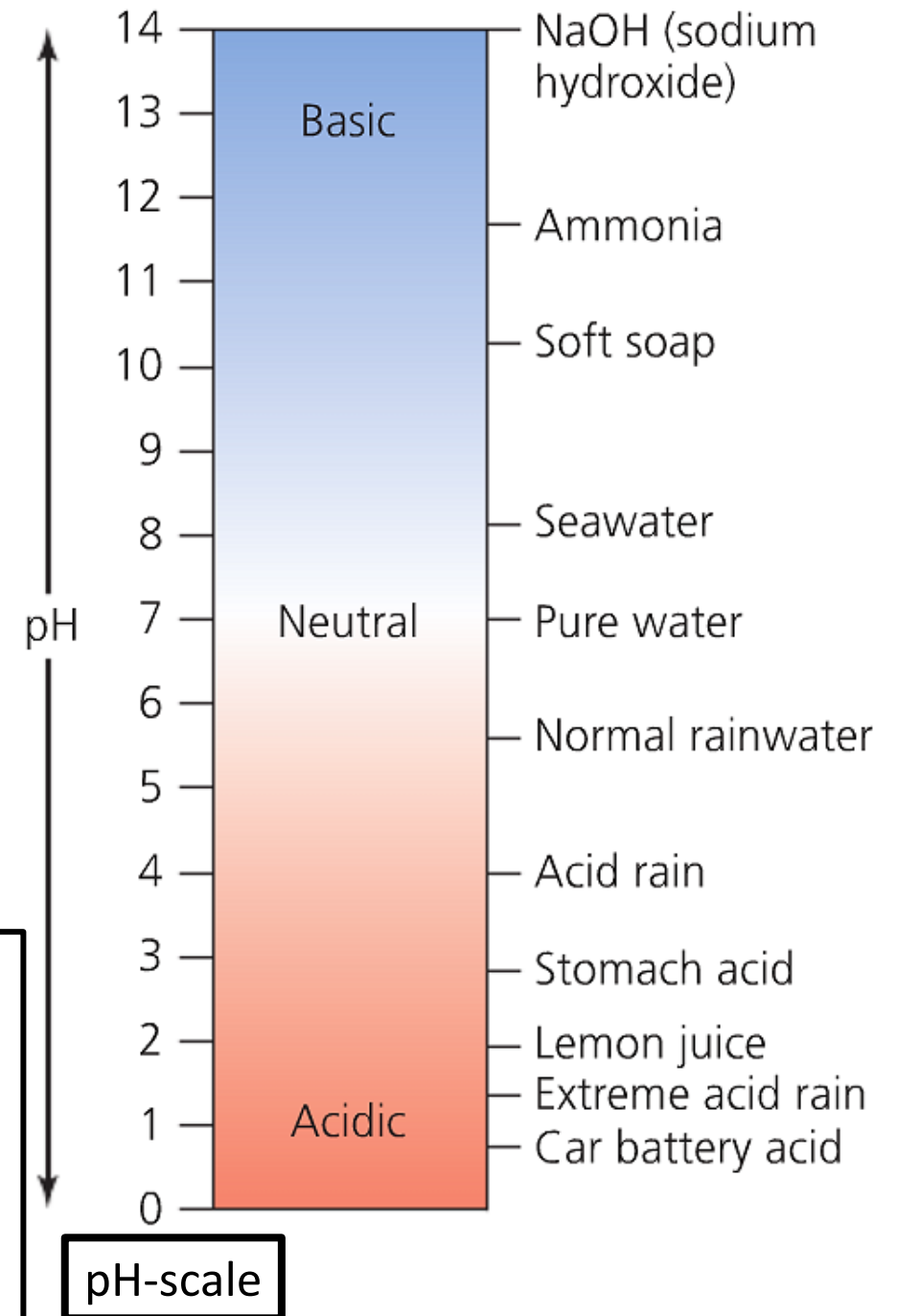
Na<sup>+</sup> surrounded by water molecules kept in solution due to electrostatic attraction by electronegative oxygen atoms.

## Water as a Solvent.



**Dissolution of salt in water:**  
 $\text{NaCl} = \text{Na}^+ + \text{Cl}^-$   
 (dissociation)

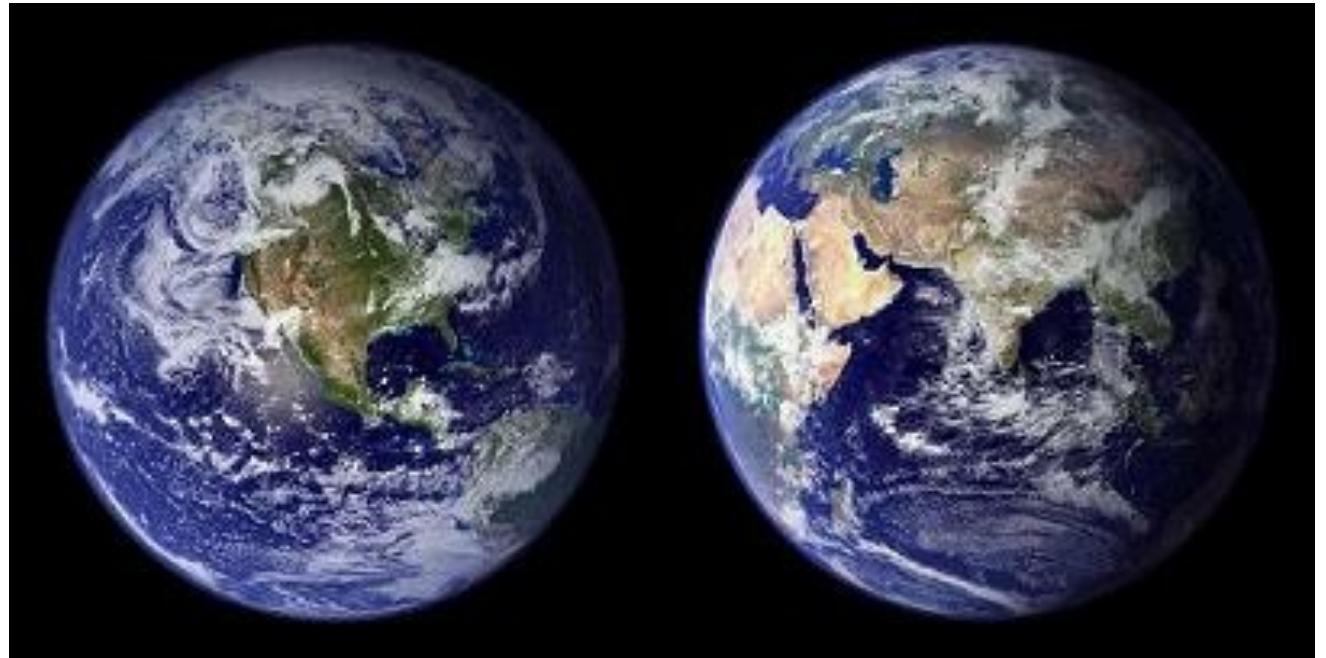
- Chemical compounds dissolved in water determine the acidity:
  - Acidity expressed as a pH value:  
 $\text{pH} = -\log [\text{H}^+]$
  - pH-scale comprises 14 orders of magnitude.
  - Some substances make water acidic ( $\text{pH} < 7$ ), others basic ( $\text{pH} > 7$ ).



# Hydrosphere.

- **Theories for Origin of Water on Earth:**

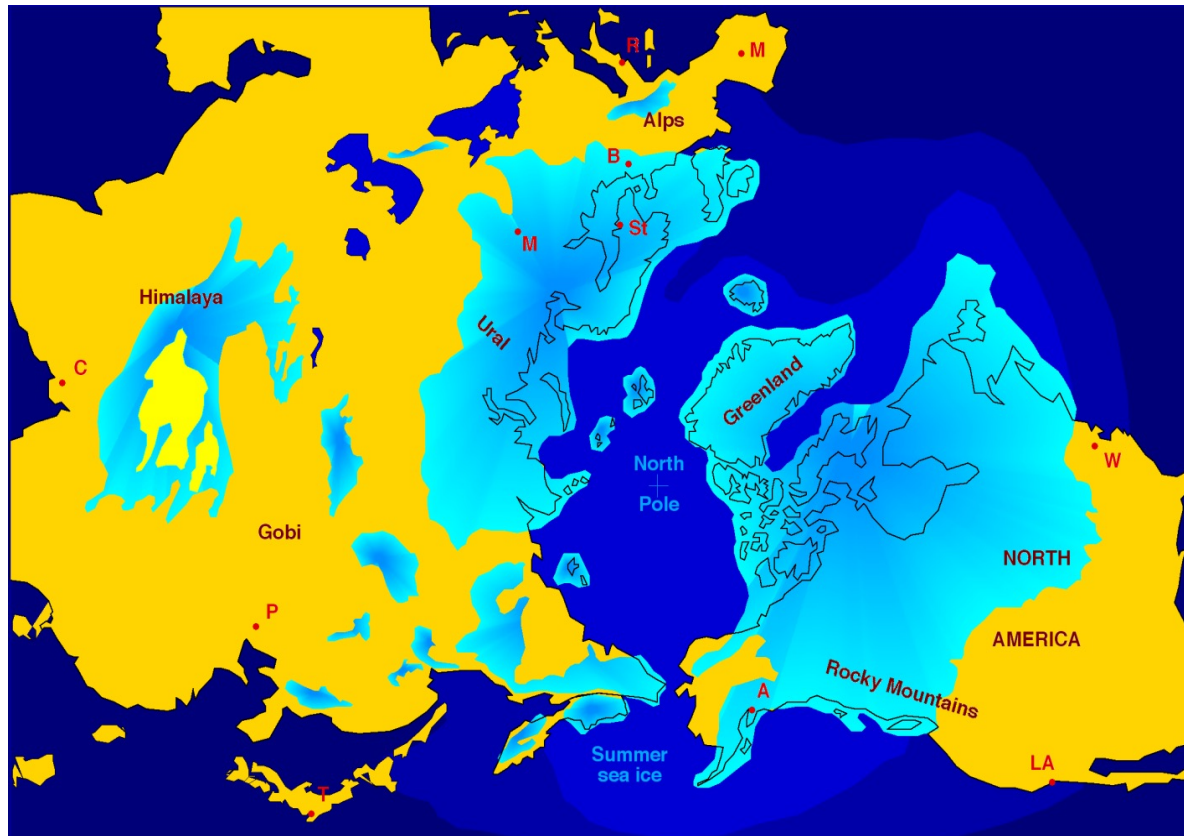
- „Classical Theory“: early earth subjected to a period of bombardment by comets and water-rich asteroids. Problem:  $^1\text{H}/^2\text{H}$  ratio of outer space water as measured by Rosetta at comet 67P/Churyumov–Gerasimenko in 2014 is very different from water on earth.
- „New Theory“: Outgassing of water from the interior of the Earth. Minerals of mantles contain 2-5% water. Sufficient to form oceans during 1 billion years.



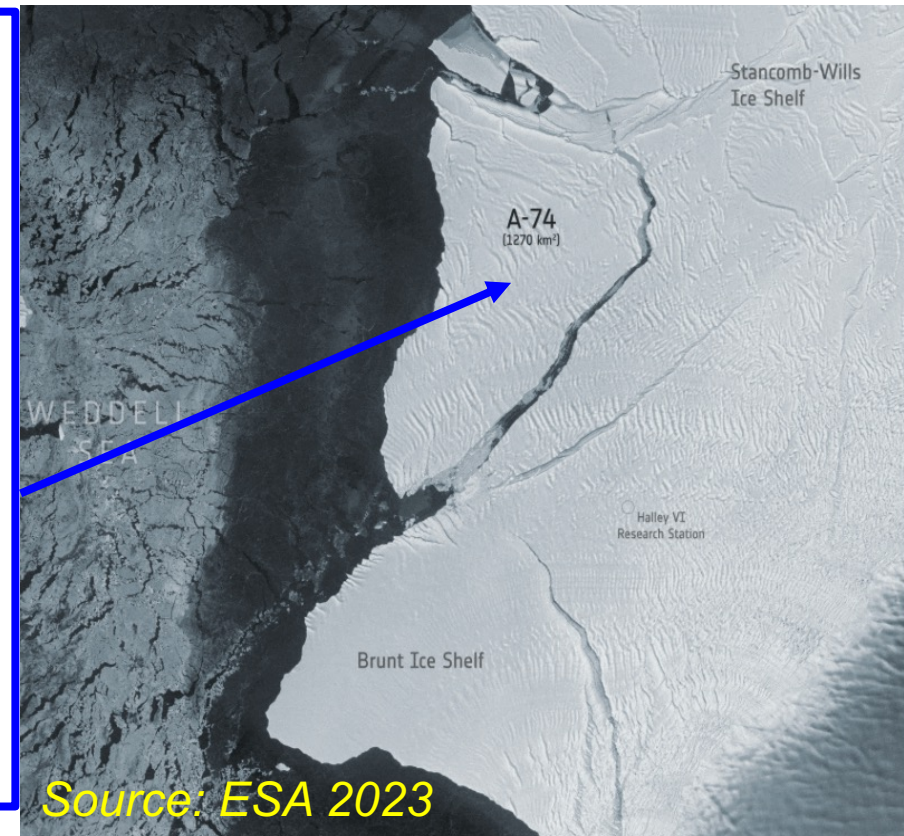
- The abundance of water on Earth is a unique feature that distinguishes our "Blue Planet" from others in the solar system.
- Approximately 70.8 percent of the Earth is covered by water and only 29.2 percent is landmass.
- 97% of the planets water resources are sea water and (only) 3% fresh water.
- Earth is actually beyond the outer edge of the orbits which would be warm enough to form liquid water.
- Without the greenhouse effect caused by water vapor Earth's average surface temperature would be - 15°C (as opposed to + 14°C) and all oceans frozen.

# Hydrosphere: The Ice Ages.

- During the history of the Earth there have been a series of periods – probably four - in which a significant portion of the hydrosphere was locked up in the form of glacial ice.
- The set up of 3 to 4 km thick ice sheets caused a sea level lowering of about 120 m.
- The last ice age began about 40 million years ago and ended about 10.000 BC.
- In present interglacial period average global temperatures are typically 5°C higher.
- Predicted changes in orbital forcing suggest that the next glacial period would occur in 50.000 years from now.



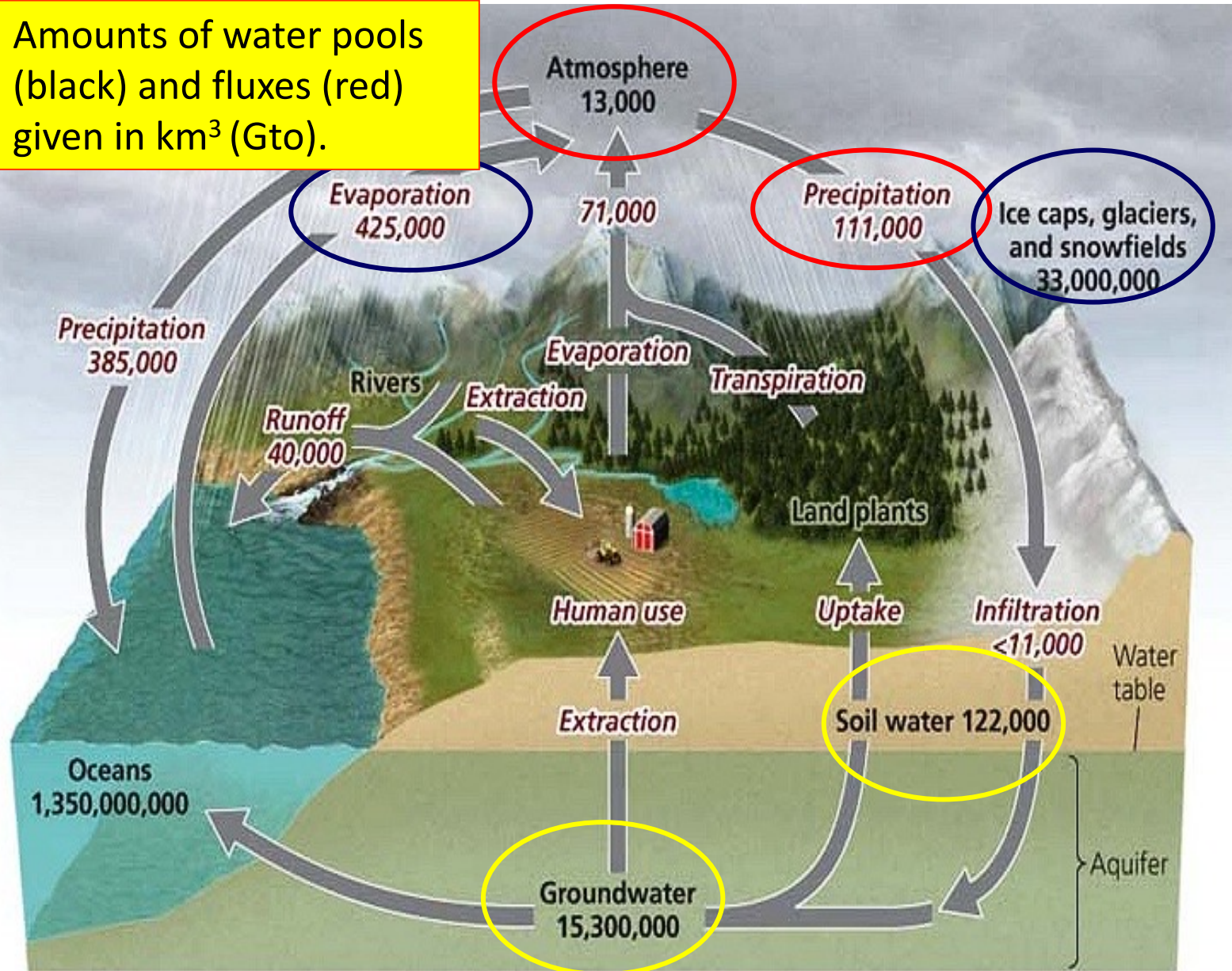
**Largest reservoir of ice:**  
Antarctic ice shield.  
Iceberg breaking off has the size of 1,585 km<sup>2</sup> (4x Vienna).  
Melting of Arctic ice shield would cause a sea level rise of 60m.



