

9. Evolutionary relationship - Position of microbes in living world – concepts and developments in classification of microorganisms

- Aristotle (384-322 BC) to Carolus Linnaeus (1735) have divided the living world into two kingdoms, Plants and animals. The one-celled organisms visible under the microscope cannot easily be assigned to the plant or animal kingdom.
- The German biologist Ernst Haeckel (1866) -three-kingdom system - Protista, Plantae and Animalia. In the third kingdom Protista he grouped all the single-celled organisms that are intermediate in many respects between plants and animals.
- Herbert Copeland (1956) establishing a fourth kingdom, originally called Mycota but later referred to as the Monera, to include the prokaryotes like bacteria and blue-green algae, which have many characteristics in common- They have a single membrane system without a nucleus, and membrane bounded sub-cellular organelles such as mitochondria or chloroplasts.
- R. H. Whittaker (1969) recognized an additional kingdom for the Fungi. The resulting five- kingdom system suggested by him has received wide acceptance.
- Currently most biologists recognize six kingdoms: two prokaryotic kingdoms (Archaeobacteria and Bacteria), a large unicellular eukaryotic kingdom (Protista) and three Multicellular eukaryotic kingdoms (Fungi, Plantae and Animalia).
- Viruses are not included in any of the present 6 kingdoms – mainly due to their many nonliving characteristics (for example, viruses are not cells).

Haeckel's kingdom Protista :

E.H. Haeckel, 1866 proposed this concept. Apart from plant and animal kingdom, the third kingdom “**Protista**” was developed by him. The protista includes unicellular organisms that are typically neither plant nor animal. These organisms, the protists, include bacteria, algae, fungi and protozoa. Bacteria are referred as lower protists and others are called as higher protists.

Whittaker's five kingdom concept :

R.H. Whittaker (1969), an American Taxonomist, classified all organisms into five kingdoms: Monera, Protista, Fungi, Plantae and Animal.

He used following criteria for classification:

(i) Complexity of cell structure

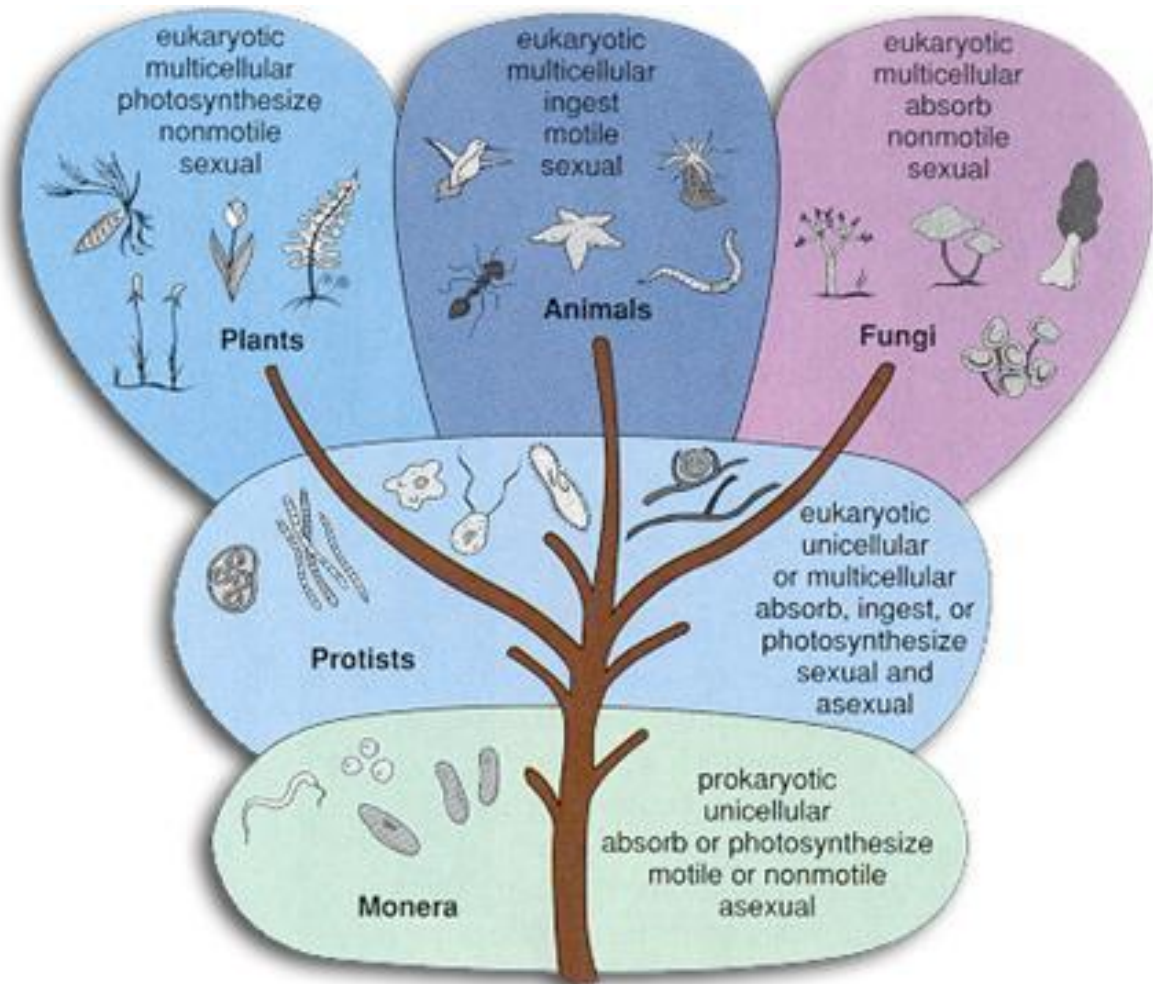
(ii) Complexity of body organization

(ii) The mode of nutrition

(iv) Life style (ecological role) and

(v) Phylogenetic relationship.

1. Planta (photosynthetic)
2. Fungi (Nutrient absorption)
3. Animalia (nutrient ingestion)
4. Protista (Eukaryotic, unicellular) includes microalgae and protozoa
5. Monera (prokaryotic) includes bacteria.



Wittaker's five kingdom model

1. Monera (Kingdom of Prokaryotes): Bacteria, Cyano bacteria (Blue green algae)

Nutrition: Absorptive or photosynthetic

Movement: By flagella (tubulin)

Reproduction: Asexual

- (a) The members of this kingdom are microscopic **prokaryotes**.
- (b) Monerans are mostly **unicellular**. But some are mycelial, filamentous (e.g. Nostoc) or colonial.
- (c) The cells are **prokaryotic with one envelope system** or organisation.
- (d) **Cell wall usually present** (except Mycoplasma) which composed of peptidoglycan or murein.
- (e) True nucleus and other membrane bounded **organelles absent**.
- (f) Genetic material is a **circular naked DNA** (without histone proteins) lies coiled near the centre of cell called nucleoid.
- (g) More than one structural genes (cistrons) arranged together and regulated in units called operons.
- (h) Ribosomes **70s type**. (30S + 50S type)
- (i) **Cytoskeleton** (microtubules, microfilaments and intermediate filaments) **absent**.
- (j) Flagella if present consists of flagellant proteins.
- (k) Nutrition **may be autotrophic** (photoautotrophic or chemoautotrophic). Saprot-ophic, parasitic or symbiotic.
- (l) Reproduction mainly occurs by **binary fission**. Sexual reproduction (Gamete formation) absent. In some cases genetic recombination occurs.
- (m) They are the important decomposers and mineralizes and help in recycling of nutrients in biosphere.
- (n) Most are found in deep ocean floor, hot deserts, hot springs and even inside other organisms.

Monera includes **archeobacteria, bacteria, cyanobacteria (BGA), and filamentous actinomycetes**.

2. Protista (Kingdom of Unicellular eukaryotes): (protozoans, Phytoplankton, Zooplankton)

Cell structure : Unicelled eukaryotes

Nutrition : Absorptive, photosynthetic

Movement : By flagella, cilia, streaming

Reproduction: Both asexual and sexual

- (a) The members are unicellular and colonial eukaryotes.
- (b) Most of them are aquatic and constitute plankton.
- (c) Their eukaryotic cell body contains membrane bounded cell organelles like nucleus, mitochondria, endoplasmic reticulum and Golgi complex etc.
- (d) They may have cilia or flagella for their movements which show 9 + 2 arrangements of microtubules.
- (e) On the basis of nutrition, the protists are grouped as: (a) Photosynthetic protists (protistan algae) like diatoms, dinoflagellates and euglenoids. They are known as phytoplankton's. (b) Consumer- decomposer protists (slime moulds) and (c) Predator protists (Protozoans).
- (f) Both asexual and sexual modes of reproduction are present.

