TOPIC 5

MARINE MICROBIAL POPULATIONS

Objectives

- Describe **microbial hab**itats in marine ecosystems
- Distinguish between different microbial populations found in marine ecosystems
- Outline the role of each microbial group in marine ecosystems

Marine microbial populations

- In the open ocean, far from the influences of coastal human habitation, sea water contains huge numbers of microbes:
- These include:
  - bacteria, archae,
  - protozoa, algae,
  - fungi, and viruses
- Coastal areas can contain even greater concentrations **(Reason?)**

Microorganisms in the marine environment

- Microorganisms are found everywhere in the marine environment from the continental shelf sloping down to the deepest sea regions.
- But their location is dependent on the availability of **growth requirements (nutrients and other biotic and abiotic factors)** of each particular microorganism.
- In the surface layers of the seas, in the zone where light penetrates, we can expect to see
  - Phototrophic organisms
  - Eukaryotic algae
  - Cyanobacteria (prokaryotes)

- Areas with **hydrogen sulphide** and **light**, phototrophic bacteria are present (algal mats)
- Free floating algae- phytoplanktons
- Algae attached to the bottom of the sea- benthic algae
- Initial production of organic matter is done by phototrophic organisms hence they are referred to as primary producers
- Biological productivity in oceans is dependent on the rate of primary production
  - Areas with high primary production > high fish yields.

- Regions of high inorganic nutrients (**phosphates and nitrates**) input where there is upwelling (caused by winds and currents) and river input , they are very fertile hence high primary production.
- Open oceans-far from the land, are low in organic nutrients and are infertile **(oligotrophic**).

- Beneath the photic zone(~200m thick) there is a zone of several km, (meso, bathy, abyssal and hadal pelagic zones)
  - dark and cold.
  - Produced organic matter can only be degraded by heterotrophic mineralization processes.
  - Water below 100m is only **2-3°C warm**
  - **Pressure** in which the organisms live is very high-every 10m it increase by 1 atmosphere.

- At 5000m depth the organisms must be able to withstand pressures of 500atmospheres
- Organisms not only tolerate pressure but actually require pressure for growth
  - Extreme obligate barophilic organisms
  - Psychrophiles (temperature)
  - Halophiles (high salt concentration)
  - Thermo-acidophiles (hydrothermal vents)

MARINE MICROBIAL HABITATS

- Pelagic habitats- :They are habitats in the water column (open sea). The top 0-200m corresponds to the **photic** zone.
- Microbes occur in all these habitats
- Benthic habitats – They are habitats on the sea floor
  - In the marine sediments ,microorganisms find a lot of niches

(a) Neuston- This is a polysaccharide protein rich microhabitat at the air water interface and contains many bacteria.

- It is a habitat rich in organic matter and contains highest level of microbes.
- Plankton- are organisms suspended in the water column that do not have sufficient power of locomotion to resist large scale water currents as opposed to the nekton (strong swimming animals)
  - Phytoplankton -plants -Zooplankton -animals
  - Bacterioplankton -bacteria –Virioplankton -viruses

(b) Nekton- large swimming animals eg. fish which consume the planktons.

- They produce organic debris, faecal pellets and they die hence producing suspended and sedimenting particles, called the seston.
- Their:
  - intestinal tracts;
  - the surfaces ,
  - faecal pellets etc. are all habitats for bacteria.

(C) Seston- are organic debris (suspended and sedimenting) particles produced by the nekton;

- Microorganisms break down the organic matter already in the water column.
- The more resistant particles sink down to the sea floor and this along with the bacteria serve as a source of nutrition for the animals dwelling in the sea floor.

(d) Hydrothermal vents

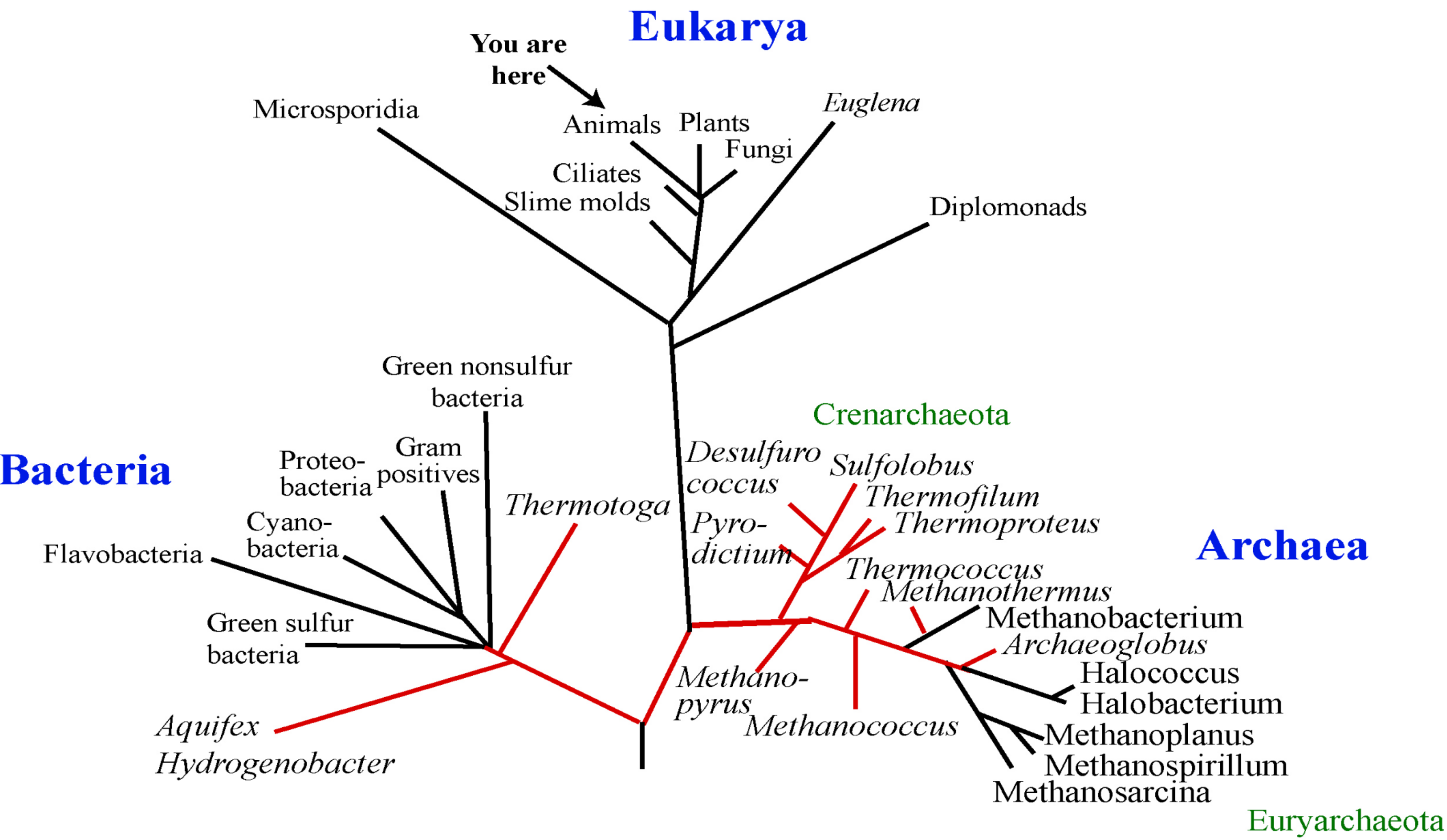
- They form a specialized and highly significant habitat for microbes
- Many of the microbes are hyperthermophilic bacteria and Archae which can grow at temperatures upto 113°C

(E) Living organisms as microbial habitats

- Microbial biofilms also form on the surface of all kinds of animals, algae, coral reefs and coastal plants which provide a highly nutritive environment through secretion or leaching of organic compounds
- Many organisms appear to selectively enhance surface colonization by certain microbes and discourage colonization by others (**biofouling of surfaces).**

- Many microalgae (diatoms /dinoflagellates) harbor bacteria on their surfaces or as endosymbionts within their cells.
- Seaweeds and sea grasses have dense populations (10^6 /cm^{-2}), but varies with;
  - the species ,
  - geographical location and;
  - climatic conditions.
- Surfaces and intestinal content of vertebrate and invertebrate animals provide a variety of habitats to a wide variety of microbes

Classification of marine Bacteria



Bacteria

- Using the technique of 16S rRNA it has been found that over 70% of marine bacteria have not been cultured and hence have no counterparts among known bacteria.
- Most of the sea bacteria belong to the **Proteobacteria**
- Microscopic **cyanobacteria**(picophytoplankton) make up 15% of all the bacteria.
- Of the cultivated bacteria, ***Roseobacter*** *spp*. form about 15% of the total bacteria,
- **Green non sulfur** bacteria make up about 6%.

