Lectures in basic bacteria

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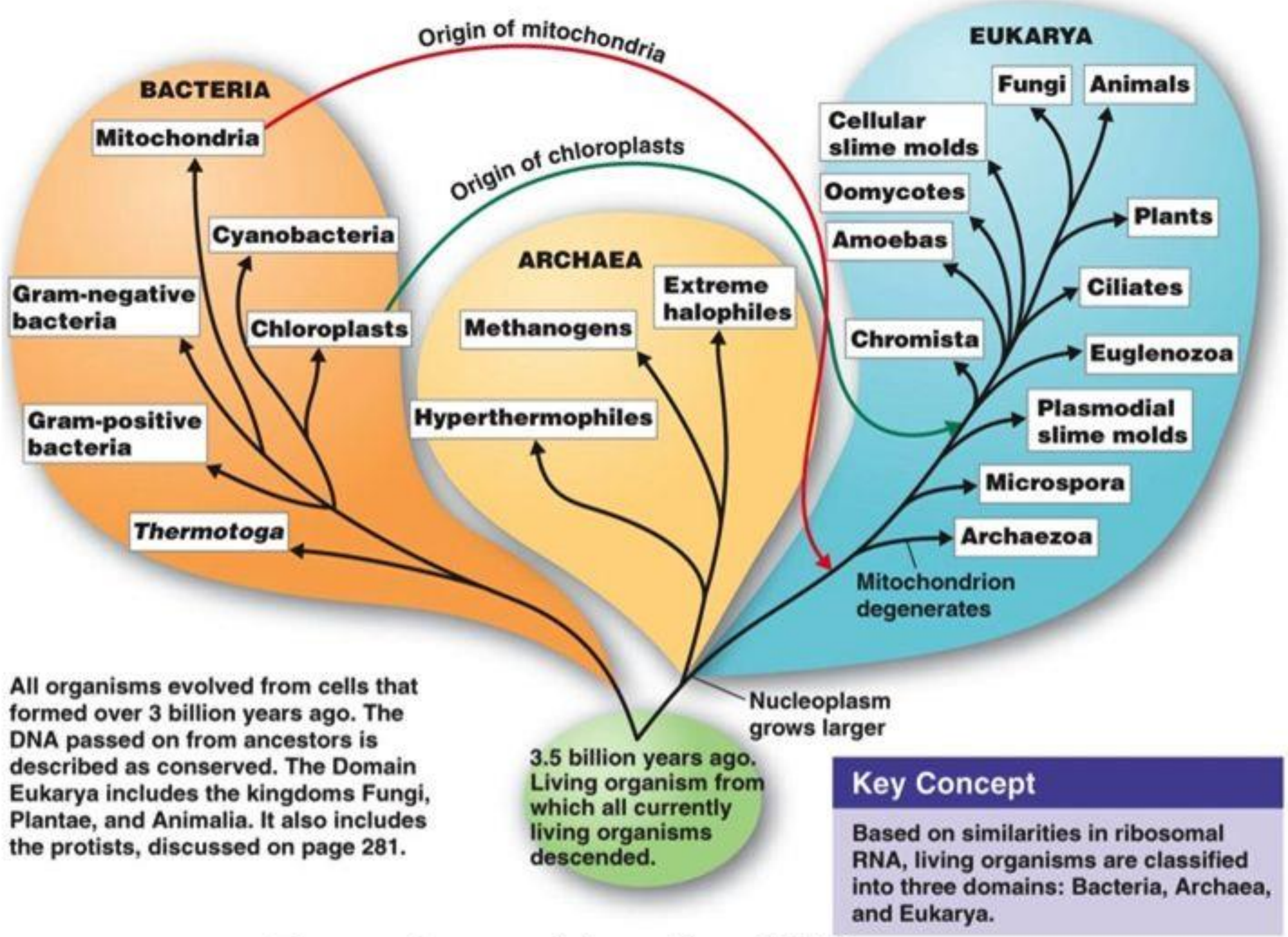
The microbial world

The microbial world includes the kinds of cells that van leeuvenhoek observed looking through his simple microscope.

The microbial world :all living organisms can be classified into one of three major groups called domains.

