SHREE H. N. SHUKLACOLLEGE OF SCIENCE

(AFFILIATED TO SAURASHTRA UNIVERSITY)

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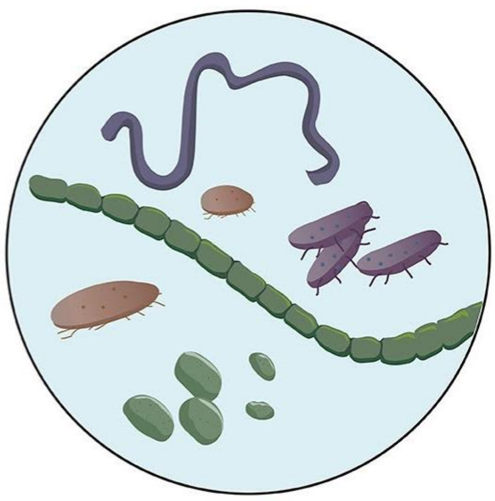
S.Y. B.Sc. (Sem. III) (CBCS)

MICROBIOLOGY

[301]: MICROBIAL DIVERSITY

Unit 3

DIVERSITY OF SOME UNUSVAL PROKARYOTES



Prepared By

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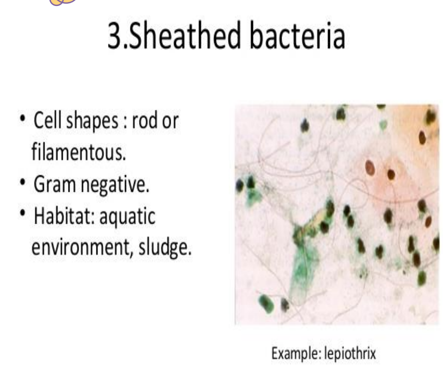
CONTENT

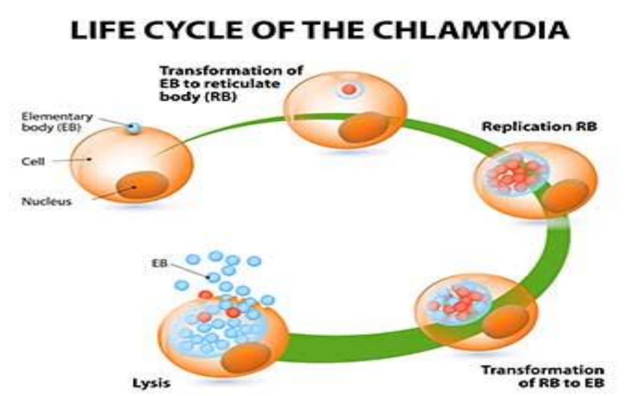
- **Bacteria with unusual morphology: Budding and appendaged bacteria, Sheathed Bacteria, Mycoplasma**
- **Bacteria with gliding motility**
- **Rickettsia and Chlamydia**
- **Archaeabacteria: Introduction and general features of archaea**
- **Types of Extremophilic Microorganisms: over view of Thermophiles, Halophiles, Acidophiles, Alkalophiles, Barophiles and Methanogens**
- **Importance of prokaryotic microorganisms**