- About 90% of the bacteria are **Gram negative**
- Gram positive Actinobacteria form 3% of the total.
- Most of the bacteria are in the **photic zone**, while the green non sulfur bacteria are confined to the **aphotic zone.**
- They are capable of anoxygenic photosynthesis in the absence of light

Cyanobacteria

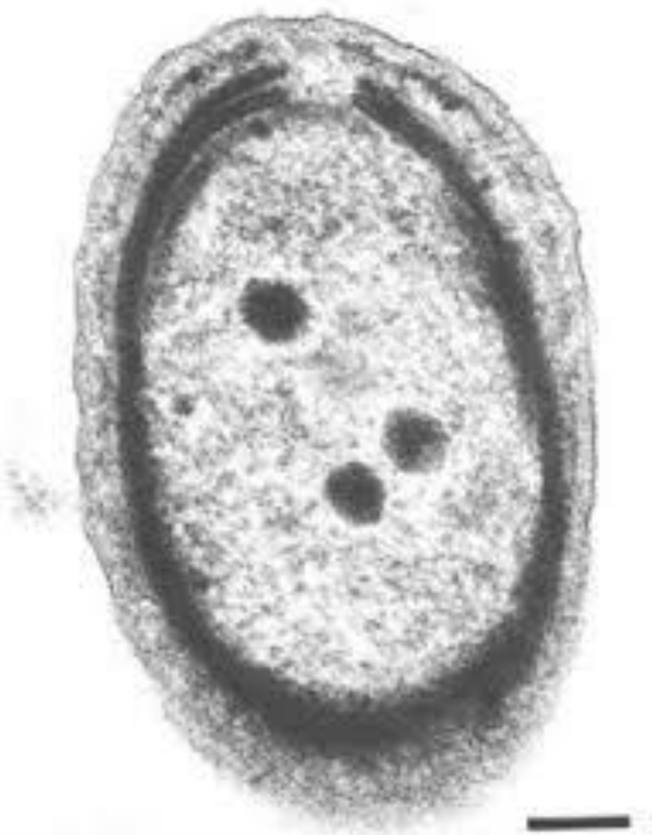
- There are two genera found in marine environment;
- **Synechococcus and Prochlorococcus**
- They constitute the most abundant photosynthetic microbes on earth.
- They contribute more than 50% of the total marine photosynthesis.

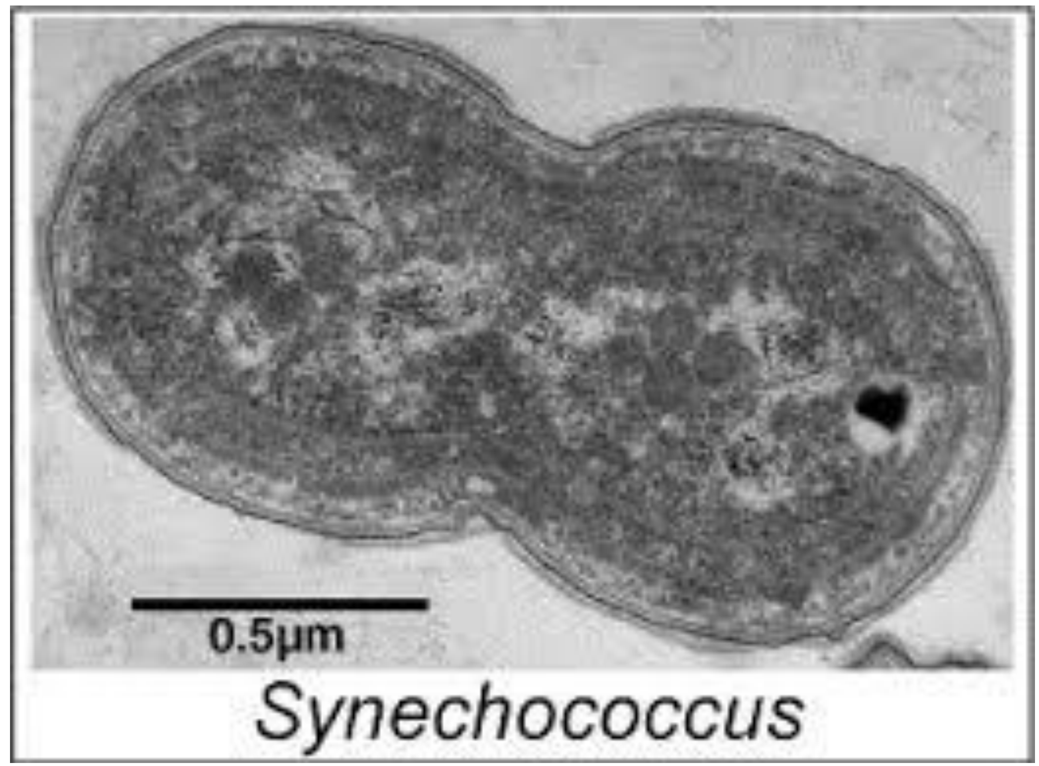
Prochlorococcus

- Occurs ubiquitously in surface waters between latitudes **40°N and 40°S**
- About **ten times more** abundant than *Synechococcus*
- Abundant in the **euphotic zone** of the world's tropical oceans.
- It is possibly the most plentiful genus on Earth:
- Dominates in the **oligotrophic** (nutrient poor) regions of the oceans.

Synechococcus

- Occurs more widely, but it **decreases in abundance beyond 14°C**;
- Cells are generally much more abundant in nutrient-rich environments.
- Prefer the **upper, well-lit portion of the euphotic zone**




0.5µm
Synechococcus

Archae

- Several groups of Archae have been found in the sea.
- Archae are divided into,
  - **Euryacheota** and **Crenarcheota**.
- *Euryacheota* contains **methanogens**, and hyperthermophilic and hyperhalophilic members.
- Methanogens are:
  - strict anaerobes and
  - produce methane
- Thermophilic methanogens are found in thermophilic hydrothermal vents in the deep sea.

- *Methanococcus jannaschi* and *Methanococcus pyrus are found in hydrothermal* vents; the latter are among the **most thermophilic organisms known**, being able to grow at 110°C.
- Hyperthermophilc archae have **optimal** temperatures of growth of 100°C.
- They include
  - *Thermococcus celer* and
  - *Pyrococcus furiosus.*

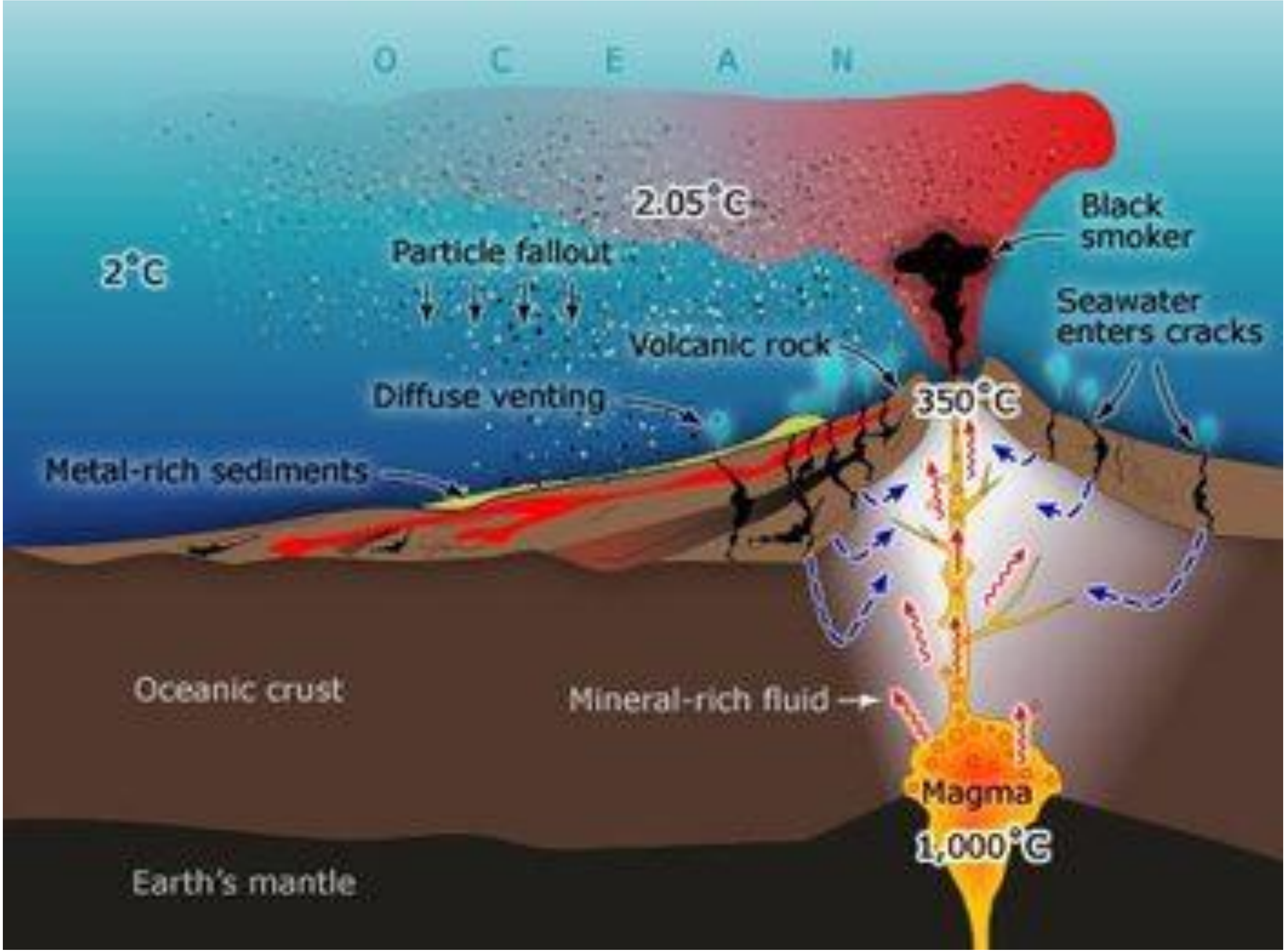
- Hyperhalophilic archae can grow in salt concentrations of more than 9%.
- Examples are
  - *Halobacterium,*
  - *Halococcus, and*
  - *Halomegaterium.*

Crenarcheota

- They are also found in thermophilic vents.
- *Desulfurococcus* is found in the upper layers of

thermophilic vents, where the temperature is highest.