Source: ESA 2023

# Hydrosphere: The Water Cycle.

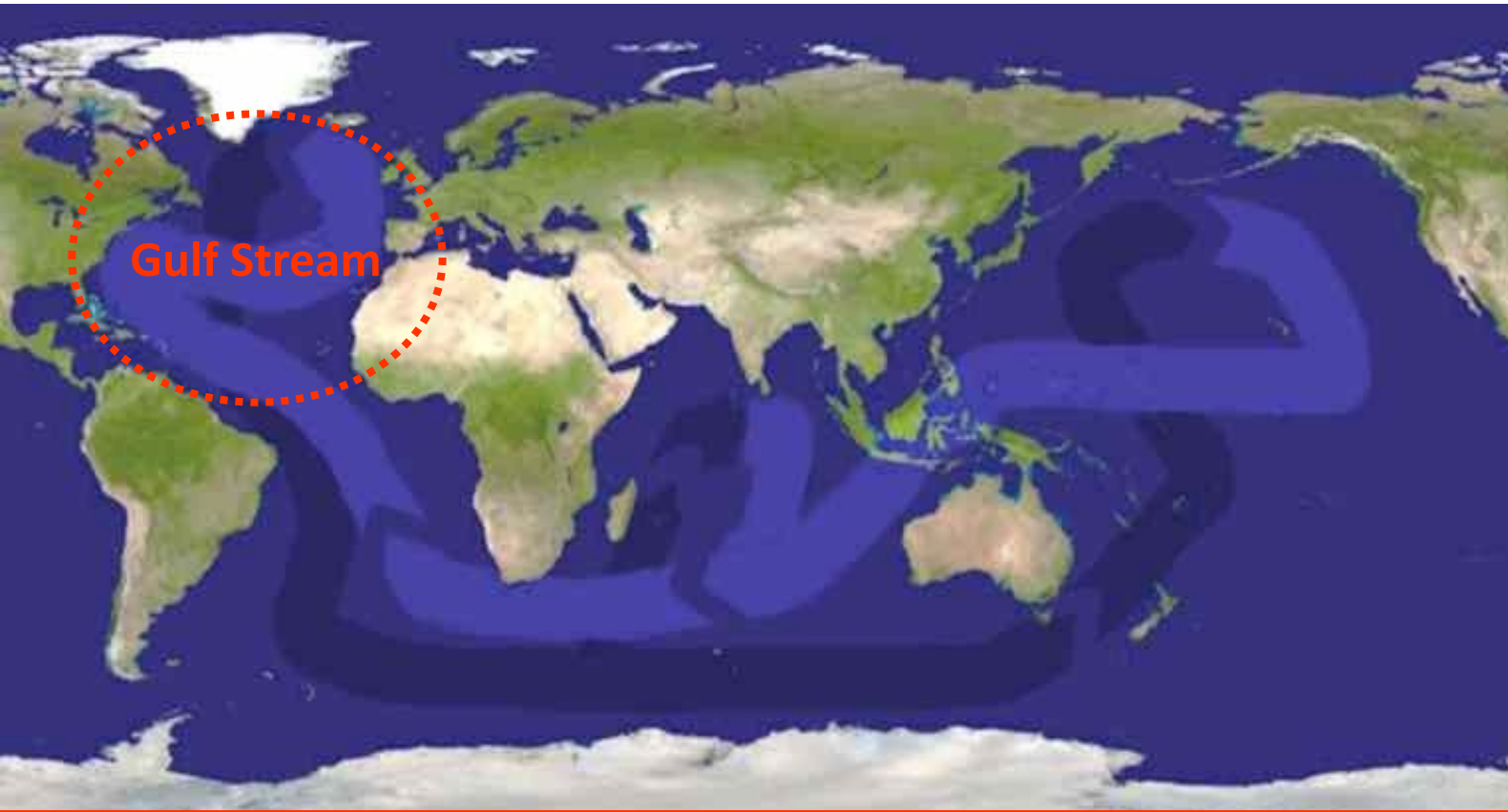
Amounts of water pools (black) and fluxes (red) given in km<sup>3</sup> (Gto).



- The water cycle describes the transport of water in the hydrosphere.
- All currently recognized forms of life rely on an active hydrosphere.
- Evaporation leads to significant amounts of water in the atmosphere (1%), which can form clouds by condensation and lead to precipitation.
- Evaporation of water from oceans and subsequent precipitation allow for the purification of salt water into fresh water.
- Precipitation also removes a large portion of pollutants from the atmosphere.

# Hydrosphere: The Oceans.

- Comprise 97% of the planet's water.
- The tremendous heat capacity of the oceans moderates the planet's climate.
- Absorption of gases affects the composition of the atmosphere ( $\text{CO}_2$ ).
- Surface temperature: from below freezing near the poles, up to  $35^\circ\text{C}$  in restricted tropical seas.
- Salinity can vary from 1.0-4.1%.

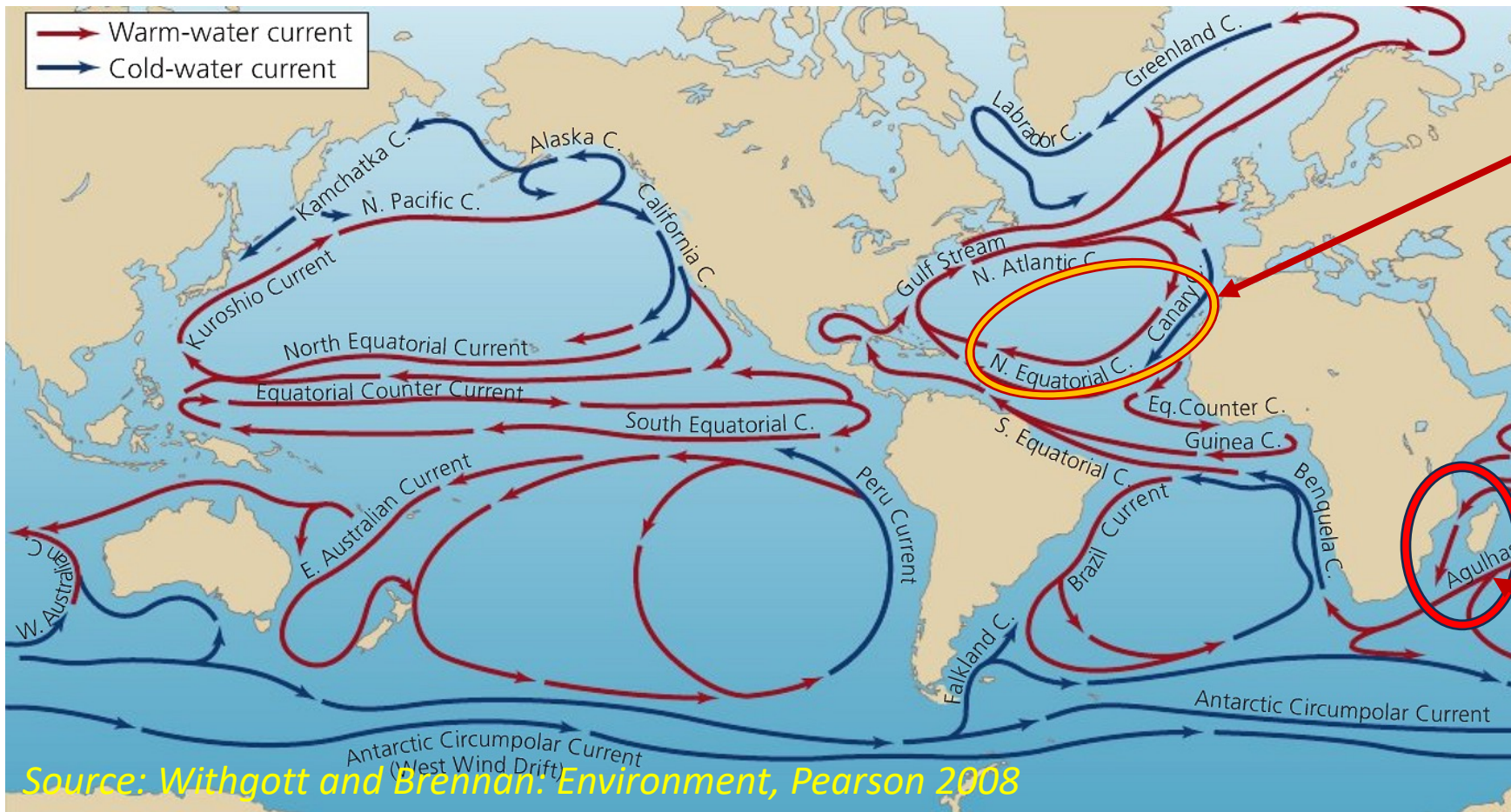


- Thermohaline circulation (THC):**
  - Refers to the part of the large-scale ocean circulation that is driven by global density gradients created by surface heat and freshwater fluxes.
  - The THC is sometimes called the ocean conveyor belt.
  - One of the most important thermohaline circulations is the Gulf Stream originating in the Caribbean, moving North-East, passing Europe and sinking to the bottom near Greenland providing for a backflow of the water to the Caribbean.

Density driven thermohaline circulation: Darker arrows represent deep-water currents, while lighter arrows represent surface currents.

# Hydrosphere: The Ocean Flows.

- The earth's ocean is composed of huge river-like flows caused mainly by density differences, heating and cooling and wind.
- Horizontal currents flow in the upper 400 m over thousands of kilometers.
- Important for the transport of heat, nutrients, pollutants and marine species.
- Ocean currents were extremely important for shipping in the past.



Columbus sailing to America on Santa Maria 1492.

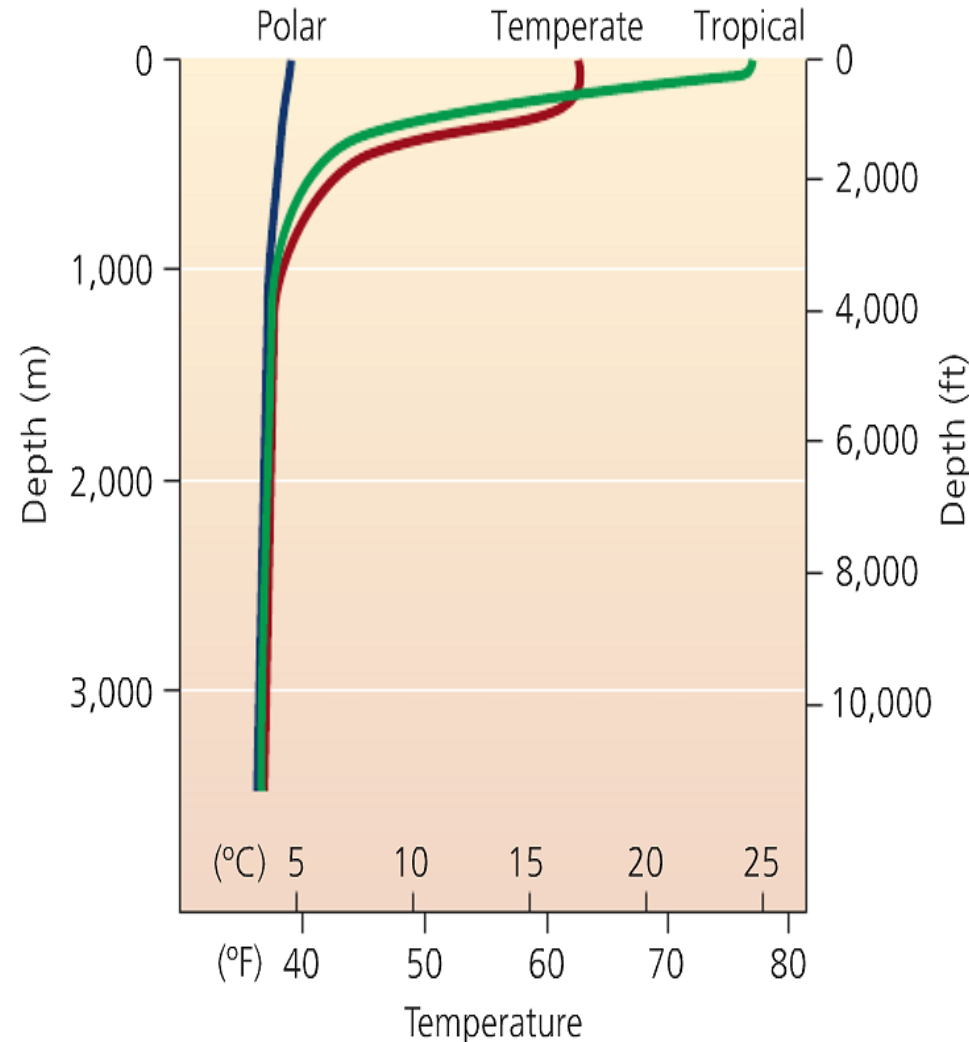


Bartolomeo Diaz sailing around Africa trying to reach India 1488.

# Hydrosphere: The Oceans.

- **Chemical composition of ocean water:**

- Ocean water contains on the average ca 3,5 % salt which increases the density of water and influences the ocean currents, like the gulf stream.
- In addition nutrients occur in sea water in trace amounts (important for life in the marine ecosystems).
- Sea water contains dissolved gases, like oxygen produced by photosynthetic processes of plants, and phytoplankton, and carbon dioxide, mainly from exchange processes with the atmosphere.



- **Temperature profile of oceans:**

- Top 10 m surface zone absorbs 80 % of solar energy:
  - „photic zone“ - practically all of the primary production of biomass by phytoplankton.
- Phytoplankton is first step in the food chain and source of all life in the oceans.
- Beneath this layer the temperature falls rapidly:
  - „pycnoclyne zone“ till about 150 m depth rich in fish.
- Water below is nearly unaffected by winds, sunlight and temperature variations in the atmosphere.

*Source: Withgott and Brennan: Environment, Pearson 2008*

# The Atmosphere.

- The Earth's atmosphere is a layer of gases surrounding the planet Earth and retained by the Earth's gravity.

