ECONOMIC IMPORTANCE OF BACTERIA

Dr.K.VENKATARAMI REDDY
Lecturer in Botany
GOVT.DEGREE COLLEGE
Porumamilla
KADAPA (Dt)

Economic Importance of Bacteria

Bacteria are harmful to us by causing diseases and spoiling valuable food materials and other objects. On the other hand they benefit us either directly or indirectly. Thus, bacteria may be considered as 'friends and foes' to man.

I. Useful Bacteria:

1. **Decomposition:** **Several saprophytic bacteria act as scavengers of nature by decomposing the dead bodies of animals plant debris. They also decompose the excreta and keep the environment clean. As a result of decomposition simple compounds are produced.**
2. **Sewage Disposal:** **The sewage contains human wastes, food wastes and cleaning compounds. Micro organisms convert sewage from organic to inorganic state by a process called mineralization. Aerobic bacteria involved in the treatment of sewage disposal or actinobactor, brevibacterium, pseudomonas, Flavobacterium.**
3. **Soil Fertility:** **Bacteria play a very important role in maintaining the soil fertility. Although the atmosphere contains more than 70% of nitrogen only 0.1% is present in the soil. Bacteria have the capacity of fixing atmospheric nitrogen. This phenomenon is called biological nitrogen fixation.**

i. **Nitrogen fixation by free living bacteria:** Many free living soil bacteria such as Azatobacter (aerobic), Clostridium(anaerobic) have the capacity to fix atmospheric nitrogen into ammonia. Nitrogen gas is reduced to amino group by the enzyme nitrogenase. The dead organic matter of plants and animals is converted into ammonia by micro organisms. These are called ammonifying bacteria and the process is called ammonification. Ex.Bacillus. The ammonia and ammonium salts are oxidized by Nitrosomonas and Nitrobacter into nitrates. This process is called nitrification.

ii. **Symbiotic Nitrogen Fixation:** symbiotic nitrogen fixation carried out by rhizobium present in the root nodules some leguminous plants. Nitrogenase is produced in the root nodules which reduce the atmospheric nitrogen into ammonia. Later amino acids are formed by transamination. These amino acids are released into the soil so that soil fertility increases

4. **Industrial Uses:**

i. **Fermentation of Dairy Products:** Bacterial fermentation of milk yields various dairy products like butter milk, cheese, cream and butter. Fermentation of milk is brought about by lactic acid bacteria. The cream is soured by steptococcus lactis. Cheese is due to combined action of staphylococcus and lactobacillus. Yogurt is obtained by fermenting milk with lactobacillus bulgaricus.

ii. **Vinegar:** Vinegar is obtained by fermentation of cane juice, molasses and fruit juice. In the first step sugars are converted into alcohol by the action of yeast. In the second step Acetobacter converts alcohol to acitic acid. Vinegar is used in the preservation of meat and vegetables.

iii. **Retting of Fibres:** **Retting is a controlled bacterial decomposition of plant material to separate the fibers. The stems of flax and hemp are immersed in water. The tough bast fibers separate from each other due to the action of anaerobic bacteria such as Clostridium botulinum, C.tetani**

iv. **Curing of tobacco and tea:** **The curing of tobacco and tea is due to fermenting action of certain bacteria. The seeds of coffee cocoa gain characteristic flavour due to the fermenting action of bacteria. (Bacillus, and some thermophillic bacteria)**

v. **Leather tanning :** **Bacteria are useful in the tanning of hides. They are dried, salted and cleared. Due to bacterial (Pseudomonas) action the leather becomes soft.**

vi. **Production of Organic Acids:**
Steptococcus lactis-lactic acid
lacto bacillus-lactic acid
Acetobacter-acitic acid
Propionibacterium-propionic acid
Clostridium butilicum-butilic acid

vii. **Enzymes:** **Biological production of enzymes is gaining importance. Bacteria of herbivores are employed in the production of cellulase that digests cellulose. Enzyme protease from bacillus subtilis, pectinase from Clastridium and amylase from bacillus diastictus are produced on commercial scale.**

viii. **Antibiotics:** **Antibiotics are substances produced by micro organisms which inhibit or kill other micro organisms. About 2100 antibiotics have been reported from actinomycitis group of bacteria of which 1922 come from streptomyces species alone. The antibiotic produced by some bacillus species are B.brevis-Gramicidine, Tyrocidine,Brevine. B.cereus-Biocerin, Cerexin, Thiobacillus subtilis-Bacitracin**

xi. Vitamins: vitamins like riboflavin(V-B12) is obtained from Clostridium acetobutylicum and vitamin C is produced from Acetobacter.

