Bacterial Cell Structure and Function

Bacterial cell components

- Bacterial cells vary in size, shape, cell to cell arrangements and in the make up of their cell walls

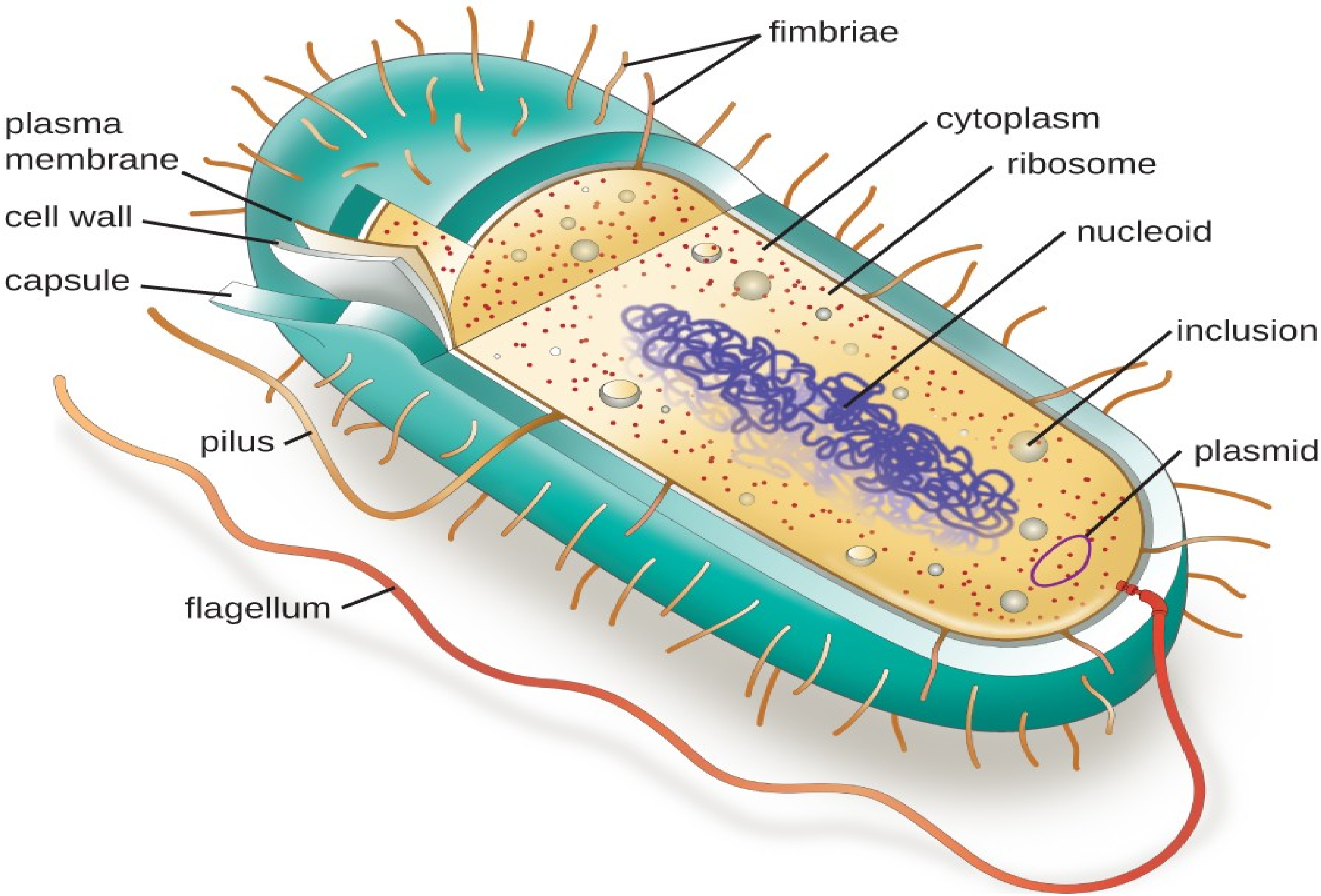
- The bacterial cell can be divided into three parts

➢ Structures external to the cell (Appendages)

➢ The cell envelope

➢ The cytoplasm

Typical Bacterial cell



Structures external to the cell (Appendages)

Flagella (singular ; flagellum)

- Responsible for movement in most motile prokaryotes.
- Long, whip-like (threadlike) complex filamentous protein structures
- Free at one end and attached to the cell surface at the other end.
- About 15-20 nm wide and up to 15 – 20 μm, a single flagellum can only be seen with a light microscope after it has been stained with special stains that increase the diameter.
- Composed mostly of protein called **flagellin**

Basically flagella are either

➢ **Polar** (one or more flagella arising from one or both poles of the cell) e.g. *Pseudomonas sp.* **OR**