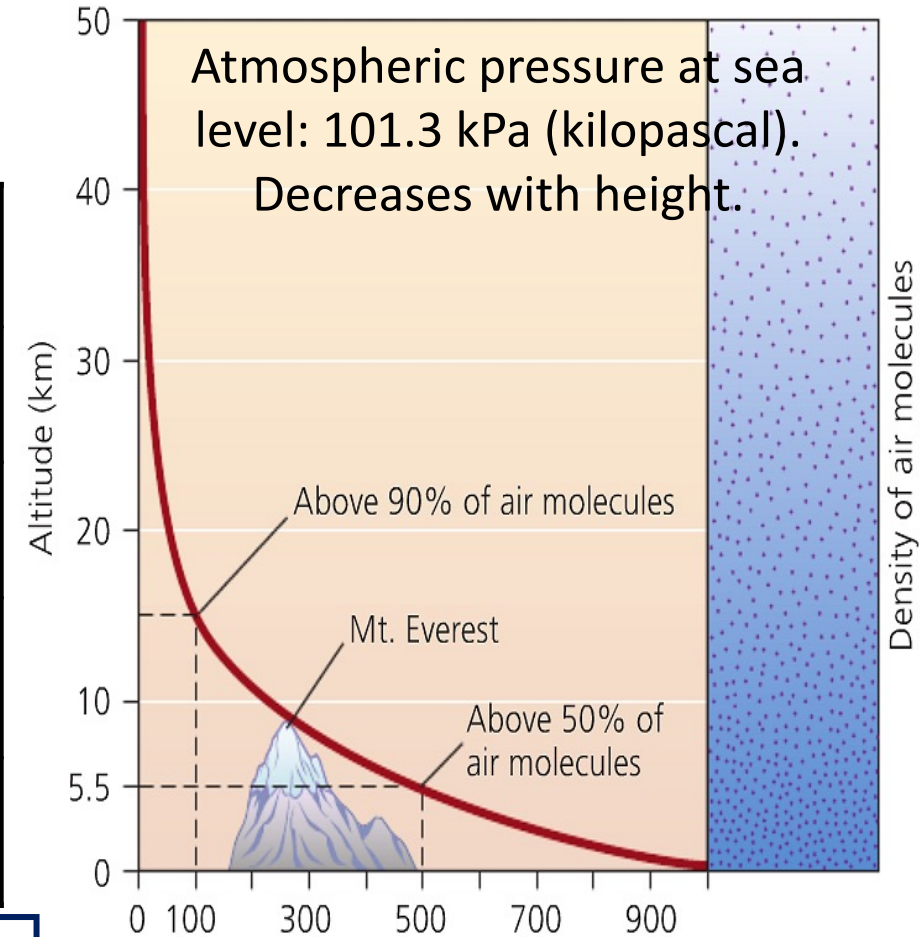


The earth seen from Apollo 17.

## Composition of the atmosphere (Vol%):

Nitrogen	78,08 %
oxygen	20,94 %
argon	0,93 %
carbon dioxide	0,04 %
trace gases	0,01%

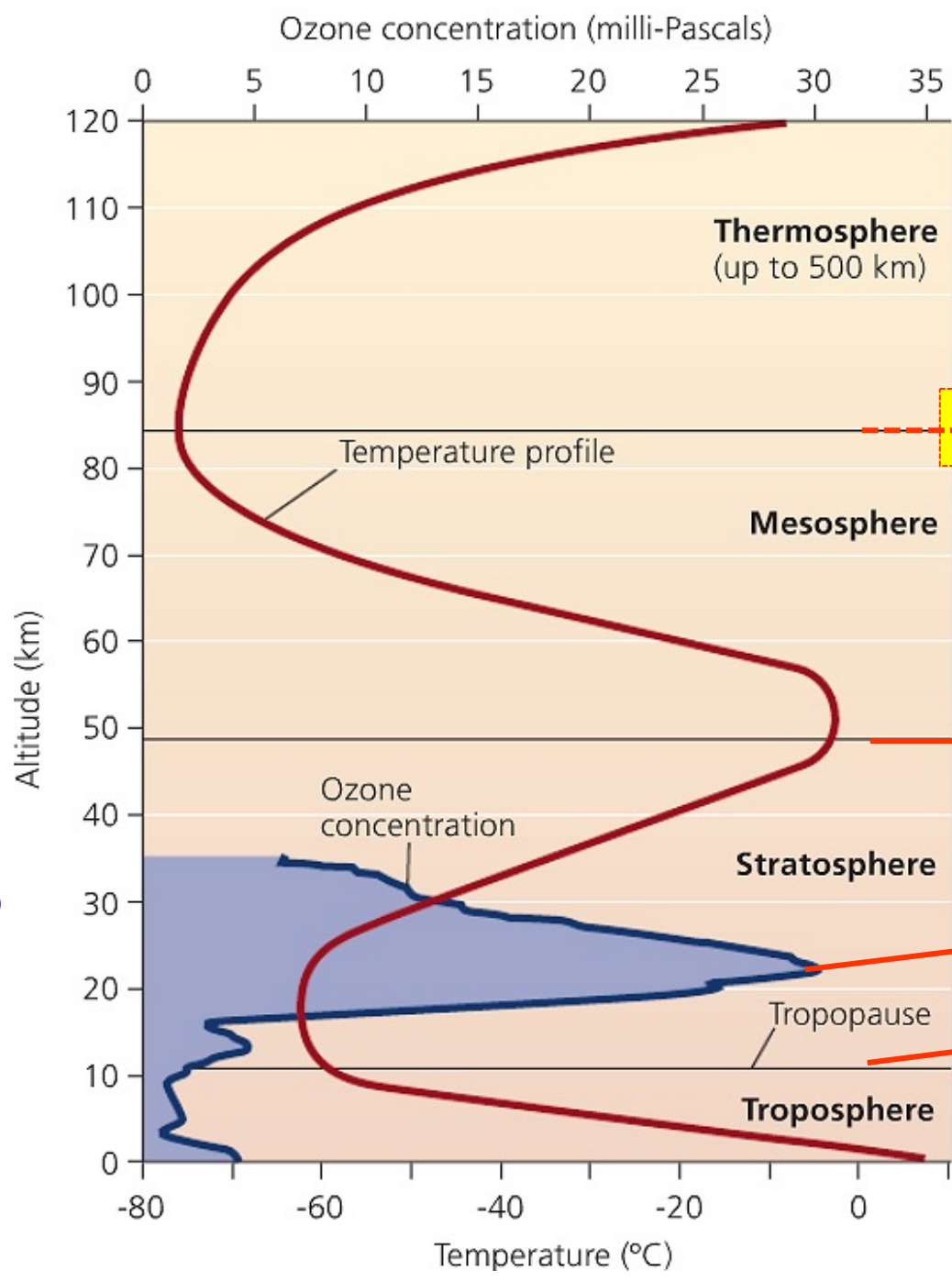
In addition: water vapour about 1% on the average.



Air pressure varies with location and time: formation of air streams and specific weather conditions (high pressure/low pressure areas).

- The atmosphere protects life on Earth by absorbing ultraviolet solar radiation and reducing temperature extremes between day and night.

Source: Withgott and Brennan: Environment, Pearson 2008



# The Atmosphere: Vertical Structure.

Atmosphere used for satellites and air traffic.

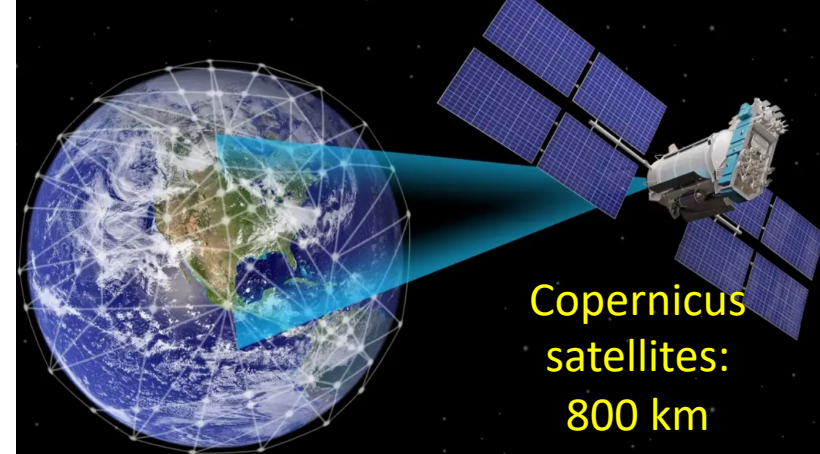
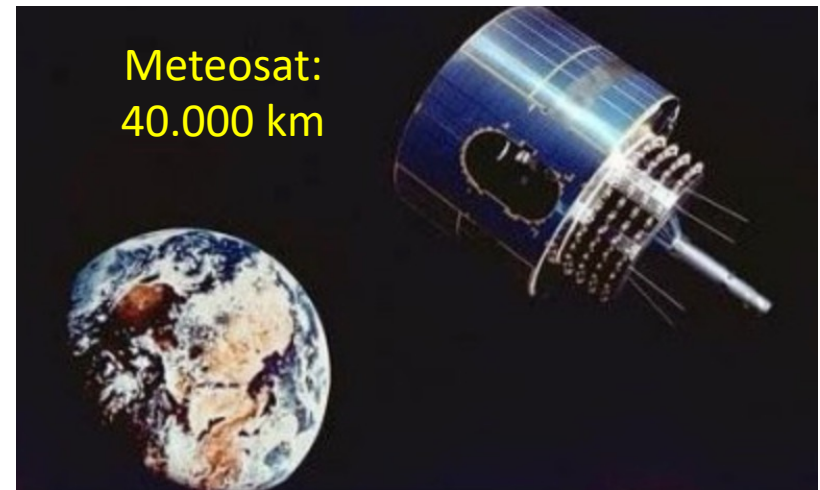
T = - 80 C in mesopause

T = + 10 C in stratopause

stratospheric ozone layer

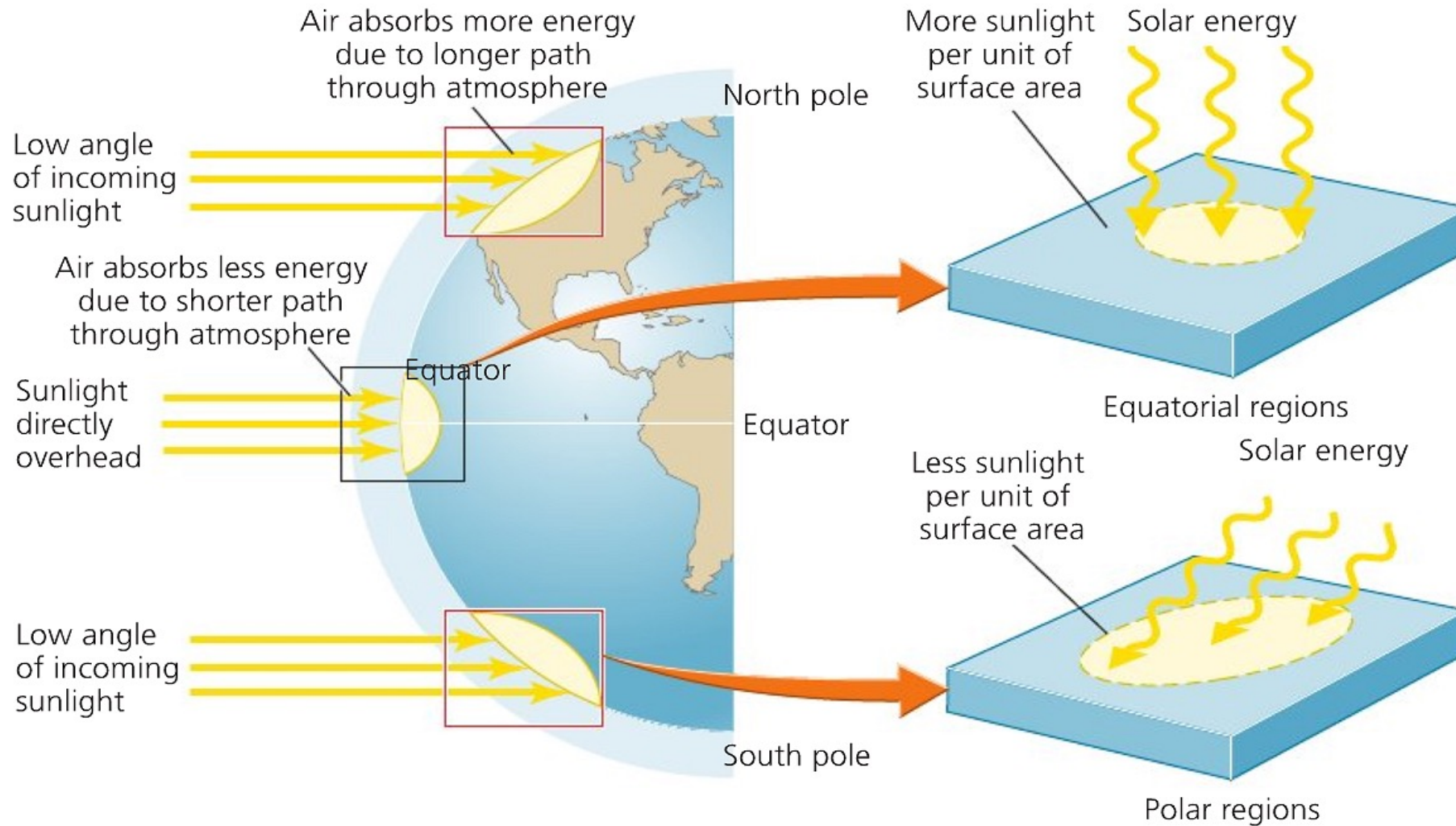
T = - 60 C in stratopause

strong vertical mixing due to solar heating at the surface: weather

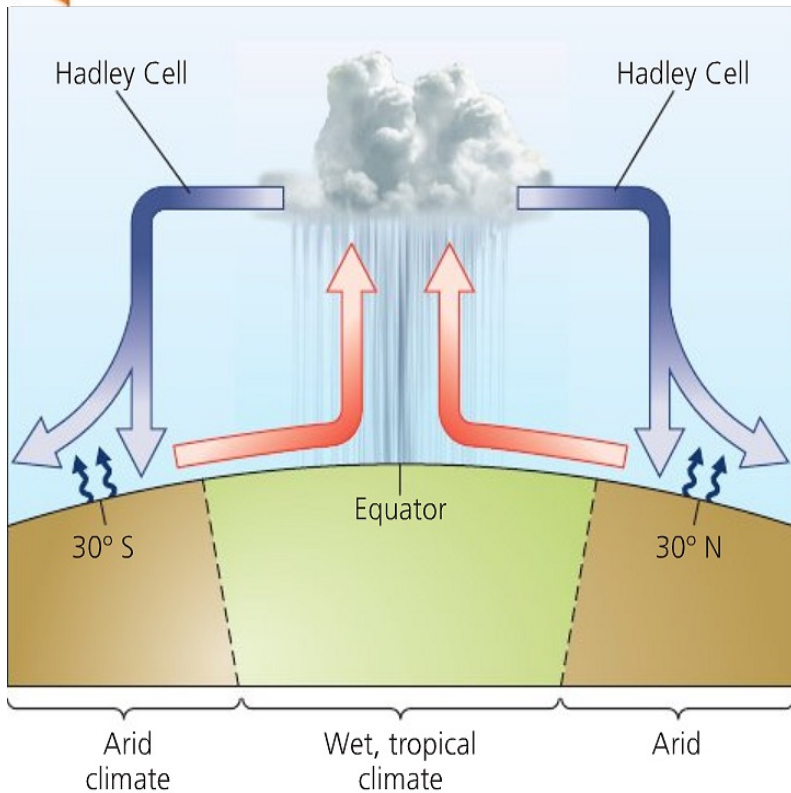
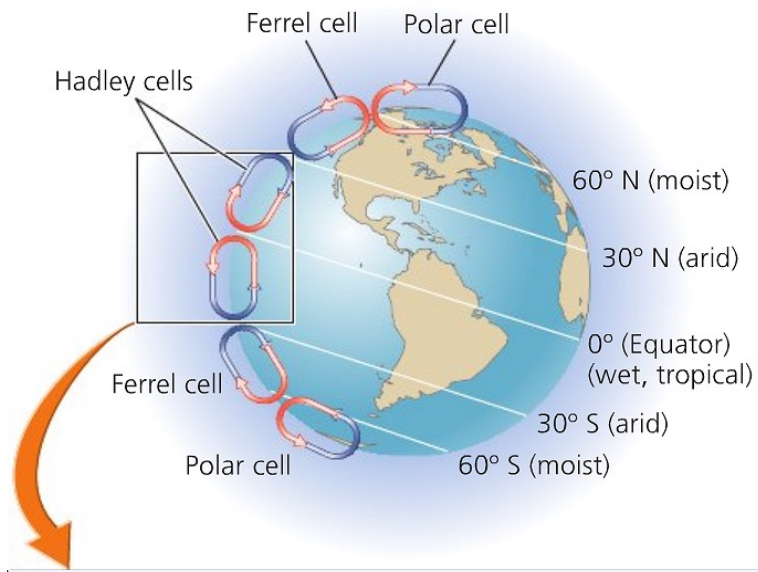


# Atmosphere: Atmospheric Circulation.

- Large scale movement of air is the main mechanism by which heat is distributed on the surface of the Earth.