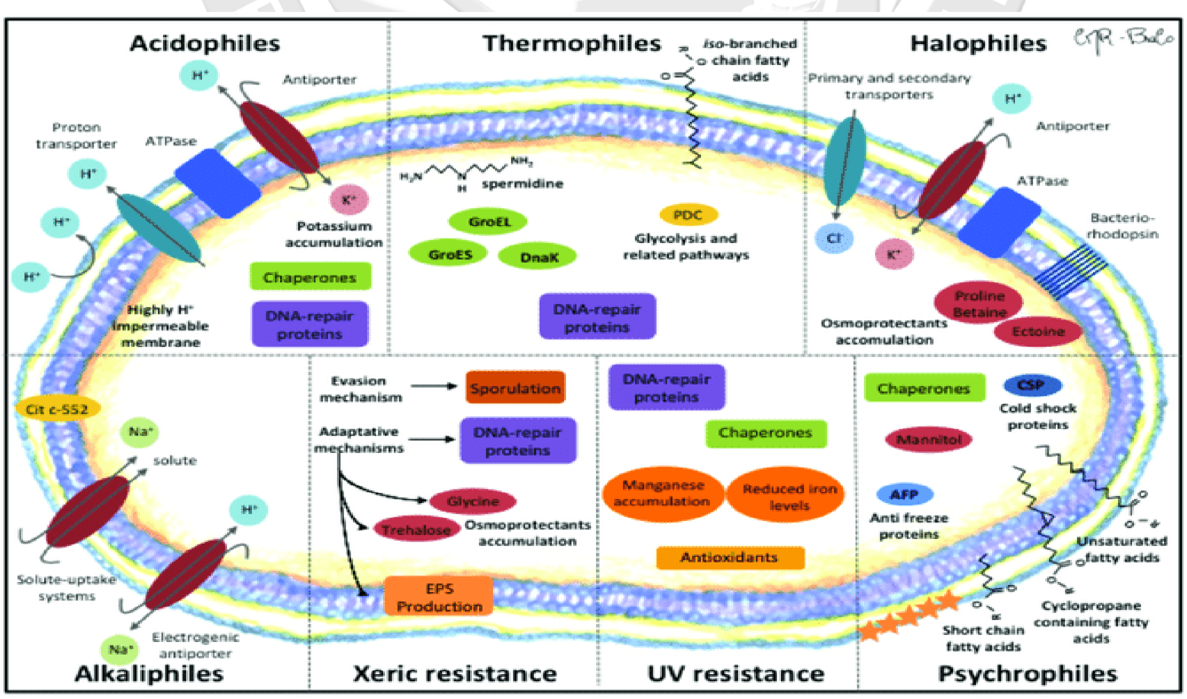
Title explanation

- **In this unit we are going to learn and discuss about different unusual morphology of bacteria like gliding motility, sheathed bacteria, mycoplasma which has no cell wall, and budding bacteria**
- **Study of rickettsia and chlamydia and which disease caused by them cause in human being.**
- **Study about archaeabacteria which are extremophiles bacteria they are living in extreme conditions such as temperature, pH, salt concentration, pressure.**
- **Study of methanogens which can produce methane in strict anaerobic condition.**
- **Discuss about importance of prokaryotic organisms.**

LEARNING OUTCOME







3.1 Bacteria with unusual morphology

The morphology and arrangement of bacteria are often a key factor in identifying their species. Their direct examination under the light microscope enables the classification of these Bacteria and Archaea. Generally, the basic morphologies are spheres (coccus) and round-ended cylinders or rod shaped (bacillus). But there are also other morphologies such as helically twisted cylinders (example Spirochetes), cylinders curved in one plane (selenomonads) and unusual morphologies (the square, flat box-shaped cells of the Archaean genus Haloquadratum). Other arrangements include pairs, tetrads, clusters, chains and palisades.

Budding and appendaged bacteria

In the budding bacteria, the prostheca is involved in a distinctive form of reproduction, in which two cells of unequal size are produced (c.f. typical binary fission, which results in two identical daughter cells). The daughter cell buds off from the mother cell, either directly, or as Hyphomicrobium spp. at the end of a hypha (stalk) (Figure). Once detached, the daughter cell grows to full size and eventually produces its own buds. Hyphomicrobium is a methanotroph and a methylotroph, so it also belongs to the methanotrophs described earlier.

