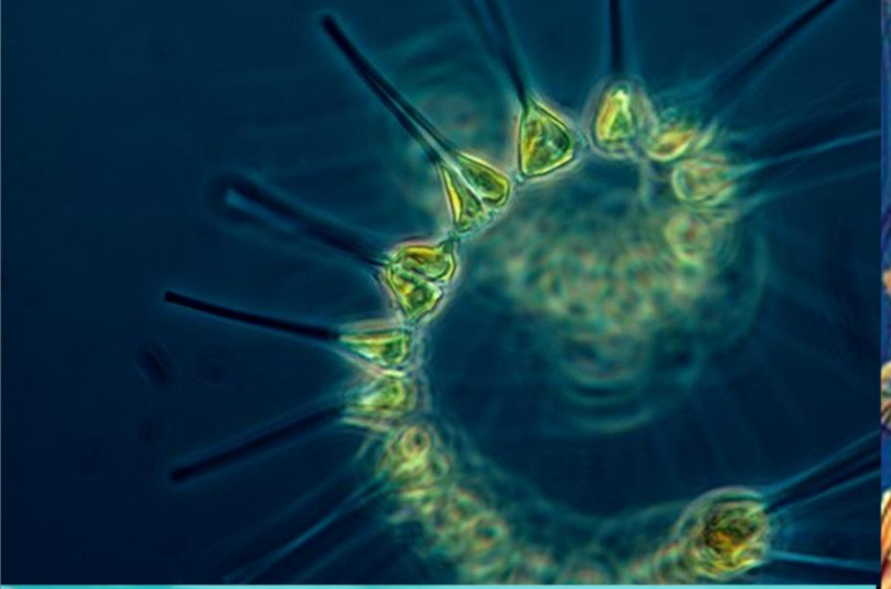


DEPARTMENT OF OCEAN SCIENCE

Overview:
A Glimpse of the Diversity of Marine Life

The Beautiful Ocean – Contains a Variety of Life Forms

- Life arose spontaneously from the early ocean between 3.8 and 2.5 billions of years ago.

- A variety of life forms have evolved in the modern ocean.

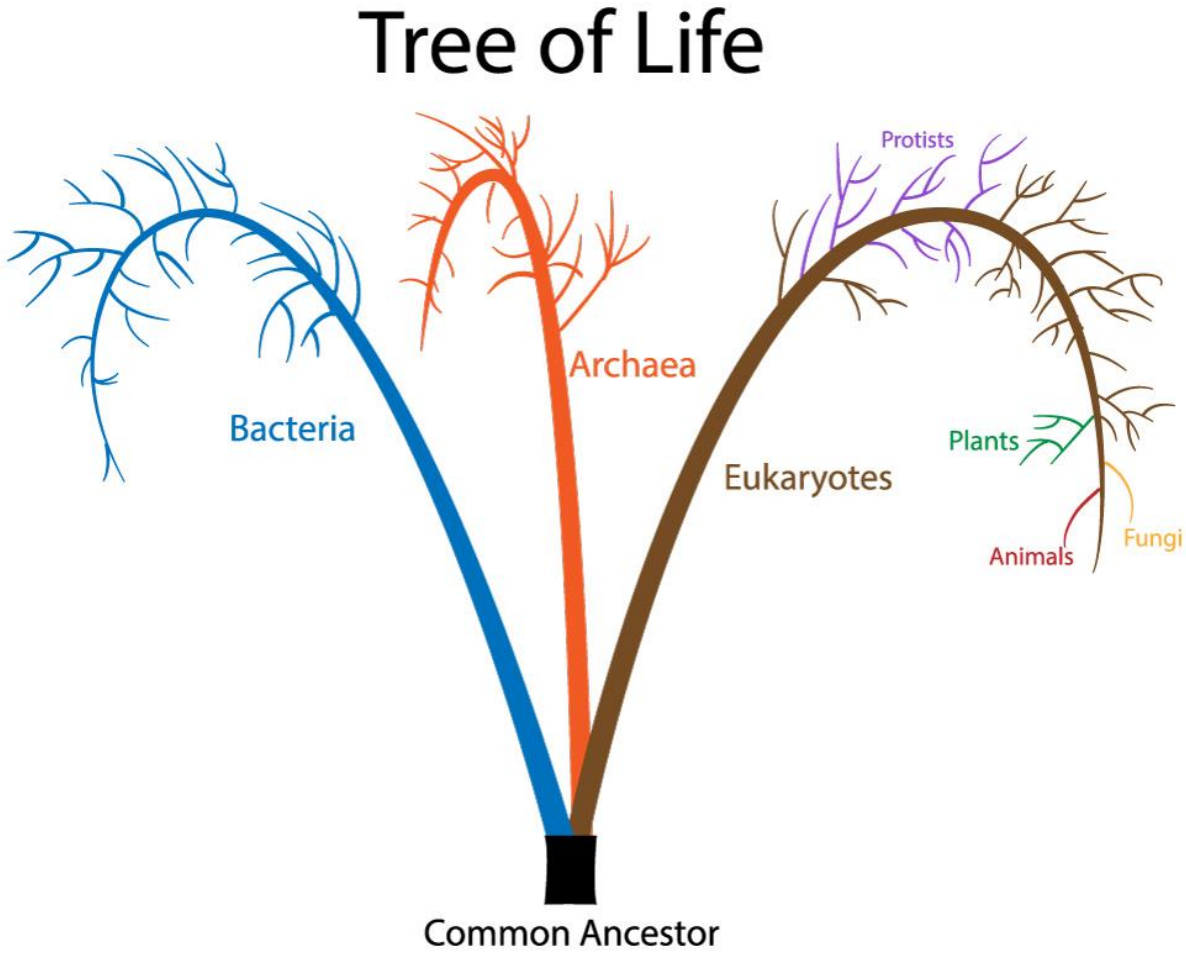
- Different life forms play different roles in the marine ecosystem.

A Glimpse of Marine Life – Part I: Diversity of Life

- The Phylogeny of Marine Life
  - Constructing a Phylogenetic Tree of Life
- Bacteria
  - Cultivating Marine Bacteria
- Archaea
- Phytoplankton
  - Counting Phytoplankton
- Seaweeds and Marine Plants
- Animals
- Viruses
  - Isolating Viruses from the Ocean

Module Goals

- Remember the **diverse life forms** in the ocean;
- Describe the **key characteristics** of different life forms;
- Explore the **study methods** of marine microorganisms



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The Phylogeny of Marine Life

Life – Originated in the Early Ocean

- **Origins of life**: The geology of early Earth gives us some clues of life's origins
- **Organisms:** The first organisms emerged between 3.8 and 2.5 billions of years ago (BYA)
- **Early ocean:** At that time, the Earth was hot and water accumulated on the surface in the chemically-rich ocean

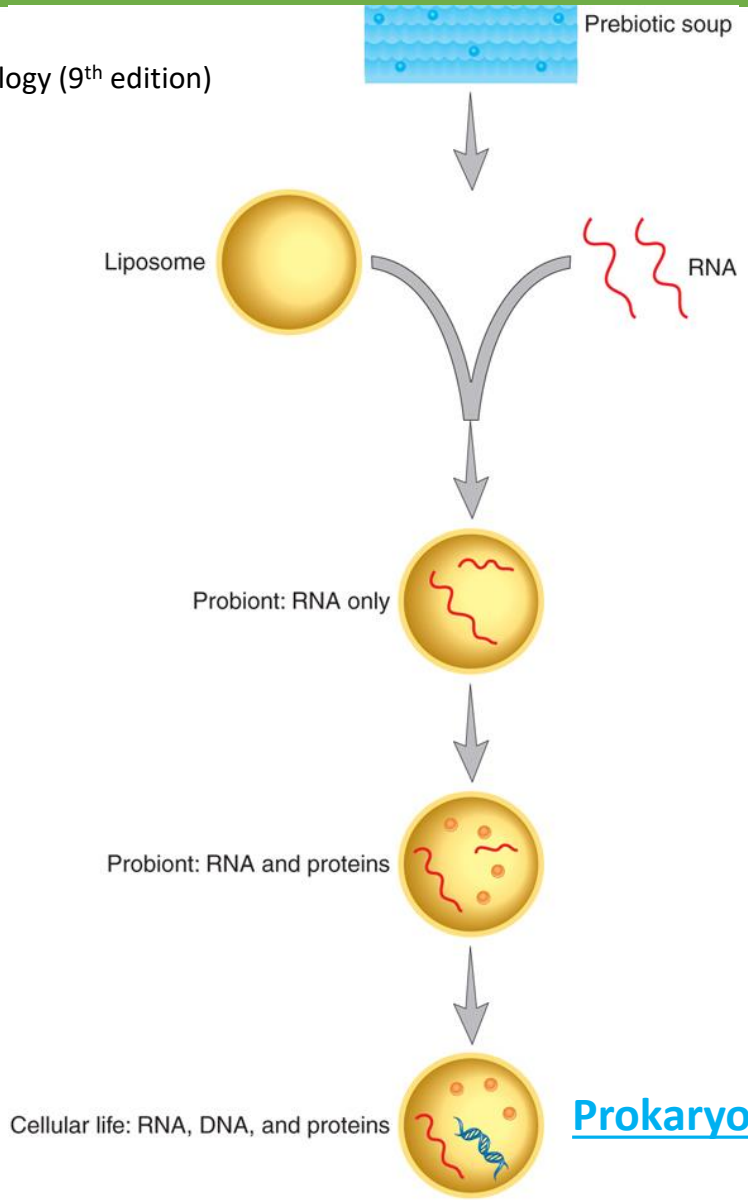
Image from Pixabay

Scientific consensus:

Life arose spontaneously from these early chemically-rich waters.

The Accidental Evolution of Cellular Life

Image:
Prescott Microbiology (9th edition)



How did Prokaryotes evolve?

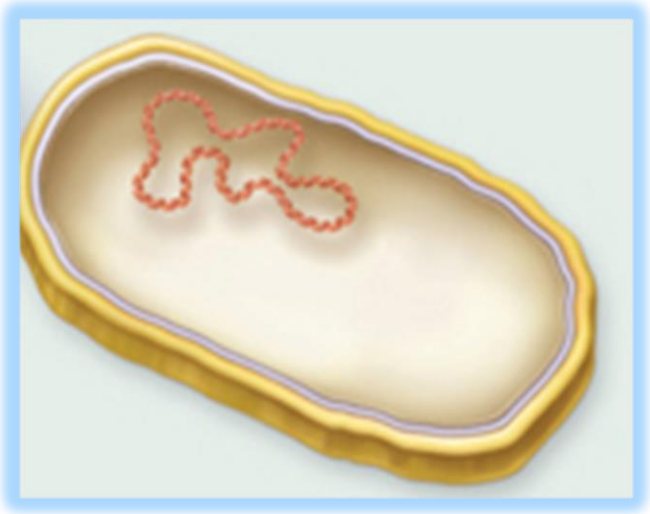
- First there were **inorganic molecules**. Then, **organic (carbon-based) molecules** formed from them. Finally, they assembled into **a functional, interdependent unit**
- Original molecules must have fulfilled **protein and genetic functions**
- Ribozymes: RNA molecules that perform cellular work and replication
- Earliest cells may have been RNA surrounded by liposomes

Prokaryotes

The first cells

The first cells were **Prokaryotes**

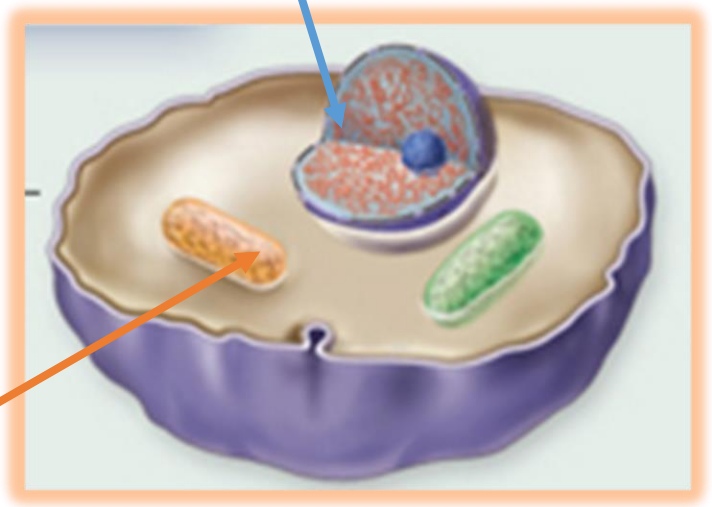
– cells WITH NO nucleus or organelle



Prokaryotes evolved into **Eukaryotes**

– cells WITH NUCLEUS and organelles

Nucleus: an organelle that contains DNA

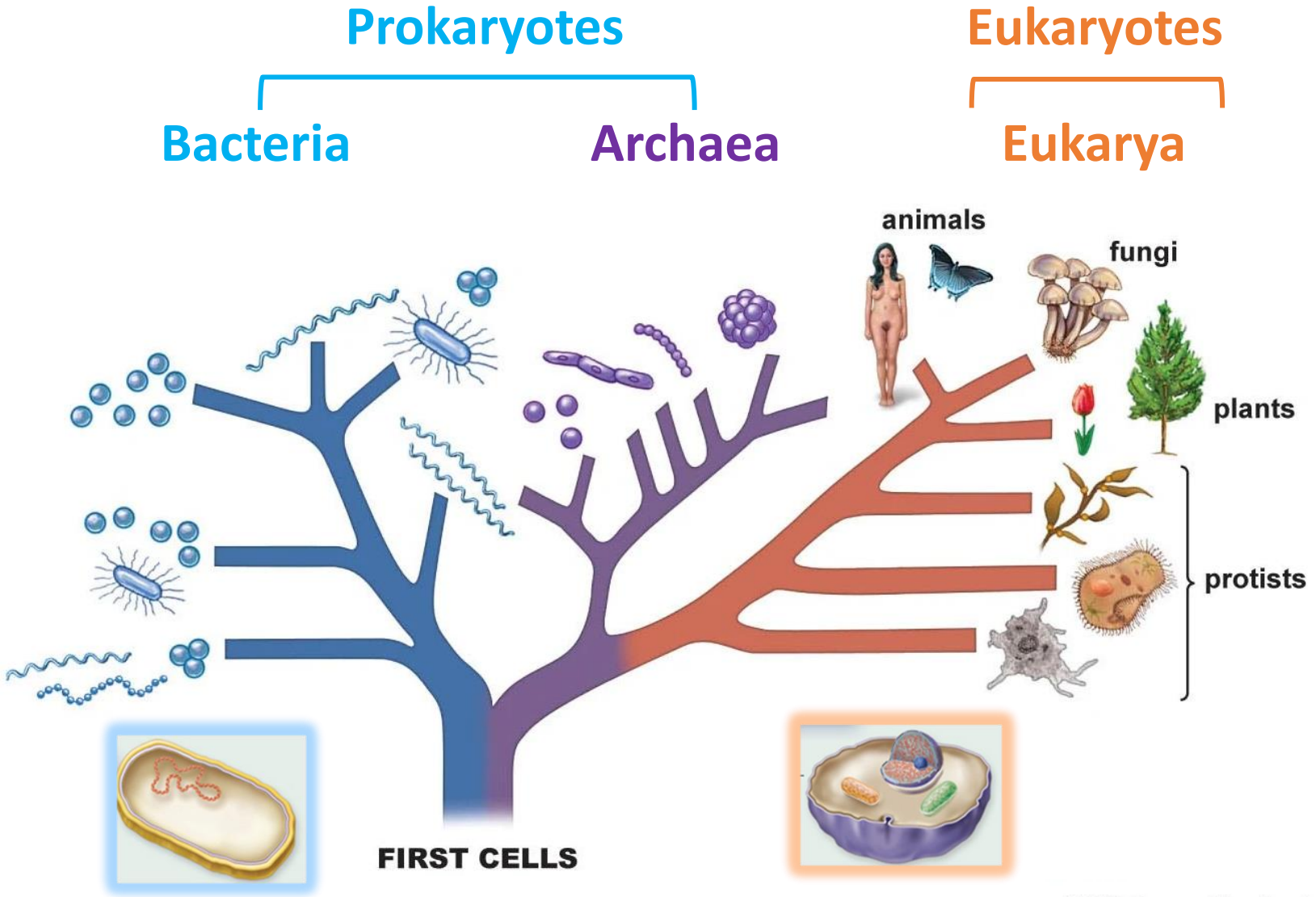


Organelle: a membrane-bound structure that performs specific functions within a cell

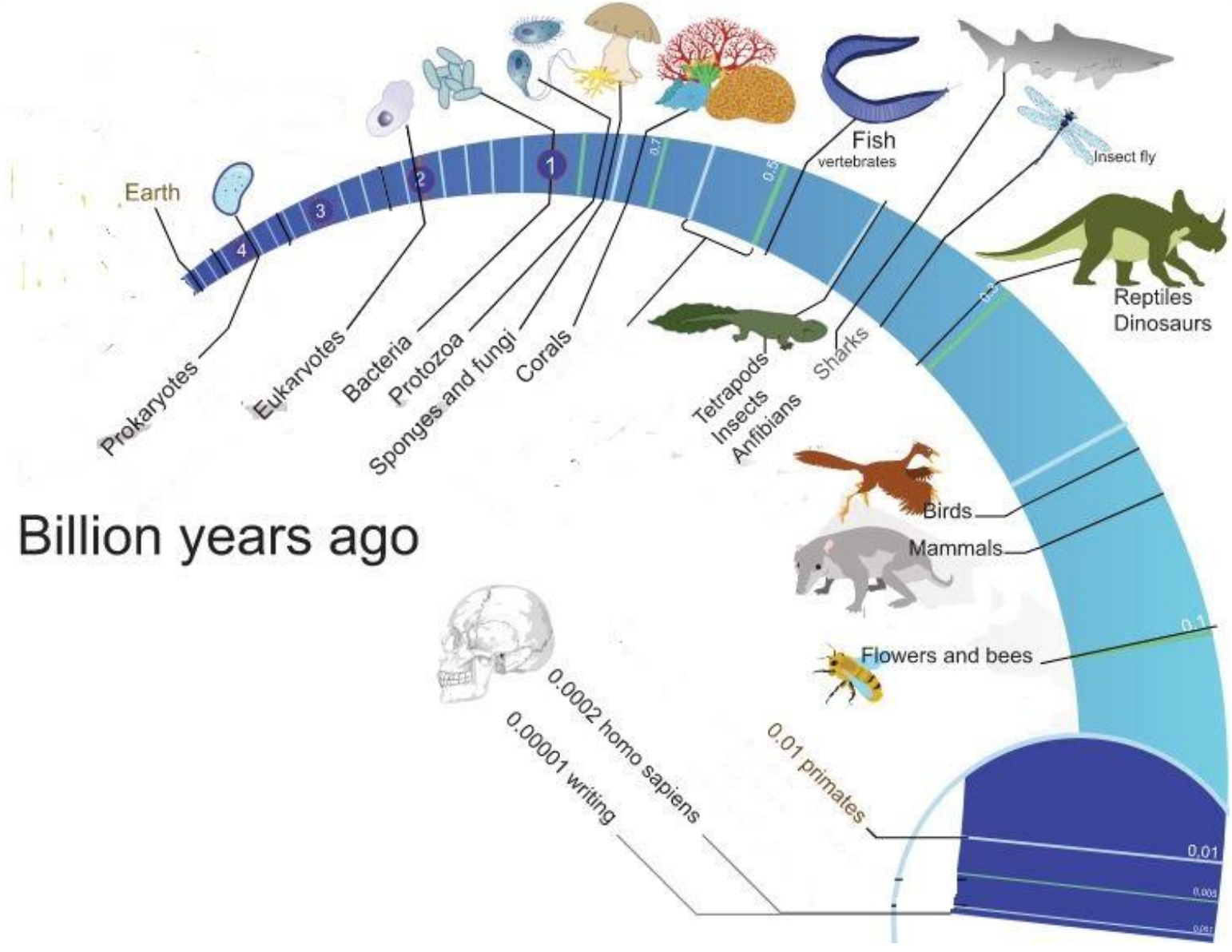
The Phylogenetic Tree of Life

The Three-domain System of phylogeny:

- **Bacteria** (no organelle)
- **Archaea** (no organelle)
- **Eukarya** (with organelles)



Evolution of Different Life Forms



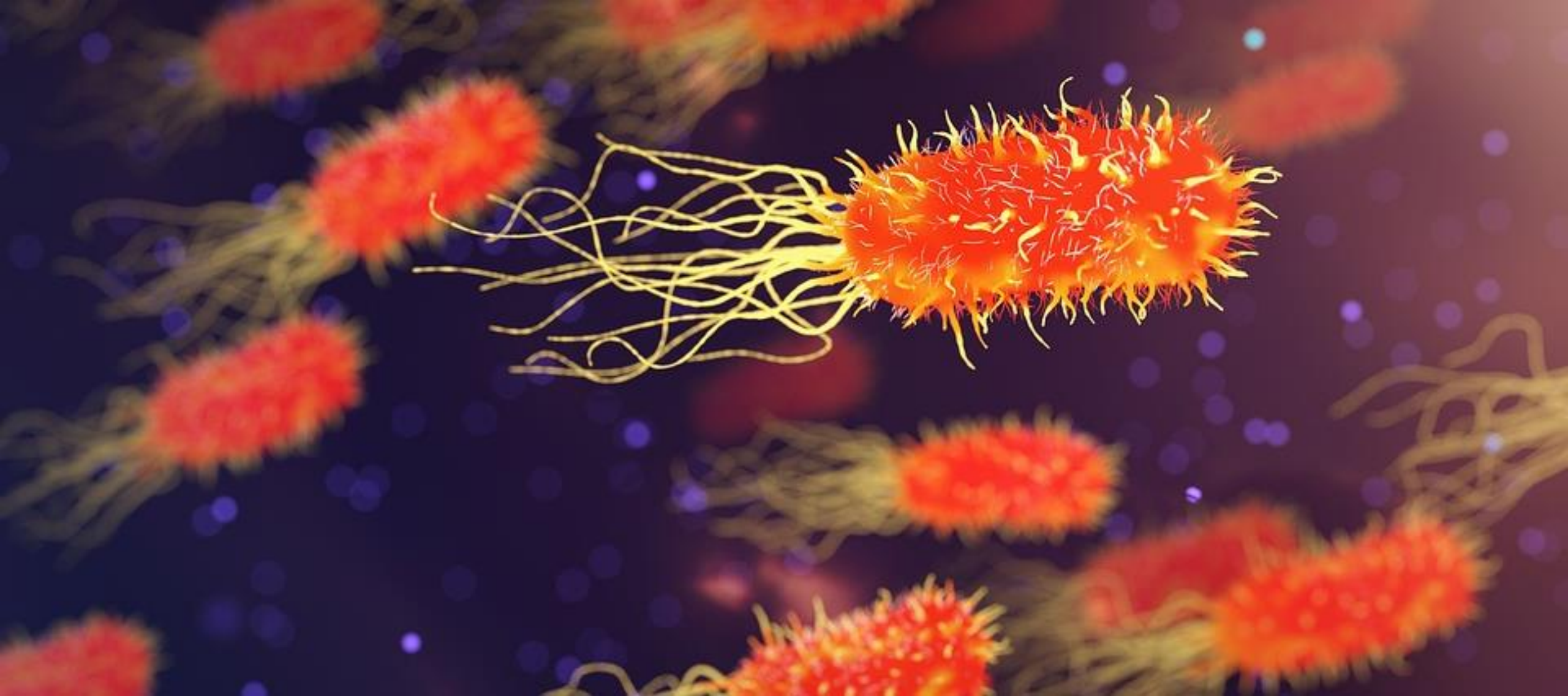
Questions

1) Where has life originated?

Hot and chemically-rich early Ocean

2) How has life evolved on Earth?

- From inorganic molecules to organic molecules to functional independent units
- From Prokaryotes to Eukaryotes



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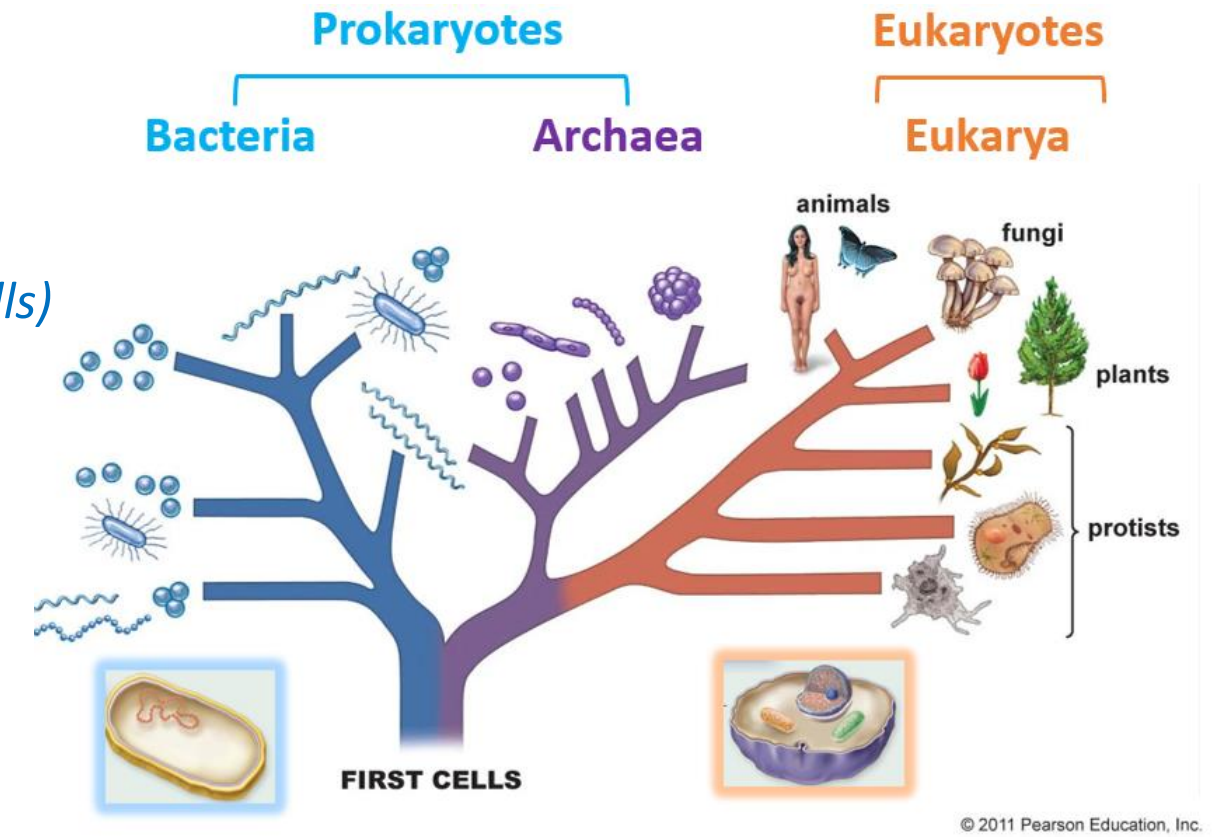
Bacteria

Microorganisms

- Organisms and acellular entities which are **too small** to be clearly seen by the unaided eye
  - Some < 1 mm, some macroscopic

(acelluar / noncellular = not made up of or containing cells)

- These organisms are relatively **simple** in their construction and **lack highly differentiated cells and distinct tissues**



Microorganisms

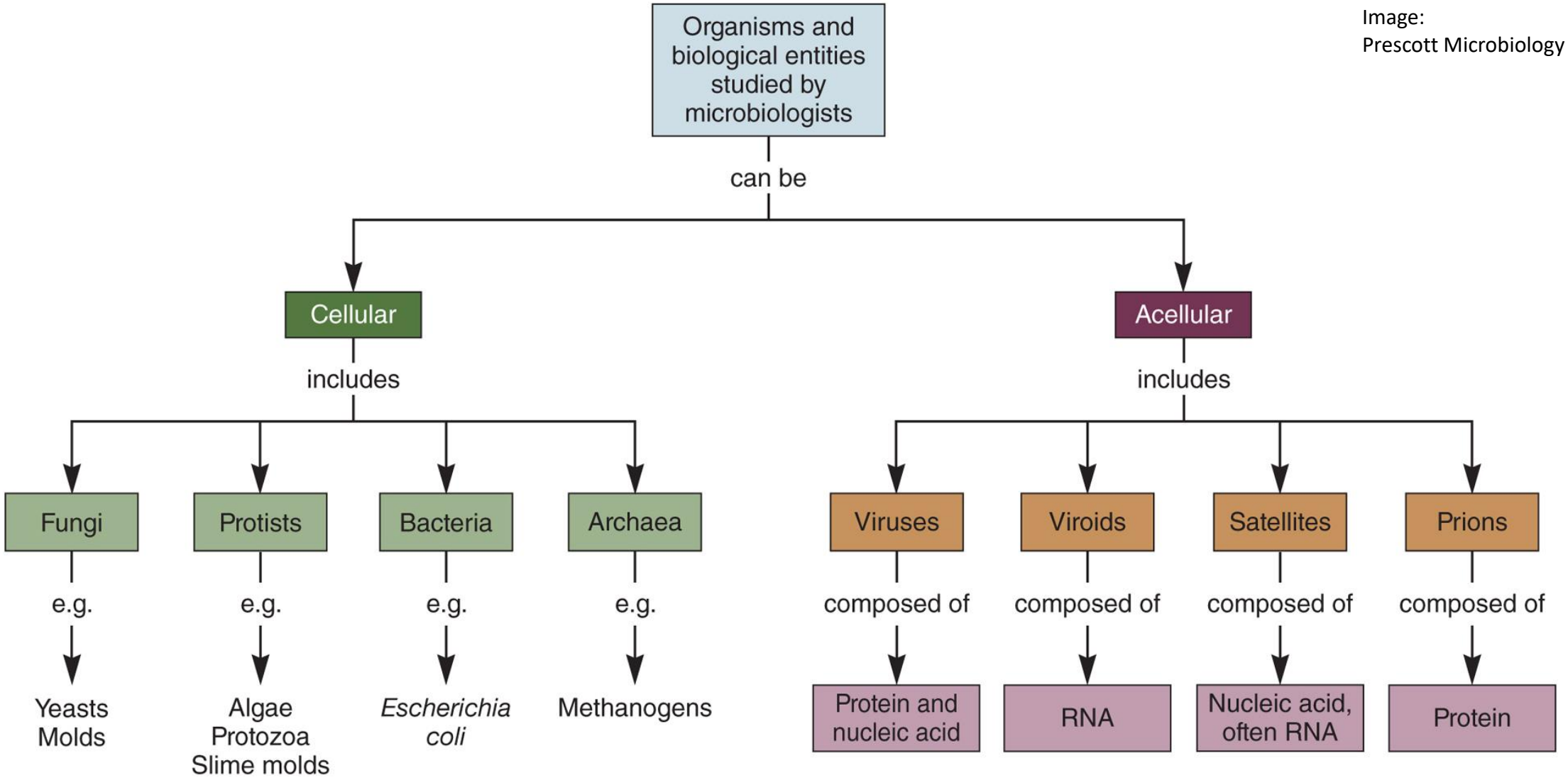


Image:
Prescott Microbiology (9th edition)

Domain *Bacteria* – Characteristics

- Usually **single-celled**
- Most **lack a membrane-bound nucleus**
- **Ubiquitous** (present everywhere) and some live in **extreme environments**

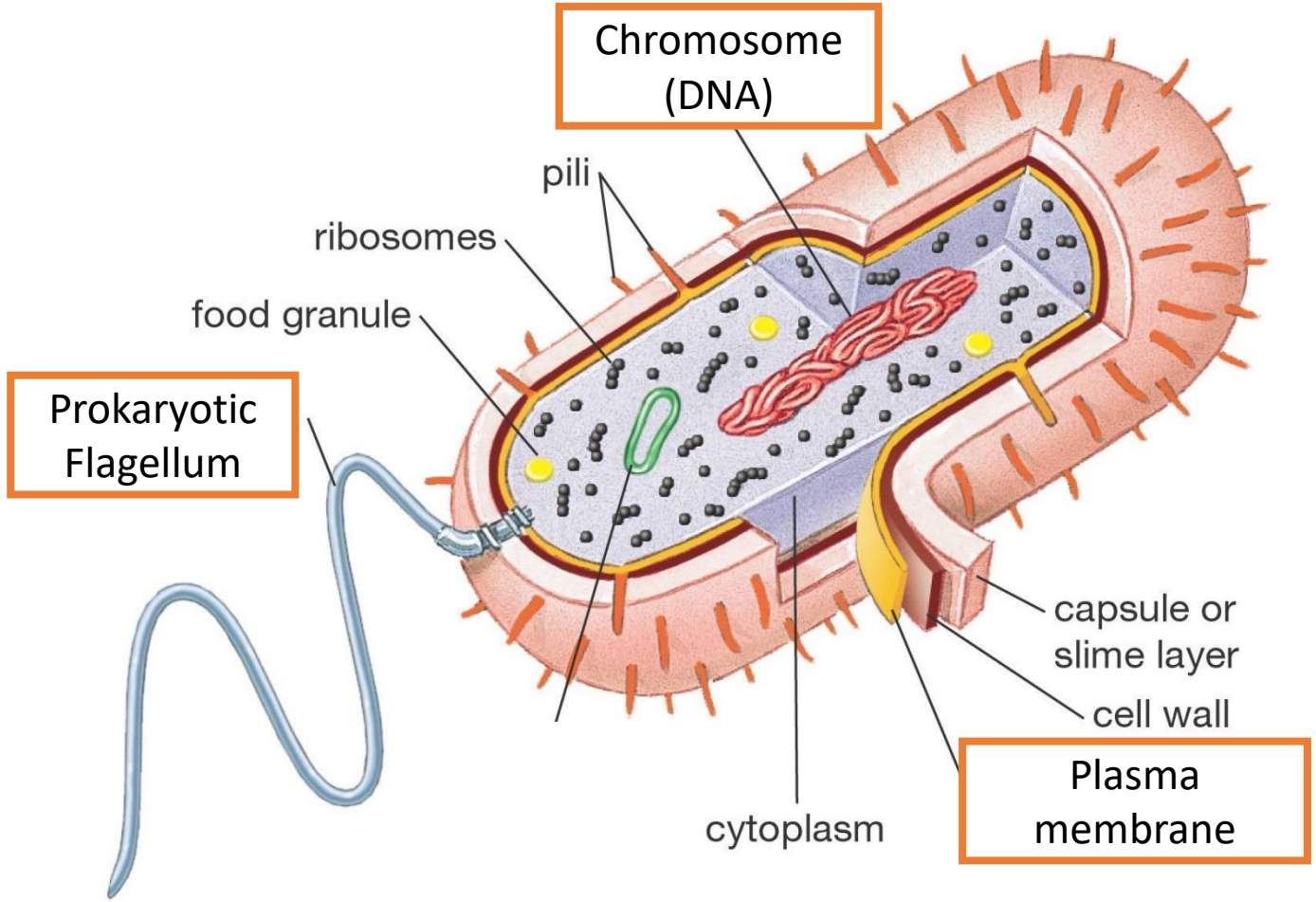
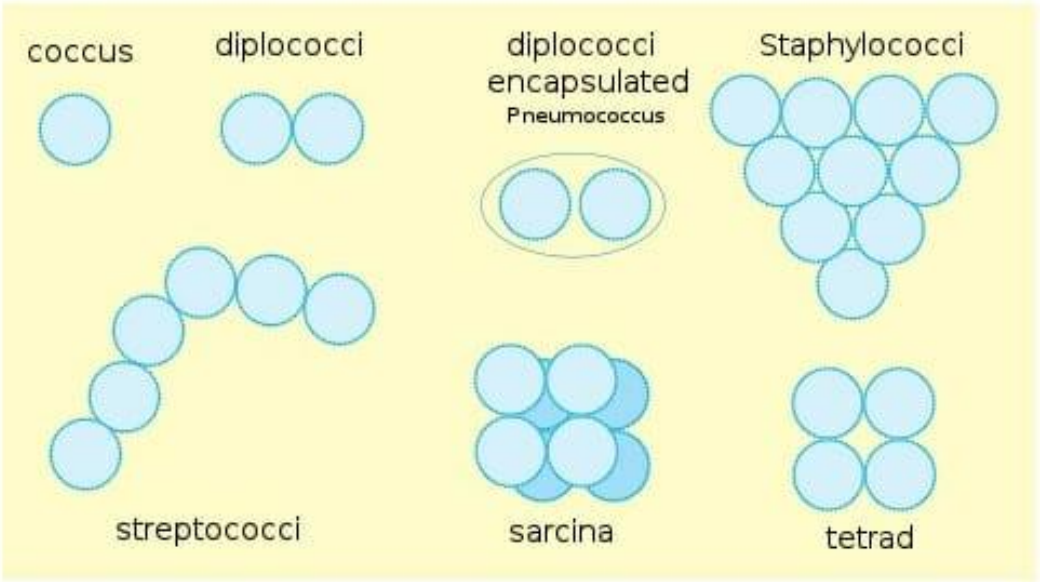
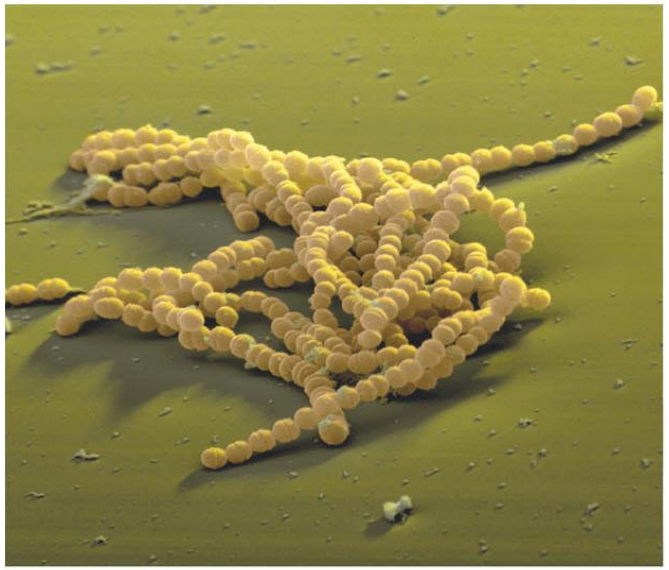