- The major driving force of atmospheric circulation is solar heating, which on average is largest near the equator and smallest at the poles.
- The atmospheric circulation transports energy poleward, thus reducing the resulting equator-to-pole temperature contrast.



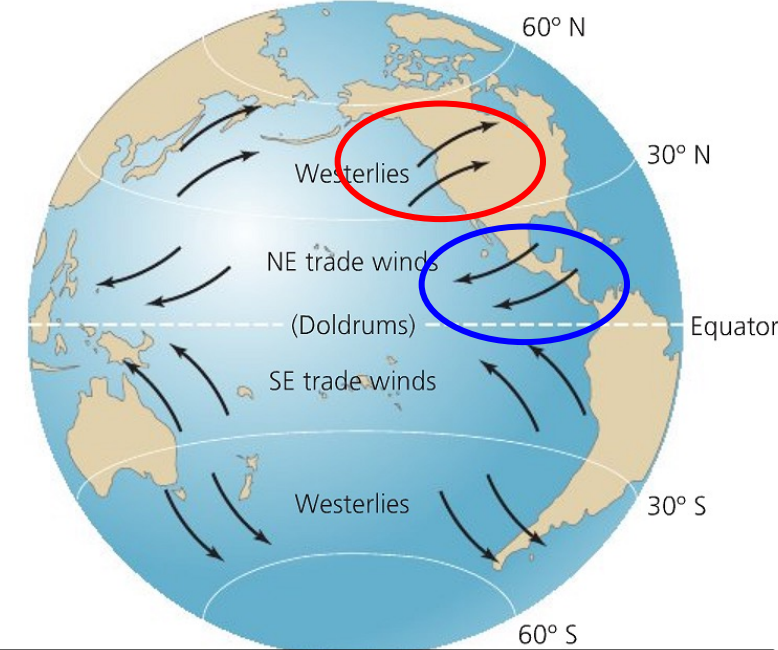
(a) Convection currents

# Atmosphere: Circulation.

- **Hadley cell:** Circulation pattern in the tropical atmosphere, with rising motion near the equator, poleward flow 10-15 kilometers above the surface, descending motion in the subtropics, and equatorward flow near the surface.
- In the tropical zone the hot air picks up lots of moisture from the surface, cools when rising and releases much of the moisture in form of rain in the tropics.
- As the air flows towards the pole it is exposed to further cooling and sinks to the ground as dry air. It warms during sinking due to (adiabatic) compression leading to a warm arid climate in these zones.
- The air then flows back to the tropical zone due to pressure differences.

Source: Withgott and Brennan

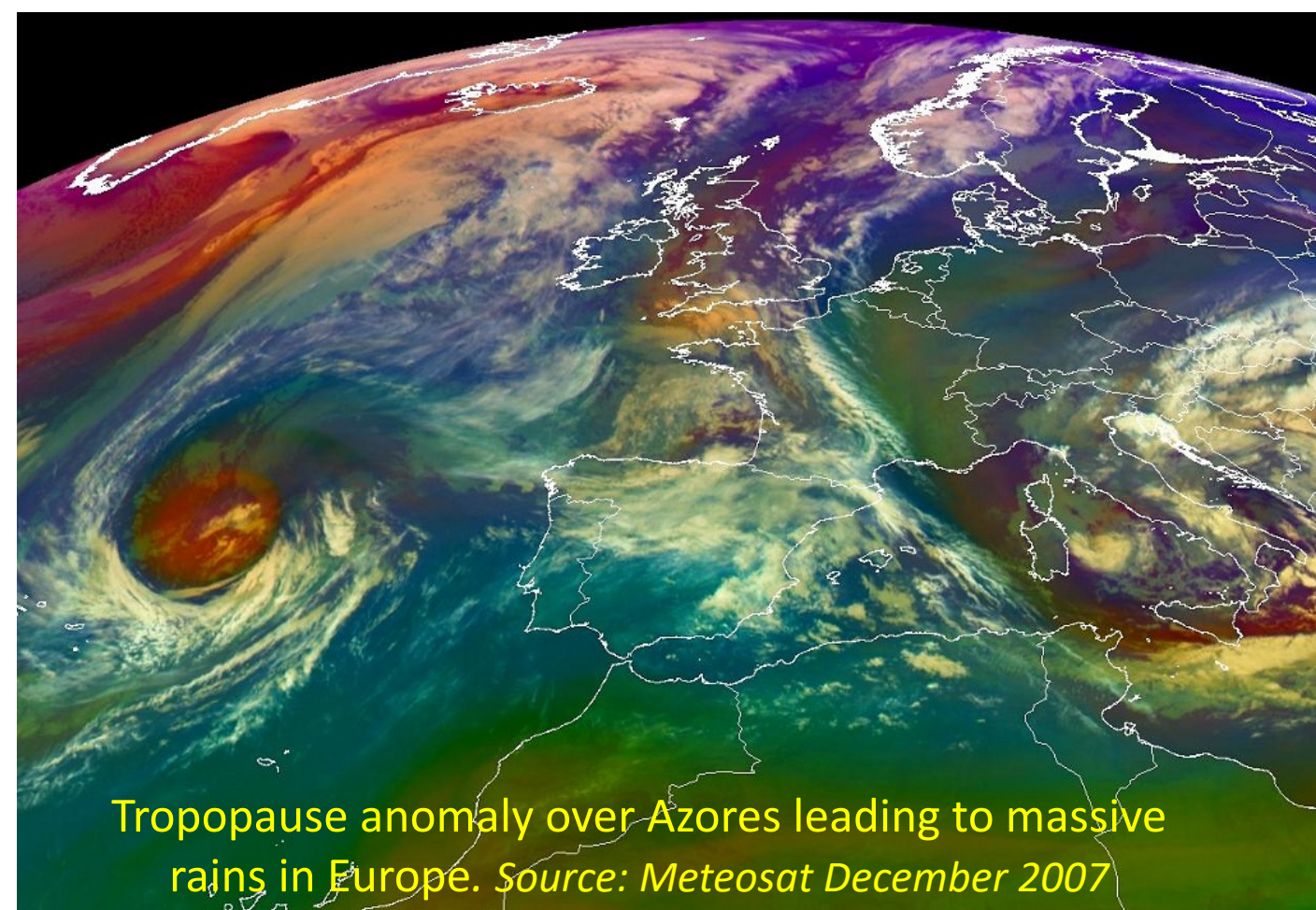
## Global wind patterns.



- Near the tropopause, the air moving north is turned eastward by the Coriolis force creating the subtropical jet streams that flow from west to east (**„Westerlies“**).
- Analogously, near the surface, the equatorward return flow is rotated to the west (**“Trade winds”**).

# Atmosphere: The Weather.

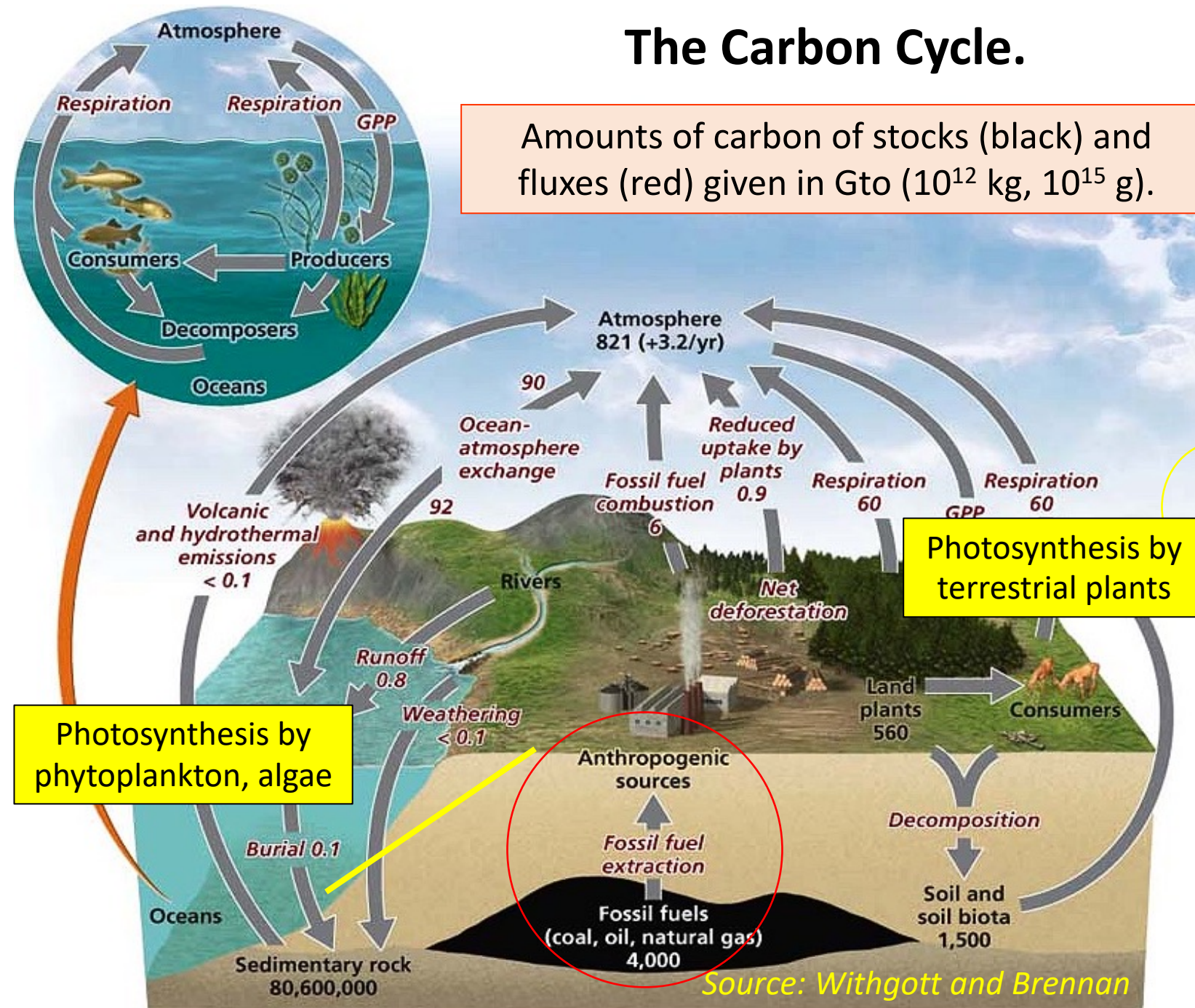
- Large-scale structure of atmospheric circulation varies from year to year, the basic structure remains fairly constant.
- Individual weather systems - depressions, tropical convective cells or tropopause anomalies - occur randomly.
- Therefore weather cannot be predicted beyond a fairly short limit: about ten days in practice.
- Nonetheless, the average of these systems, the climate, is quite stable.



Extraordinary weather phenomenon over the Arctic: Northern lights and ice clouds.

# The Carbon Cycle.

Amounts of carbon of stocks (black) and fluxes (red) given in Gto ( $10^{12}$  kg,  $10^{15}$  g).



- **Atmosphere:** carbon exists as carbon dioxide ( $\text{CO}_2$ ) – raw material for photosynthesis thus basis for all plants.
- **Biosphere:** Carbon exists as living species (plants, animals) largely consisting of organic carbon compounds (carbohydrates, celluloses, proteins.....) and of inorganic carbonates (e.g. shells of animals).
- **Lithosphere:** Carbon exists as inorganic carbonate rocks and as carbon rich deposits of dead organic matter (coal, oil, natural gas).
- **Hydrosphere:** Carbon exists as dissolved carbon dioxide, suspended carbonates, dead organic matter.

# The Carbon Cycle in the Biosphere.

- Carbon is the major element in all organic compounds which are produced essentially from glucose through a multitude of biochemical reactions.
- Glucose is produced from CO<sub>2</sub> by autotroph organisms through the process of photosynthesis.

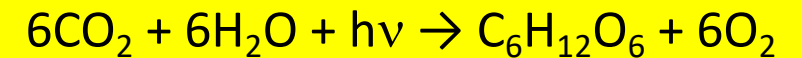
Phytoplankton – size <0,1 mm



- The most important autotrophs are trees in forests on land and phytoplankton in the oceans.
- Through photosynthesis, phytoplankton is responsible for about half of the oxygen produced in the Earth's atmosphere.
- Its cumulative energy fixation in carbon compounds (primary production) is the basis for the vast majority of oceanic and also many freshwater food webs.
- Carbon is transferred within the biosphere as heterotrophs feed on other organisms or their parts.

**Photosynthesis is the primary process for the origin of life on earth.**

It can be described by the reaction:



Photons ( $h\nu$ ) from the sun provide the energy for this endothermic reaction.

Thus the sun powers most living systems.

This reaction needs a catalyst: chlorophyll.

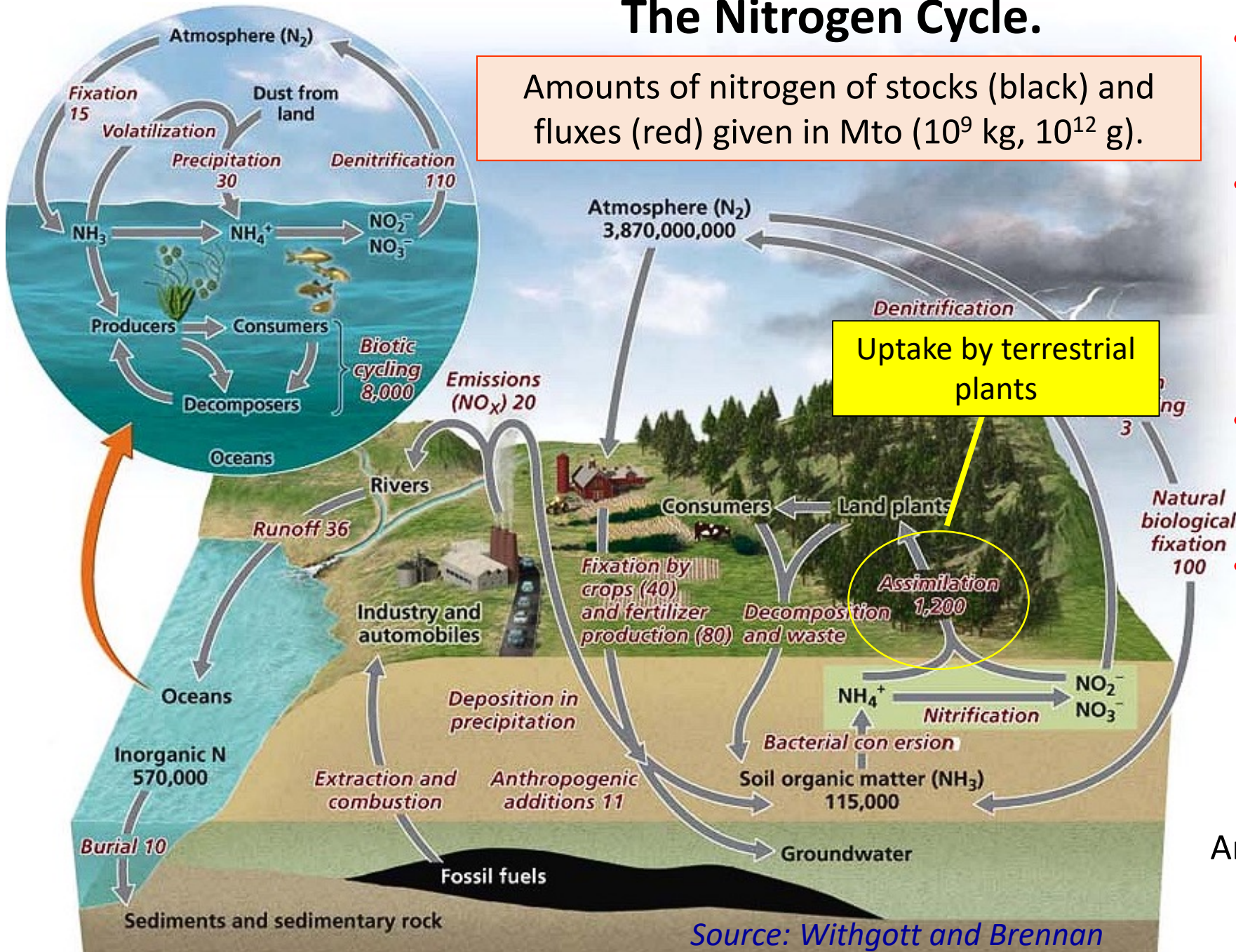
# The Carbon Cycle: Release into Atmosphere.