- It is the most thermophilic organism known, being able to grow at 113°C.


O C E A N
2.05°C
Black
smoker
2°C
Particle fallout
Seawater
enters cracks
Volcanic rock
Diffuse venting
350°C
Metal-rich sediments
Oceanic crust
Mineral-rich fluid
Magma
1,000°C
Earth's mantle

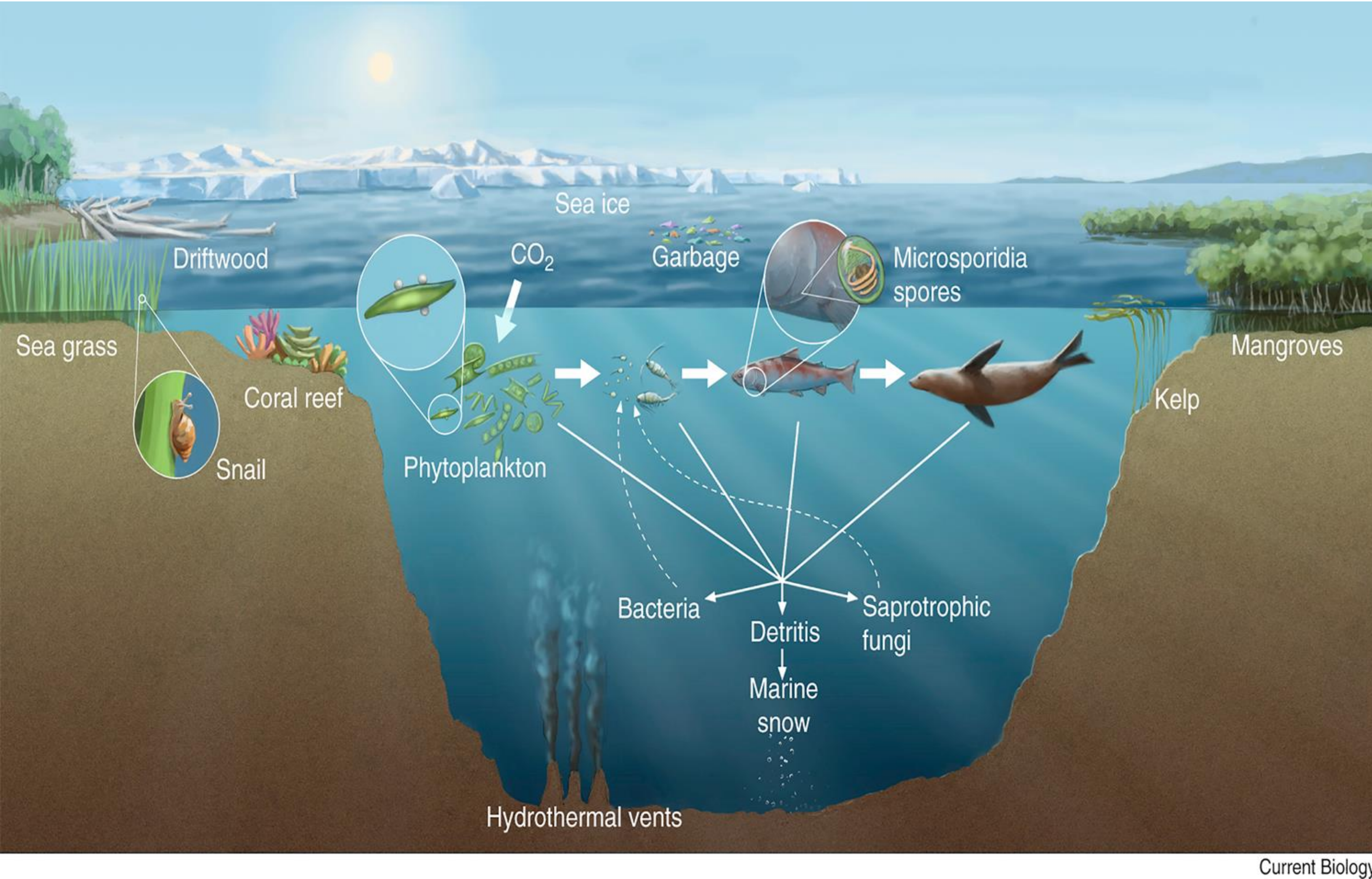
Characteristics of marine bacteria

- 95% are Gram negative rods
- Majority of the bacteria are actively motile (flagella)
- Most marine bacteria are notoriously heat sensitive
- They are smaller in size than those that occur in soil, water, milk and sewage.
- Species of *Pseudomonas, Vibrio, Flavobacterium, Achromobacter predominate in the sea in that order.*

Fungi
Aquatic yeasts and moulds

- Fungi of all classes have been encountered in the marine environment, from
  - Phycomycetes
  - Ascomycetes
  - Deuteromycetes
  - Basidiomycetes
- In nearly all the cases, they are found attached to:
  - **dead matter** and in some cases **living matter**,
  - **occasionally as parasites.**

Marine fungi Habitats; reference paper attached on Eclass



- The Phycomycete *Atkinsiella dubia, has* been found parasitizing eggs of crabs.
- A strain of the plant pathogenic Phycomycete, ***Pythium sp****,* has been found growing on the marine red alga, *Porphyra.*
- When cultivated in the lab, many marine phycomycetes fail to complete their life history unless sea water or a high (4%) salt concentration is used.

- The other three fungal groups;
  - Ascomycetes,
  - Fungi Imperfecti (Deuteromycetes), and
  - Basidiomycetes occur in the marine environment in the above order of abundance on **live plants** or **inanimate debris.**
- In the mangrove swamp of *Rhizophora apiculata,* there is vertical distribution of different fungi.

Rhizophora mucronata

- Thus some fungi are limited to upper zones of tidal flow, *such;*
  - *payrenographa xylographoides,*
  - *Julella avicennia and Aigialus grandis,*
- Others *are* found at lower reaches of the tidal ebb such as:
  - *Trichocladium achrasporum and*
  - *T. alopallonellum.*

- Around the world in both temperate and tropical regions, numerous fungi in the three groups have been found in the order given above on:
  - detritus in the intertidal regions of coastal areas
  - leaves
  - seaweeds
  - seagrass
  - chitinous substrates
  - sand (sand-dwelling fungi),
  - but most frequently on decaying wood.

- The most abundant filamentous marine fungi are **Ascomycetes**.
- Marine Ascomycetes are peculiar in that their spores show adaptation to the marine ecosystem in the production of **appendages**, which facilitate:
  - buoyancy in water
  - entrapment and
  - adherence to substrates
- The filamentous
  - Ascomycete (*Halosphaeria mediosetigera) and the*
  - Deuteromycete *(Culcitalna achraspora)* are designated marine and are able to grow in natural and artificial seawater media.
- Marine fungi are generally able to grow on woody materials in the ocean.

- Fungi are the **principal degraders** of biomass in most terrestrial ecosystems.
- Marine fungi are usually found on drifting wood in the oceans.
- They decompose the wood making the nutrients available to other inhabitants of the marine ecosystem.
- In contrast to surface environments, however, the deep-sea environment (1,500–4,000 m) has been shown to **contain very few fungi**, which occur mainly as yeasts.

- Culturable fungi recovered from sediments and bottom of the deep sea have been found to require salt concentrations of up to 4% and barometric pressures of up to atm 500 bar hydrostatic pressures at 5°C.
- Among them are strains of the:
  - Deuteromycete- *Aspergillus sydowii* and the
  - Phycomycete- *Thraustochytrium globosum.*

Role of marine fungi

- Decaying of wood (**principal degraders**) through enzymatic hydrolysis of cellulose and other cell wall constituents. They also degrade lignin
- Establishing symbioses with flowering plants
- Play key roles in nutrient cycling
- Causative agents of diseases in marine plants and animals (parasitic); they also parasitize marine algae.
  - Fungal infection has been associated with disease

in macro algae, coral, crustaceans and even marine mammals.

Applications of marine fungi

- Discovery and isolation of novel natural products, including secondary metabolites with antibacterial and anticancer properties
- They are a superpower due to their ability to degrade and metabolize recalcitrant polymers(lignin).They are slowly or non biodegradable.
- Fungi are effective at metabolizing hydrocarbons, and can be used in bioremediation of contaminated sites following oil or petroleum spills

Algae

- Marine algae vary from tiny microscopic unicellular forms of 3–10 mm (microns) to large macroscopic multi cellular forms up to 70 m long and growing at up to 50 cm per day, known as seaweeds.
- Seaweeds include;
  - Green algae (Chlorophyta),
  - Brown algae (Phaeophyta),
  - Red algae (Rhodophyta) and
  - Blue green algae (Cyanobacteria).
- Most of the seaweeds are **red** (6,000 species) and the rest known are **brown** (2,000 species) or **green** (1,200 species).