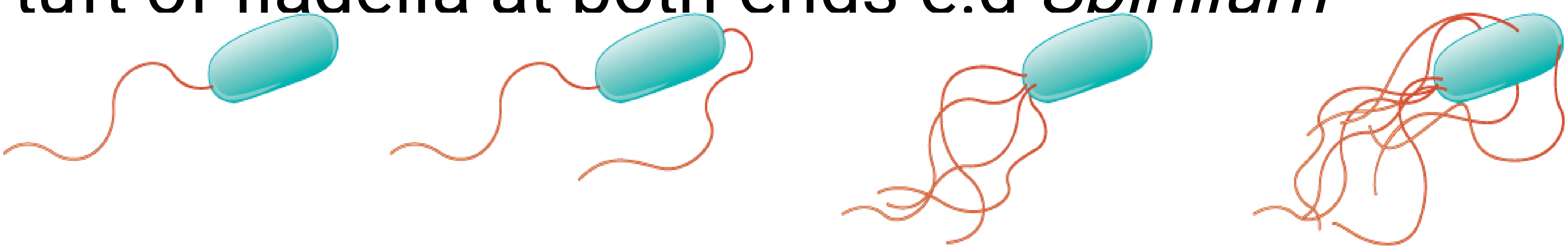
Flagella Distribution and Arrangement

- Arrangements of **polar flagella** may be

➢ **Monotrichous** - have a single flagellum at one end e.g. *Pseudomonas aeruginosa*

➢ **Lophotrichous** cells have a tuft of flagella at one end

➢ **Amphitrichous** cells have single flagellum or tuft of flagella at both ends e.g *Spirillum*



monotrichous amphitrichous lophotrichous peritrichous

Fimbriae and Pili

- **Fimbriae** (*s. fimbria*) and **pili** (*s. pilus*) are often used interchangeably to designate short, hair-like, filamentous structures on the surfaces of prokaryotic cells.
- **Fimbriae** and **pili are different.**
- Fimbriae are shorter and stiffer than flagella, and slightly smaller in diameter.
- A cell may be covered with up to 1,000 fimbriae and are only **visible with electron microscope** due to their small size.
- **Fimbriae** are most often involved in adherence of bacteria to surfaces (biofilms), substrates and other cells or tissues in nature.
- Pathogenic *Neisseria gonorrhoeae* adheres specifically

Pili

- Pili are similar to fimbriae but are typically **larger** structures (9 – 10 nm in diameter).
- Only about 1 – 10 are present per cell.
- Although they may attach to surfaces as do fimbriae, **they also facilitate the exchange of genetic materials** between prokaryotic cells in the process of **conjugation**.
- In *E. coli*, a specialized type of pilus, the **F or sex pilus**, apparently stabilizes mating bacteria during the process of **conjugation.**

The Cell Envelope

- The cell protoplasm (**cytoplasm**) is surrounded by the **plasma membrane**, a **cell wall** and a **capsule**.

Capsules, slime layers and glycocalyx

- A **true capsule** is a well-organized detectable layer of polysaccharides deposited outside but typically firmly attached to the cell walls.

Functions: Like fimbriae, capsules, slime layers, and glycocalyx often **mediate adherence** of cells to surfaces. Capsules contain significant amount of water, thus **protect cells from effects of drying** or desiccation. It also **protect bacterial cells from**

Cell Wall

- This is the fairly rigid layer that lies just outside the plasma membrane in most prokaryotes.

Functions

1. The cell wall is an essential structure for viability.
2. It provides structure, rigidity and shape to the cell.
3. It protects the cell protoplast from mechanical damage and from osmotic rupture or **lysis**.
4. It assists some cells in attaching to other cells.
5. **It also assists some cells in eluding**

Cell Wall

- The major component of bacterial cell walls is called peptidoglycan (or murein).
- It is only found in bacteria.
- Structurally, peptidoglycan resembles a layer of meshwork or fabric.
- Each layer is composed of long chains of alternating sugar molecules called **N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM).**
- The structure of the long chains has significant two-dimensional tensile strength due to the formation of peptide bridges that connect NAG and NAM within each peptidoglycan layer.
- Peptidoglycans also contain several amino acids, including **L- alanine, D- alanine, D- glutamic acid and either lysine or diaminopimelic acid (DAP).**

Cell Wall

- In Gram-negative bacteria, tetrapeptide chains extending from each NAM unit are directly cross-linked, whereas in Gram-positive bacteria, these tetrapeptide chains are linked by pentapeptide cross-bridges.
- Peptidoglycan subunits are made inside of the bacterial cell and then exported and assembled in layers, giving the cell its shape.

- The cell walls of Archaea may be composed of protein, polysaccharides, but **never** do they contain peptidoglycan.
- This feature distinguishes the Bacteria from the Archaea

Cell Wall

- **The composition of the cell wall is the basis for classification of bacteria according to the Gram staining reaction.**
- Bacterial cells are described as either **Gram-negative** or **Gram-positive** depending on;

i. the structure and
ii. chemistry of their cell wall.

- This is done by use of Gram staining procedure
- A few bacteria such as *Mycoplasma pneumoniae* lack cell walls entirely

Gram-Positive Bacteria

- The Gram-positive wall consists of about 20 to 80 nm thick homogenous layer of peptidoglycan external to the plasma membrane.
- It is composed mainly (about 90%) of peptidoglycan.
- Although some bacteria have only a single layer of peptidoglycan surrounding the cell, many Gram – positive bacteria have several sheets of peptidoglycan stacked one upon another.
- Running perpendicular to the peptidoglycan sheets is a group of molecules called **teichoic acids** which are unique to the Gram-positive cell wall.
- Certain teichioc acids are covalently bound to membrane lipids and are referred to as **lipoteichoic acids.**
- Gram-positive Bacteria **retain** the purple crystal violet dye when subjected to the Gram-staining procedure