- **Respiration performed by animals:** This is an exothermic reaction and it involves the breaking down of glucose (or other organic molecules) into carbon dioxide and water.
- **Decay of animal and plant matter.** Fungi and bacteria break down the carbon compounds in dead animals and plants and convert the carbon to carbon dioxide if oxygen is present, or methane if not.
- **Combustion of organic material:** Produces carbon dioxide (and other compounds, like water vapor). Burning fossil fuels such as coal, petroleum products, natural gas or biomass releases carbon that has been stored in the geosphere for millions of years.
- **Production of cement:** Carbon dioxide is released when limestone (calcium carbonate) is heated to produce lime (calcium oxide), a component of cement.
- **Outgassing from oceans:** At the surface of the oceans where the water becomes warmer, dissolved carbon dioxide is released back into the atmosphere.
- **Volcanic eruptions:** release primarily water vapor, carbon dioxide and sulfur dioxide.



# The Nitrogen Cycle.

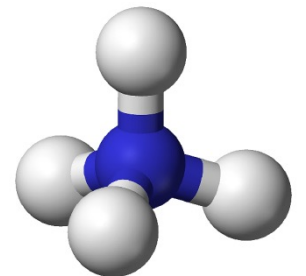
Amounts of nitrogen of stocks (black) and fluxes (red) given in Mto ( $10^9$  kg,  $10^{12}$  g).



- Nitrogen is essential for many biological processes and crucial for any life here on Earth.
- It is in all amino acids, is incorporated into proteins, and is present in the bases that make up nucleic acids, such as DNA and RNA.
- In plants, nitrogen is also used in chlorophyll molecules essential for photosynthesis.
- Important nitrogen compounds are:

Nitrates:  $\text{NO}_3^-$

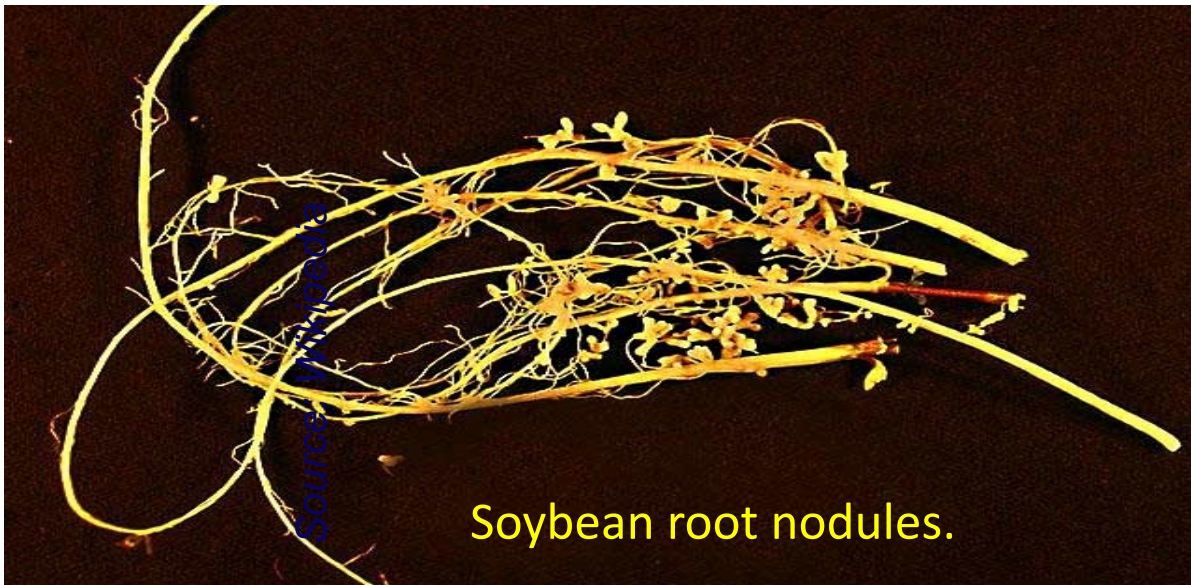
Ammonium salts:  
 $\text{NH}_4^+$



*Source: Withgott and Brennan*

# The Nitrogen Cycle: Uptake of Nitrogen by Plants.

- **Uptake of gaseous nitrogen ( $N_2$ ) from atmosphere:**
  - $N_2$  cannot normally be taken up by plants since it is a very stable molecule.
  - Conversion of  $N_2$  into forms usable by living organisms by bacteria endowed with the nitrogenase enzyme that combines gaseous nitrogen with hydrogen to produce ammonia.
  - Some nitrogen fixing bacteria, such as *Rhizobium* or *Bradyrhizobium*, live in the root nodules of legumes (such as peas or beans).



Soybean root nodules.

- **Assimilation of nitrate or ammonium ions from the soil via root hairs:**
  - To achieve proper yields in plant growth these nitrogen compounds must be added to the soil (natural or chemical fertilizers).
  - Typically fertilizers do not only provide nitrogen (nitrate, ammonium compounds, urea) but also other major plant nutrients like phosphorus and potassium, then secondary plant nutrients (calcium, sulfur, magnesium), and sometimes trace elements.
  - Fertilizers are naturally occurring compounds such as manure, bird excretions („Chile-Salpeter“), peat or mineral deposits, or manufactured through natural processes (such as composting) or chemical processes (such as the Haber-Bosch process).

# The Nitrogen Cycle: N-Compounds in the Atmosphere.

- **NO<sub>x</sub> (NO, NO<sub>2</sub>):**

- NO<sub>x</sub> (NO, NO<sub>2</sub>) is produced by combustion of materials containing nitrogen compounds (biomass) or combustion of fossil fuels (coal, oil, gas) at high temperatures enabling a reaction between N<sub>2</sub> and O<sub>2</sub>.
- Fossil fuel combustion dramatically increased in the industrial age and has contributed to a 6 or 7 fold increase in NO<sub>x</sub> flux to the atmosphere (compared to preindustrial times).
- NO, NO<sub>2</sub> are acid gases forming nitric acid in cloud droplets leading to acid rain causing acidification of surface waters and excessive nitrogen input into sensitive ecosystems.
- NO, NO<sub>2</sub> react in the presence of UV-radiation with hydrocarbons to form tropospheric ozone, which is a major air pollutant and the main component of summer smog.

- **N<sub>2</sub>O:**

- N<sub>2</sub>O is a green house gas with a climate forcing factor 25x higher than CO<sub>2</sub>
- Main source for N<sub>2</sub>O is the application of chemical fertilizers which has been heavily increasing over decades since 1960.

- **NH<sub>3</sub>:**

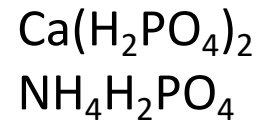
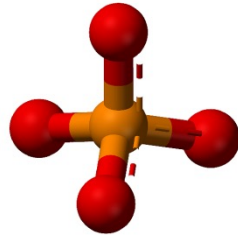
- It reacts in the atmosphere with NO<sub>x</sub> and SO<sub>2</sub>/SO<sub>3</sub> forming ammonium nitrate and sulfate as an aerosol.
- These are components of acid precipitation.

# The Phosphorus Cycle.

- **Significance of phosphorus:**

- Key component of all living matter (cell membranes) and molecules vital for life, like DNA, RNA, ATP, ADP.
- Vast amounts stored in rocks and sediments in the form of phosphates, but low solubility of these compounds and therefore small bioavailability.
- Additional supply through fertilisation for plants often necessary.

Major compounds:  $\text{PO}_4^{3-}$



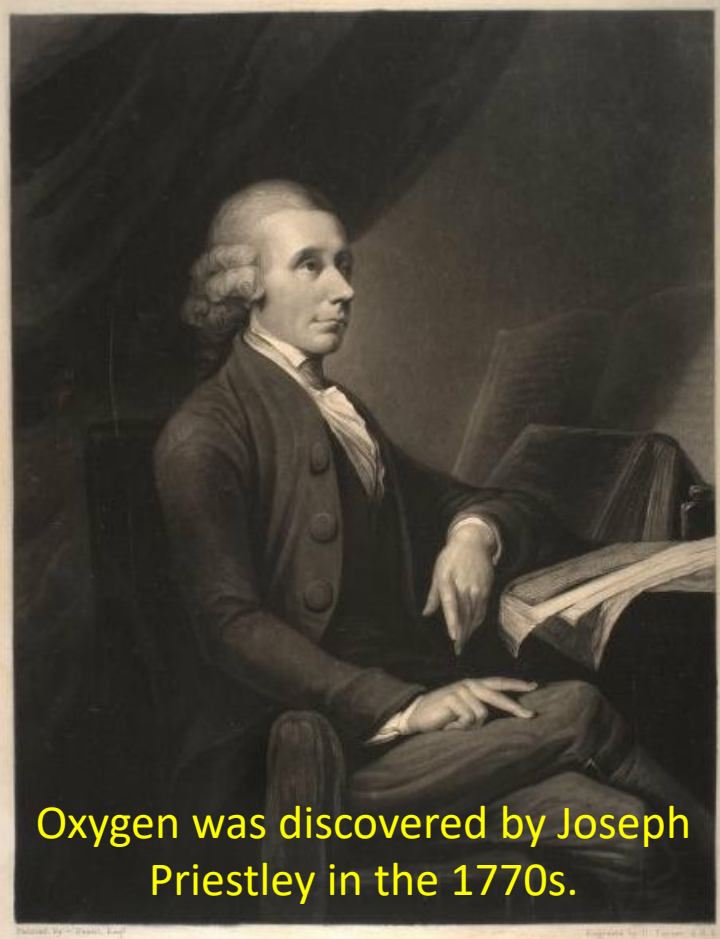
- **Supply of phosphorus to waters and soil:**

- Main input through fertilization in agriculture.
- Effluents from households (detergents), human and animal excretions and decomposition of organic compounds.

- **Effects on the environment:**

- Oversupply of waters with phosphorus contributes to eutrophication.



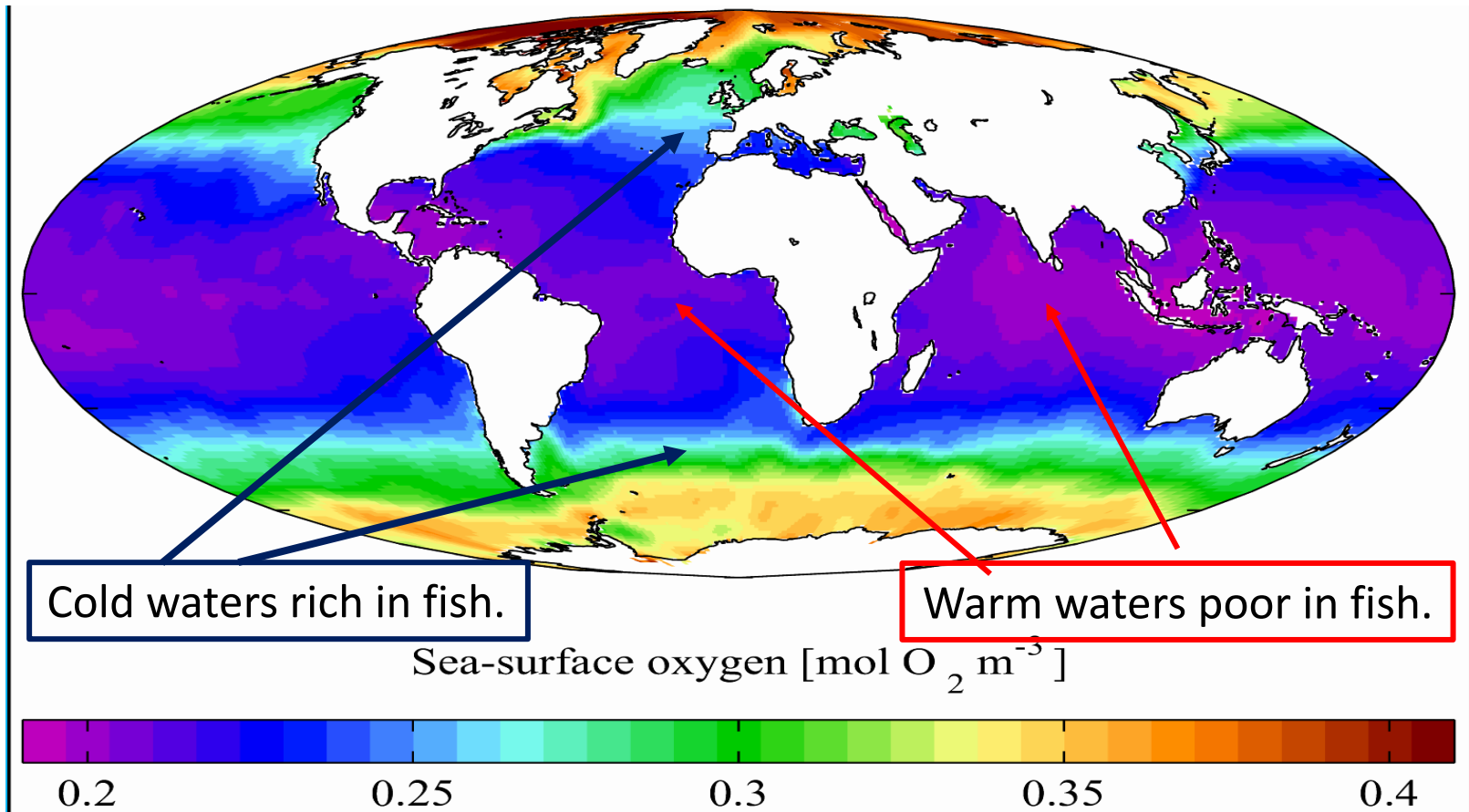


Oxygen was discovered by Joseph Priestley in the 1770s.

- Polar oceans support a much higher density of life.
- Polluted water may have reduced amounts of  $O_2$ , depleted by decaying algae and other biomaterials (see eutrophication).

# The Oxygen Cycle.

- Oxygen reacts readily with almost all other elements forming oxides.
- Most abundant element by mass in the Earth's crust.
- Oxygen constitutes 20.9% of the volume of air.
- Free oxygen also occurs in solution in the world's water bodies.
- Solubility increases with lower temperature.



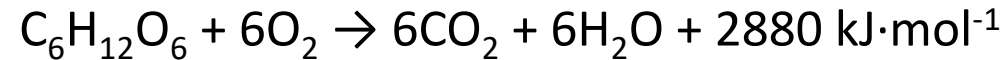
# The Oxygen Cycle: Production and Consumption.

- **Production of oxygen:**

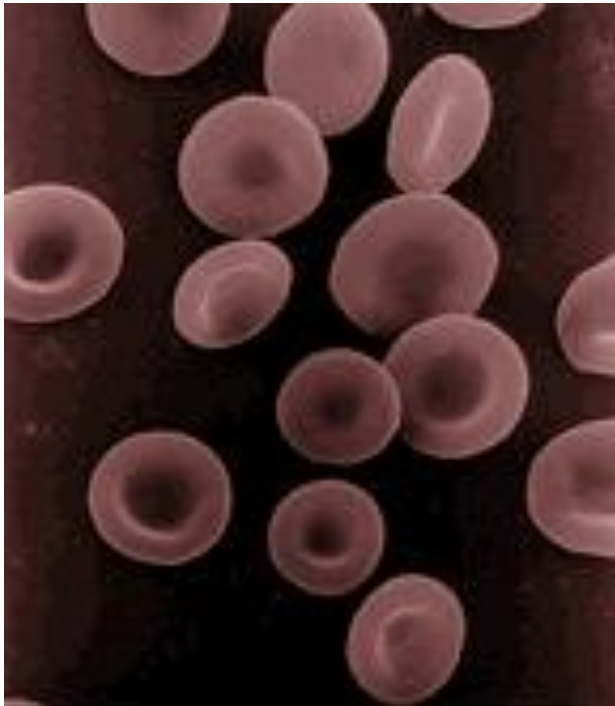
- Main source of oxygen within the biosphere and atmosphere is photosynthesis by plants and phytoplankton.