Red algae: red pigment phycoerythrin

Green algae: green pigment chlorophyll

Brown algae:

Brown color due to xanthophyll pigment **fucoxanthin**, which masks the other pigments, Chlorophyll a and c, beta-carotene and other xanthophylls.

Uses of Seaweeds

- Many maritime countries use seaweeds as;
  - a sources of food,
  - for industrial applications
  - and as a fertilizer.
- Nori (*Porphyra* spp.), a Japanese red seaweed, is very popular in the Japanese diet,
  - has a high protein content (25–35% of dry weight),
  - vitamins (e.g., vitamin C),
  - mineral salts, especially iodine.

- Industrial utilization is at present largely confined to extraction of phycocolloids, industrial gums classified as:
  - agars, carrageenans, and alginates.
- Agars, extracted from red seaweeds such as *Gracilaria* , are used in the food industry and in laboratory media culture.
- Seaweeds grow in marine environments, where there is sunlight to enable them carry out photosynthesis.

- Many of them contain air vacuoles to aid them in floatation.
- Often, they require a point to which they are

attached; some, however, are free floating.

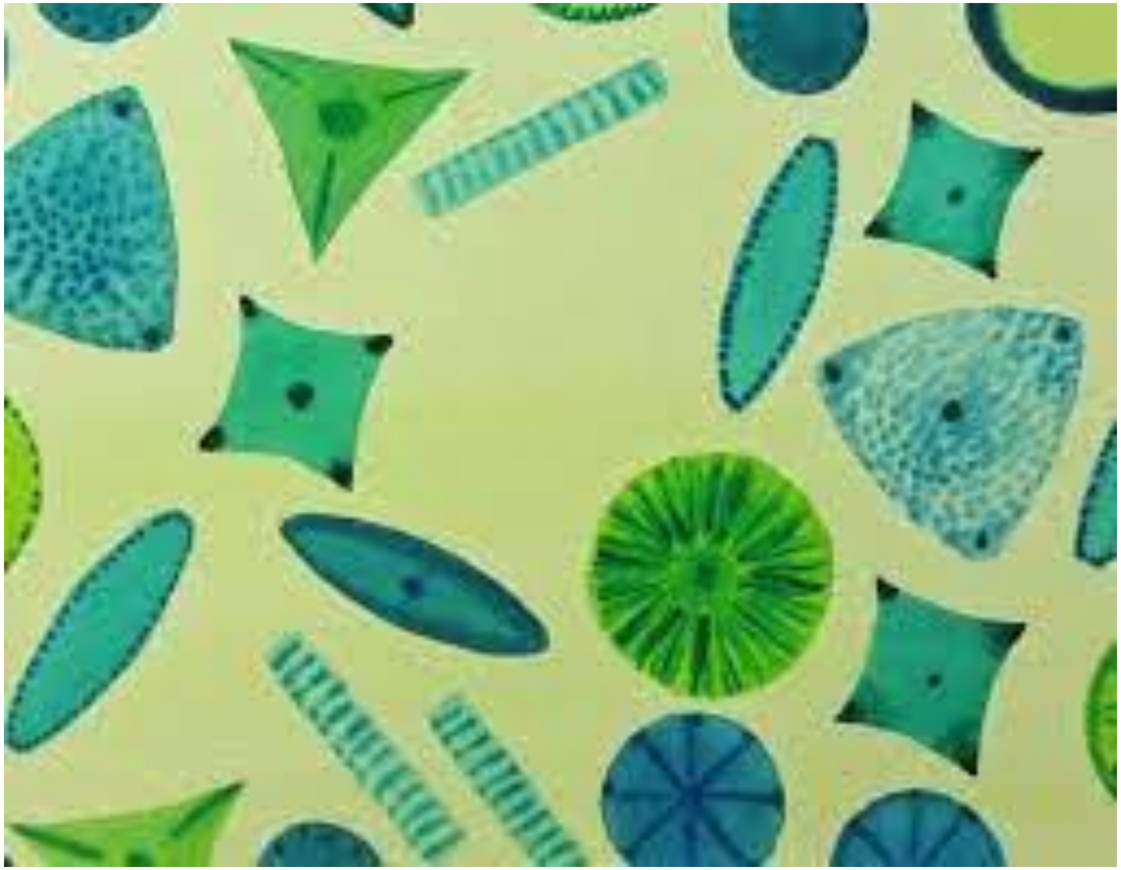
Check attached reference material on eclass for the various applications of marine algae

Diatoms

- Are golden brown algae of the group chrysophyta
- Are very small (10–200 µm) plant-like organisms (phytoplanktons) that float
- Of all the algae phyla, diatoms are the most **numerous, with ~10,000 known species**, inhabiting both marine (~75%) and fresh water and other habitats (~25%)
- The individual diatoms are solitary or sometimes form colonies.

Diatoms

- They contain chlorophylls “a” and “c,” and the carotenoid **fucoxanthin**
- A unique feature of diatom cells is that they are enclosed within a cell wall made of **silica** (hydrated silicon dioxide) called a **frustule**



- Most diatoms are unicellular, although they can exist as colonies in the shape of filaments or ribbons (e.g. Fragilaria),
  - fans e.g. Meridion,
  - zigzags e.g. Tabellaria
  - or stars e.g. Asterionella

  Being autotrophic **(photosynthesizing algae)** they are restricted to the photic zone (water depths down to about 200m depending on clarity)

Marine diatoms: most common types of phytoplanktons

- They are an important part of the primary producers of the colder parts of the world oceans .
- Diatom communities are a popular tool for **monitoring environmental conditions**, past and present, and are commonly used in studies of water quality.

Why are diatoms preferred for use as bio indicators?

1. They occur in all types of aquatic ecosystem i.e. are largely cosmopolitan.

2. They show high sensitivity to slight changes in environmental conditions

3. They collectively show **wide range of tolerance** along gradient of aquatic productivity, individual species have **specific water chemistry requirements**.

4. Among all biological indicators, they have one of the shortest generation times reproducing and responding rapidly to environmental change to provide an early warning to increasing pollution and habitat restoration success.

5. They have a well studied taxonomy and ecology.

6. They respond quickly to eutrophication and recovery. Since they are photoautotrophic organisms, they are directly affected by changes in nutrient and light availability.

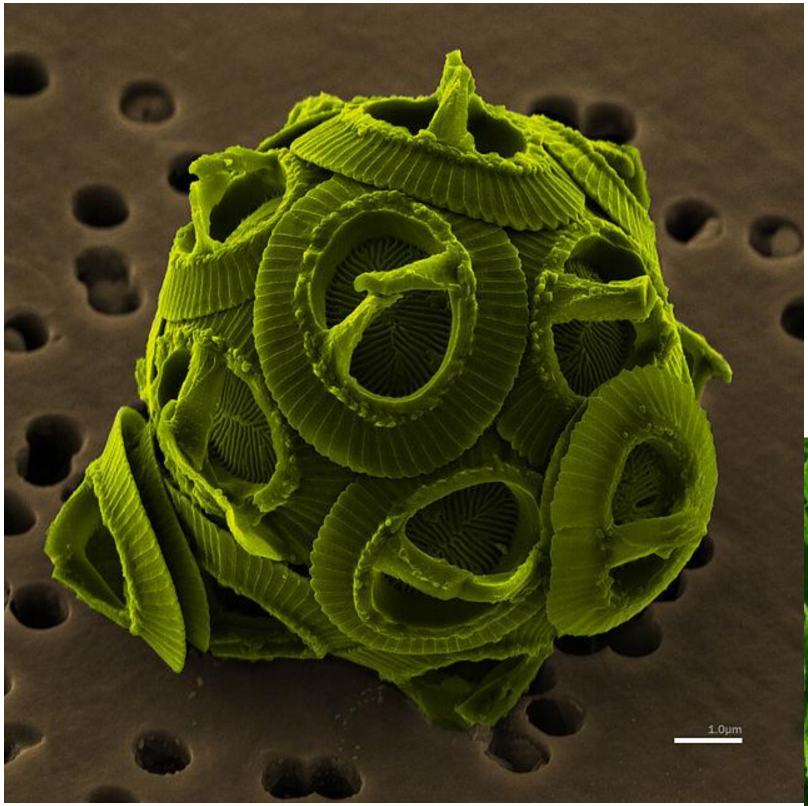
7. Sampling diatoms is easy as it can be done most times of the year and during their collection there is trivial impact on the ecosystem.