Organisms in each domain share properties of their cells that distinguish them from members of the other domain.

Classifying Living Organisms: The Three Domain System



Developed by Carl Woese

Based on 16S rRNA nucleotide sequence

Archaea and bacteria

1-Both are single celled organisms that do not contain membrane bound nucleus nor any other intracellular lipid bound organelles.

2-their genetic information is stored in fibrils composed of deoxyribonucleic acid (DNA) in region called the nucleoid.

These simple cell types have their cytoplasm surrounded by a rigid cell wall and are termed prokaryotes(prenucleus).

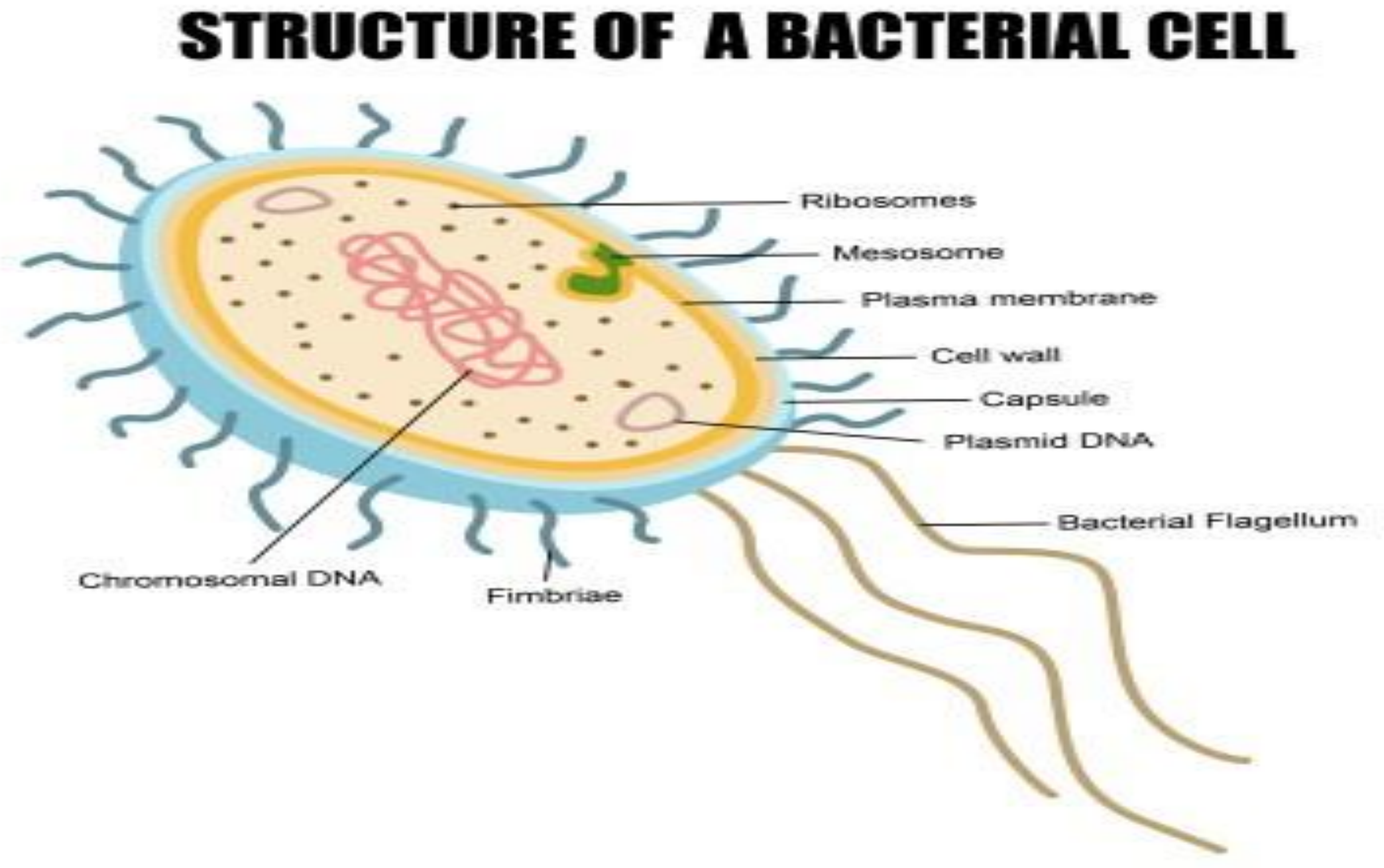
These two groups differ in their chemical composition