Image: biosjaychemist.worldpress.com

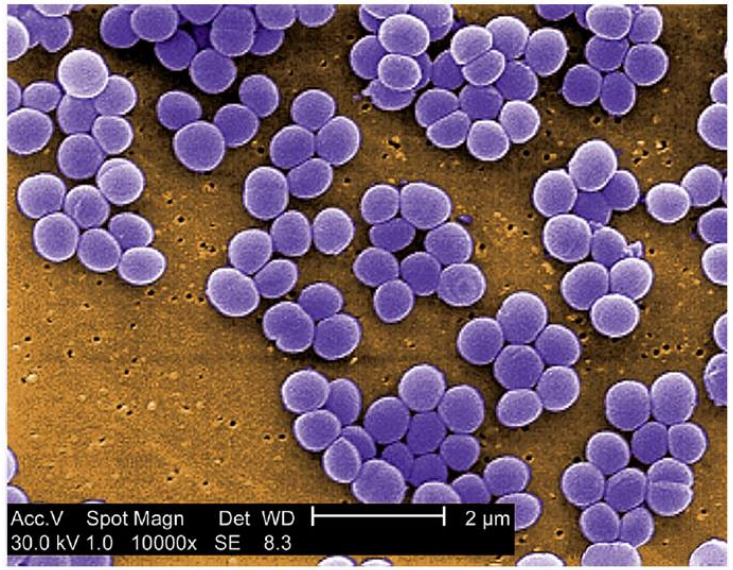
Bacteria – Shape and Arrangement (*Cocci*)

Cocci (singular, coccus): spherical





(a) *S. agalactiae*—cocci in chains

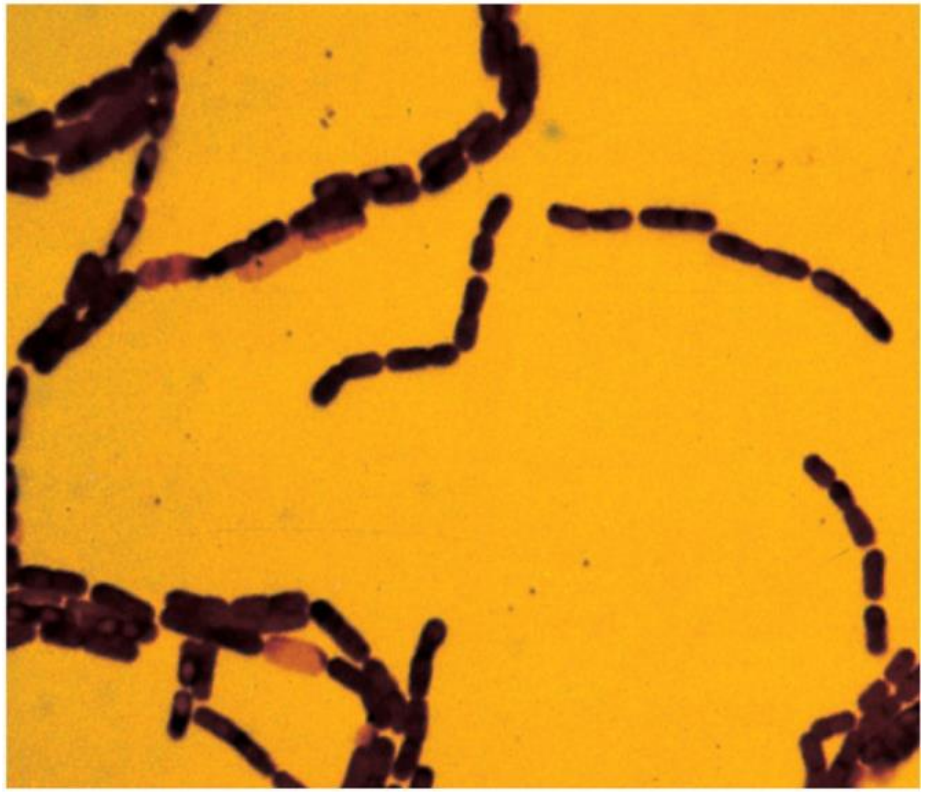


(b) *S. aureus*—cocci in clusters

Image: Prescott Microbiology (9th edition)

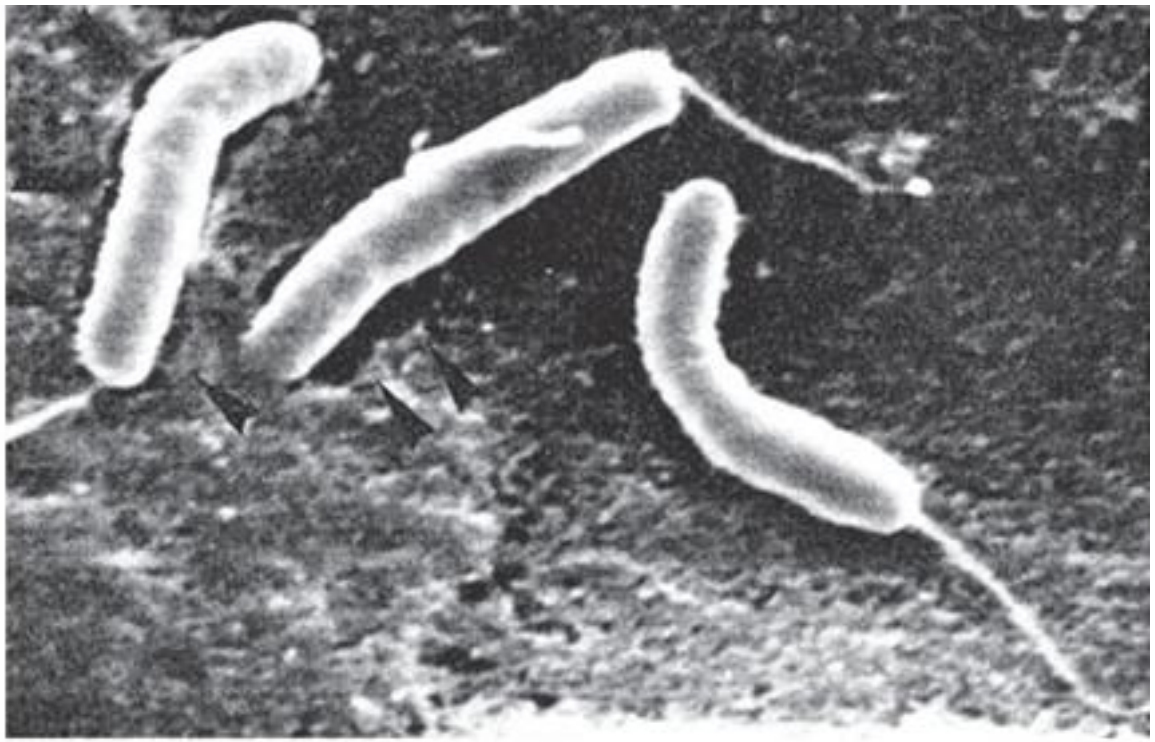
Bacteria – Shape and Arrangement (*Bacilli* and *Vibrios*)

- **Bacilli** (singular, bacillus): **rods**



(c) *B. megaterium*—rods in chains

- **Vibrios**: resemble rods, **comma-shaped**



(a) *V. cholerae*—comma-shaped vibrios

Image: Prescott Microbiology (9th edition)

Bacteria – Size

Specimen	Approximate diameter or width × length in nm
Oscillatoria	
Red blood cell	7,000
E. coli	1,300 × 4,000
Streptococcus	800–1,000
Poxvirus	230 × 320
Influenza virus	85
T2 *E.coli* bacteriophage	65 × 95
Tobacco mosaic virus	15 × 300
Poliomyelitis virus	27

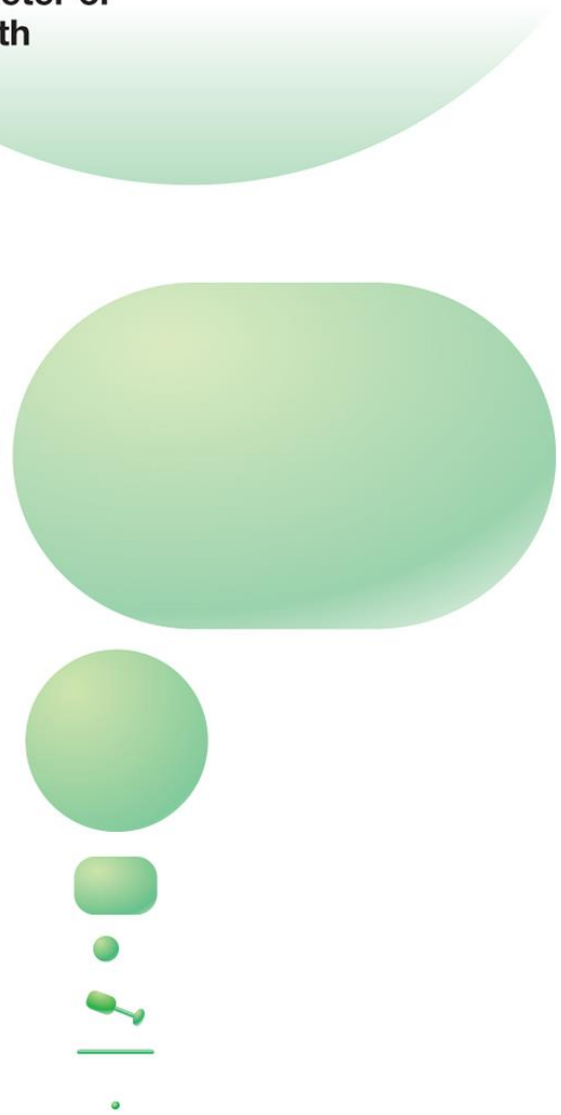


Image:
Prescott Microbiology (9th edition)

Bacteria – Cell Organization

Common Features:

- **Cell envelope** (3 layers)
  - **Plasma Membrane**
  - **Cell Wall**
  - **Capsule**
- **Cytoplasm**
- **External structures**

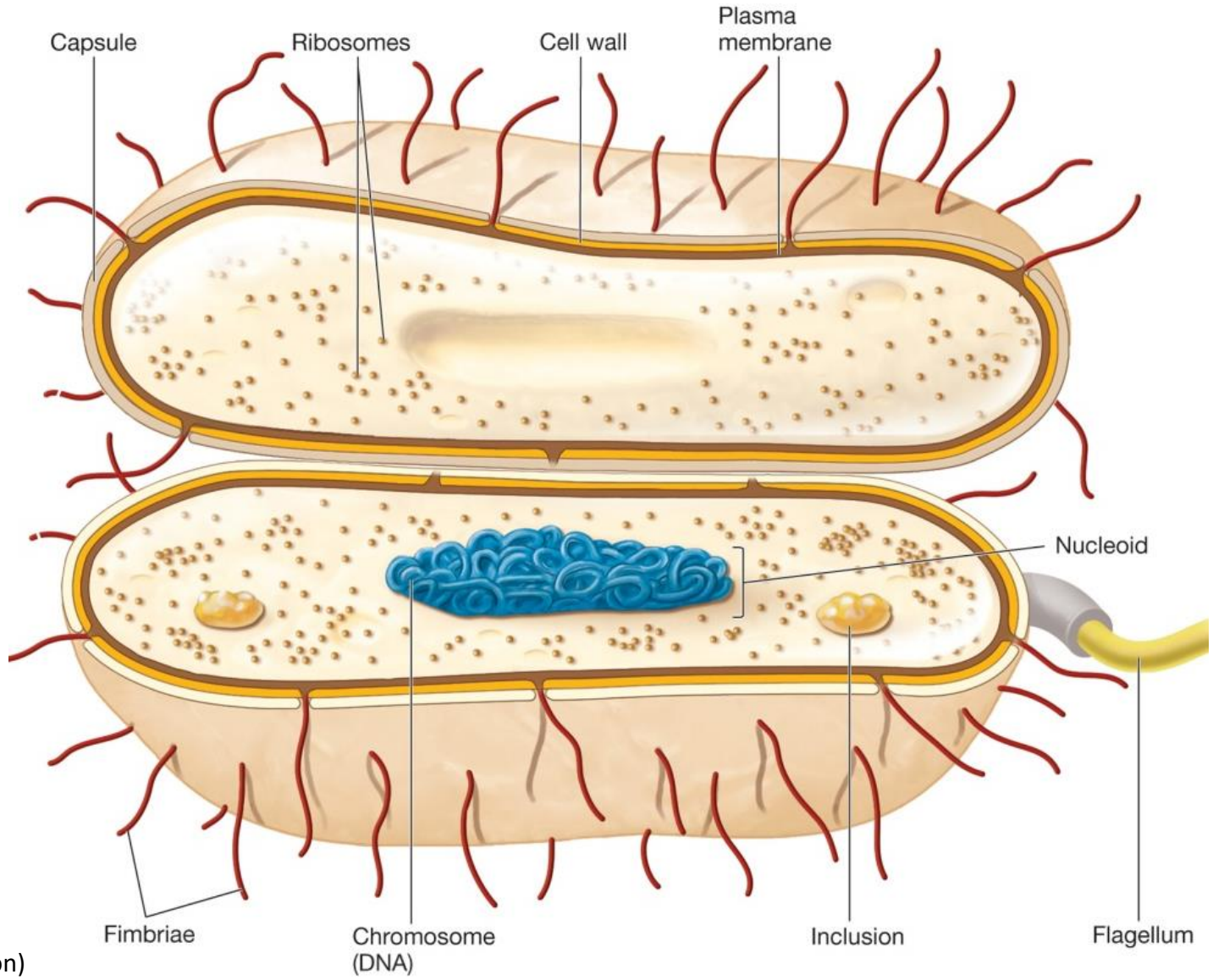


Image: Prescott Microbiology (9th edition)

Questions

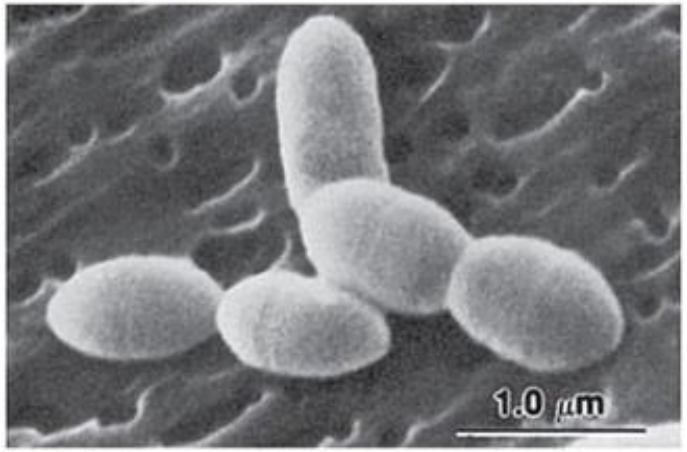
1) What is the difference between microorganism and bacterium?

Bacterium is one type of microorganism.

2) What are the common features of a bacterial cell?