Gram-Negative Bacteria

- The Gram-negative wall appears **multilayered and much more complex than gram-positive.**
- **The wall of Gram-negative bacteria is relatively thin and contains much less peptidoglycan than the Gram-positive wall.**
- It has 2 to 7 nm peptidoglycan layer covered by a 7 to 8 nm outer membrane.
- The thin peptidoglycan layer next to the plasma membrane and bounded on either side by periplasmic space is not more than 5 to 10% of the cell weight.
- The outer membrane lies outside the thin peptidoglycan layer and is linked to the cell by many adhesion sites and by Braun's lipoprotein.
- The outer membrane contains a unique component, **lipopolysaccharide** (**LPS consisting of lipid and polysaccharide**), which is toxic to animals.
- The polysaccharide portion of LPS consists of two components, the **core polysaccharide** and the **O-polysaccharide**. The lipid

Cells that lack cell walls

These include, the:

- **Mycoplasmas** comprising of the *Mycoplasma* spp. and *Spiroplasma* spp. (a group of pathogenic bacteria that cause a variety of infectious diseases in humans and other animals).
- *Thermoplasma* group which contain species of **Archaea** that naturally lack cell walls.

Cytoplasmic membrane

- This is a delicate, thin, fluid structure that surrounds the cytoplasm and defines the boundary of the cell.
- Also referred to as **plasma or cell membrane**
- Lies beneath the cell wall
- Barrier that separates the inside of the cell (the cytoplasm) from its environment.
- If the membrane is broken, the cytoplasm leaks into the environment and the cell dies.
- It is about 5nm thick
- It is a **phospholipid bilayer** with **proteins** inserted between the phospholipids
- **It is 40% phospholipid and 60% protein**

Cytoplasmic membrane

- The bilayer consist of two opposing layers composed of phospholipids
- At one end of each phospholipid molecule are **two fatty acid chains**, which act as **hydrophobic tails.**
- The other ends, containing **glycerol, a phosphate group** and **other polar molecules** functions as a **hydrophilic head.**
- The phospholipid molecules are arranged in each layer of the bilayer so that their hydrophobic tails face in, towards the other layer.
- Their hydrohipilic heads face outward.
- As a consequence, the inside of the bilayer is water insoluble whereas, the two surfaces interact freely with aqueous solution of the external or the cytoplasmic environment
- It is **selectively permeable** i.e. allows some substances (nutrients, wastes) to cross while preventing the crossing of others (antibiotics)

The Cytoplasm

The Cytoplasmic matrix composed of: cytosol, inclusions, ribosomes, nucleoid, plasmids and a cytoskeleton, etc

The cytosol

- Liquid portion of the cytoplasm; mostly (70%) water but also contains dissolved and suspended substances including ions, carbohydrates, proteins, amino acids (mostly enzymes), lipids and wastes. **Site of some chemical reactions.**

Inclusion bodies

- These are granules of organic or inorganic material which functions as energy reserves storing nutrients.

Ribosomes

- Ribosomes are very complex structures made of both

The Nucleoid

- Most bacterial species contain a single circle of double-stranded DNA but some have linear DNA chromosome which is found within the **nucleoid (nuclear region, chromatin body, nuclear region)**.
- The nucleoid does not contain a covering or membrane.
- Rather, it represents a central subcompartment in the cytoplasm where the DNA aggregates.
- The DNA contains the hereditary / genetic information or genes of the cell.
- Since most cells only have one copy of each gene, the cells are genetically **haploid.**

Plasmids

- These are extrachromosomal DNA that lies within the cytoplasm of some bacterial cells.
- Plasmids are small, double-stranded DNA molecules that can exist independently of the chromosome.
- They could be circular or linear.
- Their numbers vary from cell to cell.
- Plasmids carry genes that code for a variety of functions

i. Some plasmids posses genes for **disease- causing toxins**

ii. Many carry genes that **enhance mating ability**

iii. They can **enhance bacterial survival by conveying chemical or antibiotics resistance**

Reproduction of Prokaryotic cells

- All prokaryotes reproduce asexually either by binary fission, spore formation, fragmentation or budding.

  i. **Binary fission**

- Most common method of reproduction in prokaryotes
- This usually occurs after a period of growth in which the cell doubles in mass
- It results in the separation of a single cell into two morphologically and genetically identical daughter cells each containing at least one copy of the parental DNA.