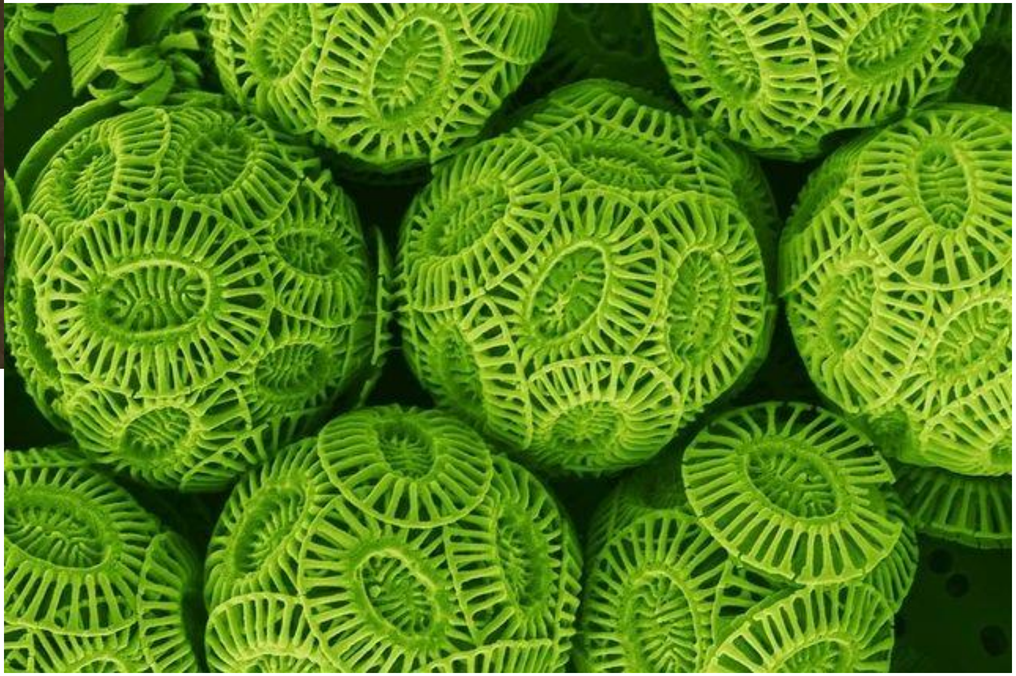
COCCOLITHOPHORES

- Are unicellular, eukaryotic phytoplankton (alga)
- They are flagellated **golden brown algae** with chlorophylls “a” and “c” and the carotenoids Diadinoxanthin and fucoxanthin.
- Coccolithophores are distinguished by special **calcium carbonate plates** (or scales) of uncertain function called **coccoliths,** which are also important microfossils.

- They are mostly marine and are found in tropical waters.
- They sometimes form heavy growths, blooms, during which they may clog the gills of fish.
- They also produce **dimethyl sulfide** (DMS), a foul-smelling compound which sometimes turns fish away from their normal migratory routes.

Gephyrocapsa oceanica

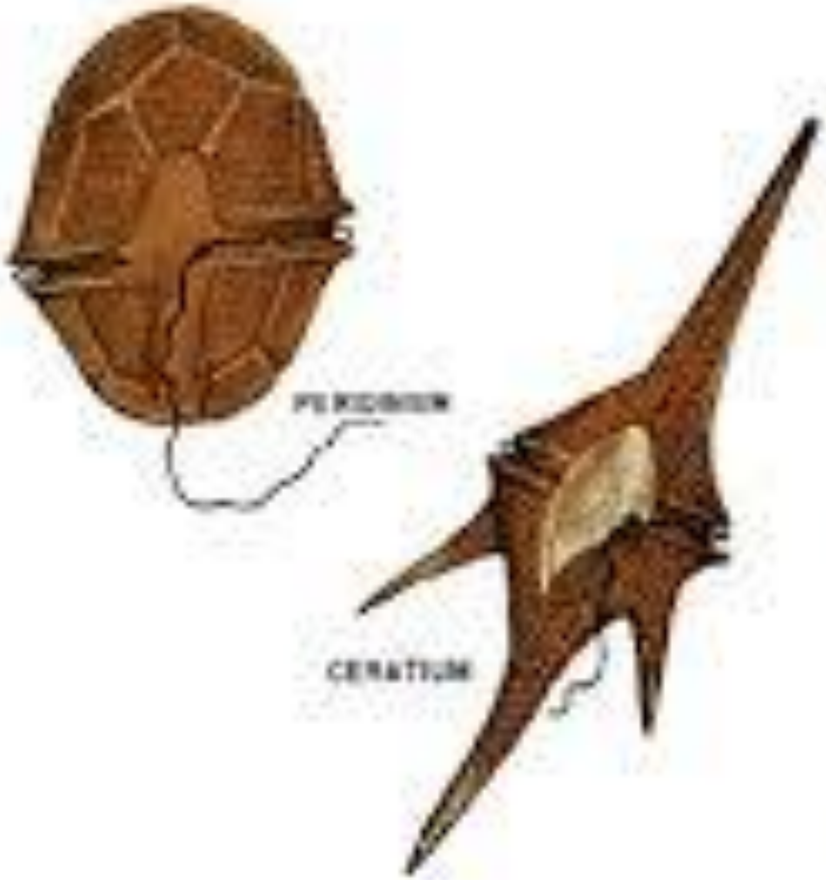


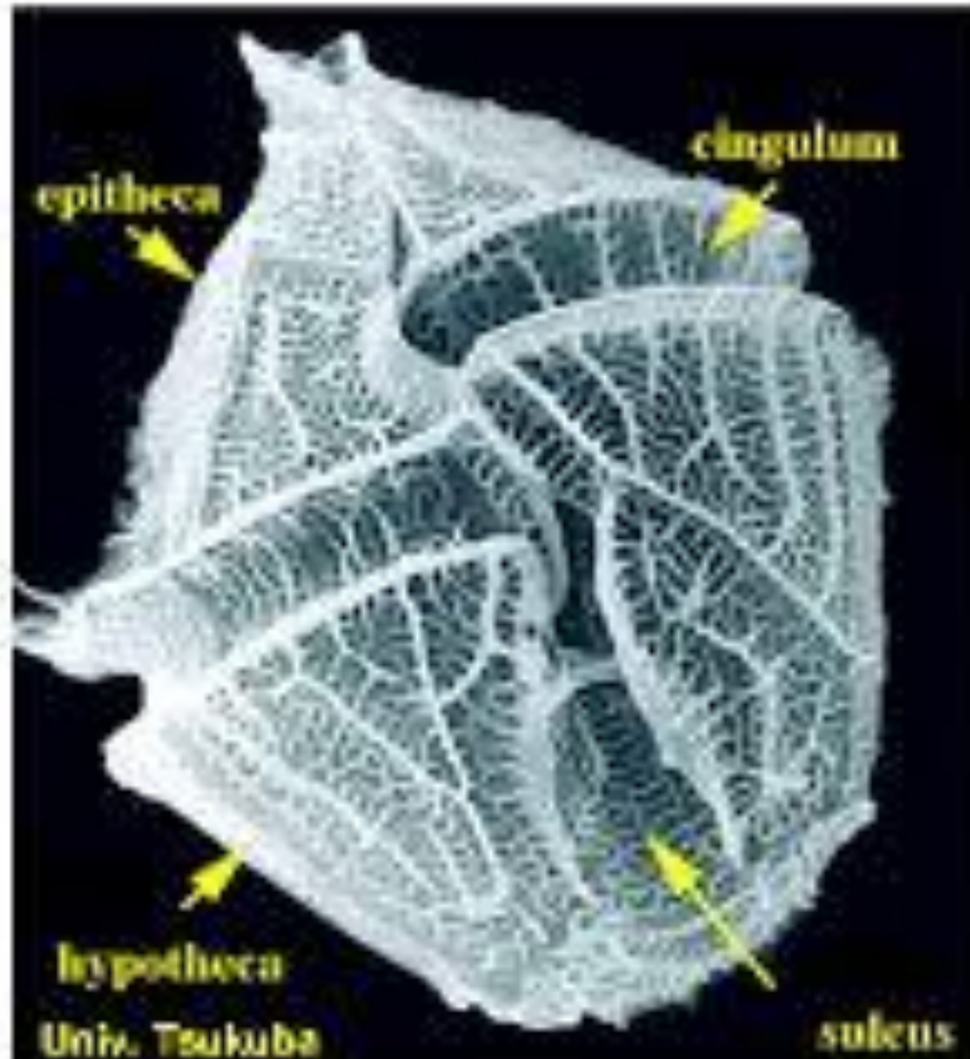


Dinoflagellates

- They are algae which are motile with flagella, such as *Euglena.*
- Dinoflagellates are distinguished by having **two flagella:**
  - one of which is a transverse flagellum that encircles the body in a groove;
  - the other flagellum is longitudinal and extends to the rear.
- They also have vesicles under their cell membrane.
- They are classified as *Pyrrophyta.*

Dinoflagellates





Protozoa

- All groups of protozoa, (i.e., Sarcodina, Mastigophora, Ciliophora, and Suctoria) except Sporozoa, are found in the marine environment;
- Sporozoa are exclusively parasitic.