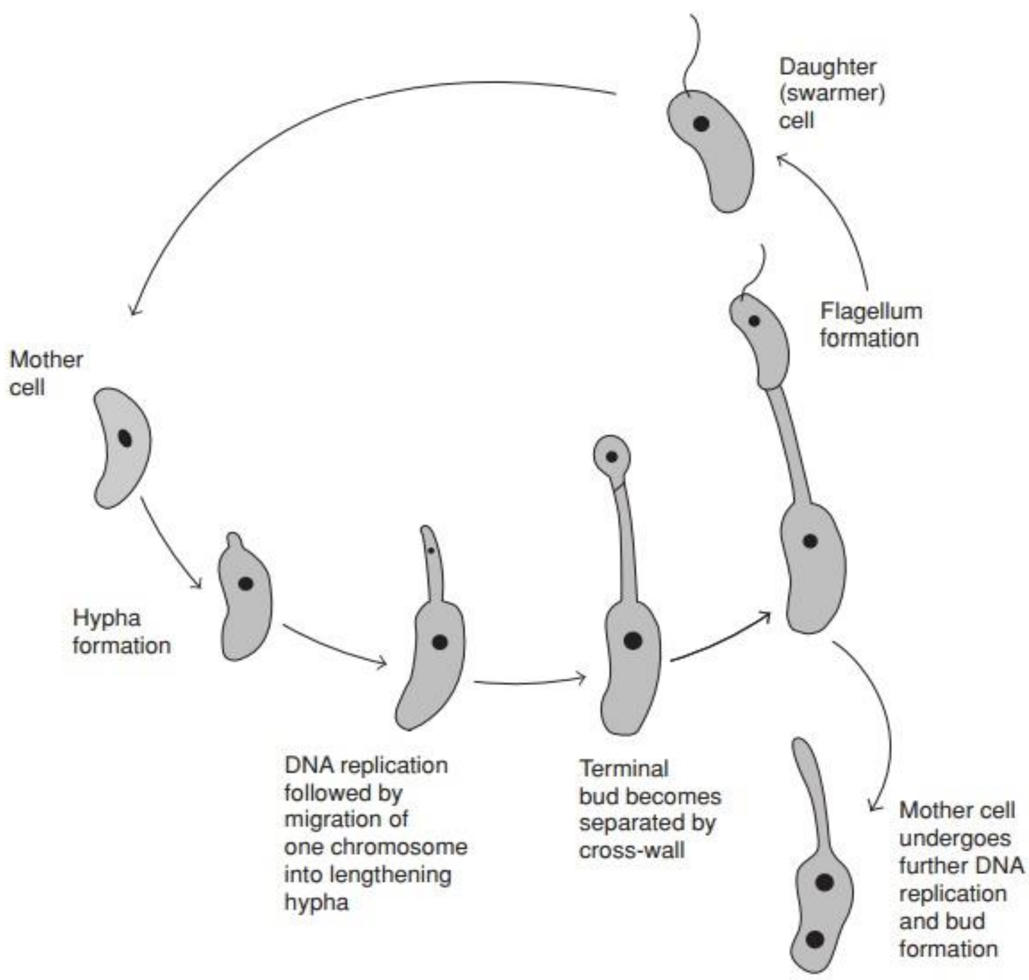


Figure 7.6 The budding bacteria: reproduction in *Hyphomicrobium*. Before reproduction takes place, the vegetative cell develops a stalk or hypha, at the end of which a bud develops. This produces a flagellum, and separates to form a motile swarmer cell

3.1.1 Sheathed bacteria

Sheathed bacteria are bacteria that grow as long filaments whose exterior is covered by a layer known as a sheath. Within the sheath, the bacteria can be capable of growth and division. Examples of sheathed bacteria include Leptothrix discophora (also known as "iron bacteria"), and Sphaerotilus natans. Sheathed bacteria are common of the bacterial communities in water and in soil. In these environments, the sheath is often coated with precipitates of elements in the water or soil environments, such as oxides of iron and manganese. The elements are unstable in solution, and thus will readily come out of solution when presented with an appropriate site.

The sheath that covers the bacteria can be of varied construction. Much of the structural information has been gleaned from the observation of thin slices of sample using the transmission electron microscope . The sheath surrounding Leptothrix species is glycocalyx-like in appearance. Often the deposition of metals within the sheath network produces areas where the material has crystallized. In contrast, the sheath of Sphaerotilus natans presents the "railroad track" appearance, which is typical of a biological membrane consisting of two layers of lipid molecules.

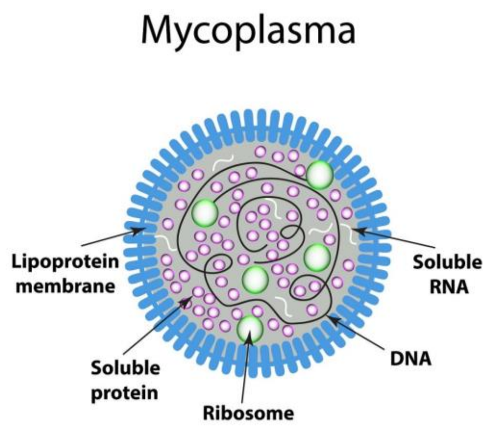
Electron microscopic studies of *Leptothrix* species have shown that the bacterium is intimately connected with the overlying sheath. The connections consist of protuberances that are found all over the surface of the bacterium. In contrast, *Sphaerotilus natans* is not connected with the overlying sheath.