Eukarya termed eukaryotes,(true nucleus)are different from bacteria and archaea

1-Eukaryotes may be single celled or multicellular

2-they contain a true membrane bound nucleus and other internal cell organelles(3-they more complex than prokaryotes

Mitochondria for generating energy
,chloroplast
algae,fungi, protozoa,parasites



Bacteria

Bacteria diversity in shape and properties of the organism

Properties of the typical bacteria

1-they are all single celled prokaryotes

2-they have specific shape ,cylindrical (rod shape),spherical(round),spiral

3-they have rigid cell walls ,the wall contain unusual chemical compound called peptidoglycan,which is not found in other domains.

4- they multiply by binary fission in which one cell divides into two cells each identical to the original cell

5-many can move using appendages extending from the cell called flagella

The archaea

The archaea have the same shape ,size and appearance as bacteria

Like the bacteria

Multiply by binary fission and move by flagella and have rigid cell walls and differ in chemical composition

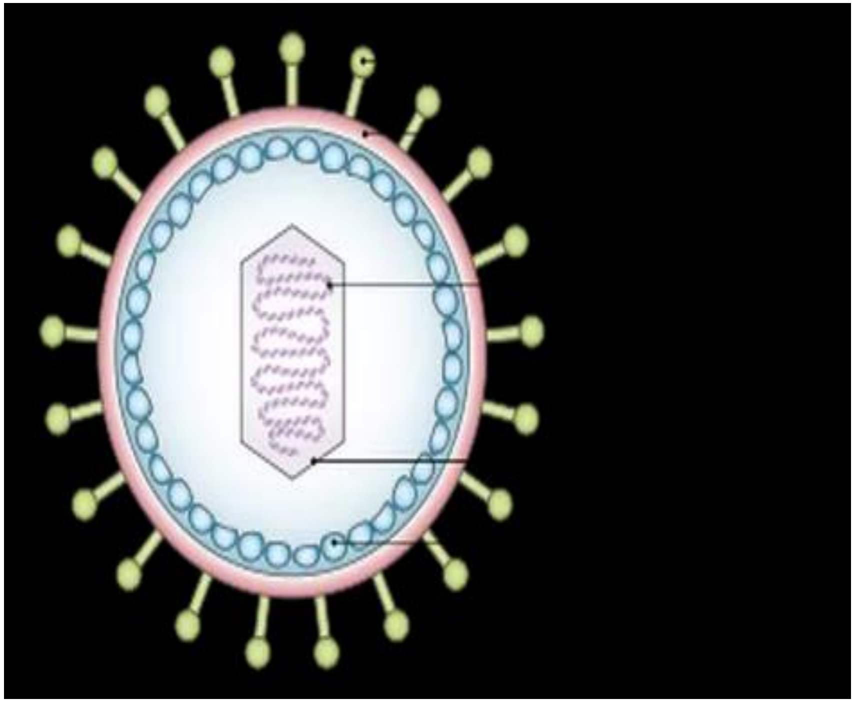
They do not have peptidoglycan int heir cell wall

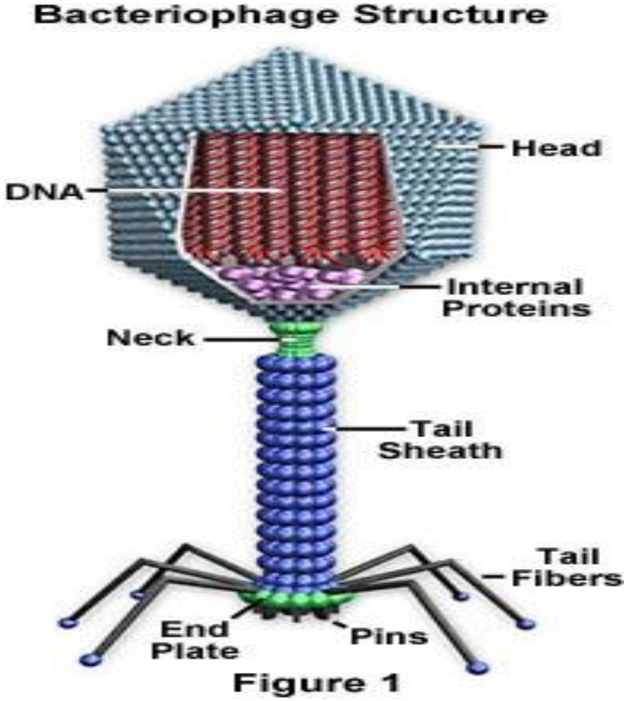
They differ from the bacteria for example some archaea can grow in salt concentrations 10 time as high as that found in sea water