3. Fungi (Kingdom of Multi-cellular decomposers): Yeasts(Unicellular) moulds, mushrooms. Multicelled eukaryotes

Cell structure :Chitinous cell wall

Nutrition :heterotrophic, Absorptive, Saprobic

Movement : Non-motile

Reproduction: Both asexual and sexual

- (a) The members are achlorophyllous, spore-bearing eukaryotic thallophytes.
- (b) It includes unicellular yeasts and multi-cellular mycelial forms but not slime moulds.
- (c) Cell wall composed of chitin (fungal cellulose), a nitrogen containing carbohydrate.
- (d) Their mode of nutrition is saprobiotic or parasitic. They can also live as symbionts in association with algae as Lichens and with roots of higher plants as mycorrhiza.
- (e) They help in decomposition of organic matter and help in recycling of minerals.
- (f) Vegetative reproduction takes place by fragmentation, fission and budding.
- (g) Asexual reproduction takes place by motile spores (zoospores) or non-motile spores (conidia, oidia, aplanospores or chlamydospores).
- (h) Sexual reproduction occurs by oospores, ascospores and basidiospores. Sexual reproduction involves three steps: (a) Plasmogamy (fusion of protoplasm between motile or non-motile gametes), (b) karyogamy (fusion of two nuclei) and (c) Meiosis in Zygote producing haploid spores.

Fungi include Phycomycetes (e.g. Mucor, Rhizopus, Albugo etc.), Ascomycetes (e.g. Saccharomyces, Penicillium, Aspergillus, Claviceps, Neurospora etc.), Basidiomycetes (e.g. Agaricus, Mushrooms; Ustilago, Smuts; and Puccinia, rust fungi), Deuteromycetes.

4. Plantae (Kingdom of Multicellular Producers): [Algae](#), Bryophytes, ferns, gymnosperms, Multicelled eukaryotes

Cell structure: cellulosic cell wall, presence of plastids

Nutrition :Autotrophic

Movement :Non-motile

Reproduction :Both asexual and sexual

1. Their members are Multicellular, eukaryotic, chlorophyll-containing organisms. A few are parasitic (e.g. *Cuscuta*) or partially heterotrophic such as insectivorous plants (e.g. bladderwort, Venus fly trap, Sun few, Pitcher Plant etc.)

2. Their cells are eukaryotic with plastids and cell wall composed of cellulose.

3. Life cycle exhibit alternation between diploid sporophyte and the haploid gametophyte. This Phenomenon is called alternation of generation.

Plantae includes Green algae, brown algae, Red algae, bryophytes, pteridophytes, gymnosperms and angiosperms.

5. Animalia (Kingdom of Multicellular consumers): (Sponges, Invertebrates, vertebrates ,Multicelled eukaryotes)

Cell structure :without cell wall, and plastids

Nutrition :Heterotrophic

Movement :Highly motile

Reproduction: Both asexual and sexual

1. The members are eukaryotic Multicellular heterotrophic consumers.

2. Cells lack cell walls. They contain glycogen or fat as reserve food.

3. The organization may be cellular level (porifera), tissue level (colenterates), organ level (Platyhelminthes and Nematelminthcs) and Organ system level (Annelids, Arthropods, Molluscs, Echinoderms and Chordates).

4. Symmetry may be radial, biradial, bilateral or asymmetrical.

5. On the basis of number of germ layers in embryonic gastrula, animals are diploblastic and triploblastic.

6. On the basis of presence of absence of coelom (body cavity) the animals are coelornates, pseudocoelomates or acoelomates.