Both Leptothrix and *Sphaerotilus natans* can exist independently of the sheath. Bacteria in both genera have a life cycle that includes a free-swimming form (called a swarmer cell) that is not sheathed. The free-swimming forms have flagella at one end of the bacteria that propels the cells along. When encased in the sheath, the bacteria are referred to as sheathed or resting bacteria.

Mycoplasma

Mycoplasma is a genus of bacteria that, like the other members of the class Mollicutes, lack a cell wall around their cell membranes. Peptidoglycan (murein) is absent. This characteristic makes them naturally resistant to antibiotics that target cell wall synthesis (like the beta-lactam antibiotics). They can be parasitic or saprotrophic. Several species are pathogenic in humans, including M. pneumoniae, which is an important cause of "walking" pneumonia and other respiratory disorders, and M. genitalium, which is believed to be involved in pelvic inflammatory diseases. Mycoplasma species (like the other species of the class Mollicutes) are among the smallest organisms yet discovered, can survive without oxygen, and come in various shapes. For example, M. genitalium is flask-shaped (about 300 x 600 nm), while M. pneumoniae is more elongated (about 100 x 1000 nm), many Mycoplasma species are coccoid. Hundreds of Mycoplasma species infect animals.

The trivial name “mycoplasma” (plural mycoplasmas or mycoplasms) is commonly used for all members of the class Mollicutes. In scientific classification, the designation Mycoplasma refers exclusively to the genus, a member of the Mycoplasmataceae, the only family of the order Mycoplasmatales (see “scientific classification”).



Gliding motility is a type of translocation used by microorganisms that is independent of propulsive structures such as flagella, pili, and fimbriae. Gliding allows microorganisms to travel along the surface of low aqueous films. The mechanisms of this motility are only partially known. Twitching motility also allows microorganisms to travel along a surface, but this type of movement is jerky and uses pili as its means of transport. Bacterial gliding is a type of gliding motility that can also use pili for propulsion. The speed of gliding varies between organisms, and the reversal of direction is seemingly regulated by some sort of internal clock. For example the apicomplexans are able to travel at fast rates between 1–10 µm/s. In contrast *Myxococcus xanthus* bacteria glide at a rate of 0.08 µm/s.

Types of gliding motility in bacteria:

a) type IV pili, b) Specific motility membrane proteins, c) Polysaccharide jet

Cell-invasion and gliding motility have TRAP (thrombospondin-related anonymous protein), a surface protein, as a common molecular basis that is both essential for infection and locomotion of the invasive apicomplexan parasite. Micronemes are secretory organelles on the apical surface of the apicomplexans used for gliding motility.

a) type IV pili: A cell attaches its pili to a surface or object in the direction it is traveling. The proteins in the pili are then broken down to shrink the pili pulling the cell closer to the surface or object that was it was attached to.

b) Specific motility membrane proteins: Transmembrane proteins are attached to the host surface. This adhesion complex can either be specific to a certain type of surface like a certain cell type or generic for any solid surface. Motor proteins attached to an inner membrane force the movement of the internal cell structures in relation to the transmembrane proteins creating net movement. This is driven by the proton motive force.

The proteins involved differ between species. An example of a bacterium that uses this mechanism would be Flavobacterium. This mechanism is still being studied and is not well understood.

c) Polysaccharide jet: The cell releases a 'jet' of polysaccharide material behind it propelling it forward. This polysaccharide material is left behind.