- **Oxygen consumption from the atmosphere:**

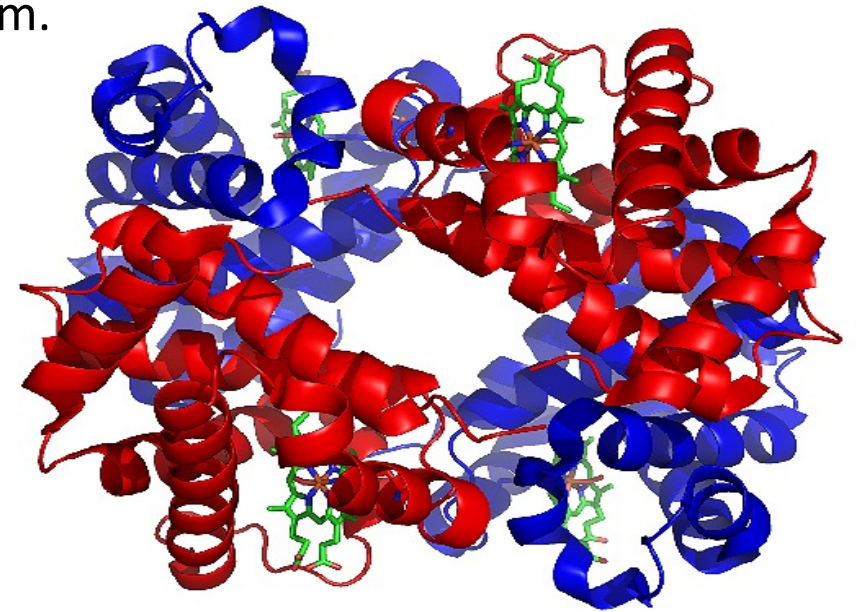
- Respiration - mechanisms in which animal life and bacteria consume oxygen and release carbon dioxide.
- The reaction for aerobic respiration is essentially the reverse of photosynthesis and is simplified as:



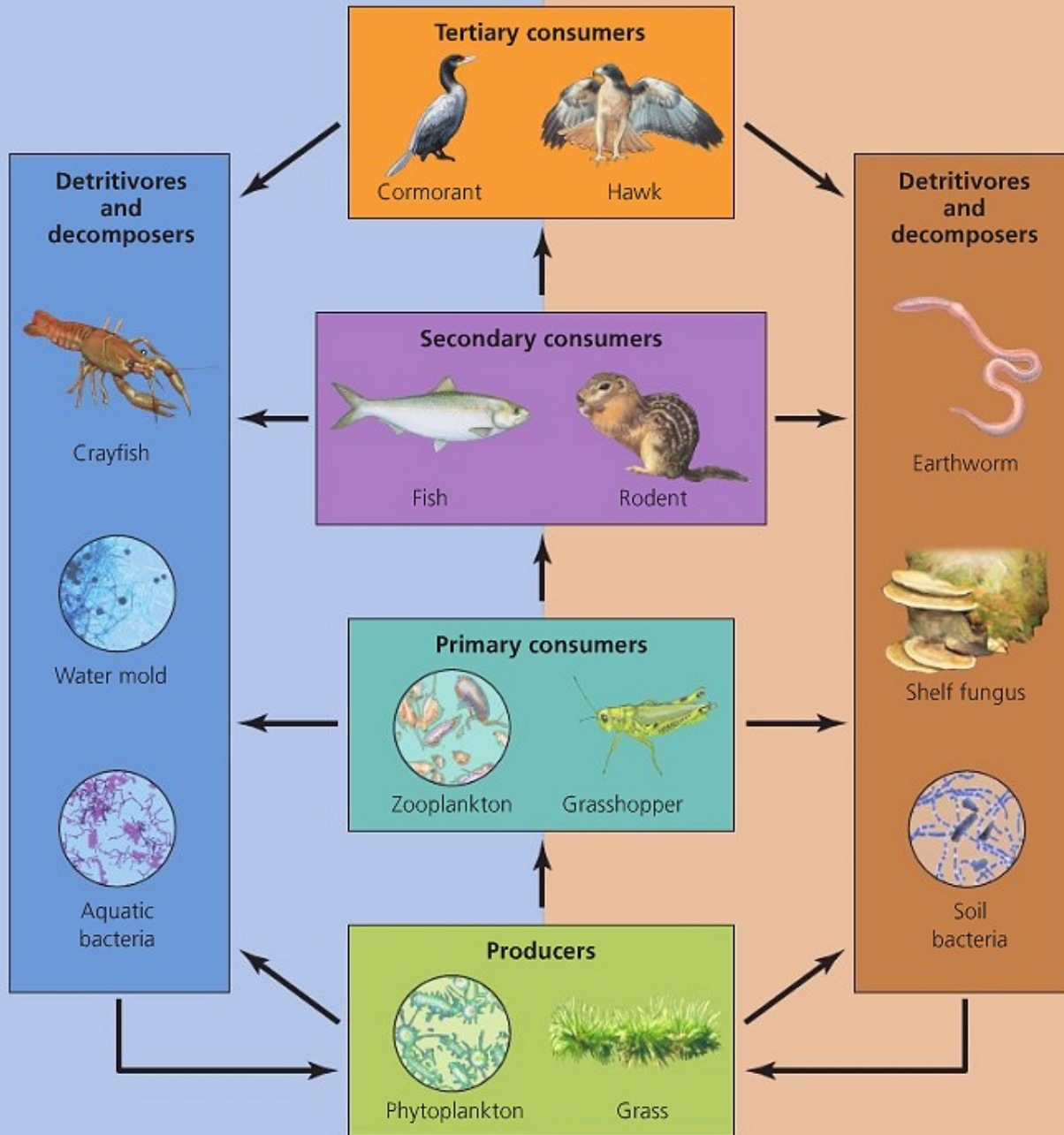
- In vertebrates,  $\text{O}_2$  is diffused through membranes in the lungs and into red blood cells (erythrocytes).



- Diameter of human erythrocyte disk 6–8  $\mu\text{m}$ .
- Oxygen can easily diffuse through the red blood cell's membrane.
- Each erythrocyte contains millions of hemoglobin molecules.
- A hemoglobin molecule contains 4 heme groups whose iron atoms temporarily link to oxygen molecules in the lungs or gills and release them throughout the body.



Structure of human hemoglobin.



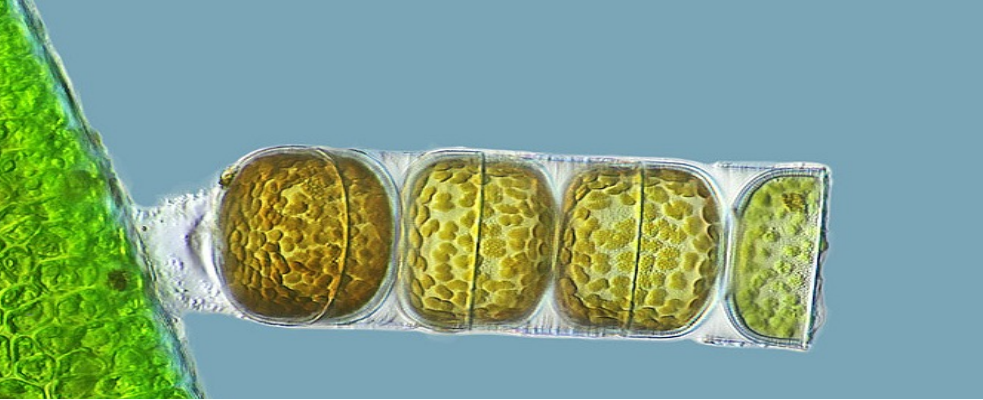
## 2.3 Ecosystem Dynamics: The Food Chain.

- Within the ecosystem, species are connected by food chains or webs.
- Energy from the sun, captured by primary producers via photosynthesis, flows upward through the chain to primary consumers (herbivores), and then to (carnivores and omnivores).
- On average, only 10% of the organism's energy are passed on to the next trophic level. The other 90% are used for the organisms life processes or are lost as heat to the environment.
- Therefore only a small amount of biomass is transferred to the next feeding level, thus showing a Pyramid of Biomass.
- As the chain is travelled along, the number of consumers at each level drops very significantly.

# Pictures of an Aquatic Food Chain.

Source:

<http://www.planktonchronicles.org>  
/.....Geo 2011



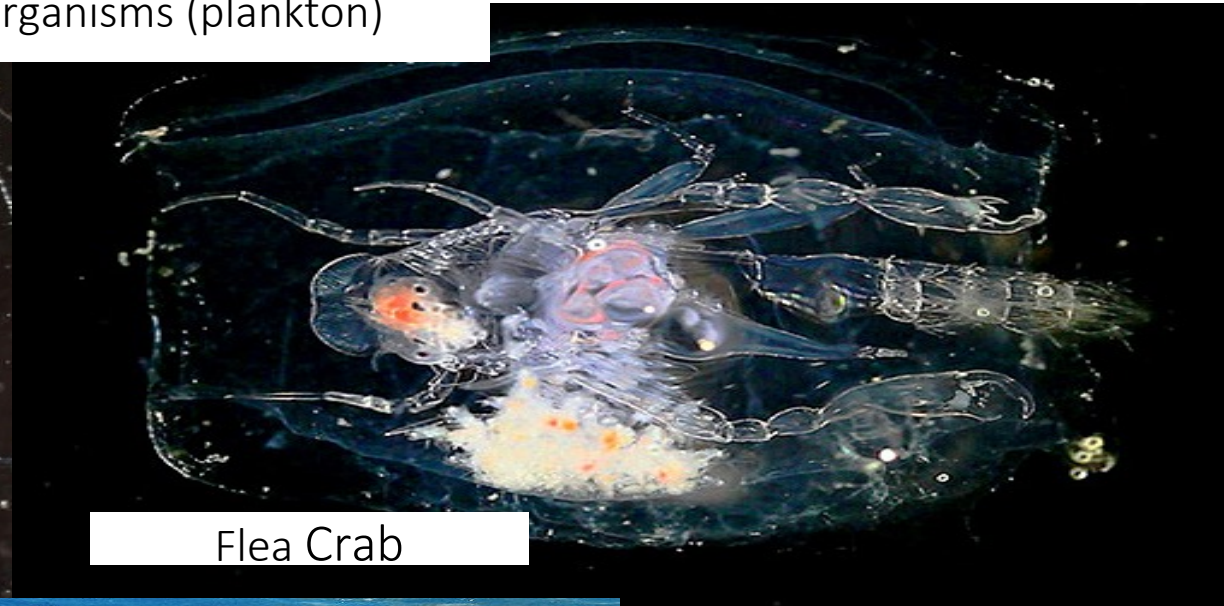
Phytoplankton *Melosira moniliformis* (320X)



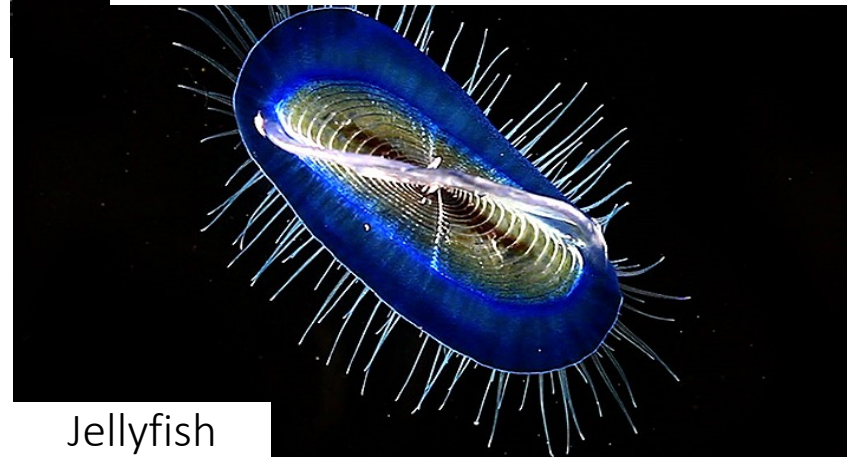
Single cell organisms (plankton)



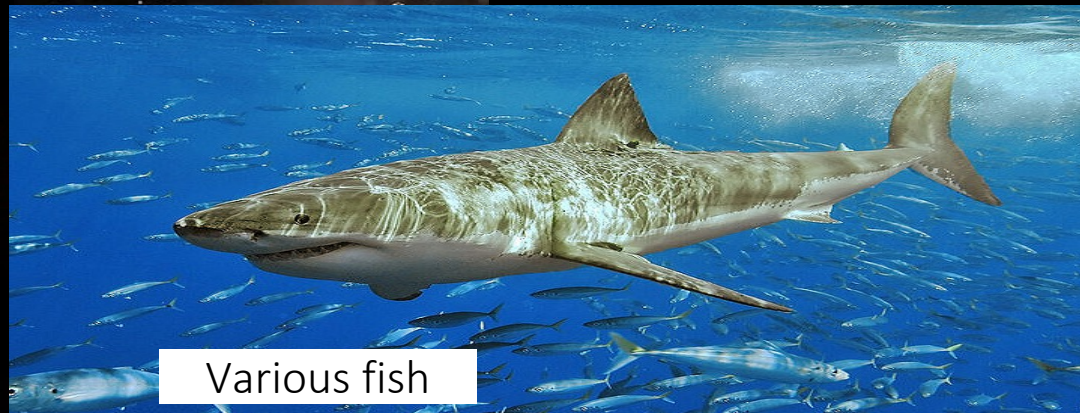
Multicellular organisms (plankton)