Three domains of life (Present concept) or Carl woese theory

The **three-domain system** is a [biological classification](#) introduced by [Carl Woese](#) *et al.* in 1977 that divides [cellular life](#) forms into [archaea](#), [bacteria](#), and [eukaryote domains](#). Carl Woese proposed that the Eubacteria, Archaeobacteria, and Eukarvota represent three primary lines of descent and accordingly he promoted them to domains, naming them Bacteria, Archaea, and Eukarya. Woese initially used the term "kingdom" to refer to the three primary phylogenic groupings, and this nomenclature was widely used until the term "domains" was adopted in 1990.

Based on the molecular taxonomy, the living organisms were divided into 3 domains. (**Domain** refers the highest level of classification like kingdom)

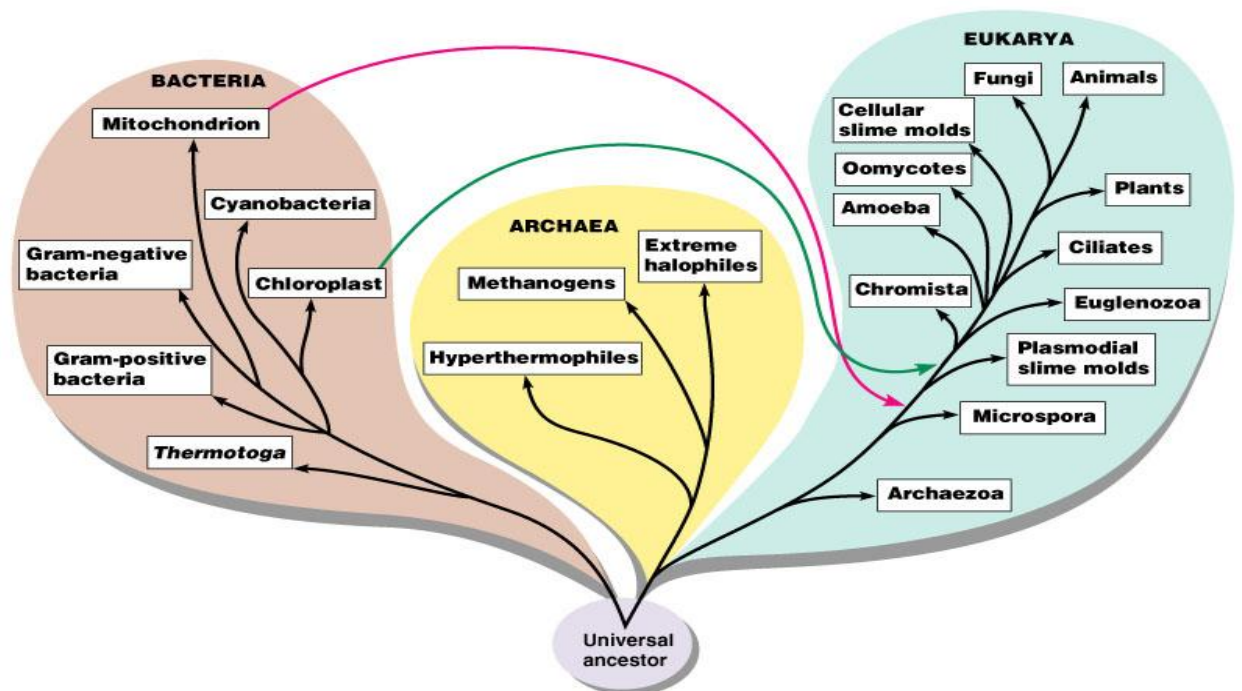
Three domains based on the following distinguishing criteria:

- u Cell wall composition
- u Membrane lipids
- u RNA sequence
- u Protein synthesis
- u Antibiotic sensitivity

I. Domain Eubacteria: “True bacteria”. includes prokaryotic organisms

II. Domain Archaeobacteria: “Ancient bacteria” includes certain prokaryotes found in enormous numbers, often from unusual habitats such as very hot, very salty, or very anaerobic (no oxygen)