- Cell envelope
- Cytoplasm
- External structures

Image: Prescott Microbiology (9th edition)



(a) *Methanobrevibacter smithii*—oval-to-short rod-shaped cells

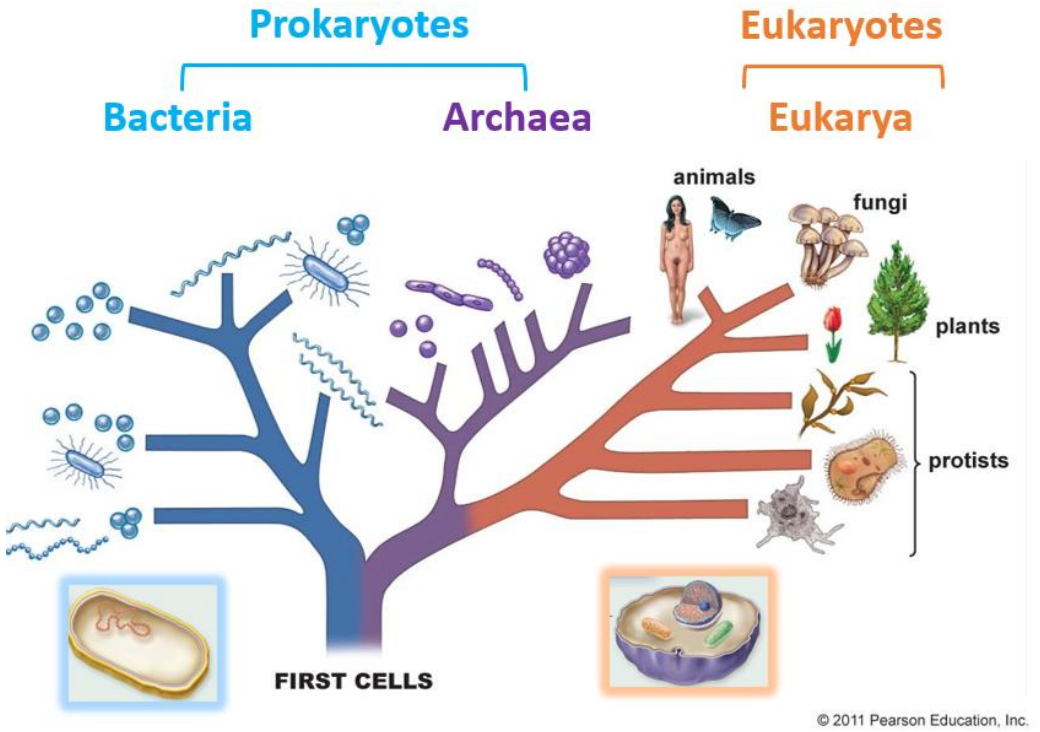
(b) *Methanosarcina mazei*—a coccus that forms clusters

- Bacteria and archaea **cannot** be distinguished by simple microscopy
- Cells in both microbial groups do **not** have a nucleus and **lack** the organelles found in eukaryotes

Archaea

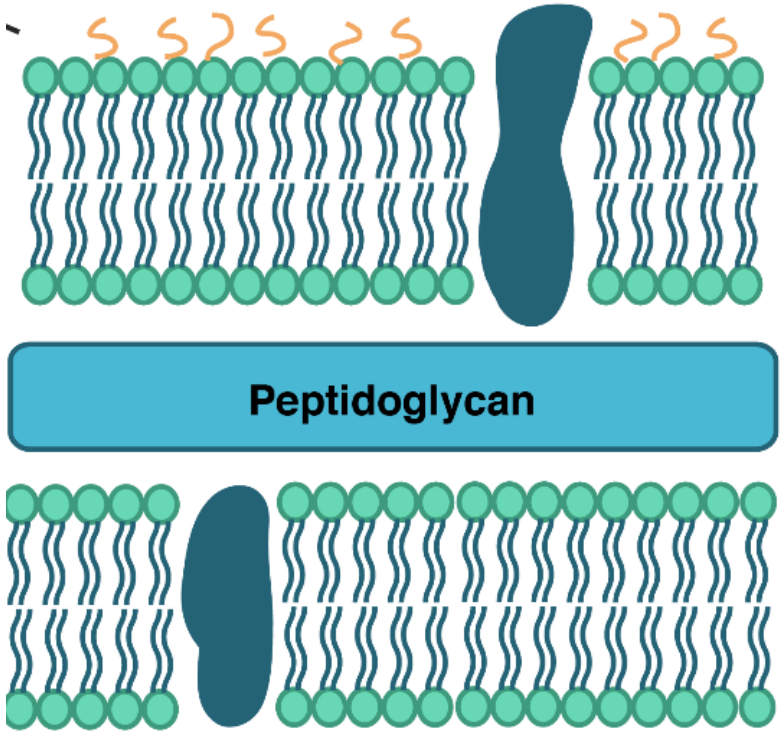
Archaea – Different from Bacteria

- Distinguished from *Bacteria* by unique rRNA gene sequences
- Lack peptidoglycan in cell walls
- Have unique membrane lipids
- Some have unusual metabolic characteristics
- **Many live in extreme environments (e.g. hot springs, deep sea)**



For visual reference only:

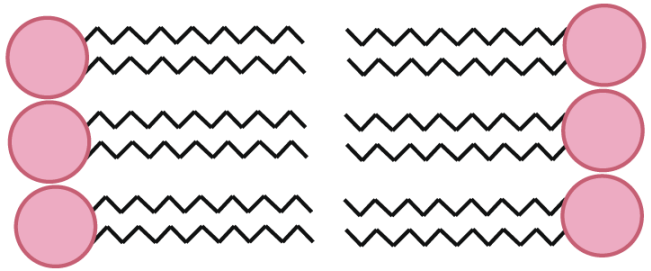
Bacteria has peptidoglycan in between cell wall; Archaea does not



For visual reference only:

Bacteria has bilayer

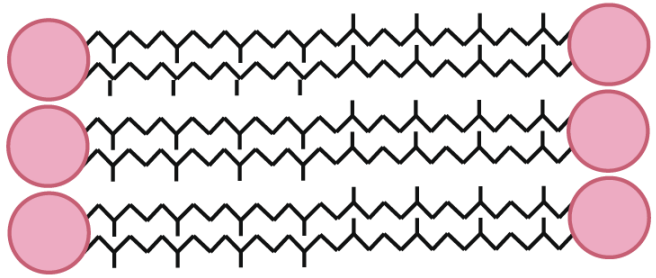
Lipid bilayer



Bacteria and eukaryotes

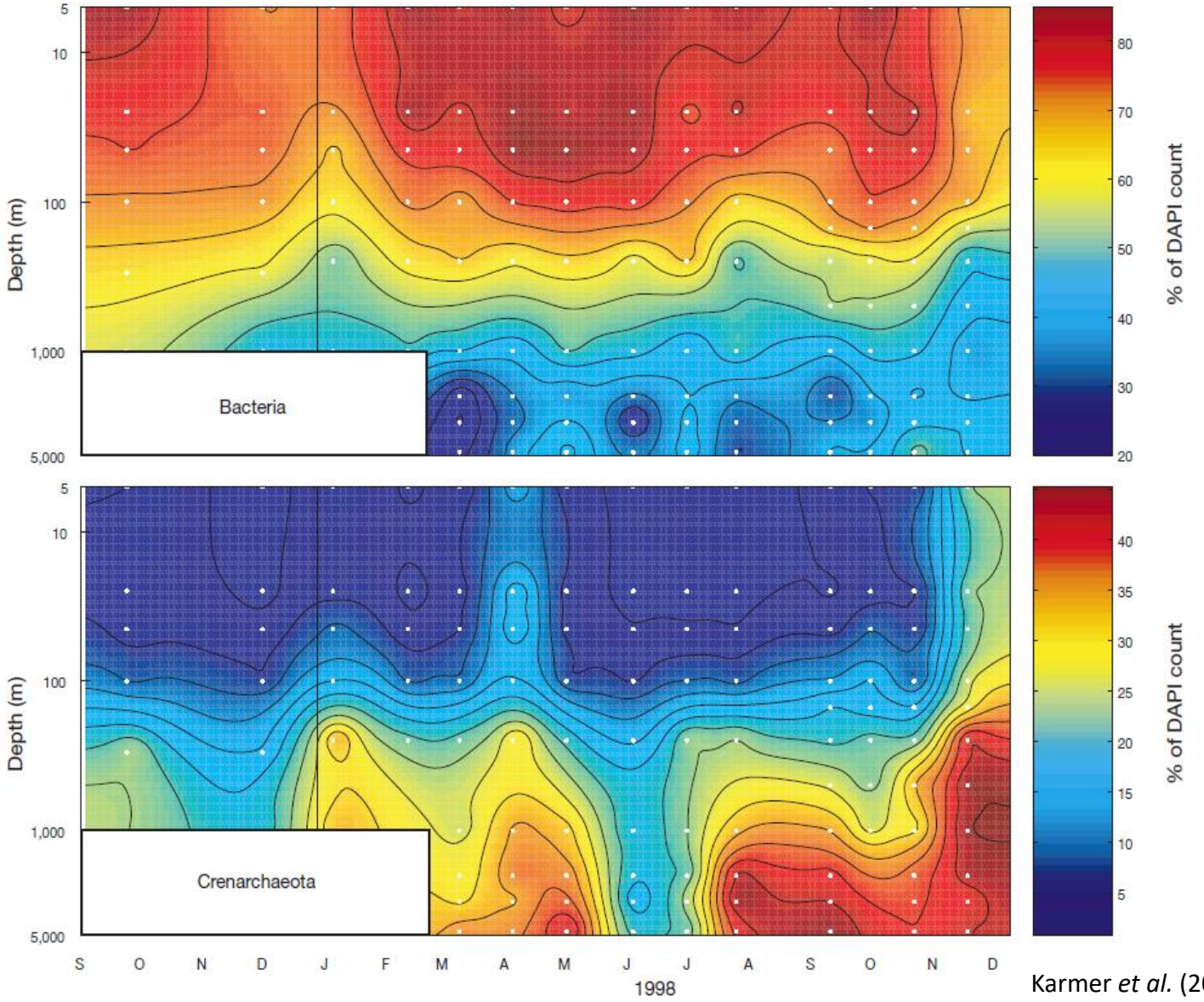
Archaea has monolayer

Lipid monolayer



Some archaea

Distribution of Bacteria and Archaea in the Ocean



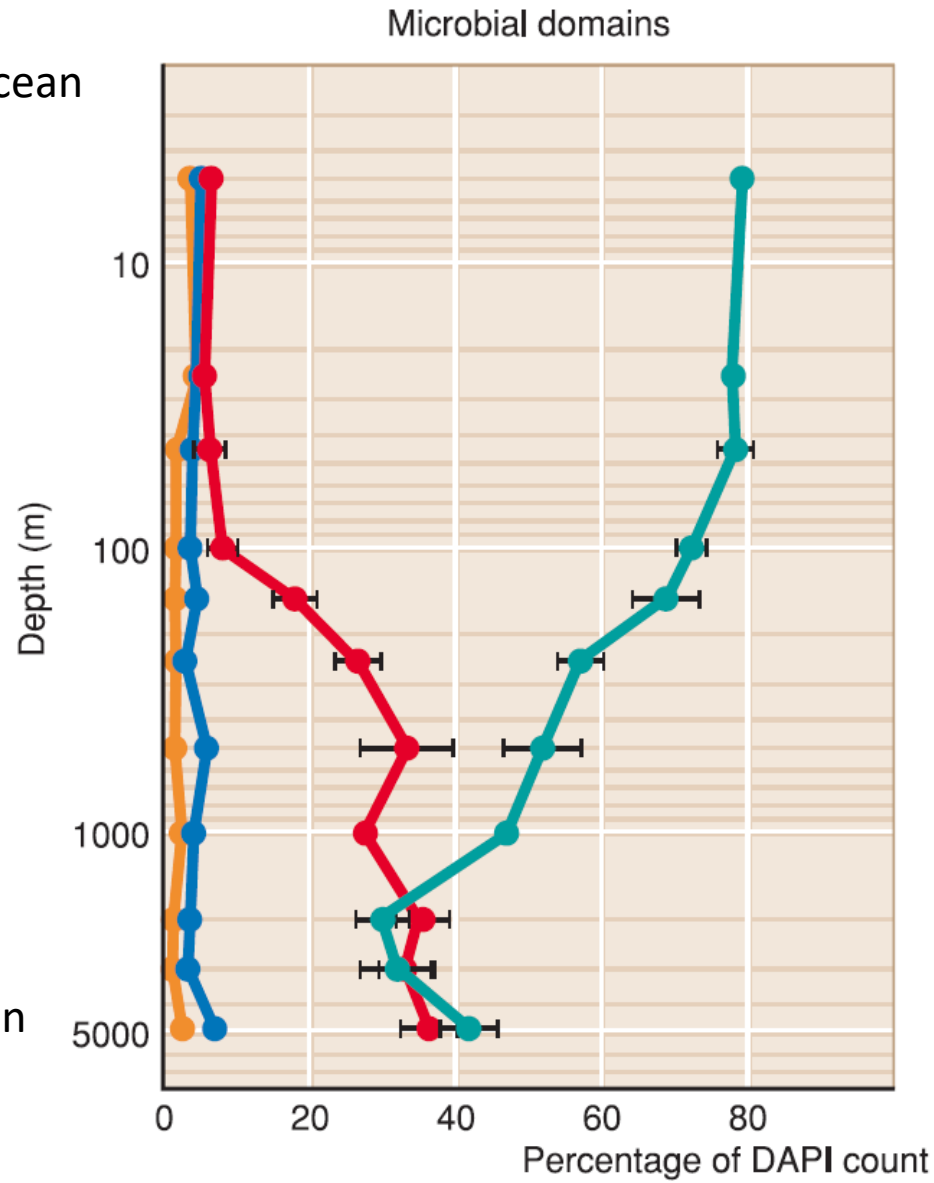
- Relative abundances of bacteria and archaea during a 1-year sampling effort at the **Hawaii Ocean Time-series Station**, ALOHA, in the North Pacific subtropical gyre.
- Total cell abundance was assessed using the DAPI nucleic acid stain.
- Bacteria and archaea were enumerated using whole-cell rRNA targeted fluorescent *in situ* hybridization with fluorescein-labelled polynucleotide probes.

Karmer *et al.* (2001), *Nature*

Distribution of Bacteria and Archaea in the Ocean

Top of the ocean

Bottom of the ocean



Average abundance of bacteria and archaea at the Hawaii Ocean Time-series Station

- **Top** of the ocean — **More bacteria**
- **Bottom** of the ocean — **More archaea**

Karmer *et al.* (2001), *Nature*

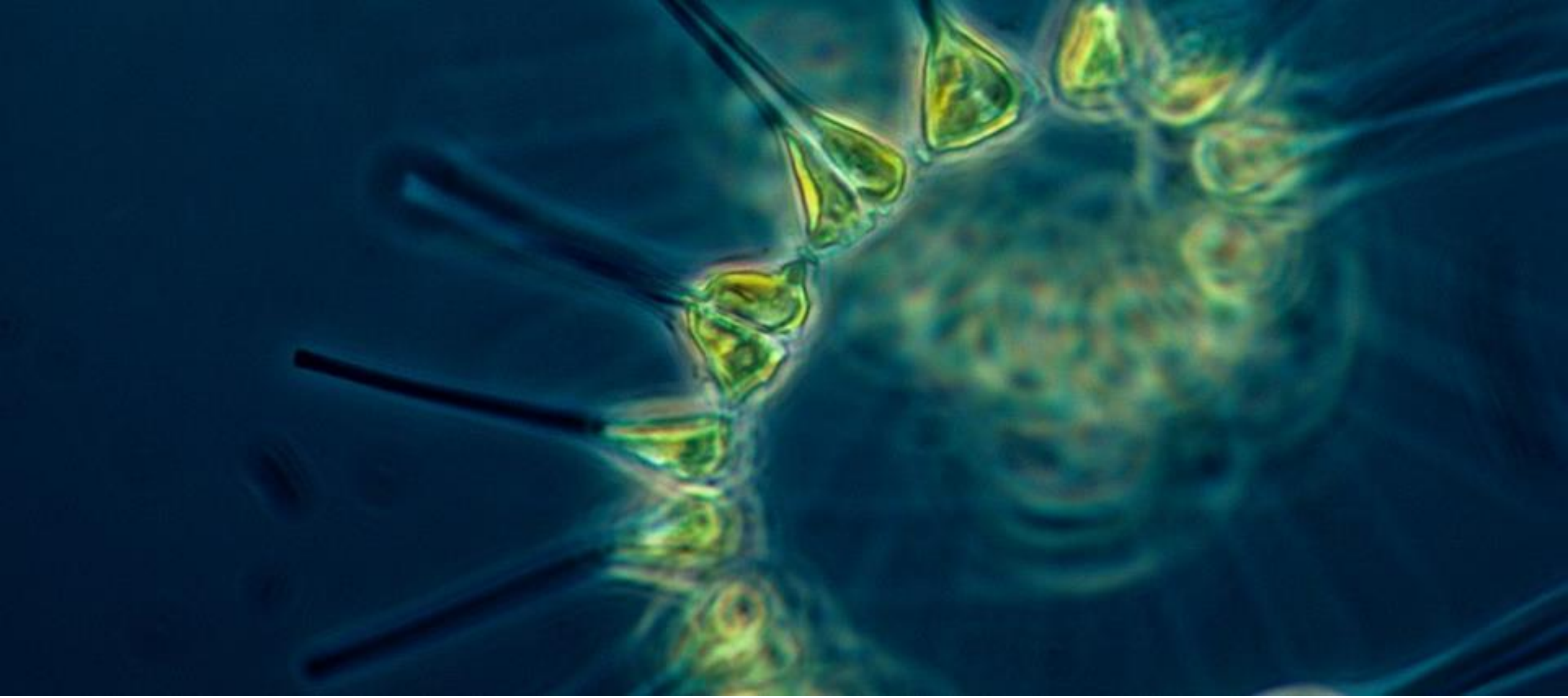
Questions

1) What are the unique cellular structures of archaea?

- Lack peptidoglycan in cell walls
- Have unique membrane lipids

2) In the ocean, do bacteria and archaea have similar or different distributions?