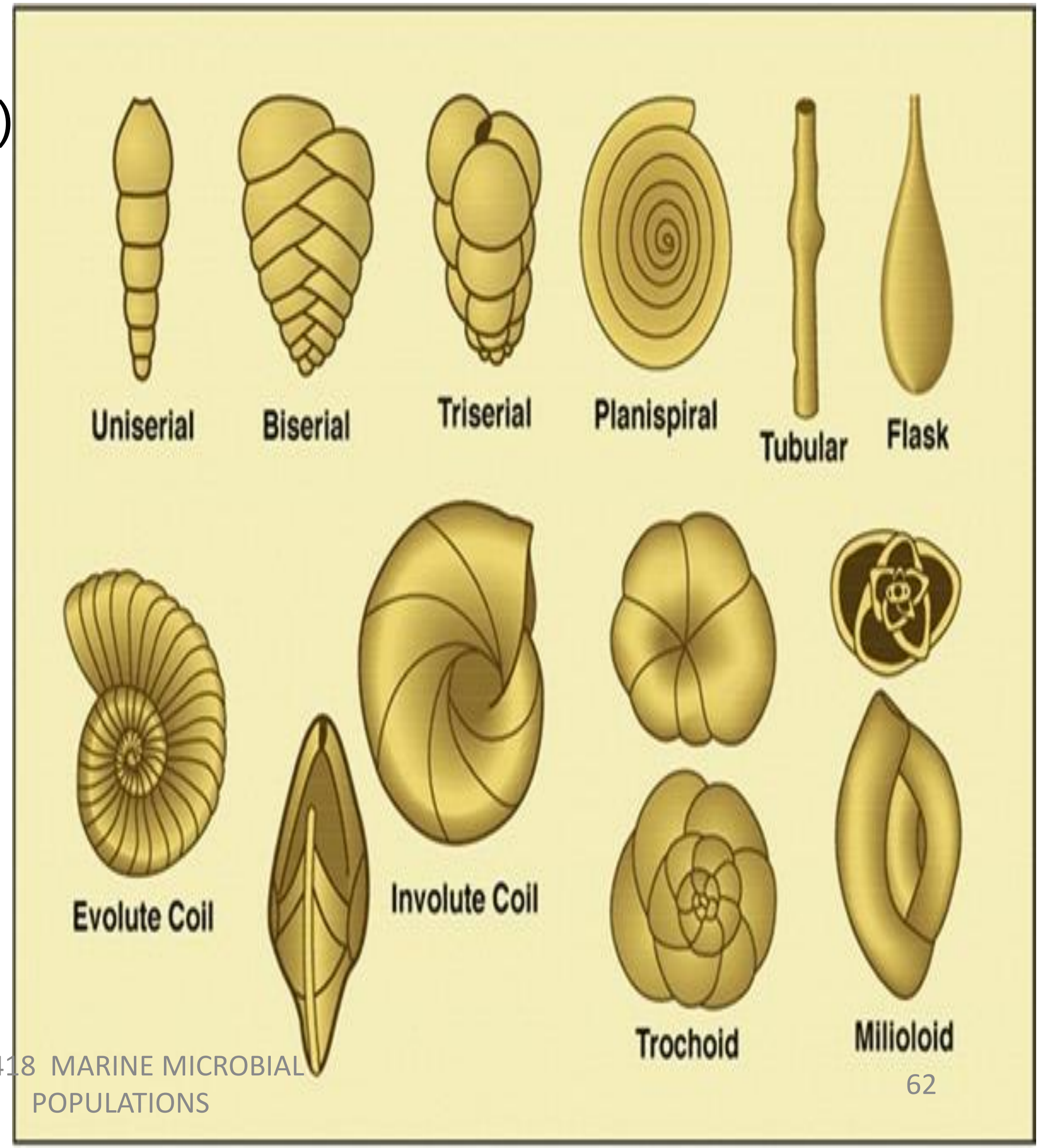
Sarcodina

Foraminifera:

- In the deep ocean, a group of Sarcodina which form shells (testa) and have fine radiating pseudopodia are known as foraminifera.
- These shells are made of calcium carbonate ($CaCO_3$).
- They are usually less than 1 mm in size, but some are much larger.

Some have algae as **endosymbionts.**

- Foramanifera typically live for about a month.



Mastigophora (*Flagellates)*

- Flagellates are protozoa which move with flagella and are classified as Mastigophora.
- Many flagellates are marine.