III. Domain Eucarya: All eucaryotes: **Protista, Fungi, Plantae, and Animalia.**



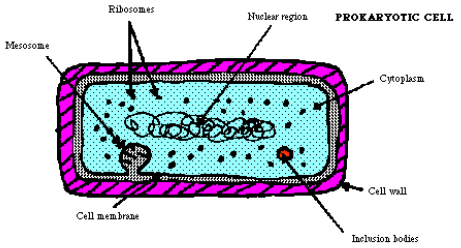
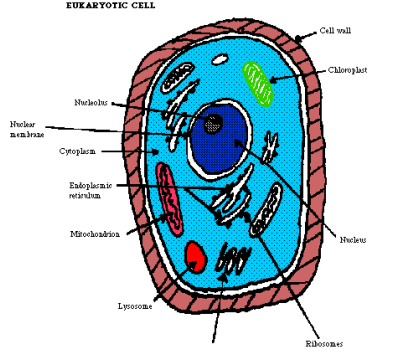
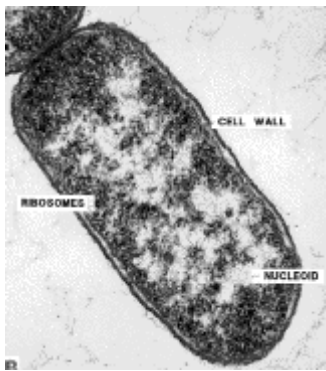

Three domains of life

Bergey’s manual of systematic bacteriology :

Bergey's manual is the international standard for bacterial taxonomy. The entire world of bacteria and archaea were divided into 2 kingdoms. Kingdom I is **Archaeota** and the Kingdom II is **bacteria**. The manual divide the bacteria into 5 volumes. Volume I include archaea, cyanobacteria and phototrophs Volume II include the proteobacteria Volume III Bacteria with low G+C Gram positives and Volume IV high G+C Gram positives Volume V. Planctomycetes, spirochaetes, Fibrobacteres, Bacteroides and Fusobacteria.

Prokaryotes – The organism **lacking** true nucleus (membrane enclosed chromosome and nucleolus) and other organelles like mitochondria, golgi body, entoplasmic reticulum etc. are referred as Prokaryotes. (Ex : Bacteria, archaea)

Eukaryotes - The organism possessing membrane **enclosed nucleus** and other cell organelles are referred as Eukaryotes (Ex : algae, fungi, protozoa)

Characteristic	Prokaryotes	Eukaryotes
Diagrammatic representation	 <p>Labels in diagram: Mesosome, Ribosomes, Nuclear region, PROKARYOTIC CELL, Cytoplasm, Cell wall, Cell membrane, Inclusion bodies.</p>	 <p>Labels in diagram: Cell wall, Chloroplast, Nucleolus, Nuclear membrane, Cytoplasm, Endoplasmic reticulum, Mitochondria, Lysosome, Nucleus, Ribosome.</p>
Electron micrograph	 <p>Labels in micrograph: CELL WALL, RIBOSOMES, NUCLEOID.</p>	
Size of cell	Typically 0.2-2.0 μm in diameter	Typically 10-100 μm in diameter
Nucleus	No nuclear membrane or nucleoli (nucleoid)	True nucleus, consisting of nuclear membrane & nucleoli
Membrane-enclosed organelles	Absent	Present; examples include lysosomes, Golgi complex, endoplasmic reticulum, mitochondria & chloroplasts
Flagella	Consist of two protein building blocks	Complex; consist of multiple microtubules
Glycocalyx	Present as a capsule or slime layer	Present in some cells that lack a cell wall
Cell wall	Usually present; chemically complex (typical bacterial cell wall includes peptidoglycan)	When present, chemically simple
Plasma membrane	No carbohydrates and generally lacks sterols	Sterols and carbohydrates that serve as receptors present
Cytoplasm	No cytoskeleton or cytoplasmic streaming	Cytoskeleton; cytoplasmic streaming

Ribosomes	Smaller size (70S)	Larger size (80S); smaller size (70S) in organelles
Mesosomes	Present	Absent
Chromosome arrangement	Single circular chromosome; lacks histones	Multiple linear chromosomes with histones
Extrachromosomal DNA	Plasmid	Mitochondria and chloroplast
Cell division	Binary fission	Mitosis
Sexual reproduction	No meiosis; transfer of DNA fragments only (conjugation)	Involves meiosis
Site for cellular respiration	Cell membrane	Mitochondria
Locomotion	Rotating flagella and gliding	Undulating flagella and cilia, and also amoeboid movement
Pili	Sex or attachment pili present	absent

Lecture 10 Group of microorganisms :

Microorganisms make up a large part of the planet's living material and play a major role in maintaining the Earth's ecosystem.