- Different distributions
  - Bacteria more abundant at top of ocean
  - Archaea more abundant at bottom of ocean



DEPARTMENT OF OCEAN SCIENCE

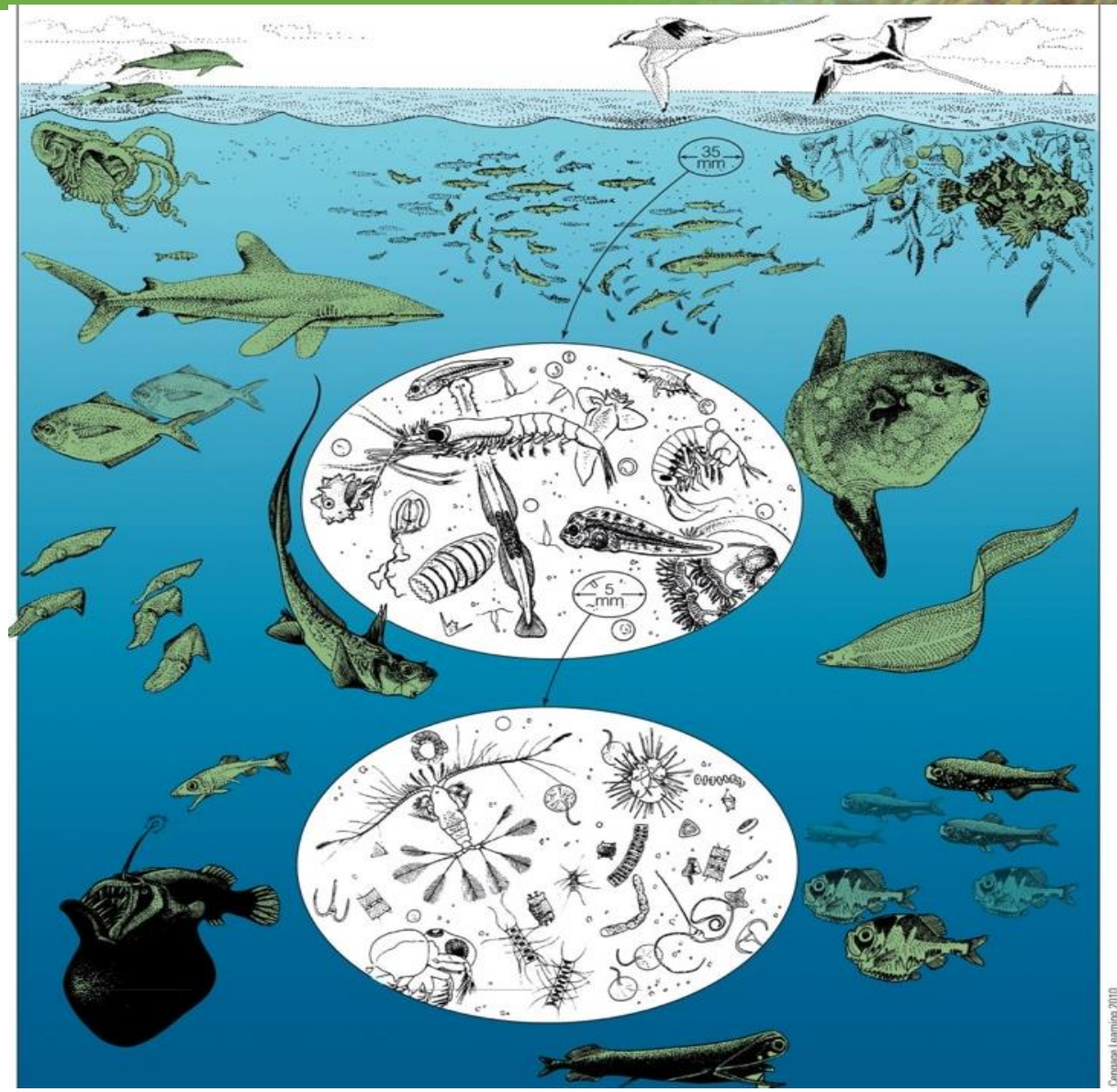
Phytoplankton

Marine Organisms – Lifestyle

Marine organisms can be divided into two broad groups based on their **lifestyle**:

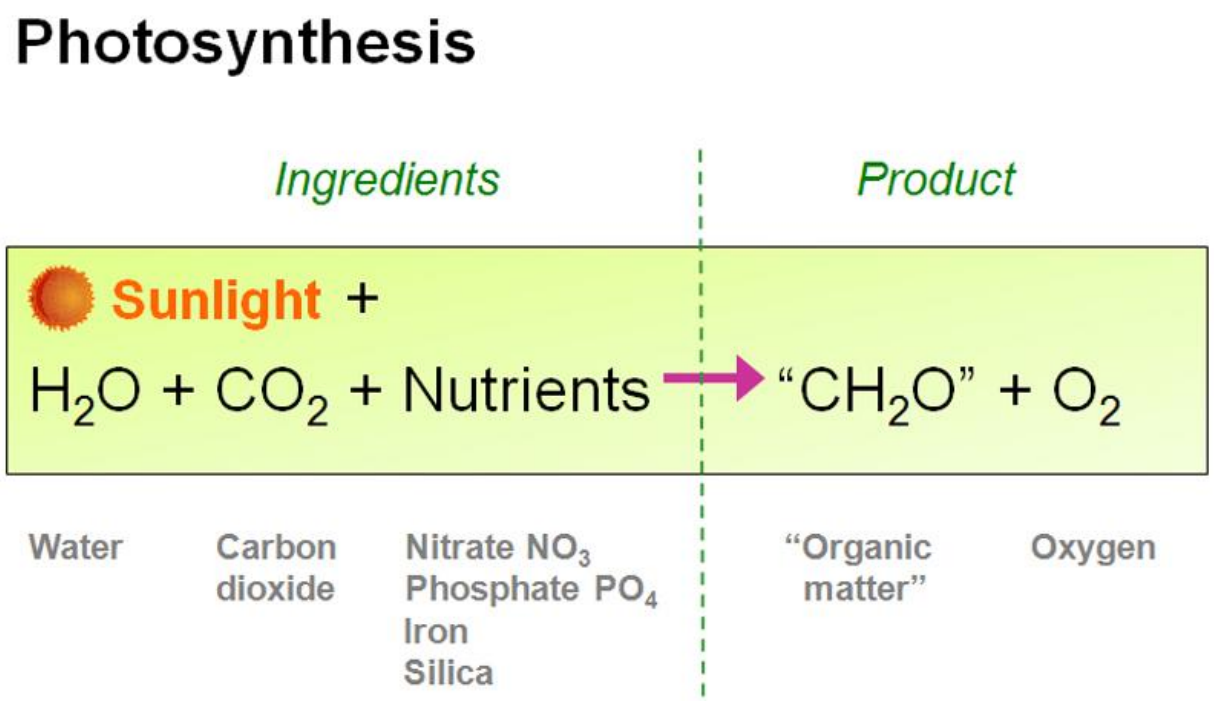
- **Plankton** (“wandering”) – drift or swim weakly, going where the ocean goes; unable to move consistently against waves or current flow (e.g. shrimp)

- **Nekton** – pelagic organisms that actively swim (e.g. fish)



Most Phytoplankton are Photosynthetic Autotrophs

- Phytoplankton can be both Eukaryotes and Prokaryotes
- **Autotrophic** plankton that generate glucose by photosynthesis—the **primary producers**—are generally called **phytoplankton** (***phyton*=plant)**

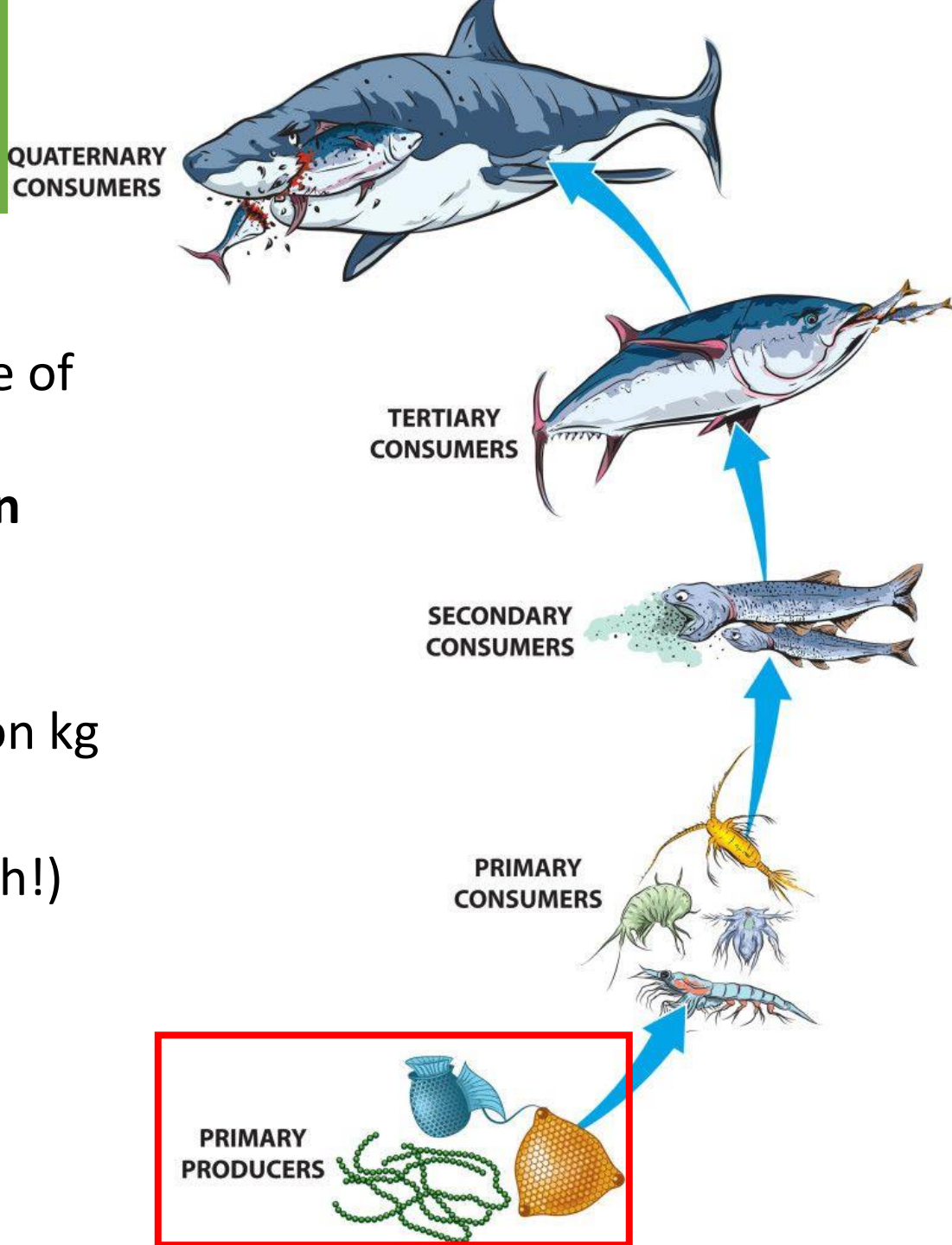


Phytoplankton and the Food Web

- Phytoplankton are critical to all life on Earth because of their **great contribution to food webs** and their **generation of large amounts of atmospheric oxygen** through photosynthesis

- Planktonic autotrophs are thought to bind ≥50 trillion kg of carbon into carbohydrates (sugar) each year

  (=~50% of the food made by photosynthesis on Earth!)



Phytoplankton – Major Types

- **Picoplankton** – encompasses most other plankton types, which are very small
- **Diatoms** – the dominant and most productive of the photosynthetic plankton; contain transparent silica frustules
- **Dinoflagellates** – widely distributed single-celled phytoplankton; use flagella to move
- **Coccolithophores** – small single-celled autotrophs; covered with disks of calcium carbonate

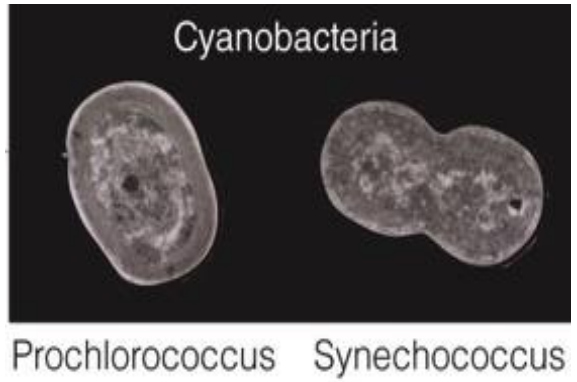
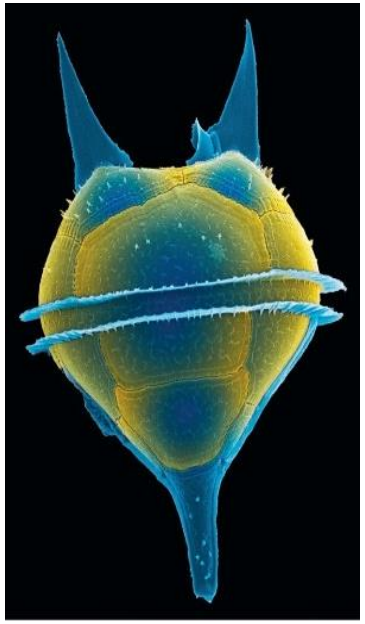
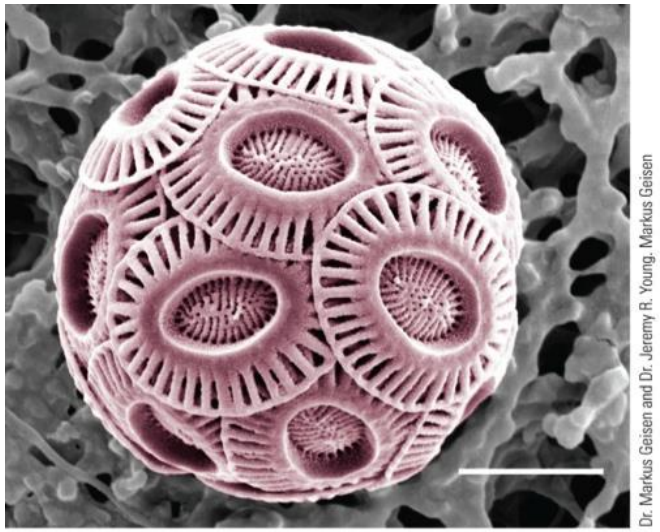


Image: Oceanography

Diatoms



Dinoflagellates



Coccolithophores

Cyanobacterium – *Prochlorococcus*

- The cyanobacterium *Prochlorococcus* is the **smallest and the most abundant photosynthetic organism** on Earth
- Chlorophyll of *Prochlorococcus*: ~ 20% globally

Prochlorococcus

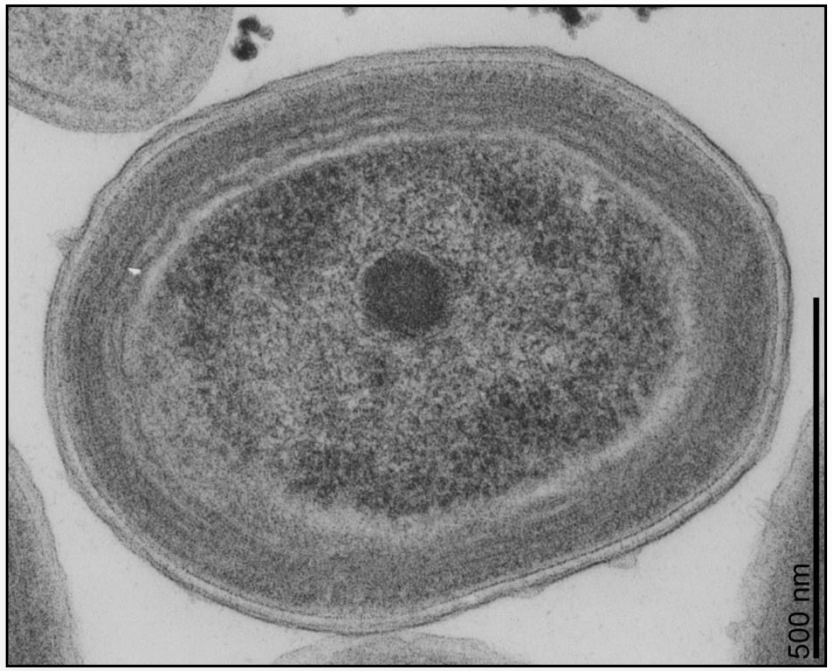
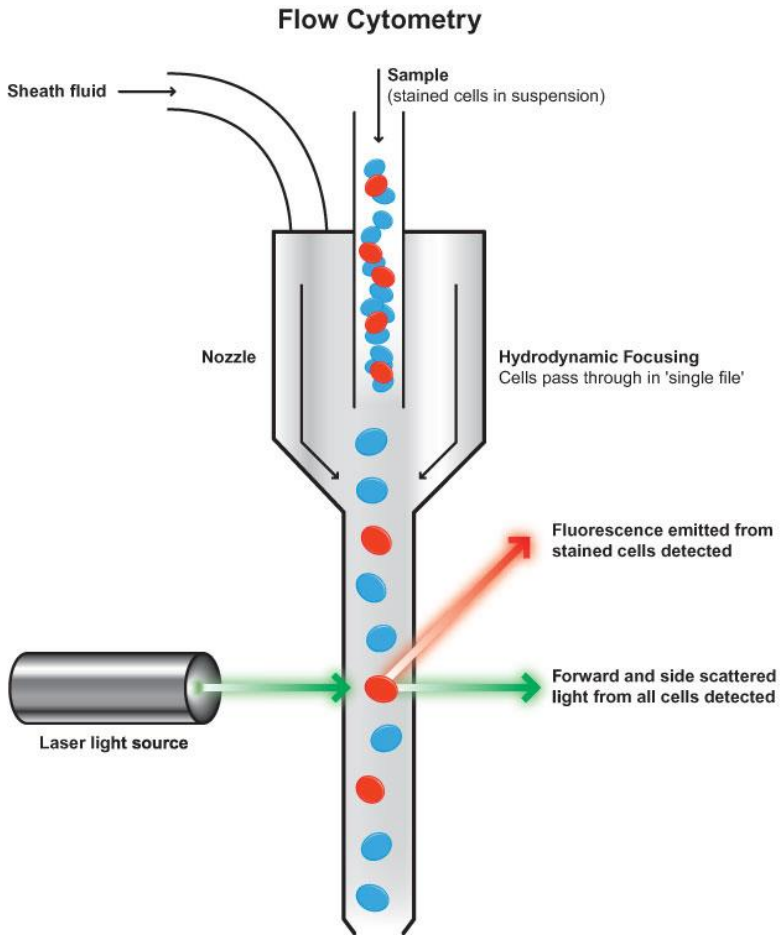