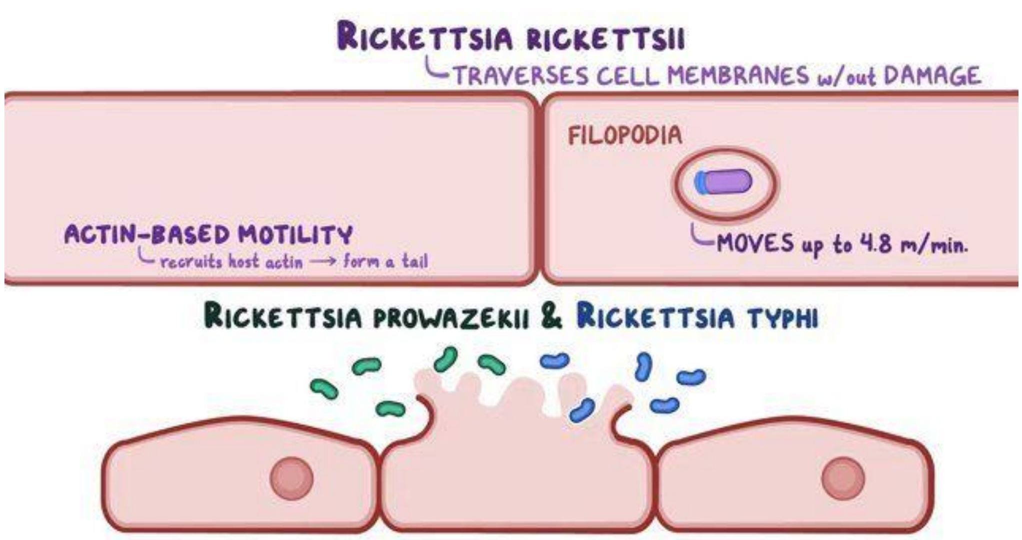
The rickettsia are bacteria which are obligate intracellular parasites. They are considered a separate group of bacteria because they have the common feature of being spread by arthropod vectors (lice, fleas, mites and ticks). The cells are extremely small (0.25 u in diameter) rod-shaped, coccoid and often pleomorphic microorganisms which have typical bacterial cell walls, no flagella, are gram-negative and multiply via binary fission only inside host cells. They occur singly, in pairs, or in strands. Most species are found only in the cytoplasm of host cells, but those which cause spotted fevers multiply in nuclei as well as in cytoplasm. In the laboratory, they may be cultivated in living tissues such as embryonated chicken eggs or vertebrate cell cultures.

Structure

The structure of the typical rickettsia is very similar to that of Gram-negative bacteria. The typical envelope consists of three major layers: an innermost cytoplasmic membrane, a thin electron dense rigid cell wall and an outer layer. The outer layer resembles typical membranes in its chemical composition and its trilaminar appearance. The cell wall is chemically similar to that of Gram-negative bacteria in that it contains diaminopimelic acid and lacks teichoic acid. Intracytoplasmic invaginations of the plasma membrane (mesosomes) and ribosomes are also seen. There are no discrete nuclear structures.