- [Microorganisms](#) are divided into six types: [bacteria](#), [archaea](#), [protozoa](#), algae, fungi, and viruses.
- Each type has a characteristic cellular composition, morphology, mean of locomotion, and reproduction.
- Microorganisms are beneficial in producing oxygen, decomposing [organic](#) material, providing nutrients for plants, and maintaining human [health](#), but some can be [pathogenic](#) and cause diseases in plants and humans.

a. Bacteria : are group of phylogenetically related prokaryotic organisms distinct from archaea. microorganism.

- 🍌 size ranges from 0.5 – 3.0 μm
- 🍌 They are unicellular,
- 🍌 presence of cell wall (composed of lipopolysaccharide and peptidoglycon)
- 🍌 simple internal structures,
- 🍌 able to grow in artificial media,

- 🌱 reproduce asexual simple cell division (binary fission)



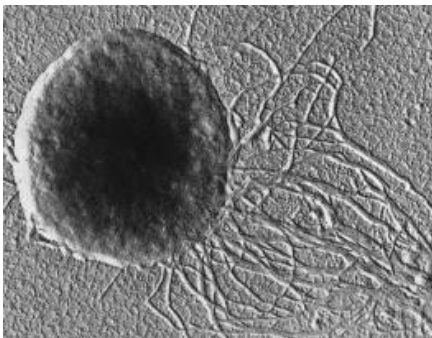
Importance :

- 🌱 some cause disease
- 🌱 important role in nutrient cycling in soil
- 🌱 useful in industrial production of antibiotics, vitamins, dairy products, value added products

Pseudomonas aeruginosa

b. Archaea : are group of phylogenetically related group of prokaryotic microorganisms which are primitive and differ with bacteria

- 🌀 size ranges from 0.5 – 2.5 μm
- 🌀 They are unicellular
- 🌀 simple internal structures
- 🌀 differ with bacteria by absence of peptidoglycon in cell wall
- 🌀 Most of them live in extreme environment (high salt, methane producing organisms, thermophiles)



Importance :

- 🌱 Methane (biogas) production;
- 🌱 Waste water treatment and energy production;
- 🌱 Temperature resistant enzymes for molecular biology and biochemistry (ex. DNA polymerase from *Thermococcus*)

Methanococcus

C. Fungi are the group of eukaryotic microorganisms lack of chlorophyll.

- 🌀 size ranges from 5 – 10 μm
- 🌀 consist of both unicellular (yeast) and multicellular (mushroom) organisms
- 🌀 saprophytic nature (derive food through dead organic matter) (renamed as **organotrophs**)

- Presence of cell wall (made of **Chitin** – polymer of N-acetyl glucosamine)
- Presence of Asexual and sexual reproduction



Importance :

- Cause plant diseases; few animal and human diseases too
- Decomposition of organic matter in the soil and nutrient cycle
- Food spoilage
- Yeast – industrial importance
- Antibiotic industry
- Used as food (mushroom)

mushroom fungus

D. Protozoa (*protos – first; zoon – animal*) are group of eukaryotic microorganisms lack of cell wall.

- size ranges from 2.0 to 200 μm
- Large number are parasites and some survive in soil, fresh water and marine water
- Most are motile
- Reproduction by asexual and sexual processes



Importance :

- They play important role in food chain of aquatic environment
- Some cause diseases
- Importance in the ecological balance of many microbial communities in soil and aquatic environment
- Industrial waste treatment
- Sewage water treatment

Euglena

E. Algae are the group of eukaryotic microorganism that contain chlorophyll and carry out the oxygenic photosynthesis



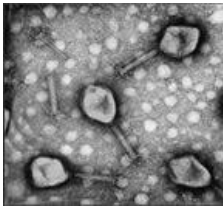
- contain different type of pigments
- size ranges from 1 μm to many meters
- Unicellular and multicellular
- Most occur in aquatic environment
- reproduction by sexual and asexual process

Importance :

- 🌱 Food producer of aquatic environment (primary producer)
- 🌱 Used as food supplements
- 🌱 Pharmaceutical industry
- 🌱 Economically important products – agar, alginic acid, carrageenan
- 🌱 Some cause disease