Flea Crab



Jellyfish

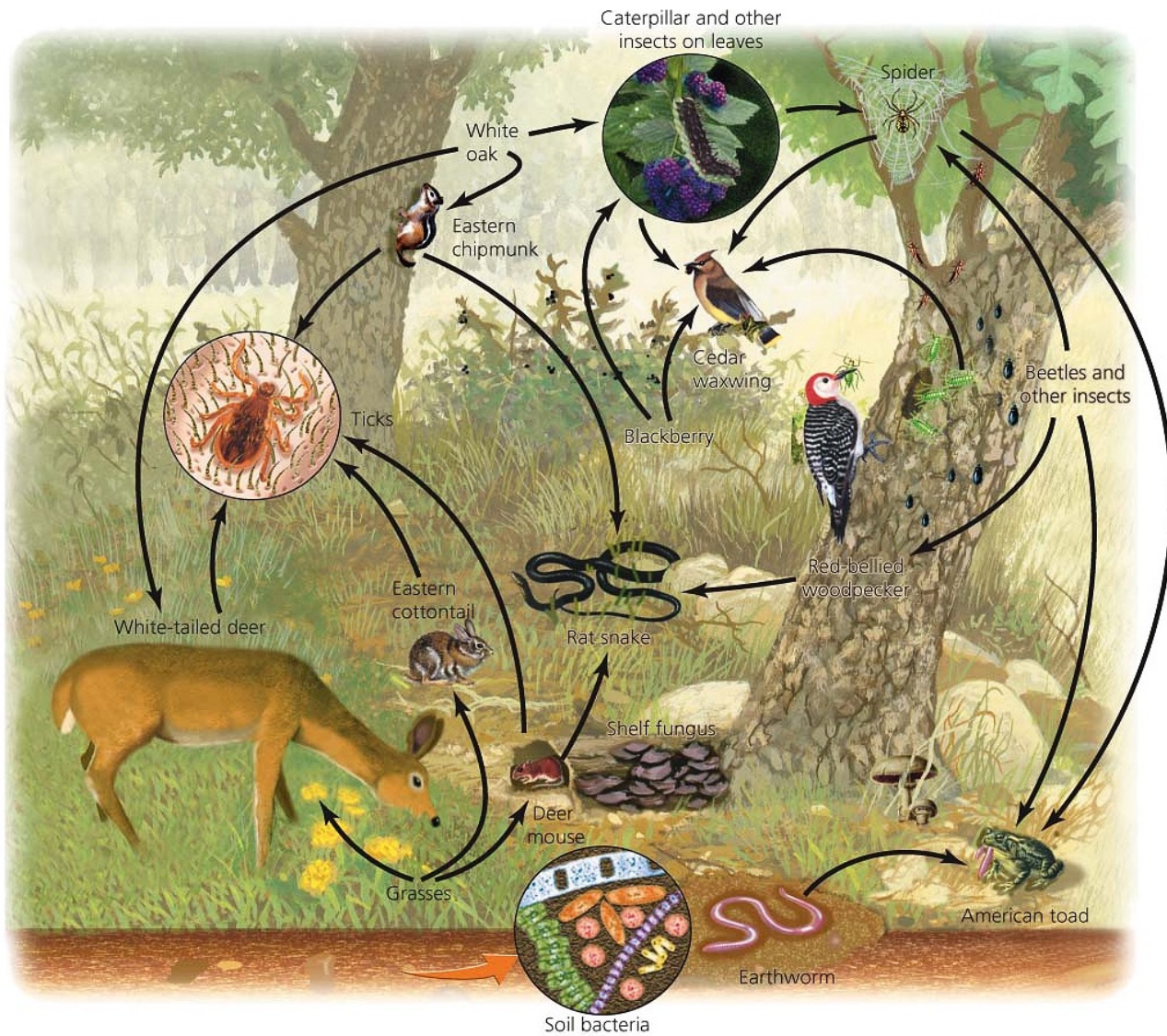


Various fish

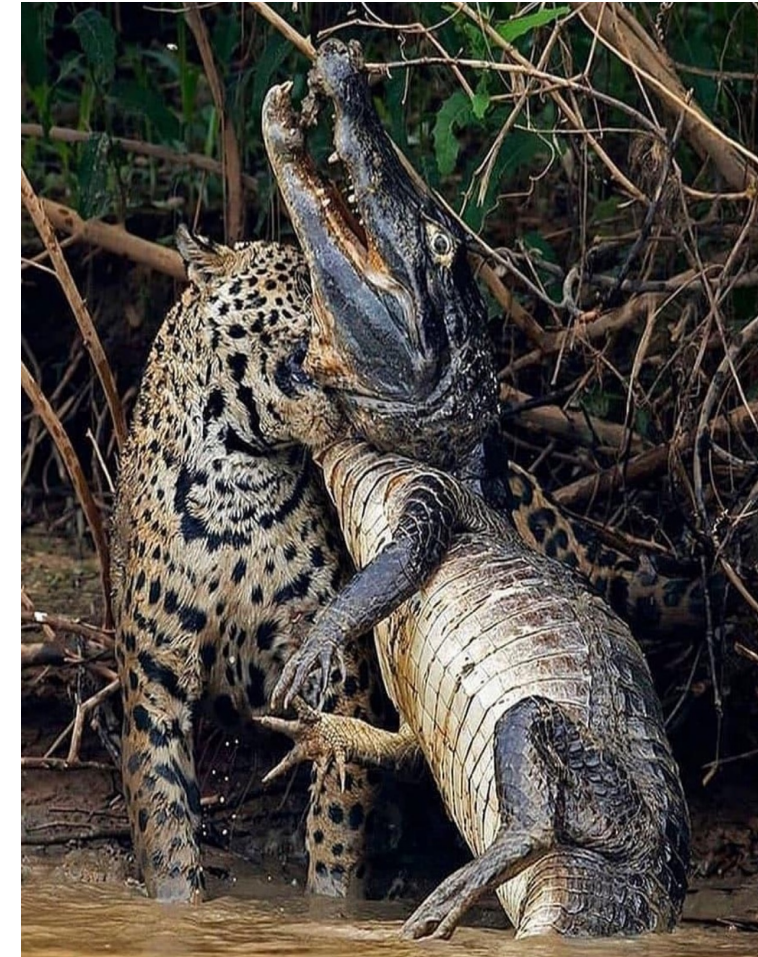


Various birds

# Ecosystem Productivity: The Food Web.



- Linear food chains are overly simplistic as most consumers feed on multiple species.
- A food web extends the *food chain* concept from a simple linear pathway to a complex network of interactions.
- Food sources of most species are very diverse and complex, resulting in a complex *web* of relationships.

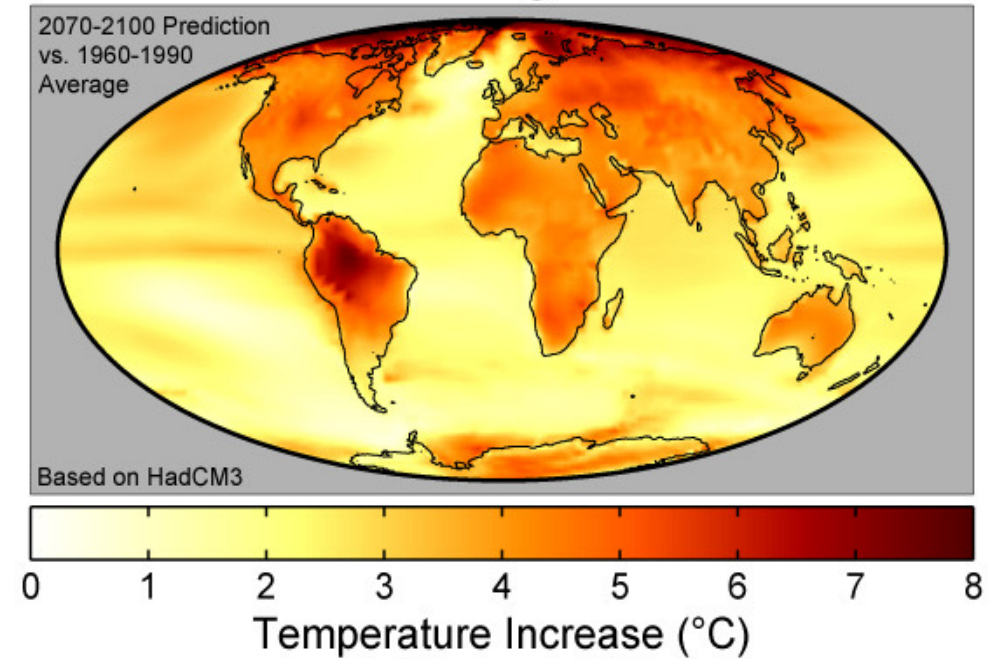


Food web for North America's deciduous forests.  
Source: Withgott and Brennan: Environment, Pearson 2008

# Ecological Crisis.

- In the case of natural disasters or strong interferences by human activities, the delicate equilibria existing in ecosystem may be significantly disturbed and may lead to gradual degradation of ecosystems and finally to ecological crisis situations.
- Ecological crisis can occur at a global, regional or local level.
- **Examples for present global ecological crisis are:**
  - Climate change
  - Loss of biodiversity
- **Examples for present regional ecological crisis are:**
  - Overpopulation, droughts, deforestation, desertification, extreme pollution of air, water, soil.
- **Examples of past global ecological crises are:**
  - Permian-Triassic extinction event 250 million of years ago.
  - Cretaceous-Tertiary extinction event 65 million years ago.
- **Examples of past regional ecological crises are:**
  - The Exxon Valdez oil spill off the coast of Alaska.
  - The nuclear meltdown at Chernobyl.

## Global Warming Predictions



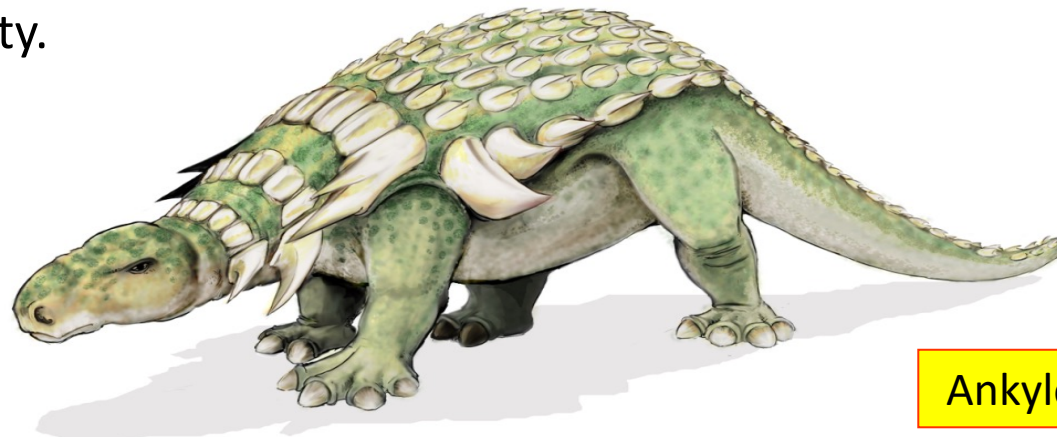
# Global Ecological Crisis: The Permian-Triassic Extinction Event.

- The **Permian–Triassic (P–Tr) extinction event**:
  - Occurred 250 million years ago and was the Earth's most severe extinction event, with up to 96 percent of all marine species and 70 percent of terrestrial vertebrate species becoming extinct.



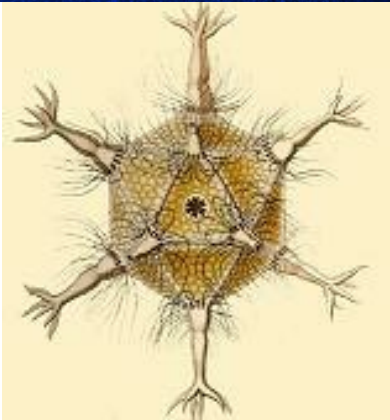
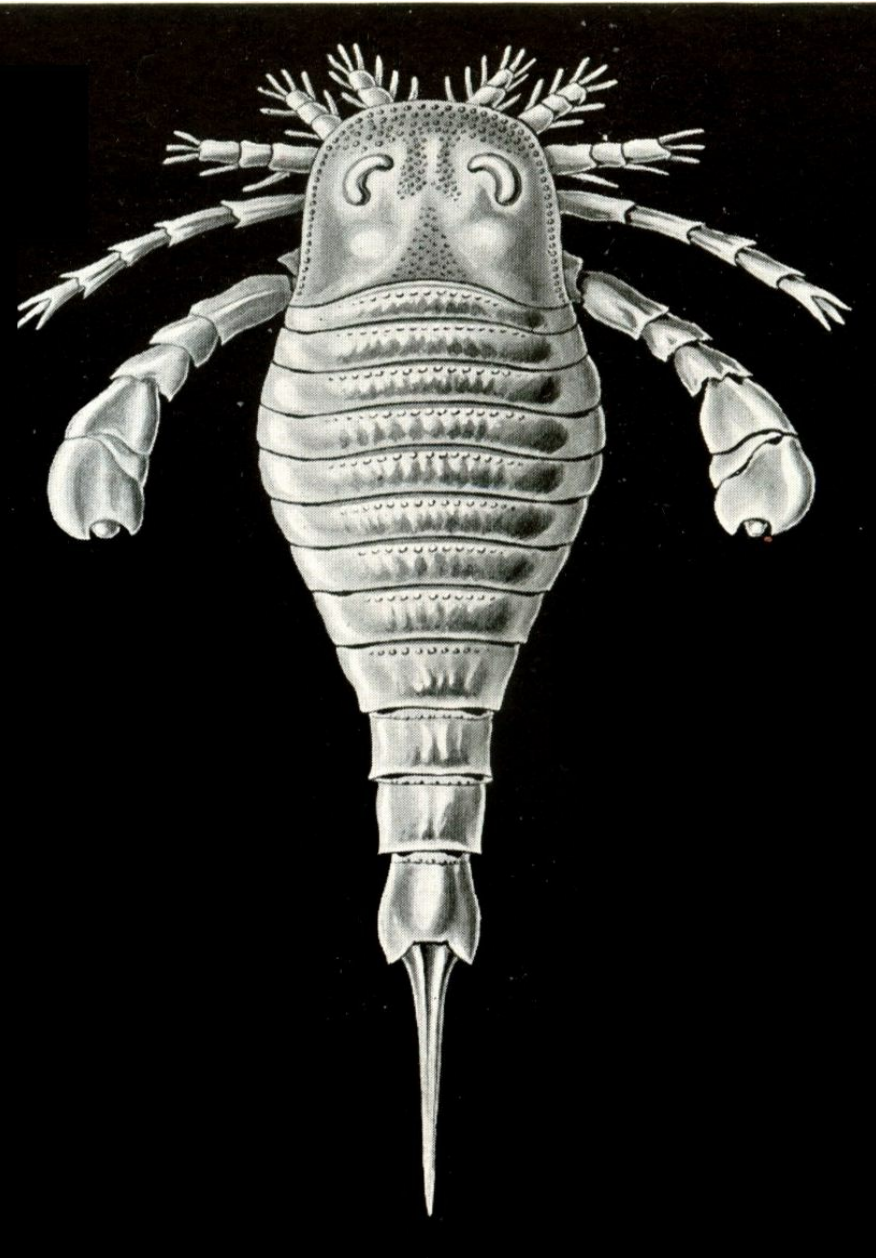
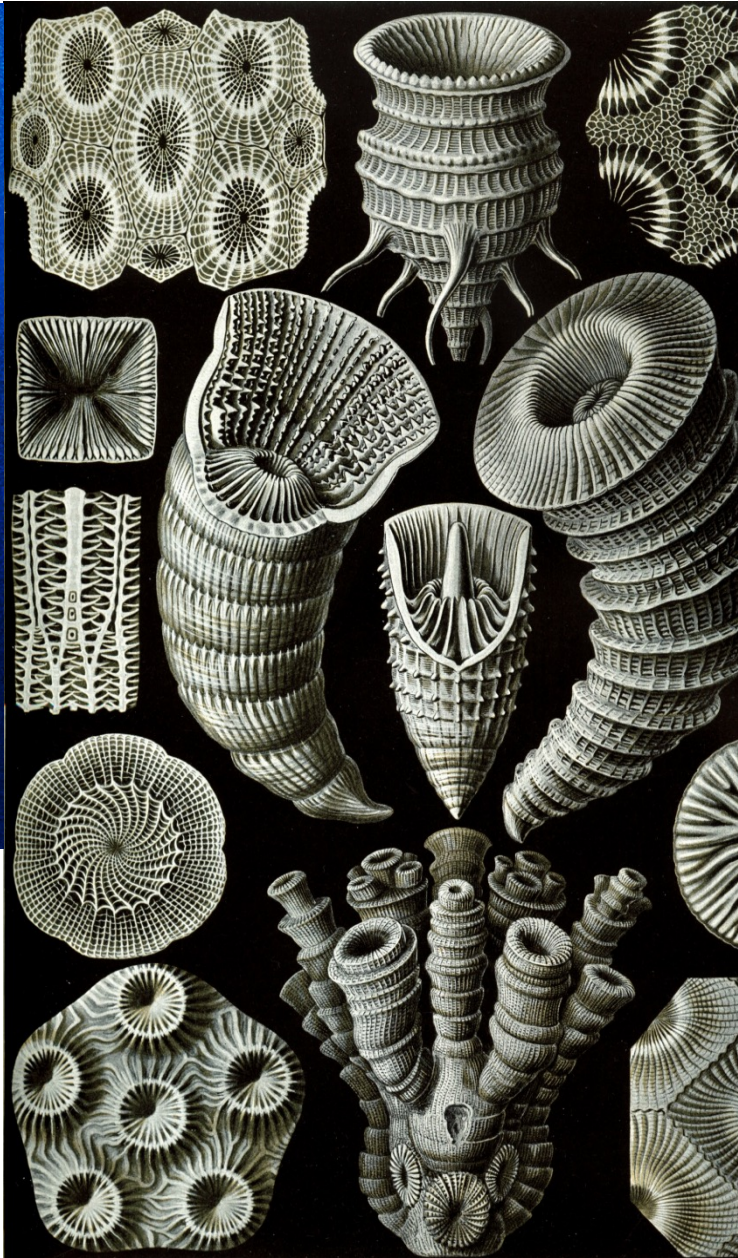
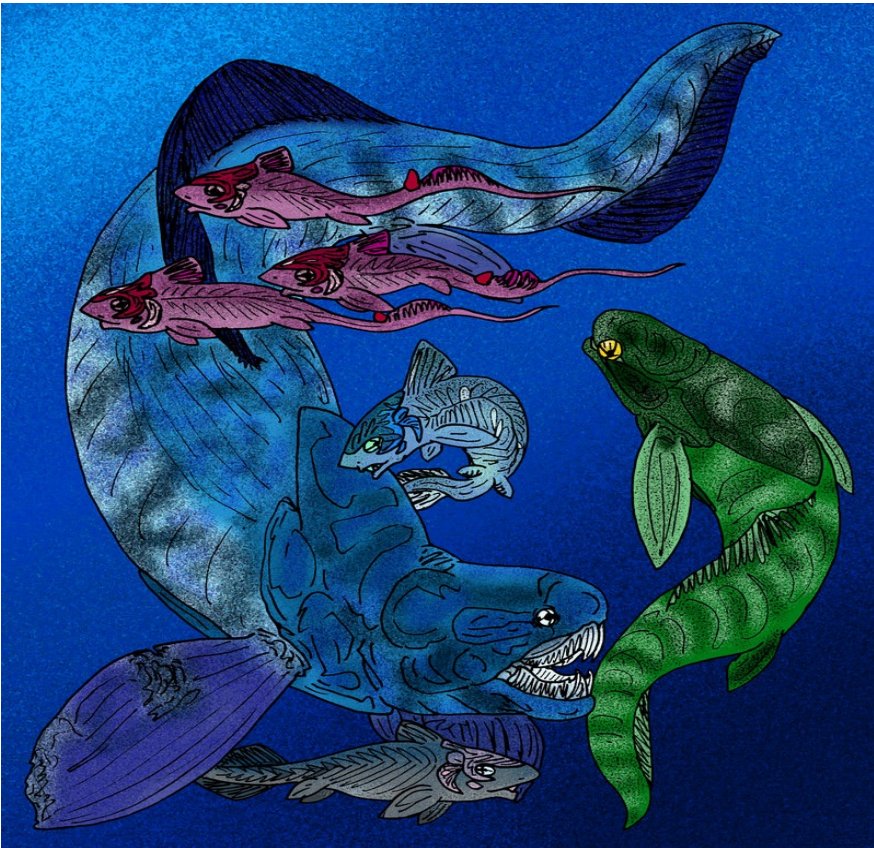
Pangea, the supercontinent existed during the Paleozoic and Mesozoic eras about 250 million years ago.