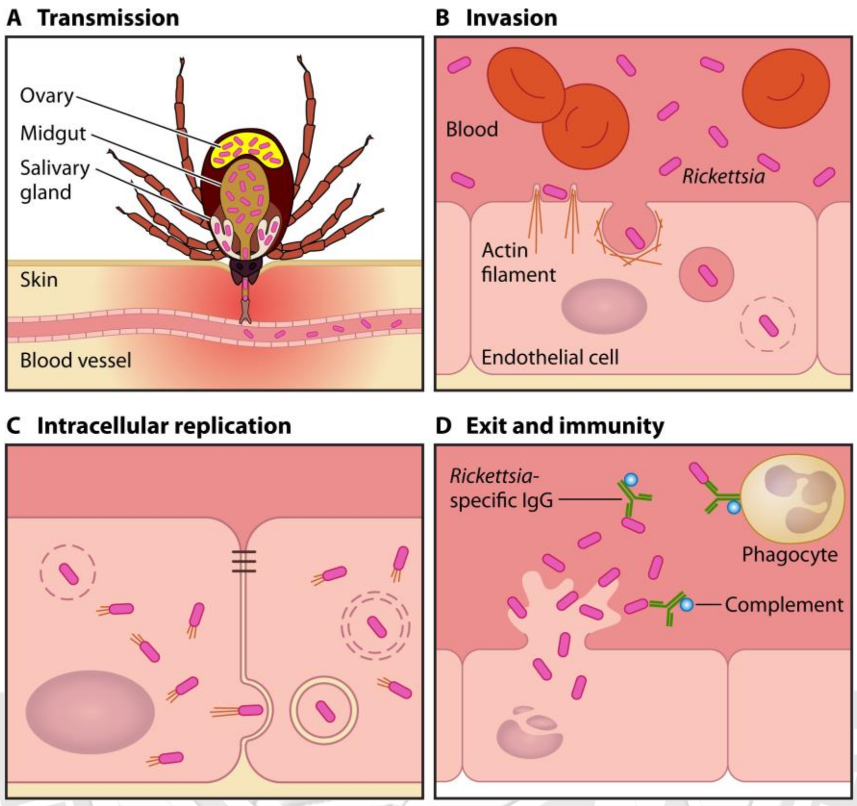
Metabolism

In dilute buffered salt solutions, isolated rickettsia are unstable, losing both metabolic activity and infectivity for animal cells. If, however, the medium is enriched with potassium, serum albumin and sucrose, the isolated organisms can survive for many hours. If ATP is added to the solution, the organisms metabolize and consume oxygen. The basis for the obligate parasitism of these cells is that they require the rich cytoplasm to stabilize an unusually permeable cell membrane. The rickettsia have many of the metabolic capabilities of bacteria, but require an exogenous supply of cofactors to express these capabilities. The response to exogenous cofactors implies an unusually permeable cytoplasmic membrane.



Growth and Multiplication

Rickettsia normally multiply by transverse binary fission. Under poor nutritional conditions, the rickettsia cease dividing and grow into long filamentous forms, which subsequently undergo rapid and multiple division into the typical short rod forms when fresh nutrient is added. Immediately after division, the rickettsia engage in extensive movements through the cytoplasm of the cell. C. burnetii differs from other rickettsia in that it is enclosed in a persistent vacuole during growth and division. Six to ten daughter cells will form within a host cell before the cell ruptures and releases them.



Pathogenicity

In their arthropod vectors, the rickettsia multiply in the epithelium of the intestinal tract; they are excreted in the feces, but occasionally gain access to the arthropods salivary glands. They are transmitted to man, via the arthropod saliva, through a bite. In their mammalian host, they are found principally in the endothelium of the small blood vessels, particularly in those of the brain, skin and heart. Hyperplasia of endothelial cells and localized thrombus formation lead to obstruction of blood flow, with escape of RBC's into the surrounding tissue. Inflammatory cells also accumulate about affected segments of blood vessels. This angiitis appears to account for some of the more prominent clinical manifestations, such as petechial rash, stupor and terminal shock. Death is ascribed to damage of endothelial cells, resulting in leakage of plasma, decrease in blood volume, and shock.

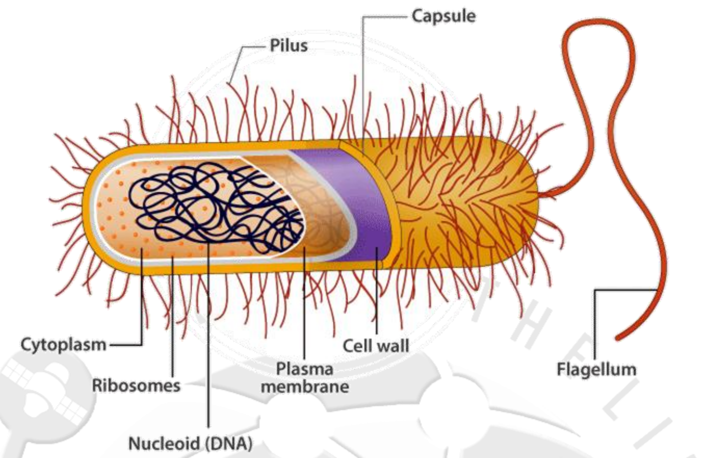
It is assumed that the observed clinical manifestations of a rickettsial infection are due to production of an endotoxin, although this endotoxin is quite different in physiological effects from that produced by members of the Enterobacteriaceae. This is inferred, although the toxin has not been isolated, from these facts:

1. IV-injected rickettsia cause rapid death in experimental animals.
2. UV-irradiation of rickettsia diminished their infectivity without reducing toxicity.
3. The use of anti-rickettsial drugs does not prevent rapid death in experimental animals.
4. Antiserum specific for cell wall antigens of the rickettsia prevents the toxic effect.

Archaeabacteria

Archaebacteria are known to be the oldest living organisms on earth. They belong to the kingdom Monera and are classified as bacteria because they resemble bacteria when observed under a microscope. Apart from this, they are completely distinct from prokaryotes. However, they share slightly common characteristics with the eukaryotes.

These can easily survive under very harsh conditions such as the bottom of the sea and the volcanic vents and are thus known as extremophiles.