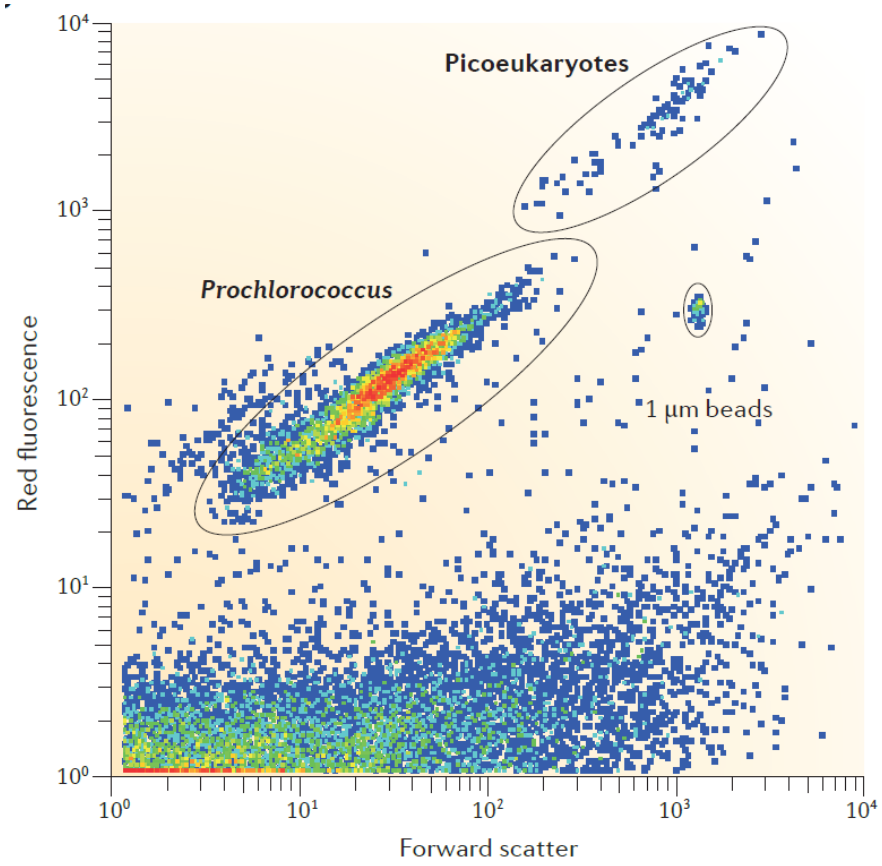
Image: N. Watson & L. Thompson

Sample taken from ocean at HKUST

Cyanobacterium – *Prochlorococcus*

Prochlorococcus was discovered in the 1980s by **Flow Cytometry.**





http://docs.abcam.com/pdf/protocols/Introduction_to_flow_cytometry_May_10.pdf

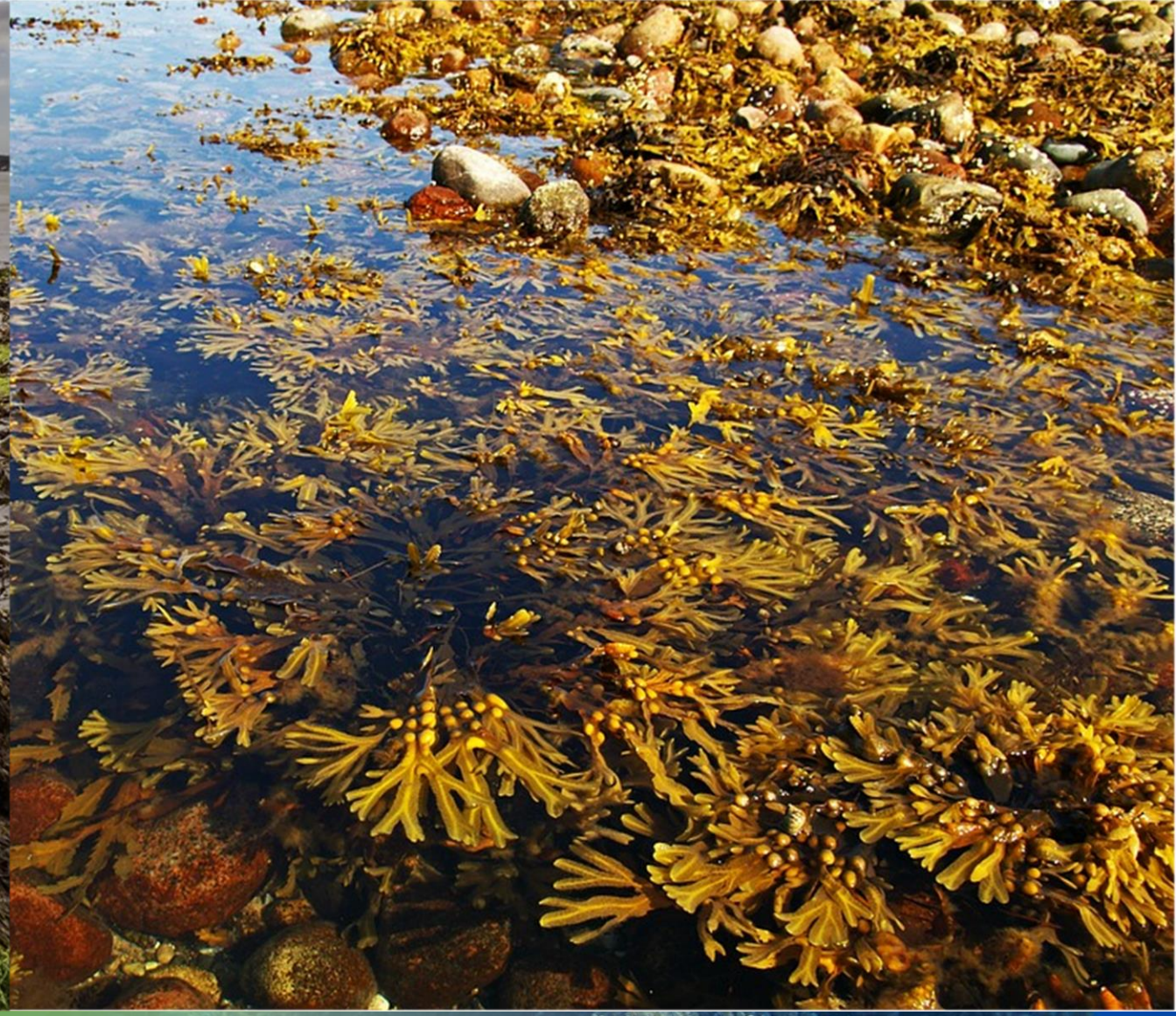
Questions

1) How do phytoplankton obtain energy and carbon?

From photosynthesis, it gets carbon from carbon dioxide and energy from sunlight.

2) Are phytoplankton prokaryotes or eukaryotes?

Both



DEPARTMENT OF OCEAN SCIENCE

Seaweeds and Marine Plants

Seaweeds and Marine Plants

Seaweeds are often called *marine algae* (or *macroalgae*); seagrasses are plants.

- Both are important **primary producers**
- **Eukaryotic**, mostly multicellular

Seaweeds *lack* leaves, stems, and roots of plants. Instead, they have these structures:

- **Blades** (leaf-like structures)
- **Stipes** (stem-like structures)
- **Holdfast** (root-like structures)

These 3 structures lack the conducting tissues (veins) of plants.

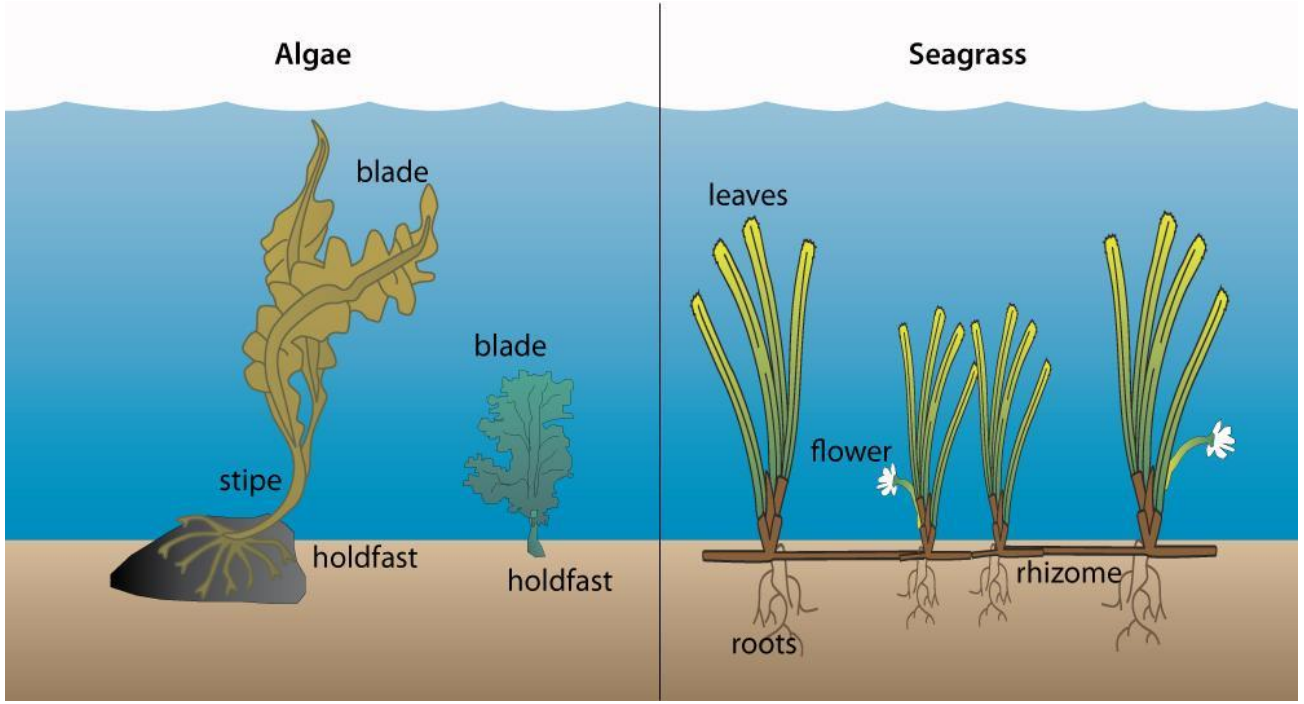


Image: The Smithsonian

Seaweeds – Kelps

- A type of **brown seaweed**
- Found in **temperate** and **polar** locations
- The **largest** of the seaweeds
  - For some species e.g. the **Giant Kelp**, each individual can be hundreds of feet in length
- **Kelp Forests – among the most productive (and richest) marine communities**
  - **High biodiversity**

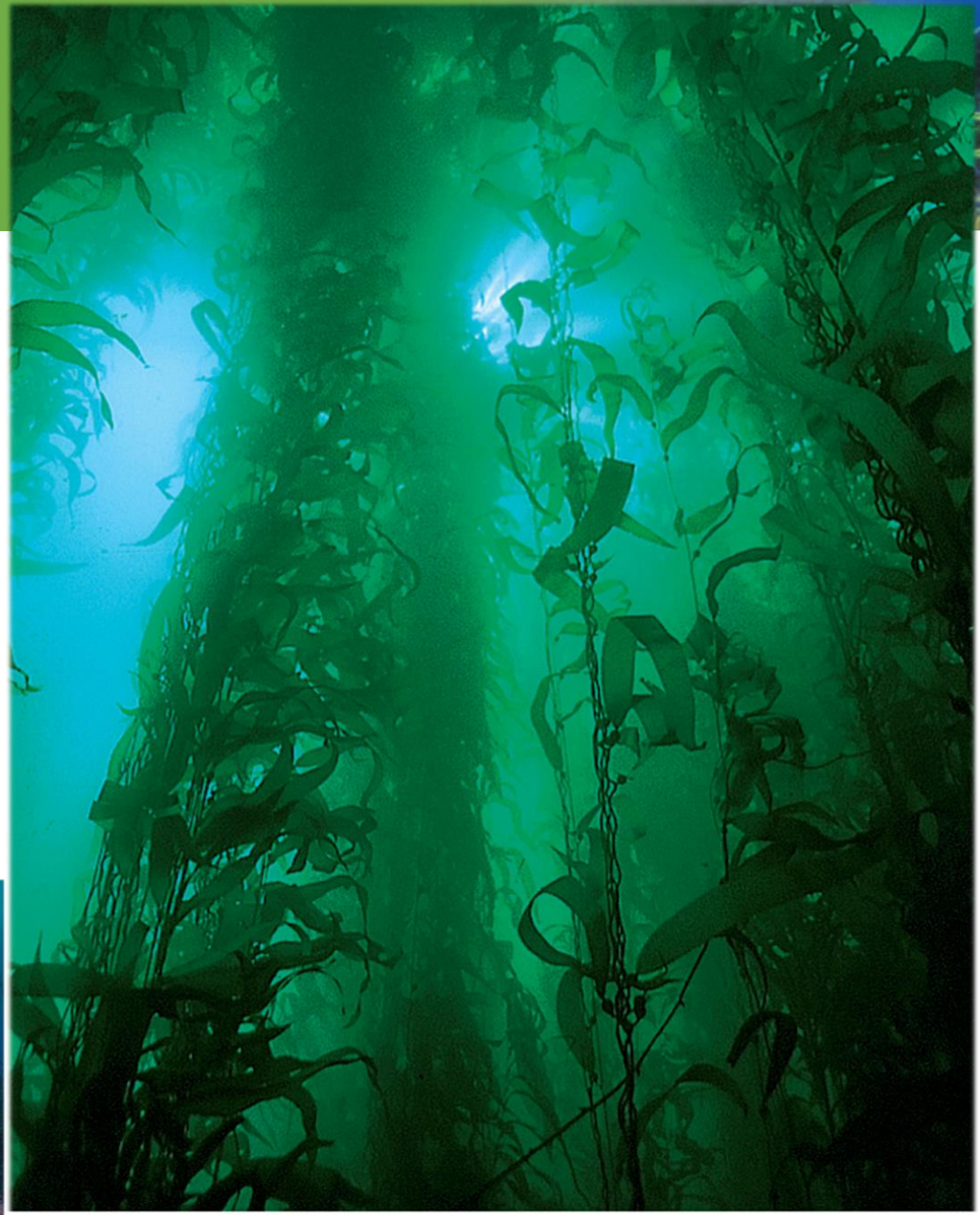


Image: Marine Biology (11th edition)

Seaweeds – Commercial Uses

Some seaweeds are commercially important:

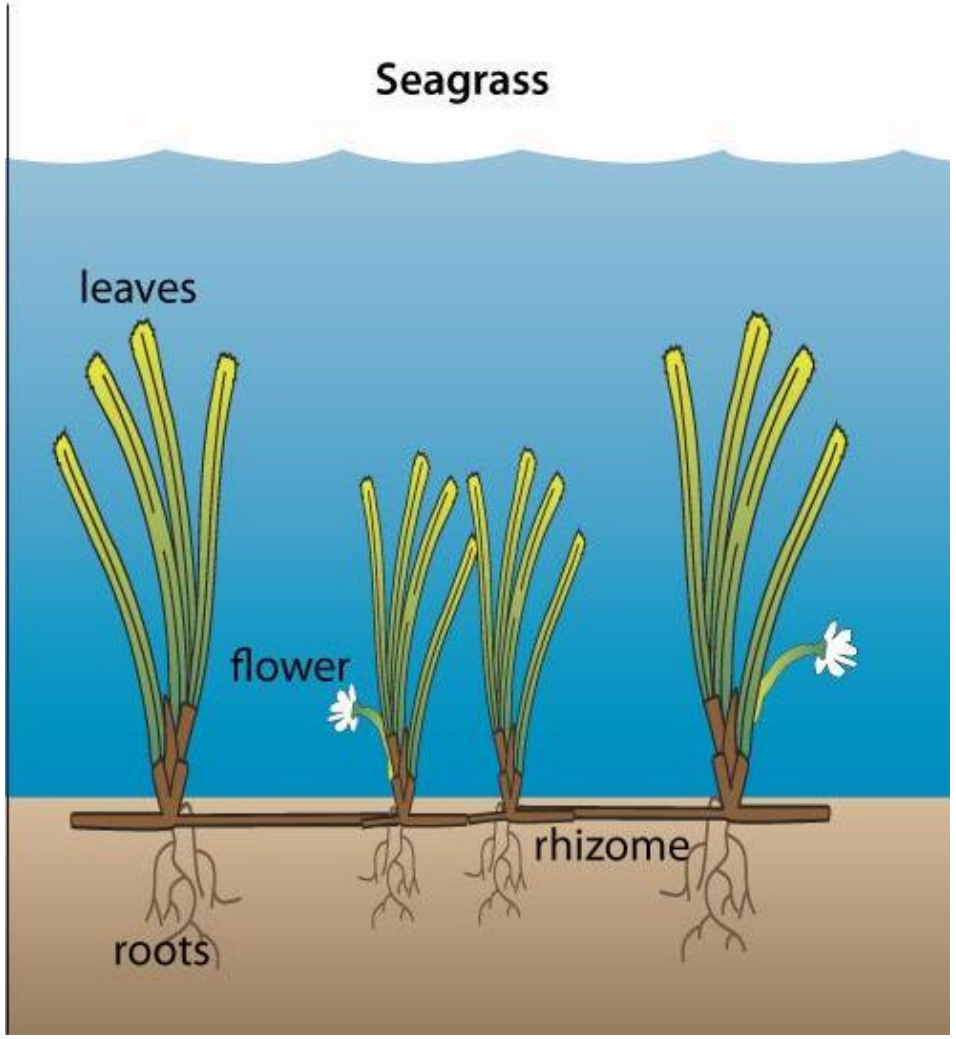
- **Carrageenan** (harvested from *red seaweeds*) – used as a thickening agent in **dairy products** (e.g. yogurt, milkshakes)

- **Agar** (from *red seaweeds*) – used to **culture microorganisms**

Flowering Plants

- **Flowering plants are *true* plants** – with true leaves, stems, roots, and conducting tissues

- >250,000 species worldwide – **only a few are truly marine**
  - Must be **adapted to live in seawater**



Marine Plants – Seagrasses

- Seagrass are **flowering plants** that grow entirely **underwater**
- ~60 species, in mostly **tropical** waters
- **Flowers are small** in most species
- **Pollen** (containing sperm) is carried by **water currents**
- **Tiny seeds** (the result of fertilization) are also carried by **water currents** or in the **feces** of animals that consume the seagrasses
- **Seagrass beds provide a habitat to many organisms that hide among the leaves**

Questions

1) What are the differences between seaweeds and seagrasses?

- Seaweeds lack leaves, stem, and roots of true plants (temperate regions, cooler)
- Seagrasses are true plants (tropical regions, warmer)

2) What are the roles of seaweeds and seagrasses in the marine ecosystem?

- Provide food and shelter to marine animals
- Produce oxygen and take up CO_2 via photosynthesis

DEPARTMENT OF OCEAN SCIENCE

Animals

Invertebrates

Invertebrates – animals *without* a backbone

Vertebrates – animals *with* a backbone

- ~97% of all animals – invertebrates
- All major animal groups *have representatives* in the marine environment
- Several animal groups are *exclusively* marine

Source: https://www.createwebquest.com/vertebrate-vs-invertebrate

Marine Invertebrates – Sponge (Possibly *the First* Animal)

- Invertebrate sea animals do not have a nervous system or brain but can reproduce
- Found on ocean floor **attached** to solid rocks
  - They **cannot move**
- **Numerous tiny pores** allow water to pass through the body for **filter feeding** **on plankton and organic matter in the water**
- Water flow also carries wastes away

Marine Vertebrates

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Marine Vertebrates – Fishes

- The **largest group of vertebrates** in terms of species (about half of all vertebrates) and abundance.