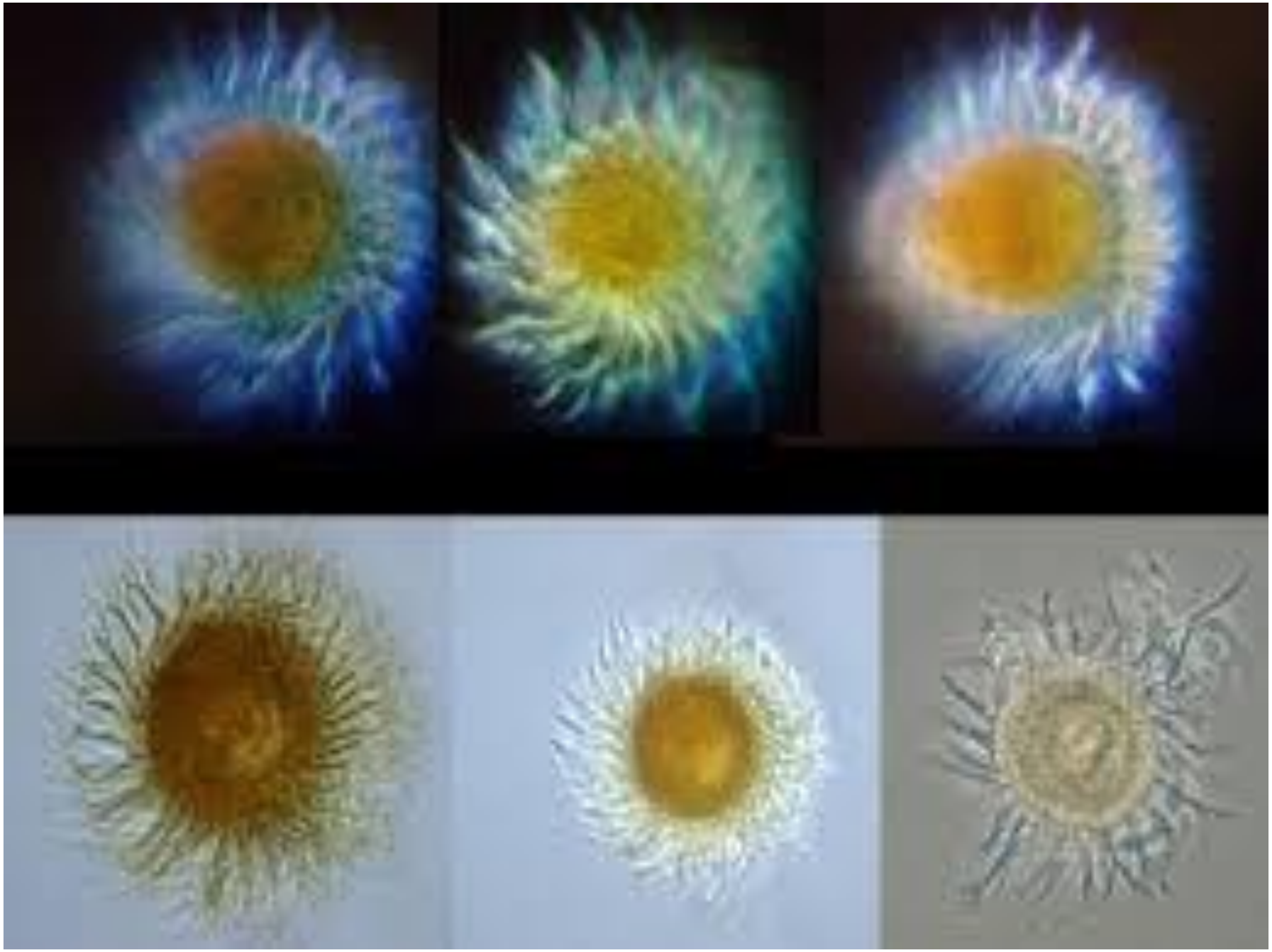
Suctoria

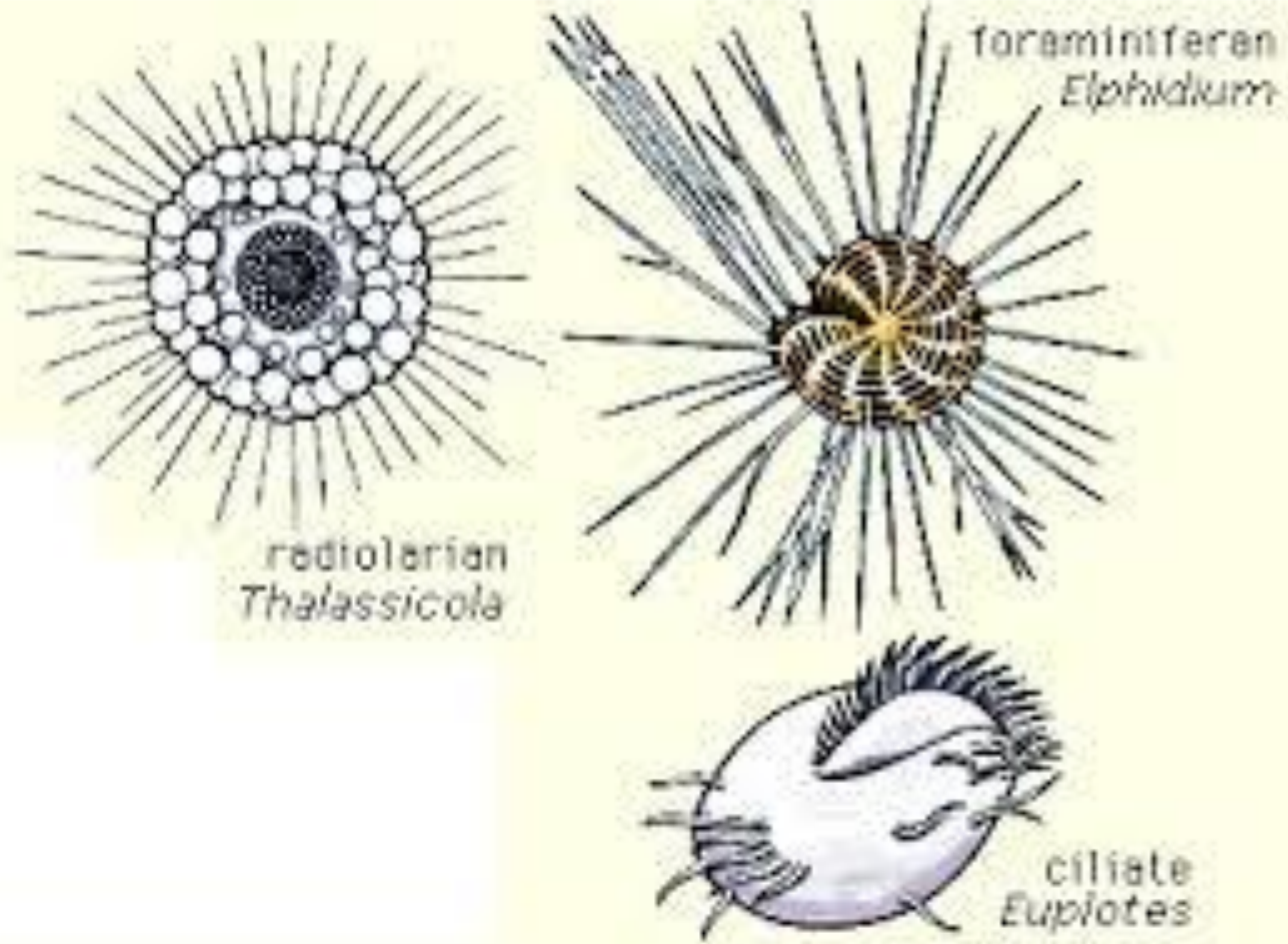
- The suctoria are exclusively marine.
- The juvenile stage is a ciliate and moves about.
- The adult stage is sessile and catches food with tentacles.


SUCTORIAS

Ciliophora (**Ciliates***)*

- Ciliates are protozoa with cilia, and are classified as *Ciliophora* .
- They posses two nuclei.
- Marine ciliates are large, about 20–80 mm with some as large as 200 mm.
- Ciliates are important in the marine food web because they **ingest (graze) bacteria** and other smaller organisms in the marine environment.




foraminiferan
Elphidium
radiolarian
Thalassicola
ciliate
Euplotes

- Some ciliates contain **photosynthetic organisms** as **endosymbionts**;
- They are able to obtain food by photosynthesis as well as by **grazing** and are said to be **mixotrophic**.
- Some ciliates do selective grazing, ingesting some organisms and leaving others.

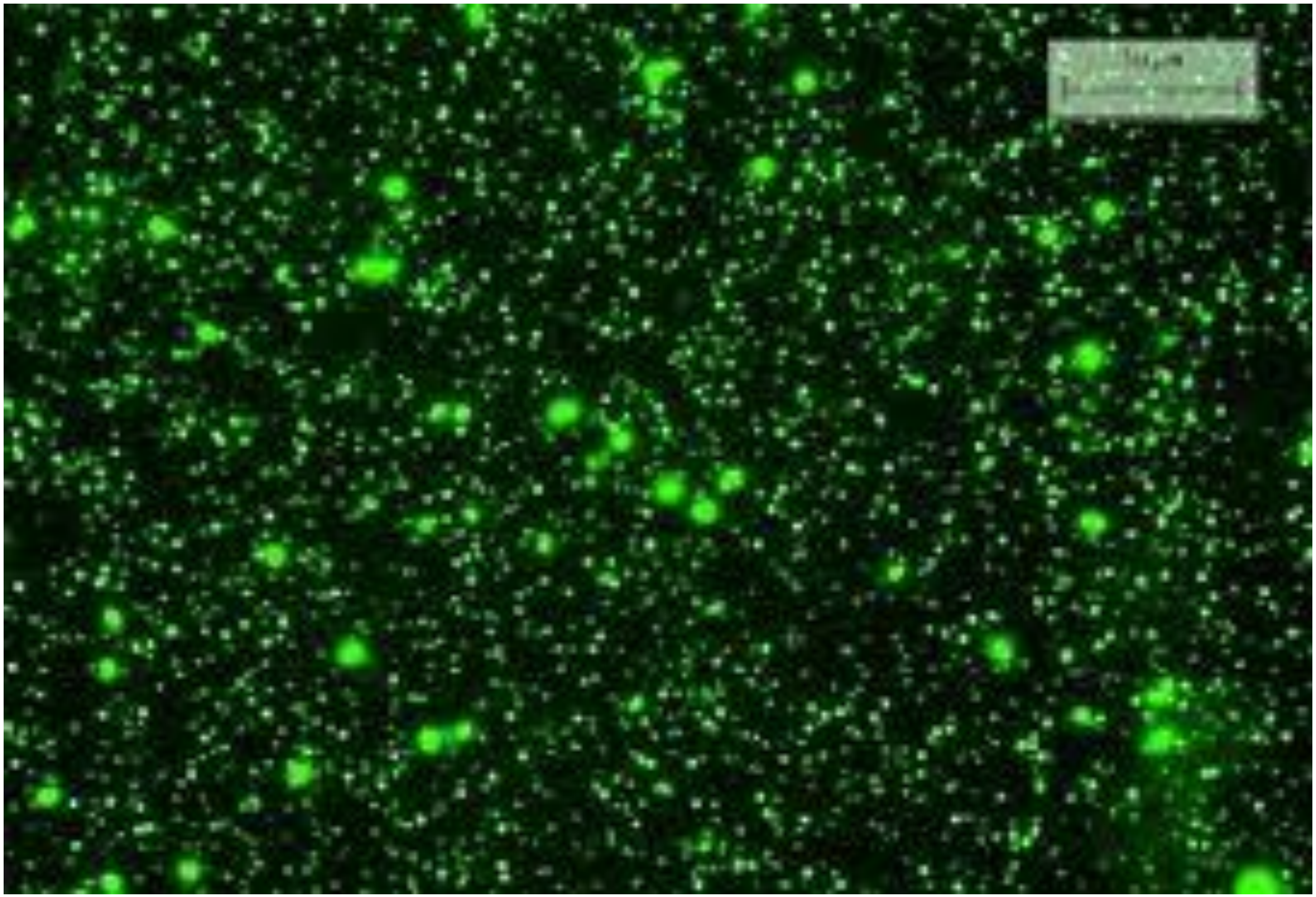
Viruses

- Until the 1990s, it was believed that oceans were deserts in terms of microorganisms, few viruses would be in the sea
- Since then, using the transmission electron microscope and epifluorescence microscopy, viruses have been shown to occur up to **10^{10}/ml of sea water**.
- The distribution of viruses follows the relative abundance of microorganisms along the water column in the ocean.

- The world’s oceans harbour nearly 200,000 virus species; 42% found in the arctic region
- Followed by temperate and tropical regions
- Every spoonful of seawater is filled with millions of viruses.
- Although most are harmless to people, they can infect a variety of marine life such as whales, crustaceans and bacteria.

Viruses in a drop of sea water:

In the ocean total number exceeds 10^{29}



- Viruses are small particles, 20–30 nm long and made of either DNA or RNA, covered with a **protein coat** and sometimes also with **lipid** .
- Viruses have no metabolism of their own, but use the host mechanism for their metabolism and reproduction.
- They attack specific hosts and marine micro organisms seem to have their own peculiar viruses.