Reproduction of Prokaryotic cells

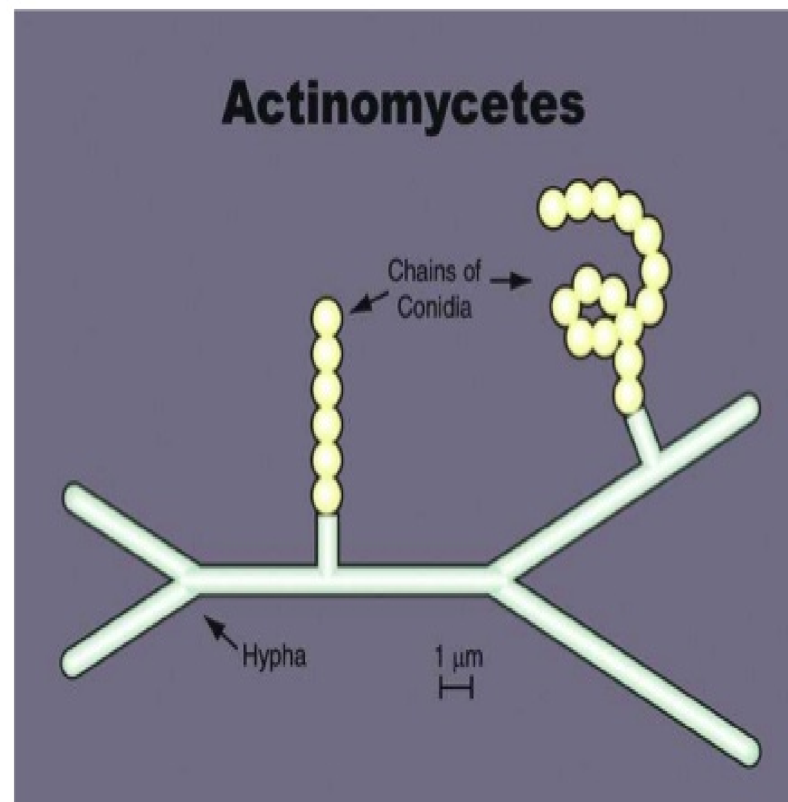
- The time required for this process is called the **generation time. Generation time or Doubling time:** This is the interval of time between successive binary fissions of a cell or population of cells.
- In the period of one generation, all cellular constituents increase proportionally
- Time required for a generation in a given bacterial species is highly variable and is dependent on both **nutritional and genetic factors.**
- Under the best nutritional conditions, the

Reproduction of Prokaryotic cells

ii. <u>Spore formation</u>

- The *Actinomycetes* produce reproductive cells called **spores** at the end of their filamentous cells
- Each cell can develop into

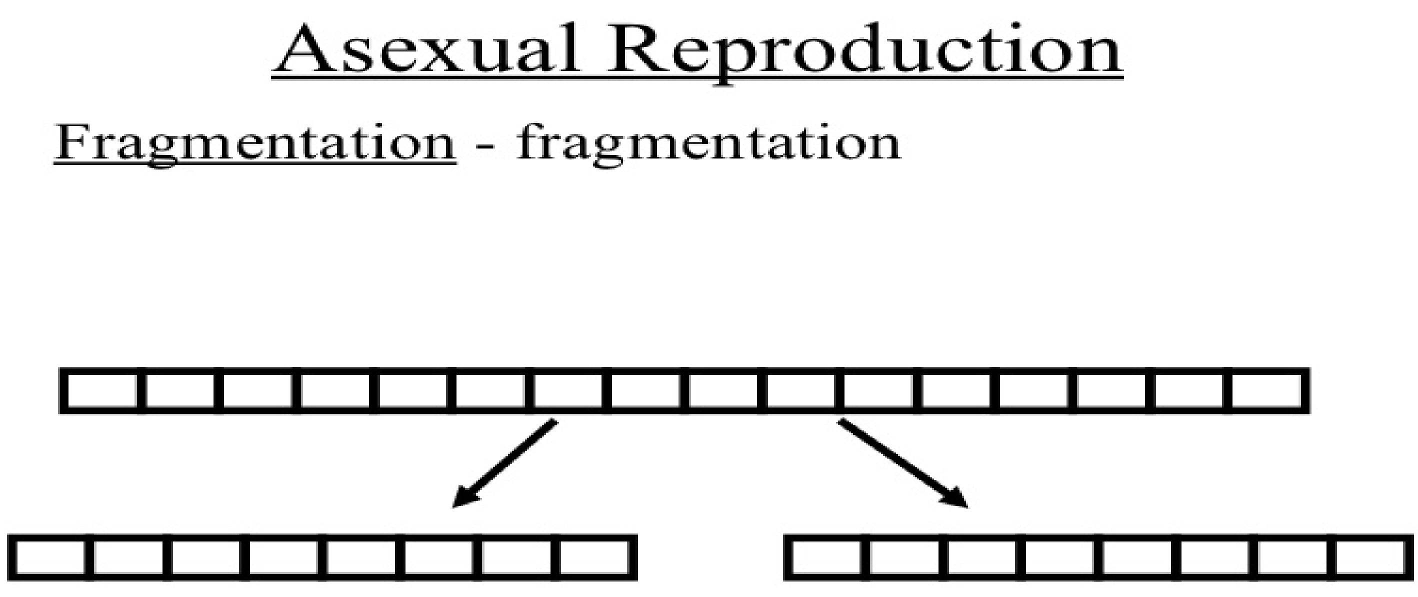
a clone of the original organis



Reproduction of Prokaryotic Cells

iii. <u>Fragmentation</u>

- Some *Cyanobacteria* reproduce by fragmentation into small motile filaments that glide away from the parental strand