They grow in great salt lake and dead sea ,other archaea grow at high tempertures above 105c

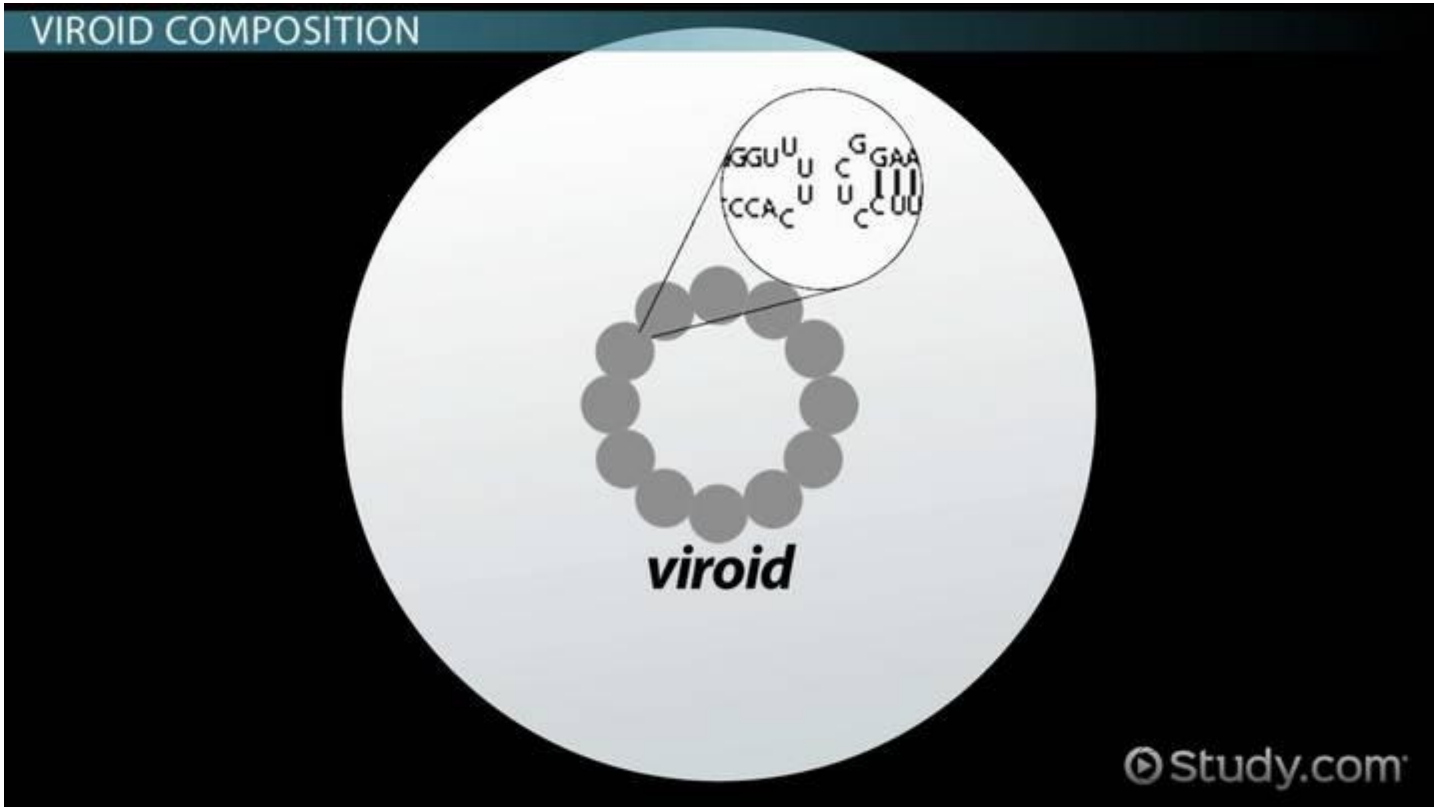
Viruses,Viroid.,Prions

The nonliving members of the microbial world are not composed of cells they are considered obligate intracllular parasites .
Viruses are apiece of nucleic acid surrounded by a protein coat. They can infect members of all three domains.