F. Viruses are non cellular microorganisms.

- 🌿 Size ranges from 0.015 – 0.2 μm
- 🌿 Cannot grow in laboratory condition (needs living host)
- 🌿 Obligate parasites
- 🌿 Lack metabolic machinery for energy generation and reproductive system for replication
- 🌿 Depends higher organisms for energy and reproduction



Importance :

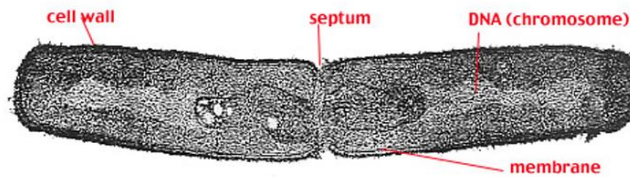
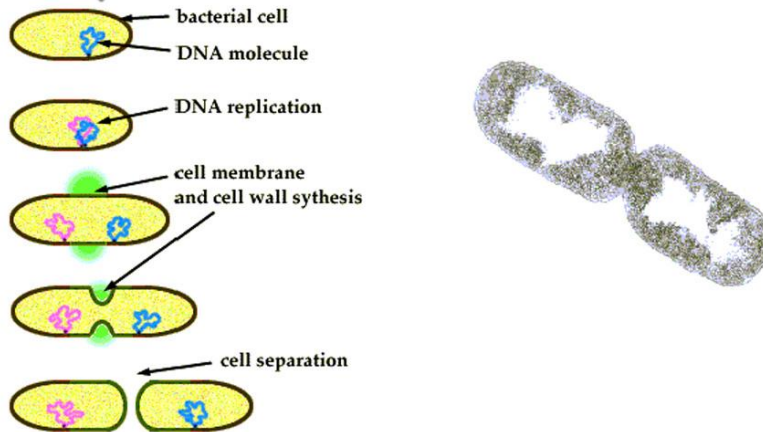
- 🌱 Cause disease to human, animal, microorganism.
- 🌱 Few used in molecular biology as vector (to transfer the genetic elements to an organism)

Bacteriophage

Bacteria - Reproduction

Since bacteria are single celled, a single cell division is enough to get reproduced into two daughter bacteria. The cell division of bacteria is referred as **transverse binary fission**. A single cell is divided into two by forming transverse septum (cross wall). The binary fission is an asexual reproduction.

Bacterial cell: Binary Fission



Binary fission process and cross section of bacterial cell before replication

The process of binary fission is as follows:

1. The cell became elongated from its original size and approximately twice length
2. DNA replication takes place and DNA moves towards polar region
3. Septum or cross wall (septum) occurs from the mesosome region
4. New cell wall formation occurs
5. After completion, the cells were separated out