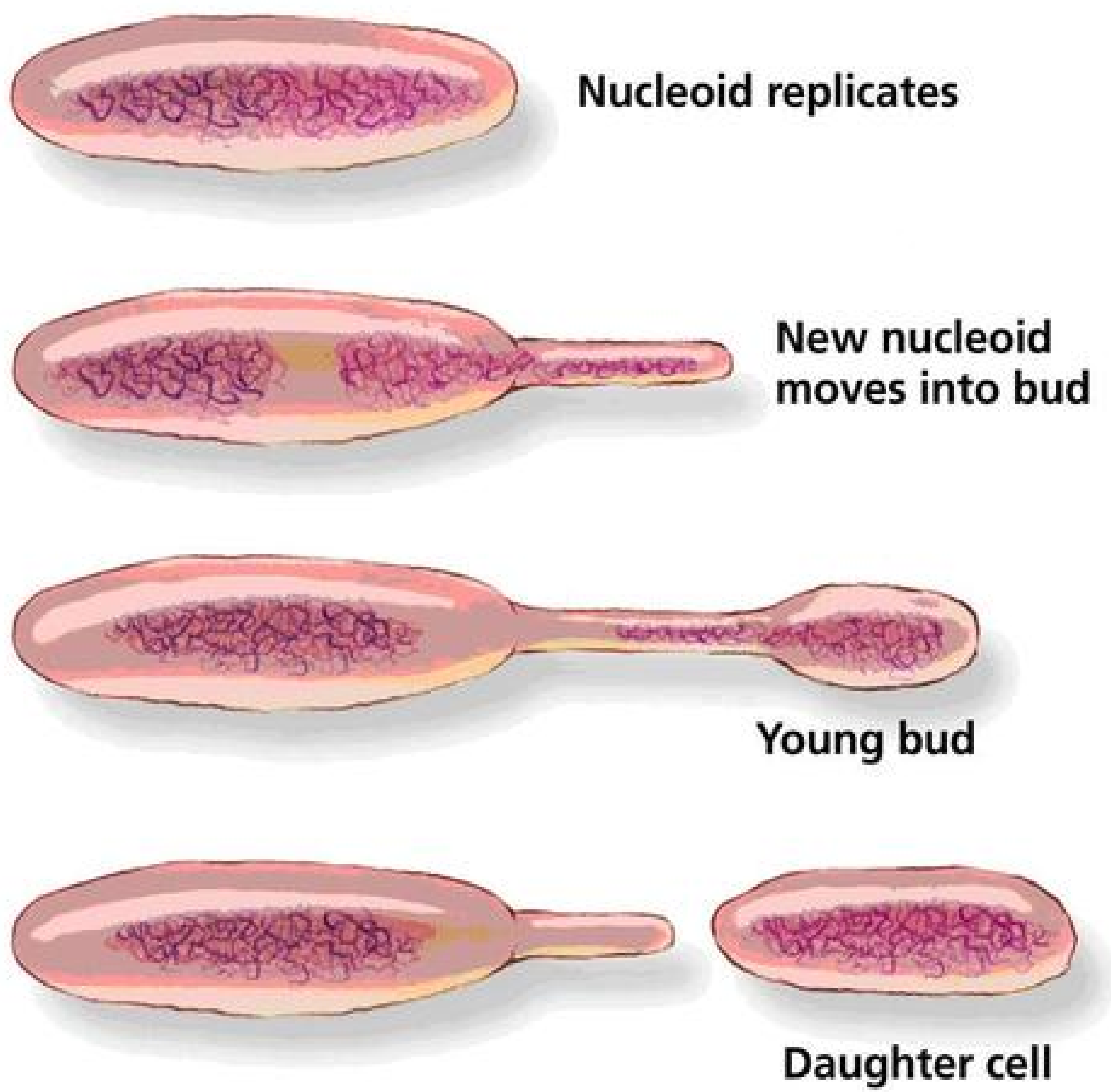


Reproduction of Prokaryotic cells

iv. **<u>Budding</u>**

- Budding involves a cell forming a protrusion that breaks away and produces a daughter cell.
- The bud receives a copy of the genetic material and enlarges
- Eventually, it cuts off from the parent material while it is still small.
- In contrast to binary fission that forms two equivalent cells, cell division in stalked and budding bacteria forms a totally new daughter cell, with the mother cell retaining its original identity.

Budding cell



Introduction to Mycology

- The term fungi refers to both **yeasts and molds**
- Fungi are eukaryotic organisms that are spore-bearing, have absorptive nutrition, lack chlorophyll, and reproduce sexually and asexually.
- The study of fungi is called **mycology.**
- A person who studies fungi is known as **mycologist**
- Fungi **(singular fungus)** have worldwide distribution
- They grow in a wide range of habitats

Characteristics of Major Fungal Groups

- Fungi also produce antibiotics such as penicillin and cephalosporin.
- The major structure of the fungal cell is the cell wall which determines the shape.
- The fungal **cell wall** is made up of network of polysaccharide chains (c**hitin**, glucan, mannan and cellulose) referred to as **microfibrils**.
- Protein and glycoprotein are known to crosslink the polysaccharide chains.
- Fungal **cell membranes** contain **ergosterol (sterol lipids)** in contrast to phospholipids found in bacterial cell membrane.
- They lack chlorophyll.
- Not susceptible to antibacterial agents.