- Possible cause: increased vulcanism for long periods - „Siberian Traps“ – lava fields of 2 million km<sup>2</sup>:
- release of huge amounts of CO<sub>2</sub> , global temperature increase of 5°C,
- dust clouds reducing photosynthesis,
- massive SO<sub>2</sub>-emissions causing highly acids rains,
- release of methane from frozen methane hydrates from the sea floor leading to a total temperature increase of 10°C, and as a consequence
- gradualistic processes like sea-level change, anoxia, and increasing aridity.



Ankylosaurus Edmontonia

# Global Ecological Crisis: The Permian-Triassic Extinction Event.



# Global Ecological Crisis: The Cretaceous-Tertiary Extinction Event.

- The **Cretaceous–Tertiary extinction event**:
  - Occurred 65,5 million years ago.
  - Extinction of dinosaurs, mosasaurs, plesiosaurs, pterosaurs and many species of plants and invertebrates.
  - Survivors were mammals and birds.



- **Causes and effects:**
  - Likely catastrophic events such as massive asteroid impacts or increased volcanic activity.
  - Dust clouds reduced sunlight and species which depended on photosynthesis became extinct.
  - Reduction of phytoplankton and land plants which were the foundation of the food chain in the late Cretaceous.
  - Marine species feeding on phytoplankton died out as well as herbivorous animals when the plants they depended on for food became scarce; consequently, top predators such as *Tyrannosaurus rex* also perished.

Tyrannosaurus Rex, 15m, 15 tons.

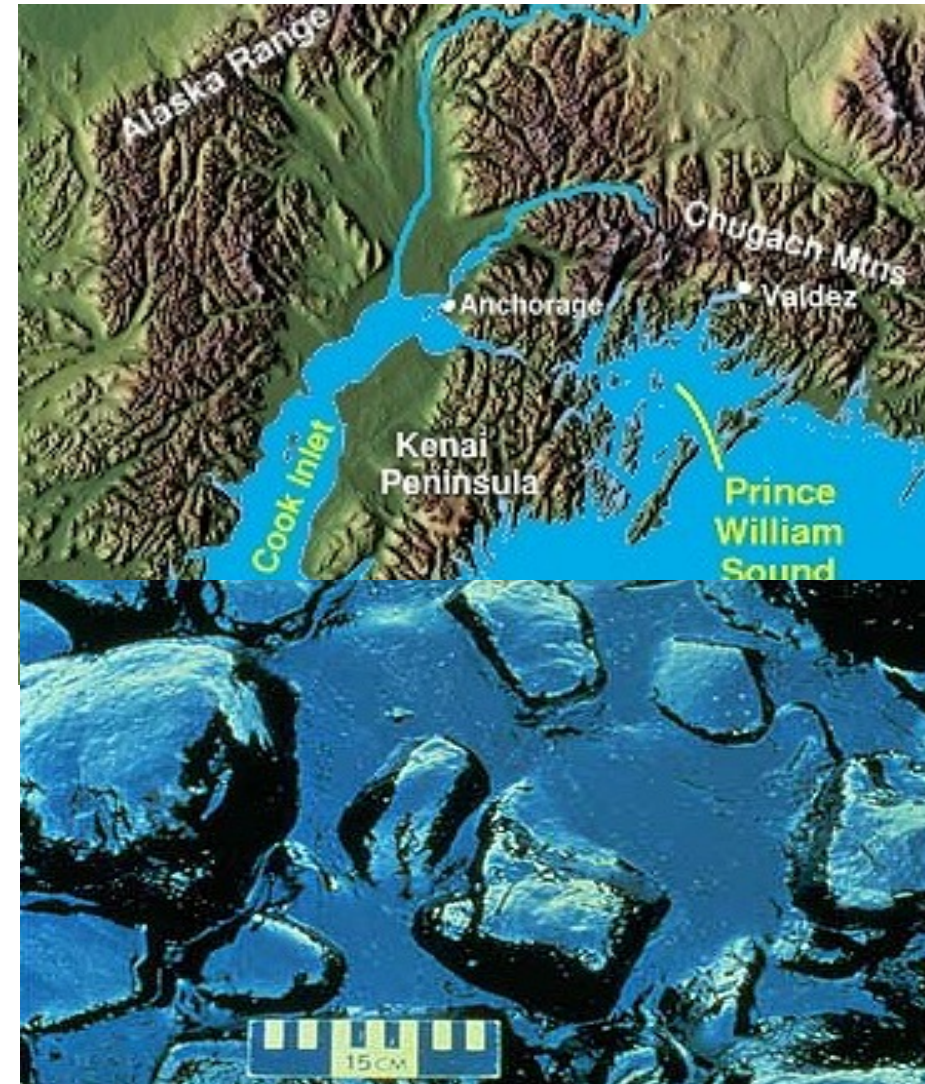
# Local/Regional Ecological Crisis: The Exxon Valdez Oil Spill of 1989.



- Thousands of animals died immediately.
  - 100,000–400,000 seabirds
  - 2,600–5,500 sea otters
  - 200 - 300 harbor seals
  - 250 bald eagles
  - 22 orcas
  - billions of salmon and herring eggs destroyed.

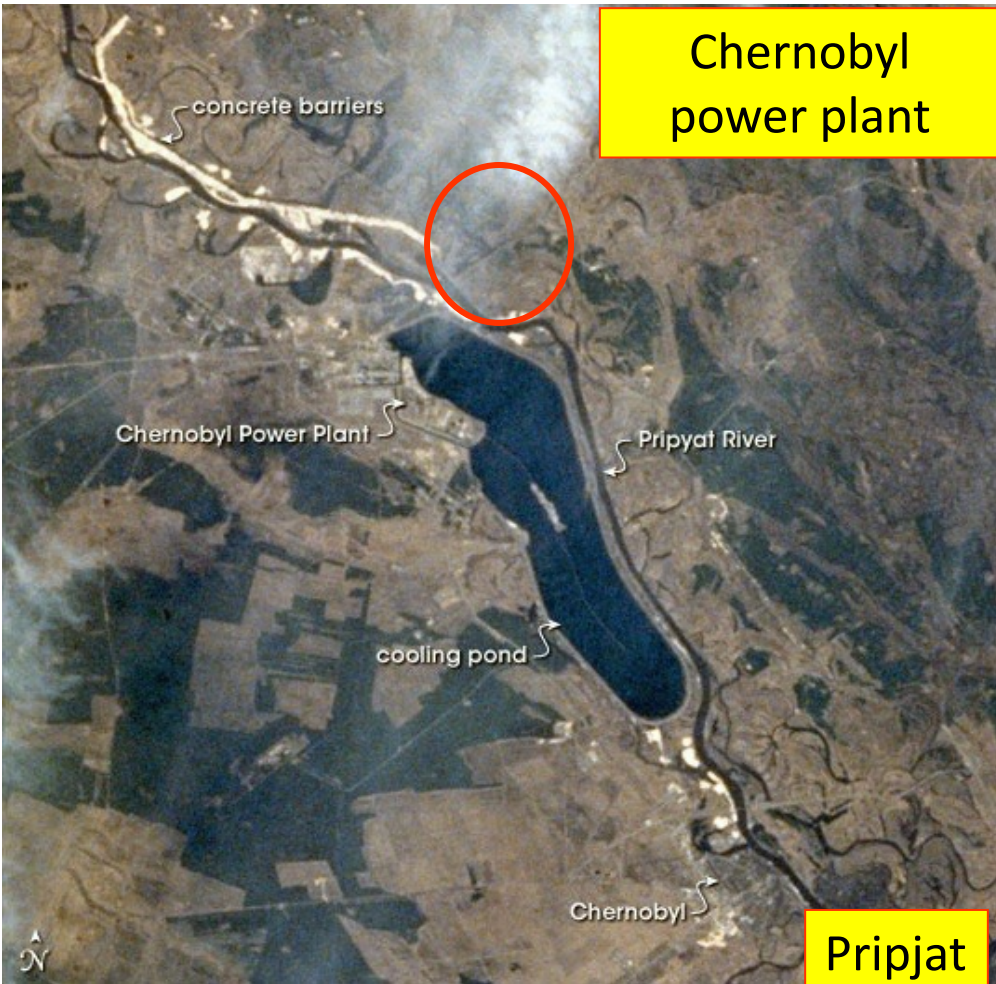
• *Exxon Valdez* struck Bligh Reef March 24, 1989 spilling 42 million liters of Prudhoe Bay crude oil into the sea at Prince William Sound in Alaska.

- During the first few days of the spill, heavy sheens of oil, covered large areas of the surface of Prince William Sound and coated 2.100 km of coastline.
- The region was a habitat for salmon, sea otters, seals, sea birds and sharks.



# Local/Regional Ecological Crisis: The Nuclear Meltdown in Chernobyl of 1986.

- **Chernobyl** is a large abandoned nuclear power plant in northern Ukraine, in the Kiev province near the border with Belarus, 10 km northwest of the city of Pripjat which had 45.000 inhabitants at that time.
- On April 26, 1986 tests with the reactor were made during which the computer-controlled safety systems were disabled and a run-away reaction occurred followed by an explosion and graphit fires.

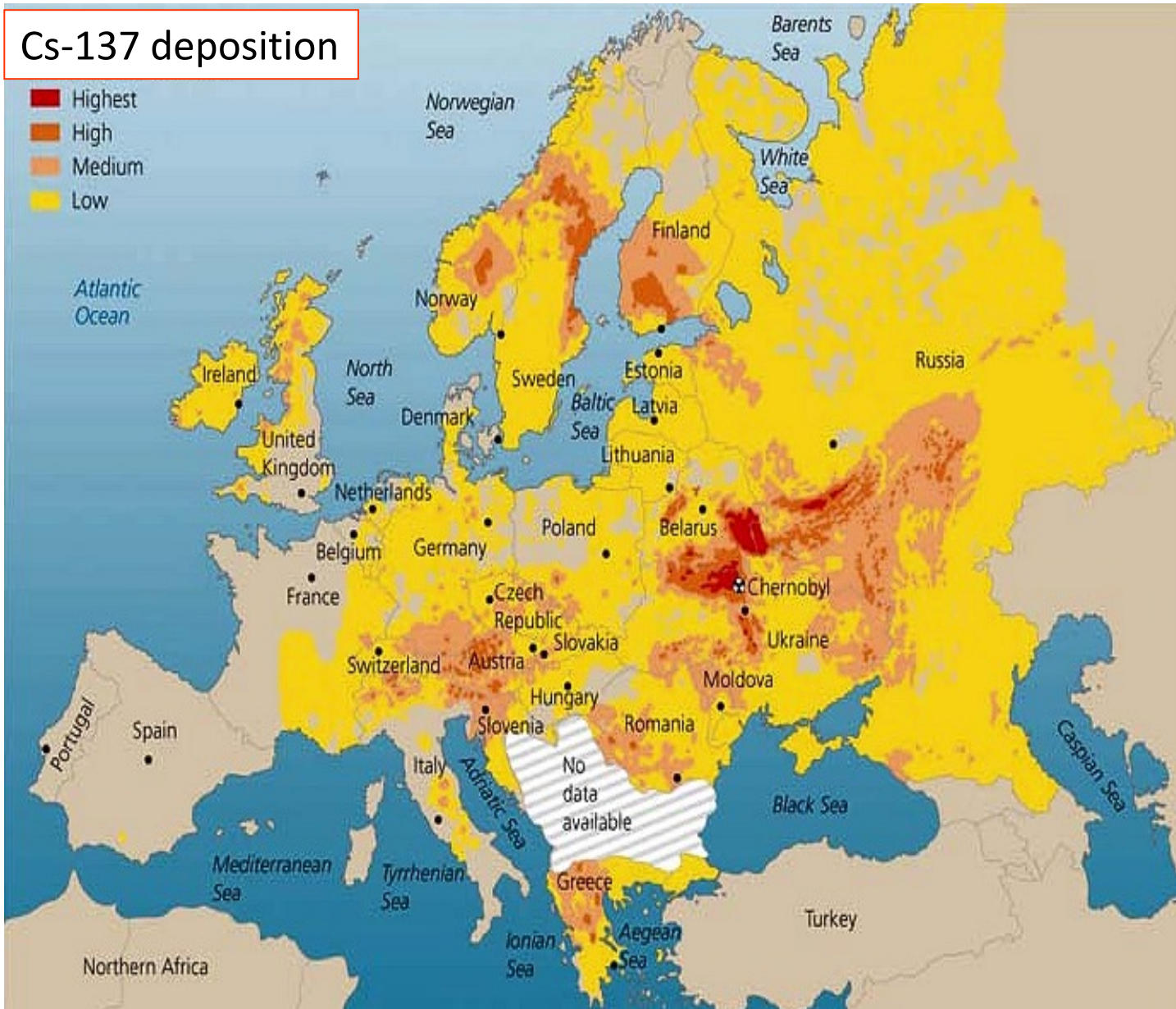


- Due to the graphite fire radioactive debris were flung high up.
- For the next 10 days the reactor spewed the equivalent of 400 Hiroshima bombs' worth of radioactivity across 300,000 km<sup>2</sup> of Europe.
- 120,000 people were evacuated and many villages were abandoned.
- Main fallout was Caesium-137, Strontium-90 and Iodine-131.



# Local/Regional Ecological Crisis: The Nuclear Meltdown in Chernobyl of 1986.

## Cs-137 deposition



- Caesium-137 (beta and gamma emitter, half-life 30 years) is water-soluble and extremely toxic.
- Strontium-90 (beta emitter, half life of 28,8 years) is incorporated in the bones and bone marrow and can cause cancer.
- Iodine-131 (beta and gamma emitter, half life 8 days) is incorporated in the thyroid glands and causes cancer.

Map of Cs-137 deposition in Europe (fall out from Chernobyl explosion). Other elements show a similar pattern.

Source:

*Withgott and Brennan: Environment, Pearson 2008*

# Local/Regional Ecological Crisis: The Nuclear Meltdown in Chernobyl of 1986.

- 200,000 young soldiers and others were rushed in from all over the Soviet Union for „clean-up“.



Contaminated military vehicles and helicopters.

- **Human damages according to IAEA and WHO 2005:**
  - 56 direct deaths (47 accident workers, and 9 children with thyroid cancer) and
  - an estimated 10,000 extra premature deaths due to cancer among the workers involved in clean-up and the population affected by the fall out.

- A 10 km<sup>2</sup> dump was filled with radioactive lorries, cement mixers, trains and helicopters.
- A concrete "sarcophagus" was hastily built over the stricken reactor showing quickly damages.
- Now a new steel containment structure has been constructed.



The city of Pripjat evacuated 24 hours after the explosion is a „dead zone“ since that time.