Ex. *Bacillus*, *E. coli*, *Streptococcus*

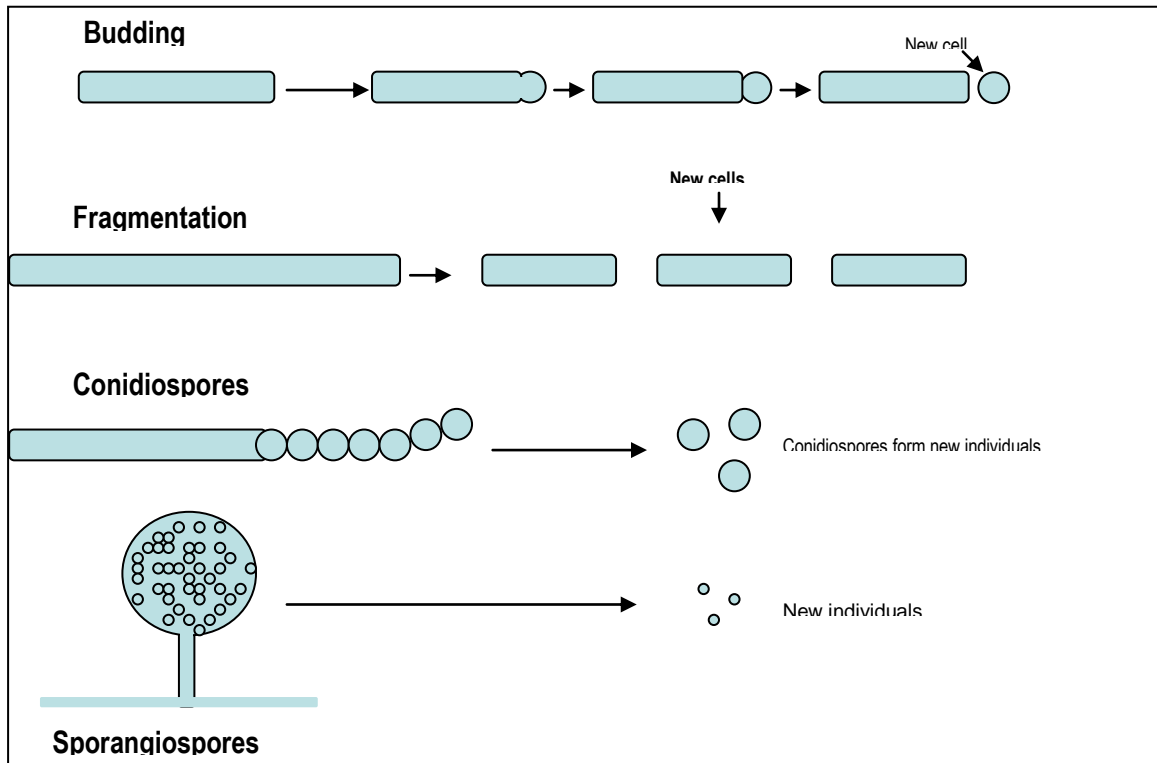
Other methods of reproduction occur in bacteria:

Budding : A small bud developed at one polar region of the cell, elongated and finally developed to new cell.

Ex. *Rhodospseudomonas acidophila*

Fragmentation : Filamentous bacteria (actinomycetes) fragment into small rods and each rod gives rise to new cells. Ex. *Nocardia*

Conidiospores and sporangiospores : The filamentous bacteria produce spores in the hyphal tips and released to the environment, referred as conidiospores and sporangiospores. If the spores are produced in sac, referred as sporangiospores and without sac are referred as conidiospores.



Staining

🌟 **Hans Chrisian Gram** (1853 – 1933) developed a staining procedure for differentiating two different group of bacteria based on the cell wall structure (Gram +ve and Gram -ve). The staining is called **Gram staining**.

Lecture 7. MORPHOLOGY AND FUNGI

Fungi are the group of eukaryotic microorganisms lack of chlorophyll.

- 🌀 size ranges from 5 – 10 μm
- 🌀 consist of both unicellular (yeast) and multicellular (mushroom) organisms
- 🌀 saprophytic nature (derive food through dead organic matter) (renamed as **organotrophs**)
- 🌀 Presence of cell wall (made of **Chitin** – polymer of N-acetyl glucosamine)
- 🌀 Presence of Asexual and sexual reproduction



Importance :

- Cause plant diseases; few animal and human diseases too
- Decomposition of organic matter in the soil and nutrient cycle
- Food spoilage
- Yeast – industrial importance
- Antibiotic industry
- Used as food (mushroom)

mushroom fungus

Protozoa (*protos – first; zoon – animal*) are group of eukaryotic microorganisms lack of cell wall.

- size ranges from 2.0 to 200 μm
- Large number are parasites and some survive in soil, fresh water and marine water
- Most are motile
- Reproduction by asexual and sexual processes



Importance :

- They play important role in food chain of aquatic environment
- Some cause diseases
- Importance in the ecological balance of many microbial communities in soil and aquatic environment

- Industrial waste treatment
- Sewage water treatment

Euglena

Algae are the group of eukaryotic microorganism that contain chlorophyll and carry out the oxygenic photosynthesis



- contain different type of pigments
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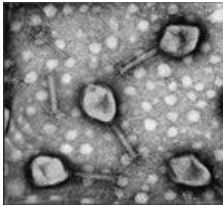
Chlamydomonas

Importance :

- 🍄 Food producer of aquatic environment (primary producer)
- 🍄 Used as food supplements
- 🍄 Pharmaceutical industry
- 🍄 Economically important products – agar, alginic acid, carrageenan
- 🍄 Some cause disease

Viruses are non cellular microorganisms.

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