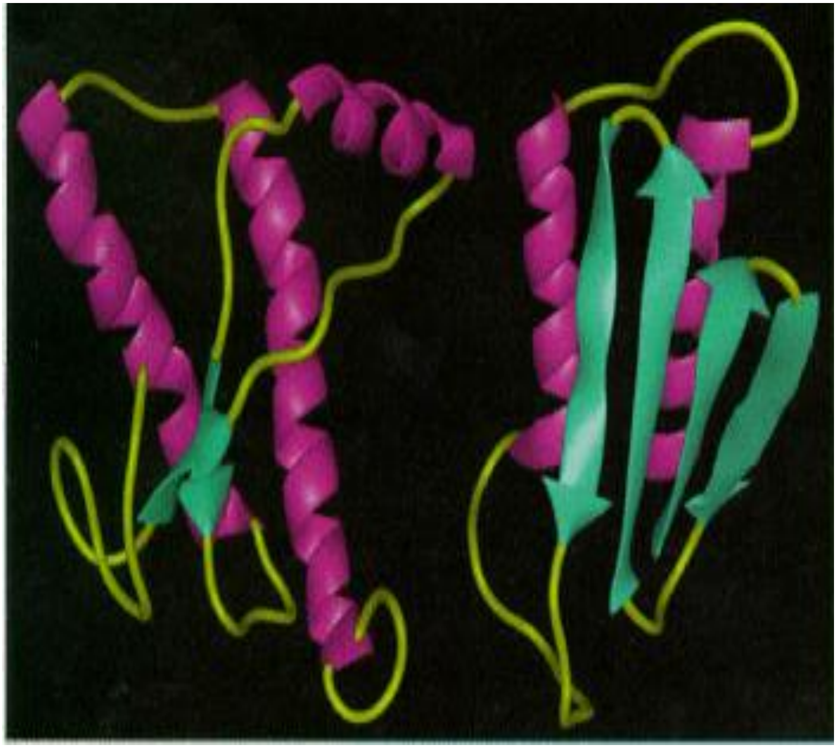


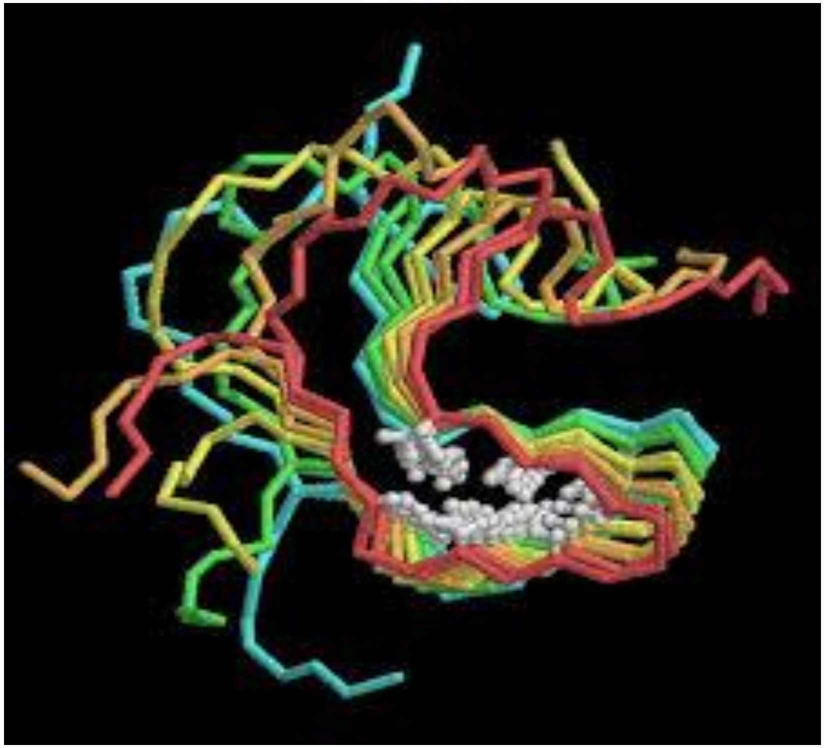


Viroids are composed of a single ,short RNA molecule,they cause disease in plants only



Prions consist of only of protein ,without any nucleic acid they cause diseases in human and animals





What causes disease

Pasteur's discovery that bacteria are responsible for spoiling wine led to his hypothesis in 1857 that microorganisms are also resposible for disease.

This idea led to germ theory of disease.

Since a particular disease is accompanied by the same symptoms in all affected individuals,early investigators suspected that diseases such as cholera,tuberculosis and anthrax are each caused by a specific germ called a pathogen

Today we know that some disease are genetic and that allergic reactions and environmental toxins cause others,so the germ theory applies only to infectious diseases

Pasteur was the chief investigator in disproving spontaneous generation and determining the cause of fermentation ,so investigations in etiology(the study of causation of disease)were dominated by Robert Kock(1843-1910).

Koch and his colleagues are responsible for many other advances in laboratory microbiology this including

1-simple staining techniques for bacterial cells and flagella

The first photomicrograph of bacteria

The first photograph of bacteria in diseased tissue

Techniques for estimating the number of bacteria in a solution based on the number of colonies that form after inoculation on a solid surface

The use of steam to sterilize growth media

The use of petri dishes to hold solid growth media

Aseptic laboratory techniques such as transferring bacteria between media using a platinum wire that had been heat sterilized in a flame

Elucidation of bacteria as distinct species

Koch s postulates

After discovering the anthrax bacterium ,koch continued to search for disease agent.In two pivotal scientific publications in 1882 and 1884 ,he announced that the cause of tuberculosis was a rod shaped bacterium,Mycobacterium tuberculosis .

In 1905 he received the nobel prize in physiology or medicine for this work.