Classification of fungi into Morphological Groups

- The vegetative (non reproductive) body of a fungus is called **thallus (pl. thalli)**
- Fungi can morphologically be classified into three groups

➢ **The yeast**

➢ **The molds or filamentous fungi**

➢ **Dimorphic fungi**

The yeasts

- The thalli of yeasts are small, unicellular, globular, round to oval in shape
- They range in size from 2 to 60 μm
- These produce moist, creamy, opaque colonies on media
- The microscopic morphologic characteristic usually appear similar for different genera and are not particularly helpful in their identification
- Most yeasts reproduce asexually by budding and binary fission.
- Examples are *Candida sp., Cryptococcus sp., Saccharomyces sp., Malasezzia sp., Geotrichum sp., Trichosporon sp.*

The molds or Filamentous Fungi

- Hyphae are either **dematiaceous** (i.e. pigmented) or **hyaline** (non-pigmented).
- Molds produce fluffy, cottony, wooly or powdery colonies on media.
- Hyphal and spore pigmentation are useful features that are used to differentiate most clinically important fungi.
- Examples are *Fusarium sp, Microsporum sp, Trichophyton sp, Aspergillus sp, Absidia sp, Mucor sp, Rhizopus sp, Monilia sp*

Dimorphic Fungi

- Several pathogenic fungi are able to exhibit either a yeastlike or filamentous form and are referred to as being **dimorphic**
- This may be in response to changes in environmental conditions like temperature or carbon dioxide concentration or nutrient availability.
- When dimorphism is temperature dependent, the fungi are designated as **thermally dimorphic**
- In general, **these fungi produce a mold form at 25 to 30°C and yeast form at 35 to 37°C**
- The medically important dimorphic fungi include *Histoplasma capsulatum, Penicillium marneffei, Blastomyces dermatitidis*

Reproduction in Fungi

1. **Asexual reproduction**

   a) Binary fission

   b) Budding

- Yeasts typically bud in a manner similar to prokaryotic organisms
- Following mitosis, one daughter nucleus is separated in a small bleb of cytoplasm that is isolated from the parent cell by the formation of a new wall.
- Spores produced from a vegetative mother cell by budding are called **blastospores**
- In some species,e.g. *Candida albicans*, a series of buds remain attached to one another and to the parent cell forming a long filament called a **pseudohyphae**

Reproduction in Fungi

c). Asexual spore formation

- Filamentous fungi reproduce asexually by producing light weight spores which enable the fungi to disperse to vast distances in wind.
- Scientists categorize the asexual spores of molds according to their mode of development.

i. **Sporangiospores** form inside a sac called a **sporangium.**

- This is often borne on a spore bearing stalk called **sporangiophore** at either the tip or sides of hyphae

ii. **Chlamydospores** form with a thick cell wall inside hyphae

iii. **Conidiosphores** (conidia) are produced at the tips or sides of hyphae but not within a sac

Reproduction in Fungi

2. **Sexual reproduction**

- Scientists designate fungal mating types as “+” and “-” rather than as male and female because their thalli are morphologically the same
- The process of sexual reproduction in fungi has four basic steps

i. Haploid (n) cells from a + thallus and a – thallus fuse to form a dikaryon

ii. After a period of time that ranges from hours to years, a pair of nuclei within the dikaryon fuse to form diploid (2n) nucleus

iii. Meiosis of diploid nucleus restores the haploid state

iv. The haploid nuclei are then separated into + and - spores

INTRODUCTION TO VIRUSES

Nature and Composition of Viruses

- A virus is an **acellular, obligate intracellular** infectious agent having one of several pieces of nucleic acid - either **DNA or RNA but never both.**
- They lack cell membranes, cytosol and organelles.
- They cannot carry out any metabolic pathway on their own.
- They can neither grow nor respond to the environment.
- They cannot reproduce independently.
- But must utilize the chemical and structural

Nature and Composition of Viruses

- The basic infective particle of a virus is known as the **virion**
- In the simplest viruses, this consist of a nucleic acid genome surrounded by a protein coat, called **capsid**
- Together, the nucleic acid and its capsid are also called **nucleocapsid**
- Viral capsids are composed of many proteinaceous individual subunits called **capsomeres**
- Depending on the arrangement of these proteins, the capsomeres may be spherical,

Nature and Composition of Viruses

- The arrangement of the capsomeres around the nucleic acid determines the symmetry of the virion.
- Some virions have a phospholipid membrane called an **envelope** surrounding the nucleocapsid.
- The outermost layer of a virion (capsid or envelope) provides both protection and recognition sites that bind to complementary chemicals on surfaces of cells.
- These are involved when viruses penetrate a cell.

Characteristics used to distinguish different viral groups

- The type of genetic material.
- Kind of host cells they attack.
- Size of viral particle.
- Nature of capsid coat and their shapes.
- Presence or absence of an envelope.

Genetic material of viruses

- The genome of every cell is double-stranded DNA.
- Whereas the genome of a virus may either be DNA or RNA but never both
- Viruses are broadly classified primarily upon the **type of genomic nucleic acid,** eg. DNA or RNA ,
- Then further by the **number of strands of nucleic acid** (e.g. double-stranded DNA , single-stranded DNA, double-stranded RNA or single-stranded RNA,
- Furthermore, viral genomes may be either linear and composed of several molecules of nucleic acid as in eukaryotic cells or circular and singular as in most prokaryotes.