Characteristics of Archaebacteria

Following are the important characteristics of archaebacteria:

- Archaebacteria are obligate or facultative anaerobes, i.e., they flourish in the absence of oxygen and that is why only they can undergo methanogenesis.
- The cell membranes of the Archaebacteria are composed of lipids.
- The rigid cell wall provides shape and support to the Archaebacteria. It also protects the cell from bursting under hypotonic conditions.
- The cell wall is composed of Pseudomurein, which prevents archaebacteria from the effects of Lysozyme. Lysozyme is an enzyme released by the immune system of the host, which dissolves the cell wall of pathogenic bacteria.
- These do not possess membrane-bound organelles such as nuclei, endoplasmic reticulum, mitochondria, lysosomes or chloroplast. Its thick cytoplasm contains all the compounds required for nutrition and metabolism.
- They can live in a variety of environments and are hence called extremophiles. They can survive in acidic and alkaline aquatic regions, and also in temperature above boiling point.
- They can withstand a very high pressure of more than 200 atmospheres.
- Archaebacteria are indifferent towards major antibiotics because they contain plasmids which have antibiotic resistance enzymes.
- The mode of reproduction is asexual, known as binary fission.
- They perform unique gene transcription.

- The differences in their ribosomal RNA suggest that they diverged from both prokaryotes and eukaryotes.

Extremophile Definition

Extremophiles are organisms that have evolved to survive in environments once thought to be entirely uninhabitable. These environments are inhospitable, reaching extreme conditions of heat, acidity, pressure, and cold that would be fatal to most other life forms. Because extremophiles live on extreme ends of the spectrum, they can indicate the range of conditions under which life is possible.

One important thing to note, however, is that extremophiles are "extreme" only from an anthropocentric perspective. For example, while oxygen is indispensible to ourselves and much of life on Earth, many organisms flourish in environments without oxygen at all.

Extremophiles can be divided into two broad categories: extremophilic organisms, and extremotolerant organisms. As the suffix "philic," translated to "loving," suggests, extremophilic organisms require one or more extreme conditions in order to thrive, while extremotolerant organisms grow optimally at more 'normal' conditions but are still able to survive one or more extreme physiochemical values.

Most extremophiles are microscopic organisms belonging to a domain of life known as archaea. However, to say extremophiles are restricted to this domain would be incorrect. Some extremophiles belong in the bacteria domain, and some are even multicellular eukaryotes!