In his publications on tuberculosis,koch elucidated a series of steps that must be taken toprove the cause of any infectious disease.thess steps now known as kochs postulates these following

1-the suspected causative agent must be found in every case of the disease and be absent from healthy hosts

2-the agent must be isolated and grown outside the host.

3-when the agent is introduced to a healthy,susceptible host,the host must get the disease

4-the same agent must be reisolated from the diseased experimental host.

The structure of prokaryotic cell

The structure of the prokaryotic cell is simple.the cytoplasmic membrane surrounds the cell,acting as a barrier between the external environment and the cell contents,the cytoplasm.
This membrane permits the passage of only certain molecules into and out of the cell .
Enclosing the cytoplasmic membrane is the cell wall,a rigid barrier that functions as a tight corset to keep the cell contents from bursting out
Cloaking the wall may be additional layers some of which serve to protect the cell from predators and enviromental assaults.the cell may be adorned with appendages giving it useful traits,including motility and the ability to adhere to select surfaces.within all of these layers are the internal structures such as DNA ,ribosomes and storage granules,all of which contribute to essential cell processes.

The bacterial cell wall

The bacterial cell wall is unique structure which surrounds the cell membrane. Although not present in every bacterial species,the cell wall is very important as a cellular component.

Structuraly the wall is necessary for

Maintaining the cells characteristis shape – the rigid wall compensates for the flexibility of the phospholipid membrane and keeps the cell from assuming a spherical shape.

Countering the effects of osmotic pressure-the strength of the wall is responsible for keeping the cell from bursting when the intracellular osmolality is much greater than the extracellular teichoic osmolality.

Providing attachment sites for bacteriophages-teichoic acids attached to the outer surface of the wall are like landing pads for viruses that infect bacteria.

Providing a rigid platform for surface appendages flagella,fimbriae, and pili all emanate from the wall and extend beyond it.