Hosts of viruses

- All types of organisms are susceptible to viral attack
- They infect plants, bacteria, fungi and animal cells.
- A virus that infect bacteria is referred to as a **bacteriophage**
- Most viruses infect only particular host's cells
- This specificity is due to the specific affinity of viral surface proteins or glycoproteins on the surface of host cell
- Viruses may be specific in that they infect not only a host, but a particular kind of cell in the host.
- HIV specifically attacks helper T lymphocytes in humans and have no effect on other cells like human muscle cells or bone cells
- By contrast, some viruses are generalists i.e., they infect many kinds of cells in many different hosts e.g. Rabies

Viral capsid coat and their shapes

- Some capsomeres are composed of only a single type of protein whereas others are made of several different protein subunits
- There are three basic types of viral shapes
- These are **helical, icosahedral and complex**
- Helical capsids are spiral shaped with the appearance of a hollow tube around the nucleic acid
- Icosahedral – shaped capsids are cubical with 20 equilateral triangular faces
- Complex viruses have capsids of many different shapes that do not readily fit into either of the other two categories
- The complex shape of many bacteriophages include icosahedral heads, attached to helical tails

Algology

- **Algae** are eukaryotic organisms that have no roots, stems, or leaves but do have chlorophyll and other pigments for carrying out photosynthesis.
- They include both
  - ✓ microscopic unicellular members and
  - ✓ macroscopic multicellular organisms
- What distinguishes algae from other eukaryotic photosynthetic organisms such as land plant is their lack of an organized vascular system.
- Also they have relatively simple reproductive system

Algology

- Most algae are **photoautotrophic** and carry on photosynthesis (i.e. they obtain energy from light and photosynthesize).
- They use light energy to convert CO_2 and H_2O to carbohydrates and other cellular products with the release of oxygen.
- Some forms are **chemoheterotrophic** and obtain energy from chemical reactions and nutrients from preformed organic matter.
- Most species are saprobes, and some are parasites.

Algology

- Additionally, algae are the source for agar, agarose, and carrageenan, solidifying agents used in laboratories and in food production.
- Although algae are typically not pathogenic, some produce toxins.
- Harmful algal blooms, which occur when algae grow quickly and produce dense populations, can produce high concentrations of toxins that impair liver and nervous-system function in aquatic animals and humans.
- Like protozoans, algae often have complex cell structures.
- Different algal groups have different pigments, which are reflected in common names such as red algae, brown algae, and green algae.

Algology

- Reproduction is both in asexual and sexual forms.
- Asexual reproduction occurs through the **fragmentation** of filamentous algae or by **spore formation** (as in fungi).
- **Binary fission** also takes place (as in bacteria).
- During sexual reproduction, algae form differentiated sex cells that fuse to produce a diploid **zygote** with two sets of chromosomes.
- The zygote develops into a sexual spore, which germinates when conditions are favorable to reproduce and reform the haploid organism having a single set of chromosomes.
- This pattern of reproduction is called **alternation of generations.**

Structure of Algae: Cell walls

- Algal cell walls are rigid and mostly composed of **cellulose**, often associated with **pectin.**
- Some multicellular species e.g. red algae contain large amounts of other compounds in their cell walls.
- The red algae cell wall components such as **carrageenan and agar** are harvested commercially and commonly used in foods as stabilizing compounds.
- **Agar is also used to solidify growth media in the laboratory**

Structure of Algae

- Algae have a membrane – bound nucleus
- In addition, algae have other organelles in their cytoplasm such as chloroplasts and mitochondria
- **Chloroplasts** where photosynthesis occurs, contain chlorophyll as well as other light-trapping pigments such as **carotenoids and phycocyanin**
- Respiration and oxidative phosphorylation occur in the mitochondria

Structure of Algae

- **Diatoms** are algae that have **silicon dioxide** incorporated in their cell walls
- When these organisms die, their shells sink to the bottom of the ocean, and the silicon-containing material does not decompose
- Deposits of diatoms that formed millions of years ago are mined for a substance known as **diatomaceous earth** used for filtering systems, abrasives in polishes, insulation e.t.c.

Unicellular Red Algae

- The red algae, also called **Rhodophytes**, are found mostly in marine habitats
- But a few species inhabit the freshwater and terrestrial habitats
- They are phototrophic and contain chlorophyll a
- The reddish colour of many red algae results from **phycoerythrin**, an accessory pigment that masks the green color of chlorophyll
- Examples are *Cyanidium, Cyanidioschyzon and Galdieria*

Unicellular Green Algae

- These are also called **chlorophytes**
- They bear chloroplasts containing **chlorophylls a** and giving them their characteristic green color