- ~58% of the 32,000 known species of fishes are marine

Marine Vertebrates - Reptiles

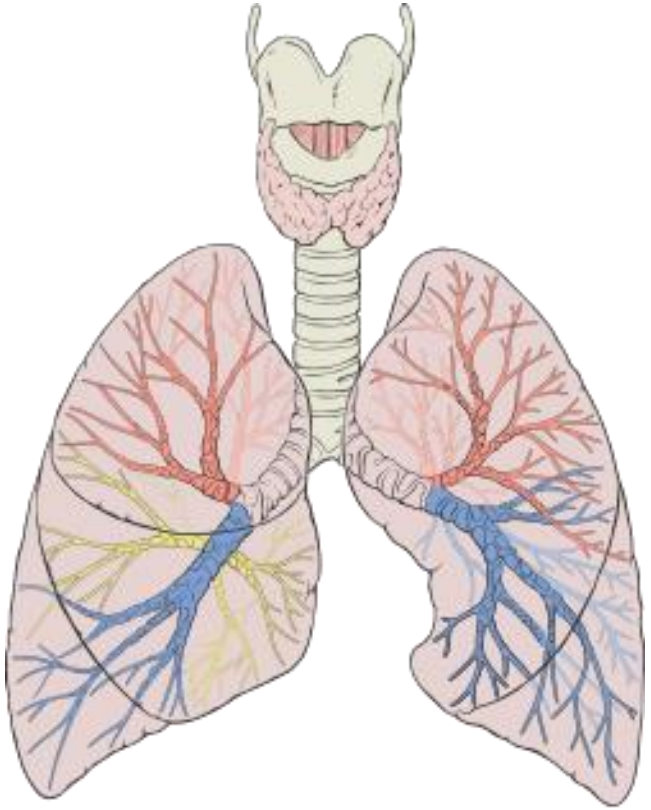
- **Air-breathing:** presence of **lungs** not gills
  - May be able to hold breath to go underwater but eventually need to come back to surface to breathe
- Mostly "**cold-blooded**"
  - Need to warm themselves using external heat (sun)
- Body covered with **scales**
- **May lay their eggs on land**

For visual reference only

Fish gills

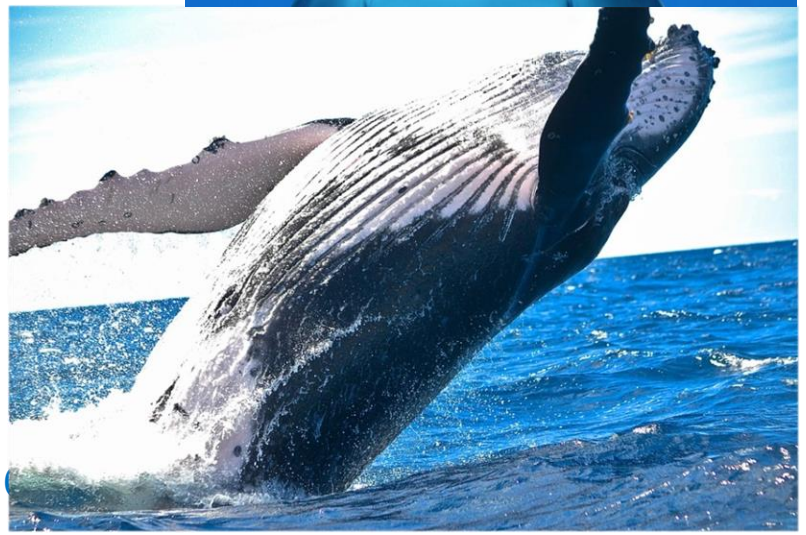
From Wikipedia

Example of human lungs



Marine Vertebrates – Mammals

- **Breathe air, give live birth, produce milk for their young**
- **Warm-blooded**
  - Generate their own heat like humans
- ~130 different species of living and extinct marine mammals
- **Active predators at the top of the food chain** who rely on the ocean and feed on marine life



Questions

What are the major types of Marine Animals?

(97%) Invertebrates

No backbone

Sponges

Jellyfishes

Worms

Sea stars

Octopuses

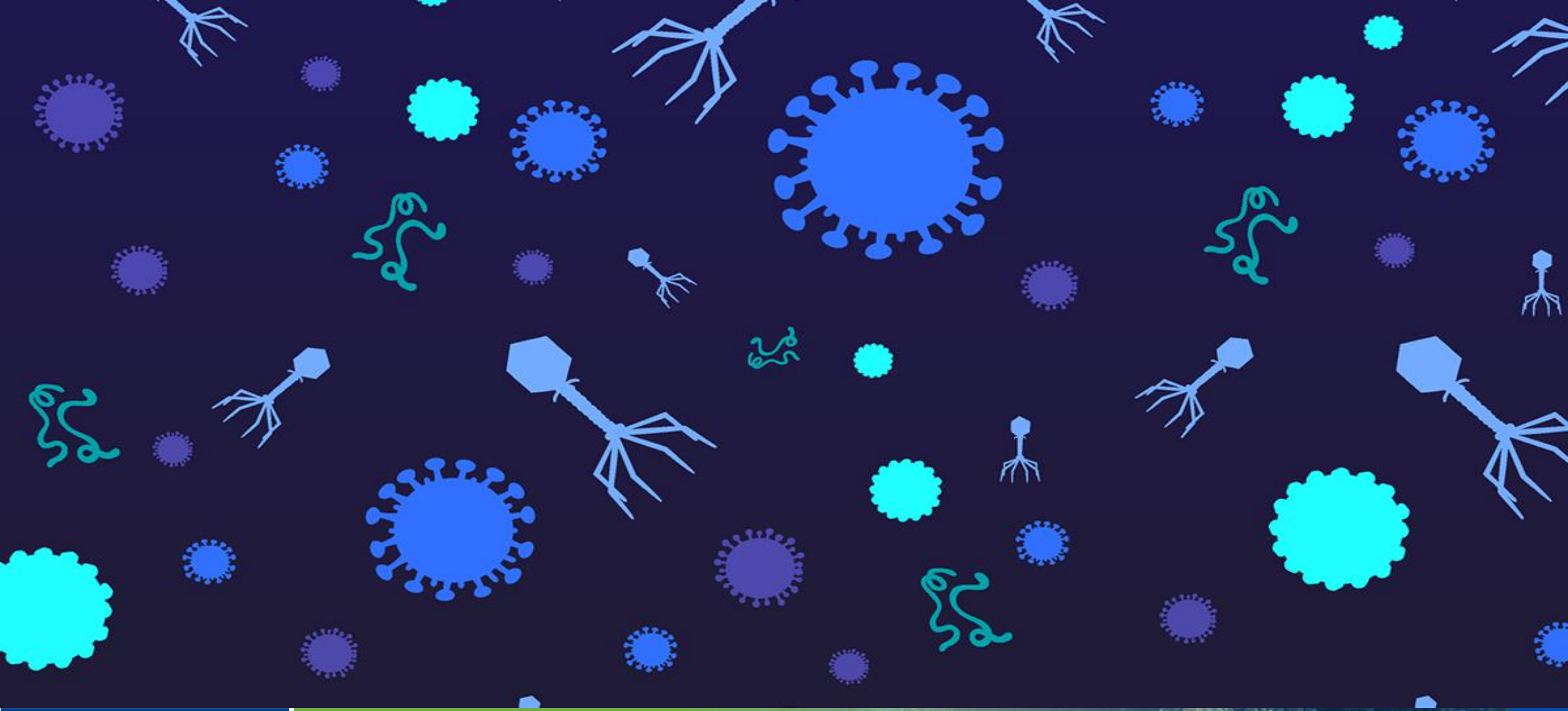
(3%) Vertebrates

Have backbone

Marine fishes

Marine reptiles

Marine mammals



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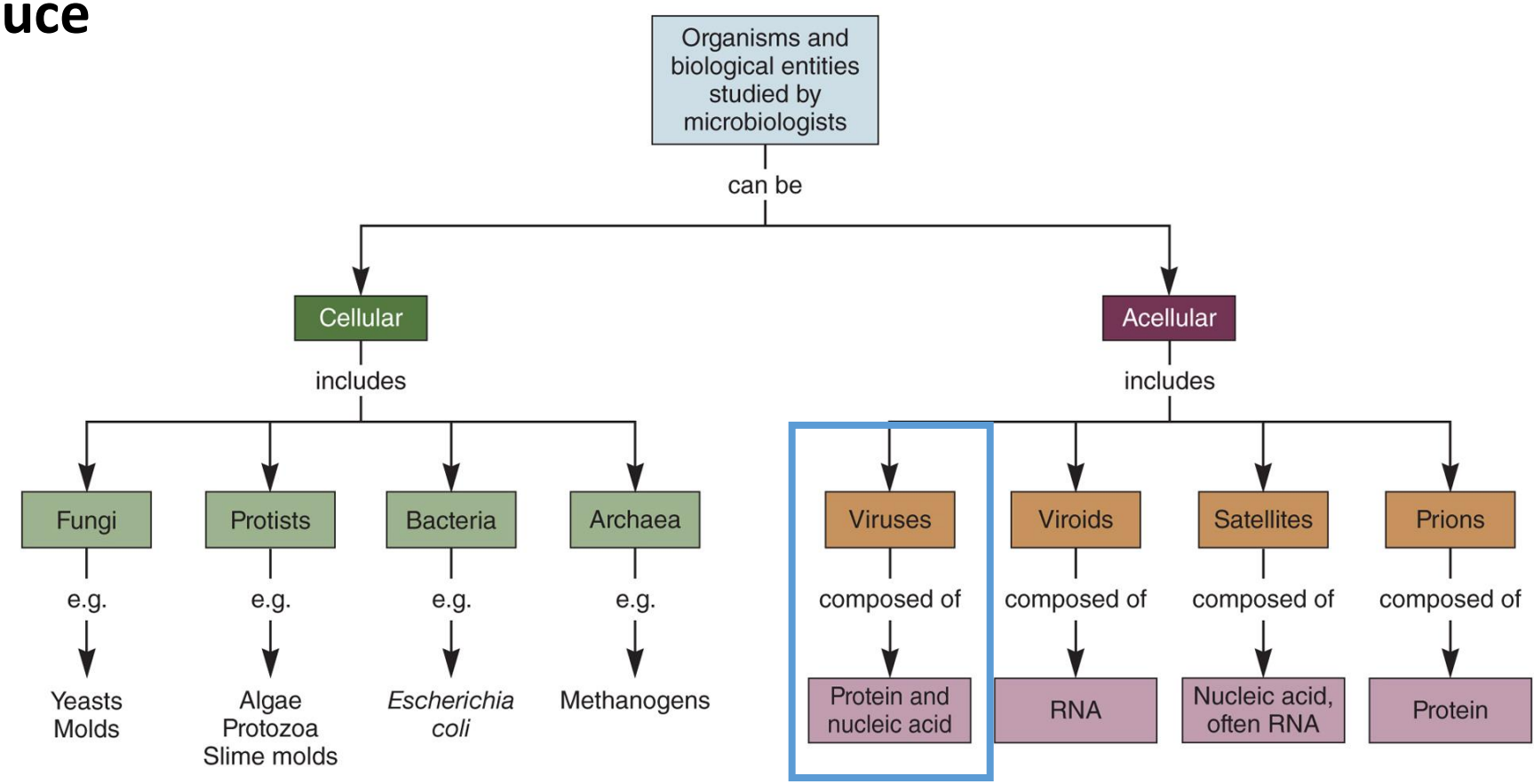
Viruses

What is a Virus?

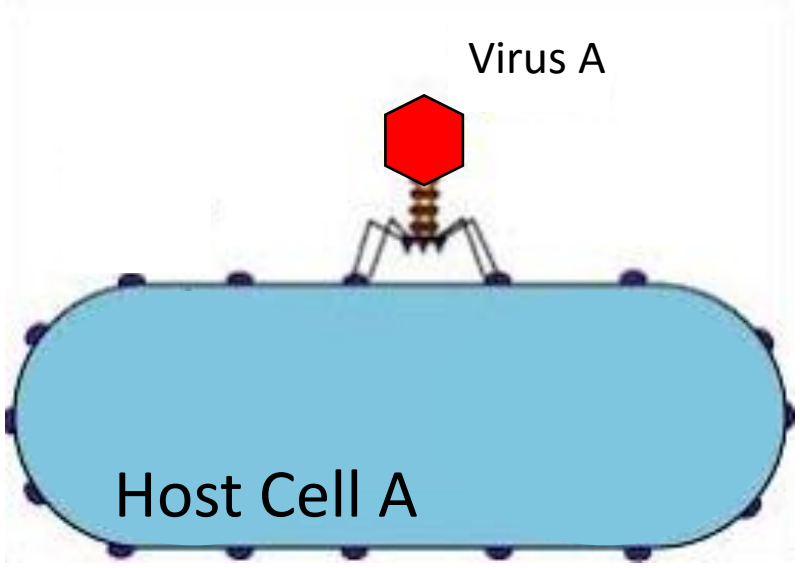
Virus – a *noncellular* particle that *must infect a host cell* to reproduce

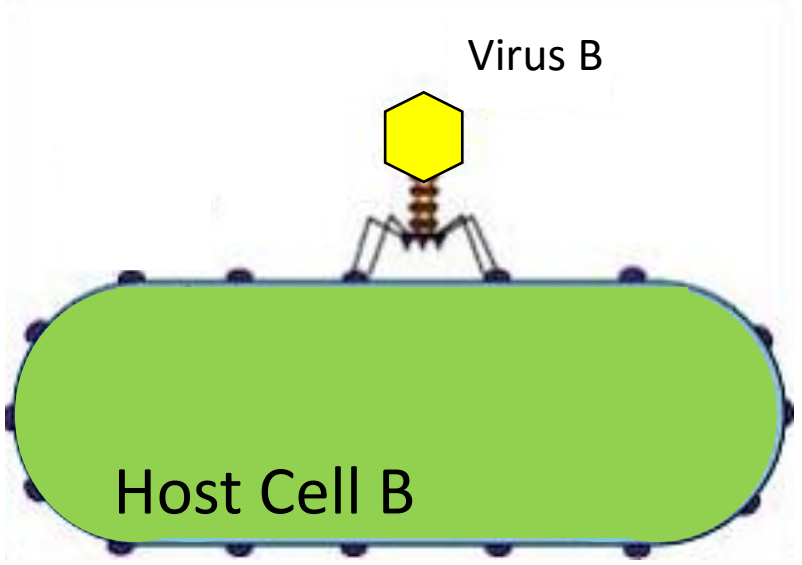
- It typically re-programs the cell's machinery and directs it to produce viral particles



Viruses – Infect All Forms of Life

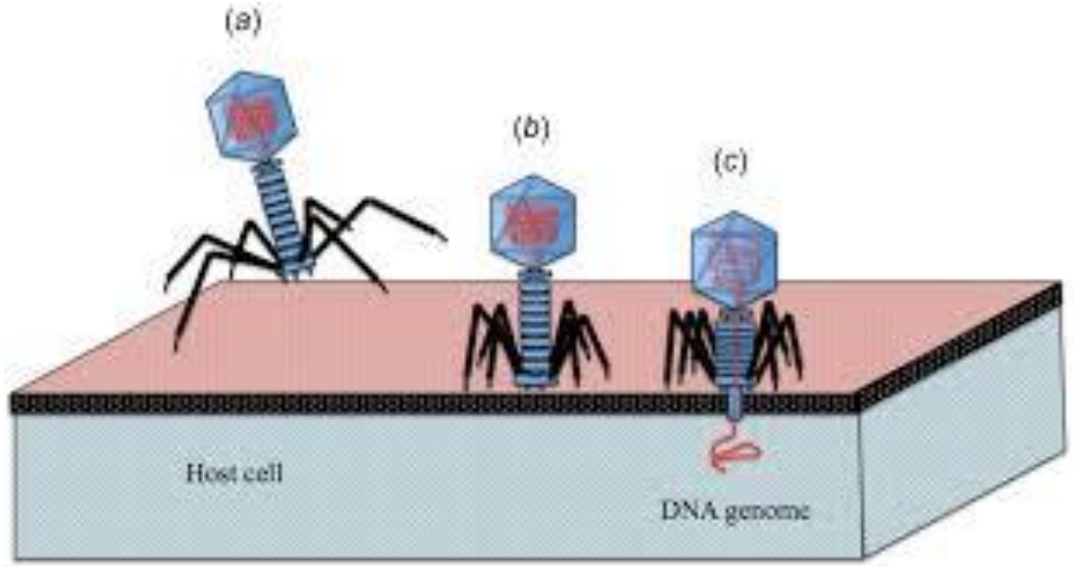
- Viruses are **everywhere** in all environments
- Viruses are **part of our daily lives**
- Different viruses infect every group of organisms
  - Each species of virus infects **a particular group** of host species, or host range





Virus Structure

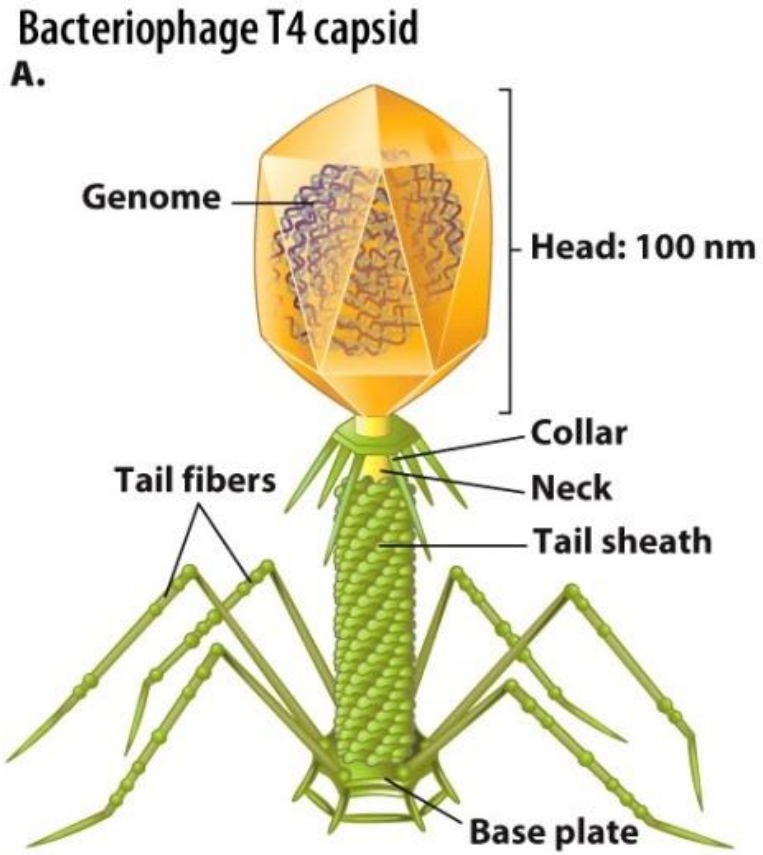
- The **viral capsid** is composed of **repeated protein subunits**
  - This maximizes the capacity while minimizing the required number of genes
- The capsid **packages** the viral genome and **delivers** it into the host cell
- **Different viruses make different capsid forms**



Source: https://azretina.sites.arizona.edu/node/251

Viruses Infecting Bacteria

T4 bacteriophages (*phages infecting bacteria*) – Icosahedral "head" + Helical "neck"



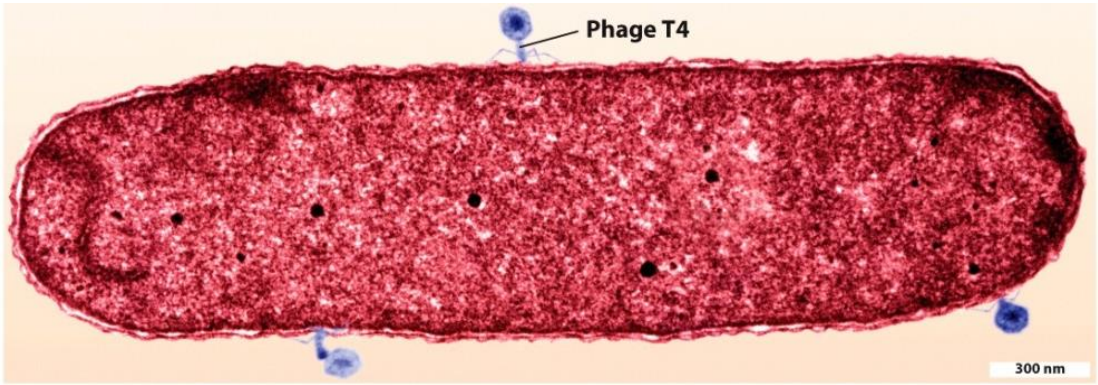


Image: Microbiology (3rd edition)

Viral Genomes

The reproduction of viruses is **similar to the spread of "computer viruses",** whose information "infects" the computer memory.