The cell walls of all bacteria are not identical.
Cell wall composition is one of the most important factors in bacterial species analysis and differentiation.there are two major types of walls:Gram-positive and gramnegative.the cell wall of gram positive bacteria consists of many polymer layers of peptidoglycan connected by amino acid bridges.a schematic diagram provides the best explanation of the structure.the peptidoglycan polymer is composed of an alternating
Sequence of N-acetylglucosamine and N- acetyl muramic acid it’s a lot easier to just remember NAG andNAMA.each peptidoglycan layer is connected ,or crosslinked to the other by bridge made of amino acids and amino acid derivatives.the particular amino acids vary among different species .the crosslinked peptidoglycan molecules from a network which covers the cell like a grid.also 90% of the gram positive cell wall is comprised of peptidoglycan.

The cell wall of gram negative bacteria is much thinner being comprised of only 20%peptidoglycan .gram negative bacteria also have two unique regions which surround the outer plasma membrane **the periplasmic space** and **the lipopolysaccharide layer**.the periplasmic space separates the outer plasma membrane from the peptidoglycan layer. It contains **proteins** which destroy potentially dangerous foreign matter present in this space.the **lipopolysaccharide layer** is located adjacent to the exterior peptidoglycan layer.it is a phospholipid bilayer construction similar to that in cell membrane and is attached to the peptidoglycan by **lipoproteins.**

The **lipid** portion of the LPS contains a toxic substance,called **lipid A** which is responsible for most of the pathoginic affects associated with harmful gram negative bacteria.**polysacchrides** which extend out from the bilayer also contibute to toxicity of the LPS .the LPS ,lipoproteins ,and the associated .

Polysaccharides together form what is known as the outer membrane.

*cell wall is not a regulatory structure like the cell membrane. Although it is porous ,it is not selectively permeable and will let anything pass that can fit through its gaps

Antibacterial compounds that target peptidoglycan compounds that interfere with the synthesis of peptidoglycan or alter its structural integrity weaken the rigid molecule to a point where it is not strong enough to prevent the cell from bursting .these compounds include the **antibiotic penicillin** and the **enzyme lysozyme**,which is found in many body fluids including tears and saliva.

Penicillin

Penicillin is the most thoroughly stuthed of a group of antibiotics that interfere with peptidoglycan **synthesis.penicillin binds to proteins involved in cell wall synthesis and prevents the cross-linking of adjacent glycan chains**. These proteins are called penicillin –binding proteins a name that reflects their medical importance rather than their role in peptidoglycan synthesis.

Generally,but with notable **exceptions,**penicillin is far more effective against gram positive cells than gram negative cells. This is because the outer membrane of gram negative cells prevents the medication from reaching its site of action ,the peptidoglycan layer. The structure of penicillin can be modified to create penicillin derivatives that can pass through porin channels.these drugs are effective against a range of gram negative bacteria.

Lysozyme

Lysozyme breaks the bond that links the alternating N-acetylglucosamine and N- acetylmuramic acid molecules and thus destroys the structural integrity of the glycan chain ,the backbone of the peptidoglycan molecule.

Lysozyme is sometimes used in the laboratory to remove the peptidoglycan layer from bacteria for experimental purpose .removing that layer from a gram positive bacterium creates a protoplast that lacks a cell wall .in contrast ,removing the peptidoglycan layer from a gram negative bacterium creates a spheroplast. Spheroplast retain some portions of the outer membrane because they lack their rigid cell wall ,protoplsts and spheroplasts both become spherical regardless of the original cell shape due to osmosis they will burst unless maintained in a solution that has the same relative concentration of ions and small molecules as the cytoplasm.

Differences in cell wall composition and the gram stain

Differeces in the cell wall composition of gram positive and gram negative bacteria account for their staining characteristics .it is not the cell wall but the inside of the cell that is stained by the crystal violat iodine complex.the gram positive cell wall somehow retains the crystal violet iodine complex even when subjected to the trauma of acetone alcohol treatment whereas the gram negative cell wall cannot .