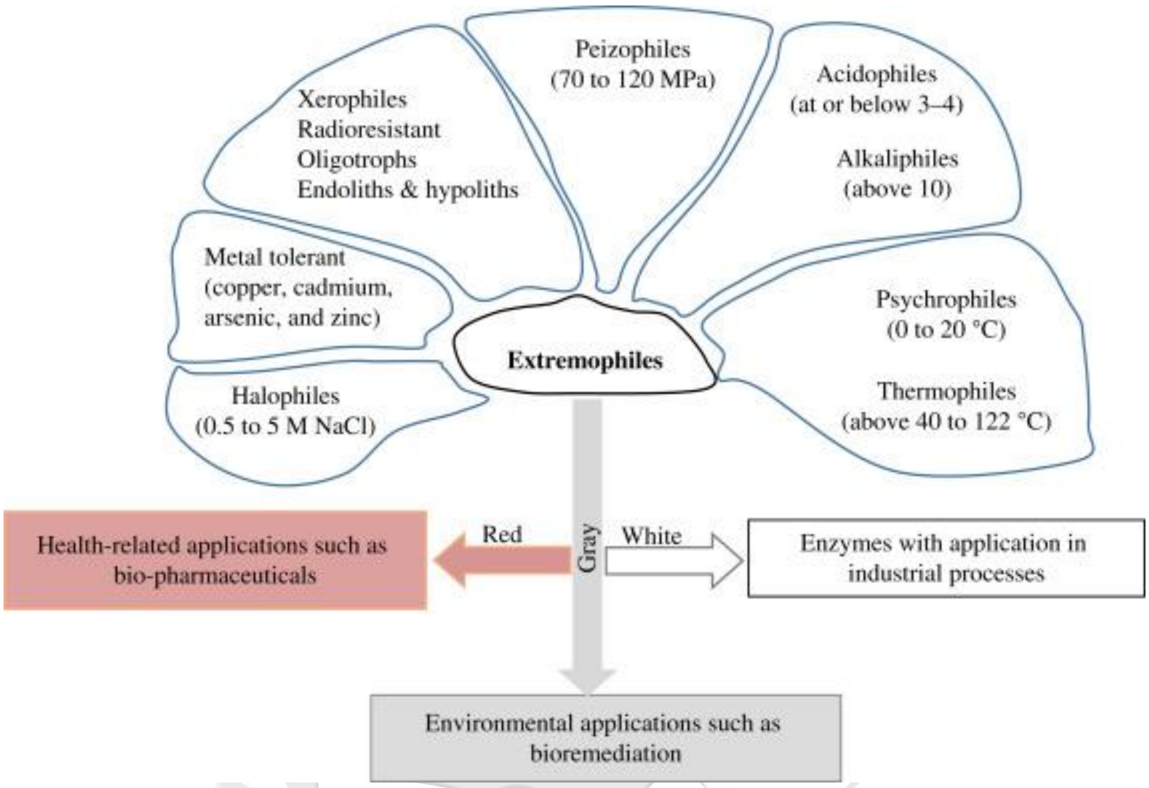
Importance in Research

The enzymes secreted by extremophiles, termed "extremozymes," that allow them to function in such forbidding environments are of great interest to medical and biotechnical researchers. Perhaps they will be the key to creating genetically based medications, or creating technologies that can function under extreme conditions.

Astrobiologists have also taken interest in extremophiles for their remarkable resilience in freezing environments. Extremophiles, or "psychrophiles," that are active in such environments raise the possibility of life on other planets, as the majority of bodies in the solar system are frozen. Additionally, the biochemical properties of such psychrophiles, such as the ability to use arsenic rather than phosphorus to create energy, furthers the possibility of extraterrestrial life. And, because extremophiles can indicate the range of conditions under which life is possible, they can also provide clues about how and where to look for life on other solar bodies.

Types of Extremophiles

Of course, different environmental conditions require different adaptations by the organisms that live those conditions. Extremophiles are classified according to the conditions under which they grow. Usually, however, environments are a mix of different physiochemical conditions, requiring extremophiles to adapt to multiple physiochemical parameters. Extremophiles found in such conditions are termed "polyextremophiles."



Acidophile

Acidophiles are adapted to conditions with acidic pH values that range from 1 to 5. This group includes some eukaryotes, bacteria, and archaea that are found in places like sulfuric pools, areas polluted by acidic mine drainage, and even our own stomachs.

Acidophiles regulate their pH levels through a variety of specialized mechanisms— some of which are passive (not exerting energy), and some of which are active (exerting energy). Passive mechanisms usually involve reinforcing the cell membrane against the external environment, and may involve secreting a biofilm to hinder the diffusion of molecules into the cell, or changing their cell membrane entirely to incorporate protective substances and fatty acids. Some acidophiles can secrete buffer molecules to help raise their internal pH levels. Active pH regulation mechanisms involve a hydrogen ion pump that expels hydrogen ions from the cell at a constantly high rate.

Alakaliphiles

Alkaliphiles are adapted to conditions with basic pH values of 9 or higher. They maintain homeostasis by both passive and active mechanisms. Passive mechanisms include pooling cytoplasmic polyamines inside the cell. The polyamines are rich with positively charged amino groups that buffer the cytoplasm in alkaline environments. Another passive mechanism is having a low membrane permeability, which hinders the movement of protons in and out of the cell. The active method of regulation involves a sodium ion channel that carries protons into the cell.

Thermophile

Thermophiles thrive in extremely high temperatures between 113 and 251 degrees Fahrenheit. They can be found in places like hydrothermal vents, volcanic sediments, and hot springs. Their survival in such places can be accredited to their extremozymes. The amino acids of these types of enzymes do not lose their shape and misfold in extreme heat, allowing for continued proper function.

Barophiles are organisms that grow best under high pressures of 400 atm or more. They can survive by regulating the fluidity of the phospholipids in the membrane. This fluidity compensates for the pressure gradient between the inside and outside of the cell, and the external environment. Extreme barophiles grow optimally at 700 atm or higher, and will not grow at lower pressures.

Halophile

Halophiles are organisms that require high salt concentrations for growth. At salinities exceeding 1.5M, prokaryotic bacteria are predominant. Still, this group belongs to all three domains of life, but in smaller numbers.