- There are two main groups of green algae

❖ The **chlorophytes** e.g. *Chlamydomonas* and *Dunaliella*

❖ The **charophyceans**

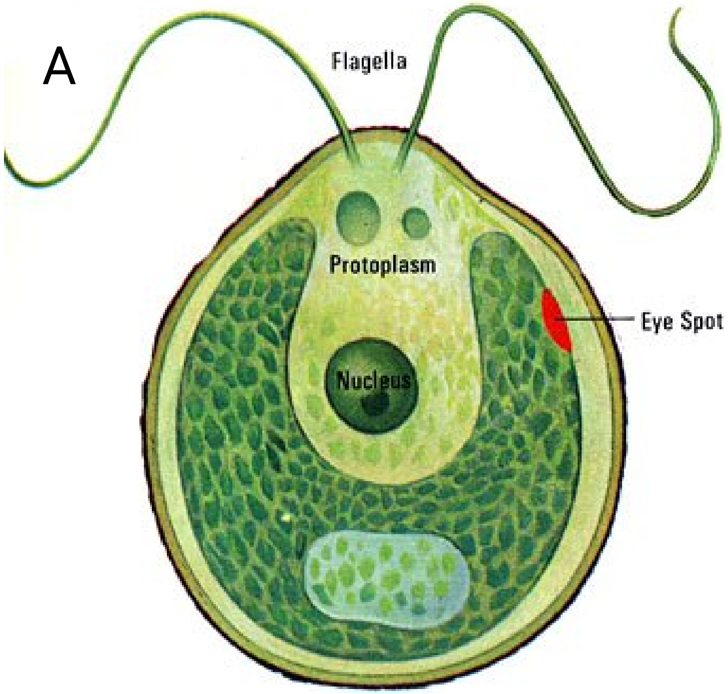
MAJOR GROUPS OF AlgAE

A blanket of algae covering a pond or lake

Examples of algae

- *Chlamydomonas* is a unicellular green alga that has a single large chloroplast, two flagella, and a stigma (eyespot);
- It is important in molecular biology research.
- *Chlorella* is a non motile, large, unicellular alga.
- *Acetabularia* is an even larger unicellular green alga.
- The size of these organisms challenges the idea that all cells are small, and they have been used in genetics research
- *Volvox* is a colonial, unicellular alga.
- A larger, multicellular green alga is *Ulva*, also known as the sea lettuce because of its large, edible, green blades.
- They have rigid cell walls containing agar or carrageenan, which are useful as food solidifying agents and as a solidifier added to growth media for microbes.

A



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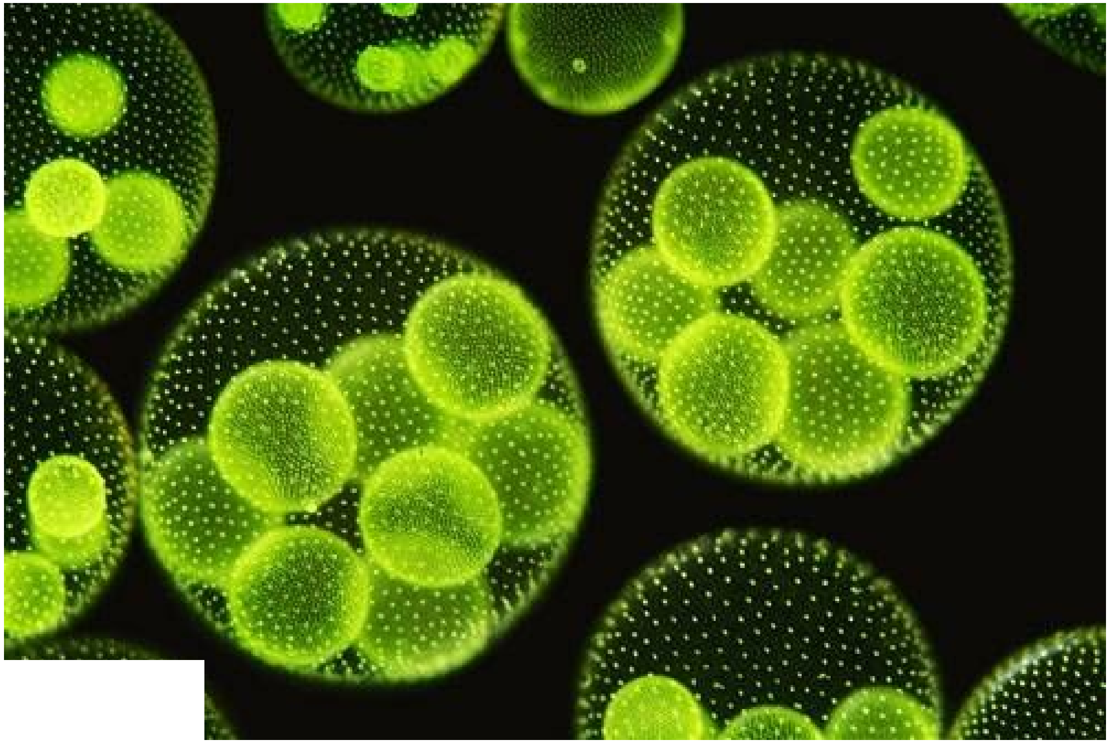

C

A: *Chlamydomonas;*
B*: Volvox;*
C: *Ulva*

Edible products from alga

PROTOZOOLOGY

- **Protozoology is the study of protozoa**
- These are **unicellular microscopic eukaryotic** organisms that lack photosynthetic capability. They have a membrane bound nucleus as well as other membrane –bound organelles such as mitochondria. Generally, exist in two basic forms: **i. Trophozoite** – actively feeding, growing and reproducing vegetative form which proliferates tissues causing damage that results in clinical disease.

ii. Cyst – Dormant, immotile, resistant form which permits survival when environmental conditions are hostile

- Parasitic protozoa are **divided into 4 groups** based primarily on their means of locomotion:

- **Sarcodina** (Amoebae) – Pseudopodia; E.g. *Entamoeba histolytica*
- **Mastigophora** (Flagellates) – Flagella; E.g. *Giardia lamblia, Leishmania species, Trichomonas vaginalis, Trypanosoma species*
- **Ciliophora** (Ciliates) - Cilia; E.g. *Paramecia, Balantidium coli*
- **Sporozoa** (Apicomplexa)- Non-motile; E.g. *Plasmodium* species, *Cryptosporidium parvum and Toxoplasma gondii.* *<u>**Note-**</u> Sarcodina and Mastigophora collectively called **Sarcomastigophora**

Thank you for listening