Three kinds of relationships exist between <u>viruses and their microbial hosts</u>

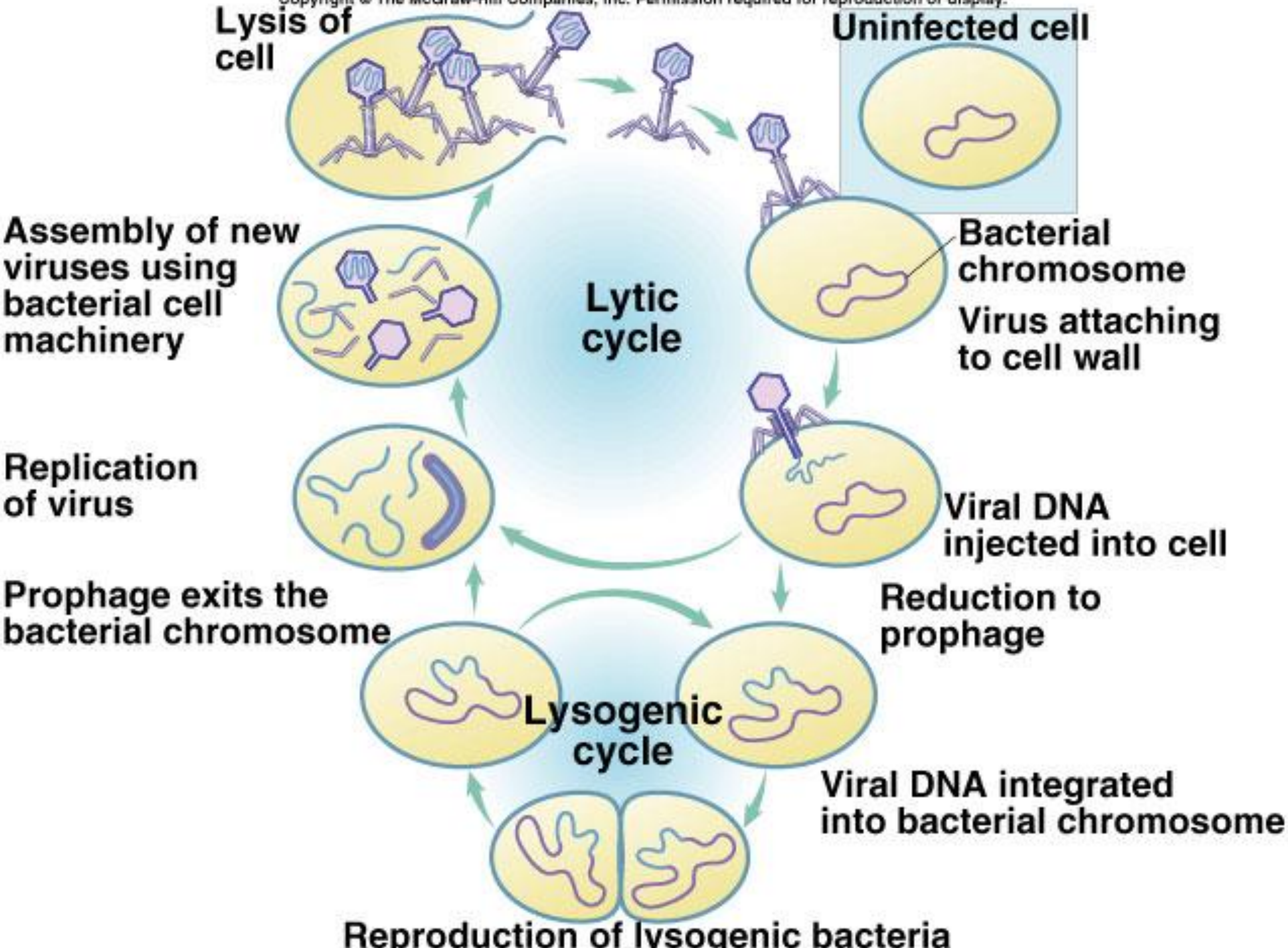
(a) ***Lytic infections***

- After attaching to its host, the virus injects its nucleic acid into the host and causes it to produce numerous viruses like itself;
- The cell bursts and releases the new viruses.
- Each of the new daughter viruses can start the process again in a new host.

- The process stops carbon in the bacteria from passing up the food chain, and instead releases the carbon back into the ocean for use by other microorganisms

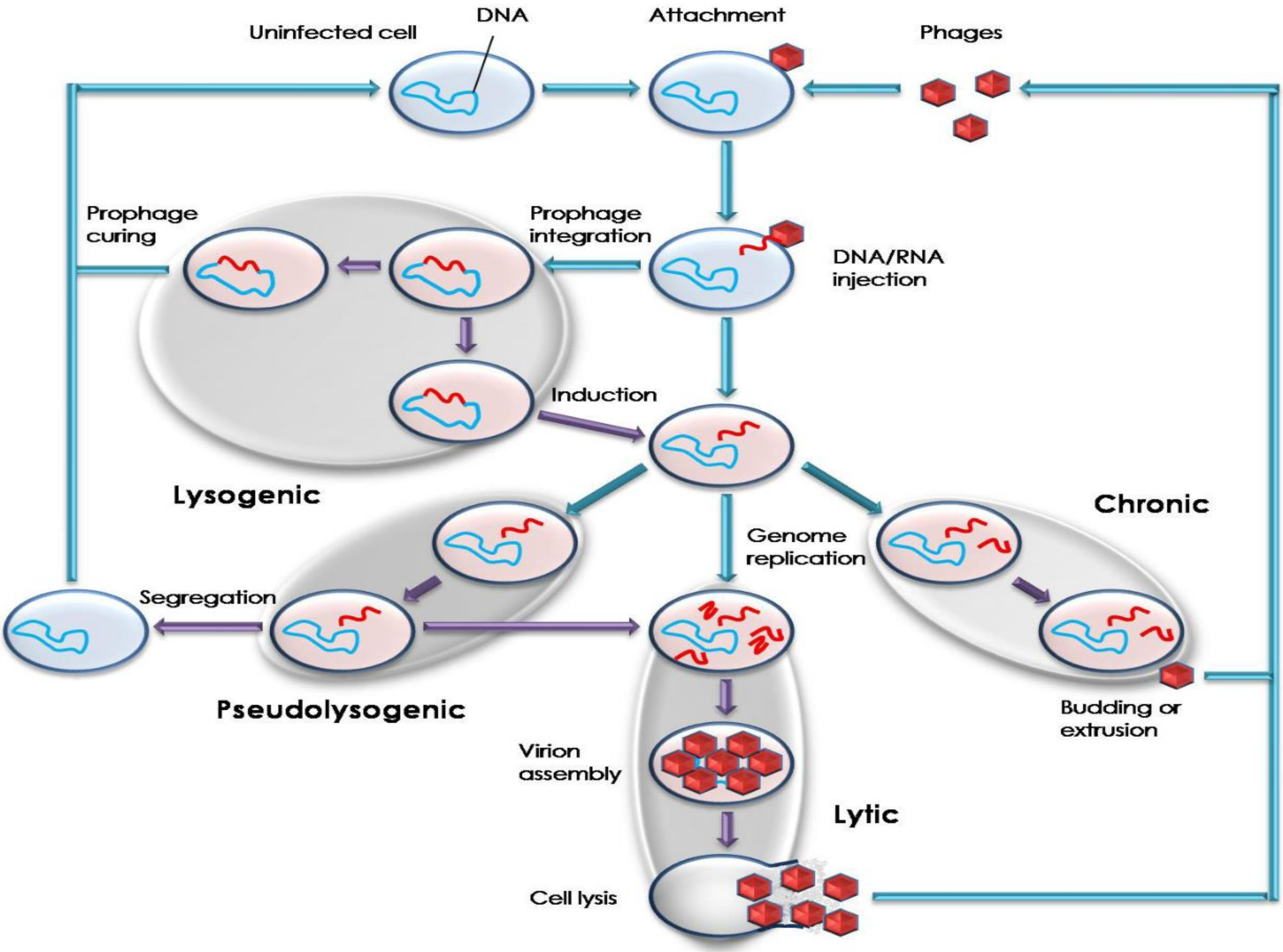
(b) Lysogenic cycle

- On injection of the viral nucleic acid into the host, the host is not lysed
- The viral nucleic **acid attaches to and becomes part of the genetic apparatus of the host.**
- It may be induced to become lytic by ultra violet and some chemicals.


Lysis of cell
Uninfected cell
Assembly of new viruses using bacterial cell machinery
Bacterial chromosome
Lytic cycle
Virus attaching to cell wall
Replication of virus
Viral DNA injected into cell
Prophage exits the bacterial chromosome
Reduction to prophage
Lysogenic cycle
Viral DNA integrated into bacterial chromosome
Reproduction of lysogenic bacteria

(c) Chronic relationship

- The new viruses do not lyse the host, but are released by budding over many generations.
- *Budding* is a type of asexual reproduction in which a new organism develops from an outgrowth or bud due to cell division at one particular site
- The proliferating cytoplasm or cells (the bud), eventually develops into an organism duplicating the parent.


DNA
Attachment
Uninfected cell
Phages
Prophage
curing
Prophage
integration
DNA/RNA
injection
Induction
Lysogenic
Chronic
Genome
replication
Segregation
Pseudolysogenic
Budding or
extrusion
Virion
assembly
Lytic
Cell lysis

Role of marine viruses

- Marine viruses can be both detrimental and beneficial to the ocean's health.
  a) **Some viruses <u>attack and kill plankton</u>, eliminating the base of the ocean food chain in a particular area.**

  This carbon is prevented from moving to the next trophic level

  Bacteriophages and other viruses are credited with killing roughly 20% of bacteria in the ocean every day.

b) Viruses are important in the food economy of marine organisms because the materials released when they lyse their hosts **contribute to:**

- **the dissolved organic matter (DOM)**
- **and particulate organic matter (POM) of the oceans.**

- The dead plankton can become a source of carbon that is not otherwise readily available to other sea life.

•It is estimated that up to 25% of all living carbon in the oceans is made available through the action of viruses

C. Viruses contribute to gene transfer among marine organisms .

d. diseases

Assignment

Read through the reference paper from the eclass for additional information on marine viruses

Title: Marine Viruses: Key Players in Marine Ecosystems