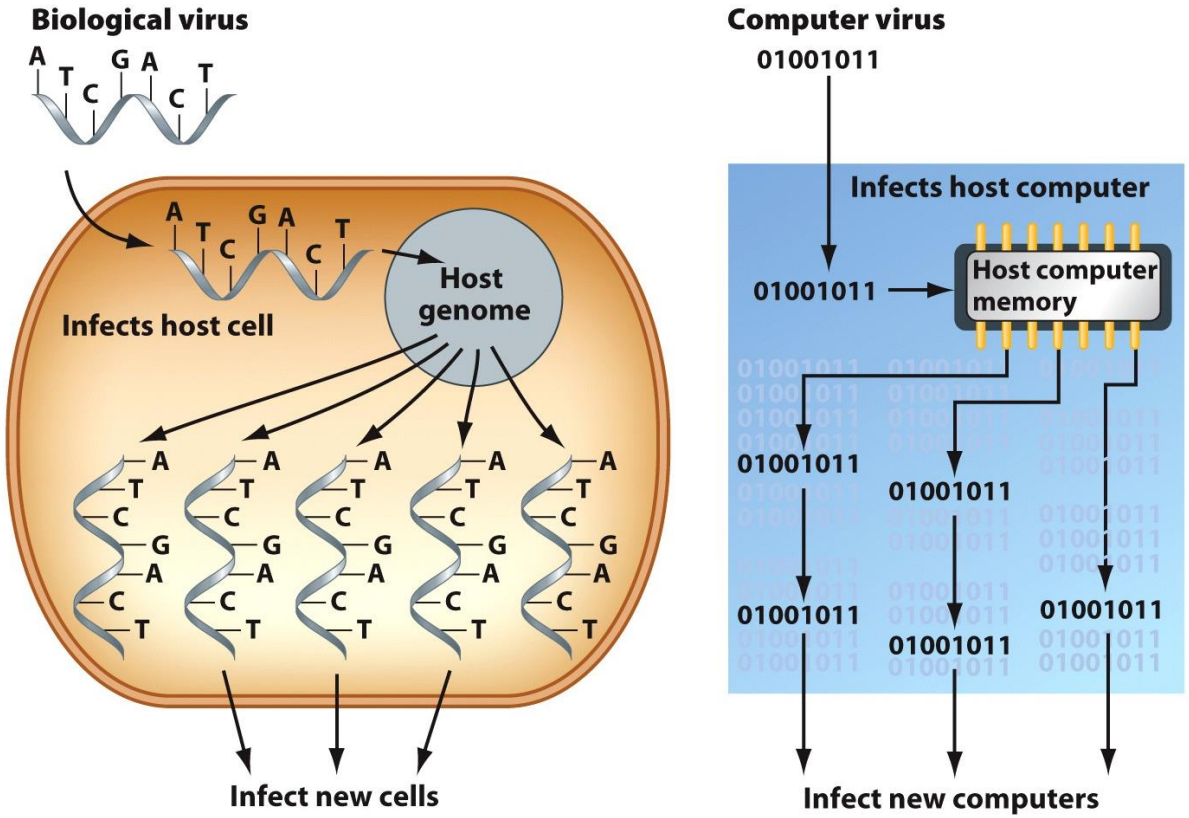
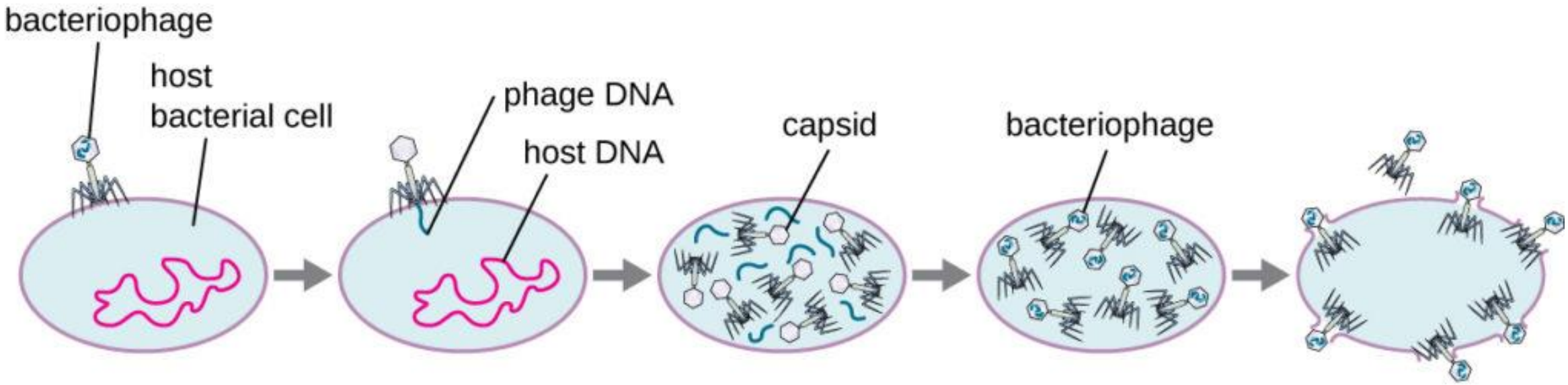


Image: Microbiology (3rd edition)

Replication of Bacteriophages



1 **Attachment**
The phage attaches to the surface of the host.

2 **Entry**
The viral DNA enters the host cell.

3 **Replication**
Phage DNA replicates and phage proteins are made.

4 **Assembly**
New phage particles are assembled.

5 **Release**
The cell lyses, releasing the newly made phages.

https://courses.lumenlearning.com/microbiology/chapter/the-viral-life-cycle/

Viruses Help Balance the Marine Ecosystem

Viruses fill important niches in all ecosystems.

- **Limiting host population density**
  - Without extinction of the host
  - In animals, viruses participate in population decline and resurgence

- **Selecting for host diversity**
  - Prevent dominance of any one species
  - Foster the evolution of many distinct host species

Viruses in the Open Ocean

- Viruses are important members of the marine and aquatic microbial (microoganism) communities
- Although the **biomass** of viruses are **relatively low**, the **abundance** of viruses are the **highest**

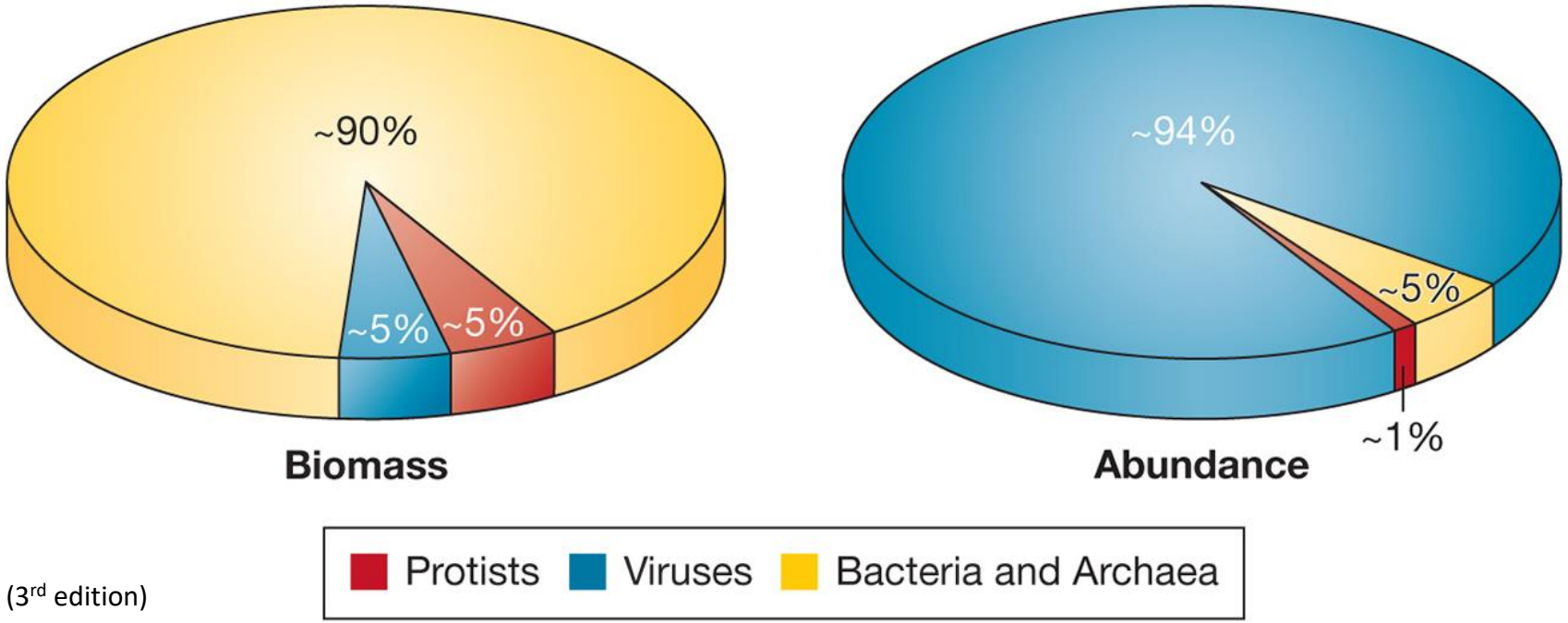


Image: Microbiology (3rd edition)

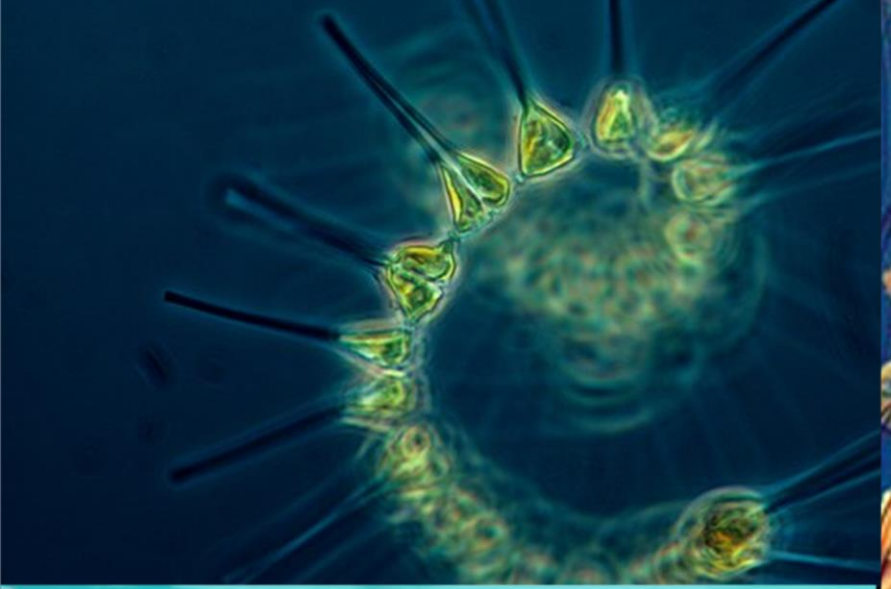
Questions

1) Describe the structure of a bacteriophage.

Capsid, genome, tails

2) Why are viruses important in the marine ecosystem?

- Limiting host population density
- Selecting for host diversity



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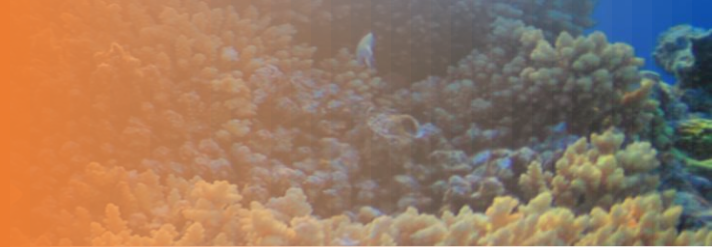
Summary:

A Glimpse of the Diversity of Marine Life

A Glimpse of Marine Life – Part I: Diversity of Life

- The Phylogeny of Marine Life
  - Constructing a Phylogenetic Tree of Life
- Bacteria
  - Cultivating Marine Bacteria
- Archaea
- Phytoplankton
  - Counting Phytoplankton
- Seaweeds and Marine Plants
- Animals
- Viruses
  - Isolating Viruses from the Ocean

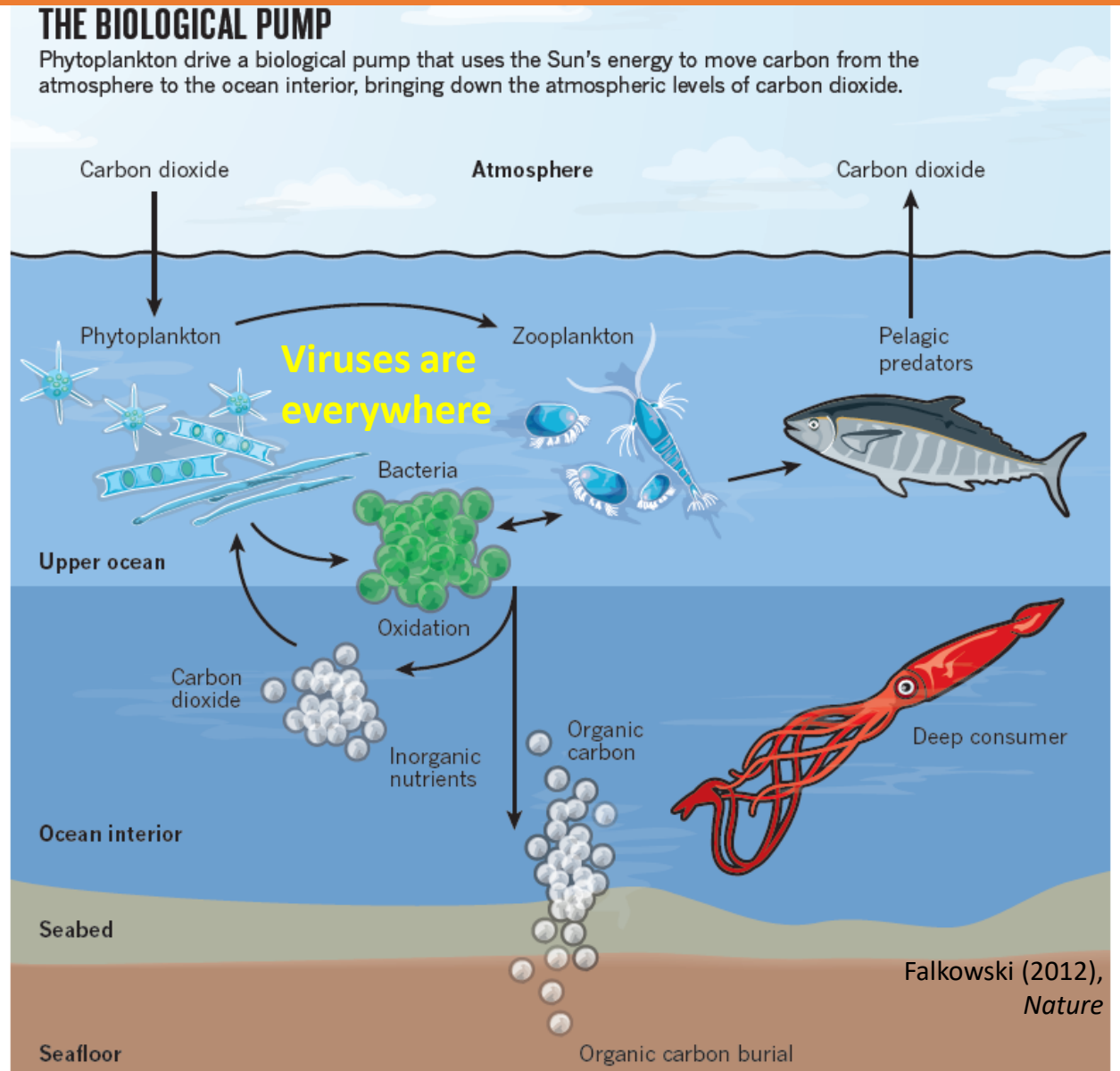
Summary



- There are **many different life forms** in the ocean.

- Organisms fulfil **unique functions** which are essential for the **functioning of the marine ecosystem.**

Humans Need a Balanced Marine Ecosystem



- Phytoplankton are **primary producers** – consume CO_2 from the atmosphere to grow, and **which all other organisms, from bacteria to big fish, need to live**.
- **Viruses** are everywhere and help balance the marine ecosystem.
- **Humans & marine environment:**
  - The dead bodies of marine organisms sink to the bottom, get buried and provide us with gasoline we use today.
  - The marine ecosystem can reduce global warming with the help of phytoplankton pumping CO_2 from the atmosphere.