The precise mechanism that accounts for the differential aspect of the gram stain is not entirely understood.presumably, the decolorizing agent dehydrates the thick layer of peptidoglycan and in this dehydrated state the wall acts as a permeability barrier,retaining the dye .In contrast the solvent action of acetone alcohol easily damges the outer membrane of gram negative bacteria their relatively thin layer of peptidoglycan cannot retain the dye complex. These bacteria lose the dye complex more readily than their gram positive counterparts. Also as gram positive cells age they often lose their ability to retain the dye. This probably results from damge to their peptidoglycan layer that occurs as a consequence of aging.

Characteristics of bacteria that lack a cell wall

Some bacteria lack a cell wall .species of mycoplasma ,one of which causes , a mild form of pneumonia, have an extremely variable shape because they lack a rigid cell wall

As expected ,neither penicillin nor lysozyme affects these organisms .mycoplasma and related bacteria can survive without a cell wall because their cytoplasmic membrane is stronger than that of most other bacteria .they have sterols in their membrane, these rigid, planar molecules stabilize membrane making them stronger.

Cell walls of the domain archaea

As a group ,members of the archaea inhabit a wide range of extreme environments, and so it is not surprising they contain a greater variety of cell wall typed than do members of the bacteria.because most of these organisms have not been studied as extensively as the bacteria,less is known about the structure of their walls .none contain peptidoglycan ,but some do have a similar molecule.pseudopeptidoglycan.

Cell membrane

The cell membrane also called the plasma membrane or plasmalemma,is a semipermeable lipid bilayer common to all living cells. It contains a variety of biological molecules ,primarily **proteins** and **lipids**,which are involved in a vast array of cellular processes .it also serves as the attachment point for both the intracellular cytoskeleton and,if present,the cell wall .Robert hooke was the first one to name the cells parts including the plasma membrane.

The cell membrane surrounds the cytoplasm of a cell and physically separates the **intracellular** components from the **extracellular** environment, there by serving a **mechnical function** similar to that of **skin** .this **barrier is able to regulate what enters and exits the cell** as it is selectively permeable.cells require a variety of substances to survive and the cell membrane serves as **gatekeeper** to what,and how much ,enter and exits.the movement of substances across the membrane can be either passive,occurring without the input of cellular energy,or active requiring the cell to expend energy moving it across the membrane.

Functions

In animal cells the cell membrane alone establishes a separation between interior and environment .whereas in fungi ,bacteria and plant an additional cell wall forms the outermost boundary.the cell wall plays mostly a mechanical support role rather than a role as a selective boundary.one of the key role of the membrane is to maintain the cell potential .the functions of the cell membrane include,but are not limited to:

*controlling what goes in and out of the cell.

*anchoring of the cytoskeleton to provide shape to the cell

*attaching to the extracellular matrix to help group cells together in the formation of tissues.

*transportation of particles by way of ion pumps,ion channels,and carrier proteins

*containing receptors that allow chemical messages to pass between cells and systems

*participation in enzyme activity important in such things as metabolism and immunity.

Surface layers external to the cell wall

Bacteria may have one or more layers outside of the cell.the functions of some of these are well established,but that of others are unknown.

Glycocalyx

Many bacteria envelop themselves with a gel-like layer called a glycocalyx that functions as a mechanism of either protection or attachment.if the layer is distinct and gelatinous,it is called a capsule,recall that capsules can be seen microscopically using a capsule stain .if instead ,the layer is diffuse and irregular, it is called a slime layer.colonies of bacteria that form either of these extracellular layers often appear moist and glistening..

Capsules and slime layer vary in their chemical composition depending on the species of bacteria **.most** are composed of **polysaccharides** such as **dextrans** and **glucans.** These take the form of tiny ,short, hairlike structures or fibrils,which form a network on the outside of the cell wall.a **few** capsules consist of polypeptides made up of repeating subunits of only **One** or **two** amino acids .

Some types of capsules and slime layers enable bacteria to adhere to specific to surfaces, including teeth,rocks,and other bacteria.these often enable microorganisms to grow as a **biofilm**,a mass of bacteria coating a surface.one example is dental plaque ,a biofilm on teeth.*Streptococcus mutans* uses sucrose to synthesize a capsule, which enable it to adhere to and grow in the crevices of the tooth.other bacteria can then adhere to the layer created by the growth of S.mutans. Acid production by bacteria in the biofilm damages the tooth surface.