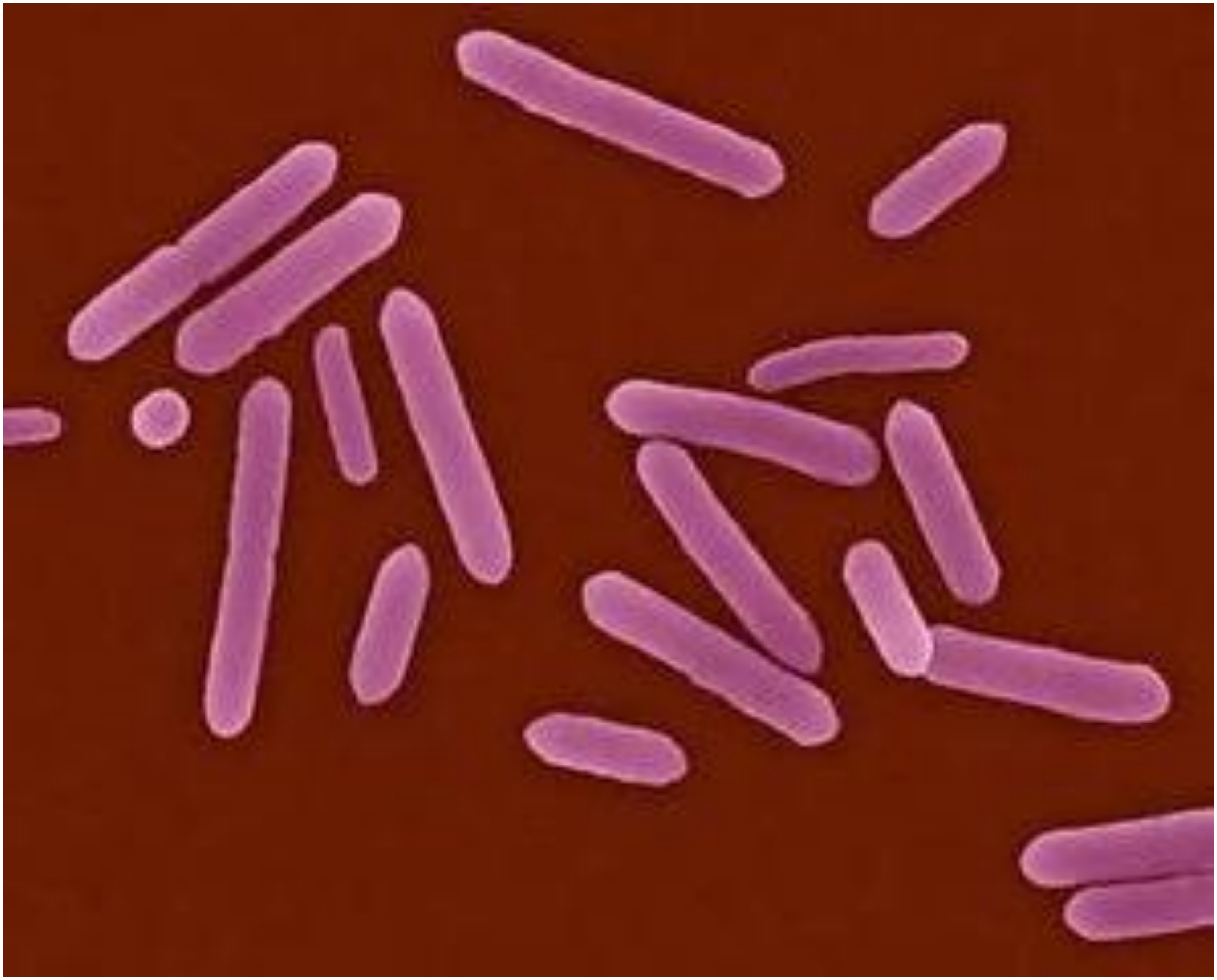
x. Biogas: Methane gas is used as fuel. It is obtained by anaerobic action of Methanobacillus. They act upon decaying organic matter and cattle dung. This bacterium occurs in marshes and ponds

5. Bacterial Pesticides: Bacterial pathogens are currently investigated as alternatives to pesticides. These include Bacillus, Clostridium, Pseudomonas, Enterbacter. Many pests of vegetable crops are suppressed by the toxic action of Bacillus thuringiensis. Mosquito larvae can be destroyed by Bacillus species.

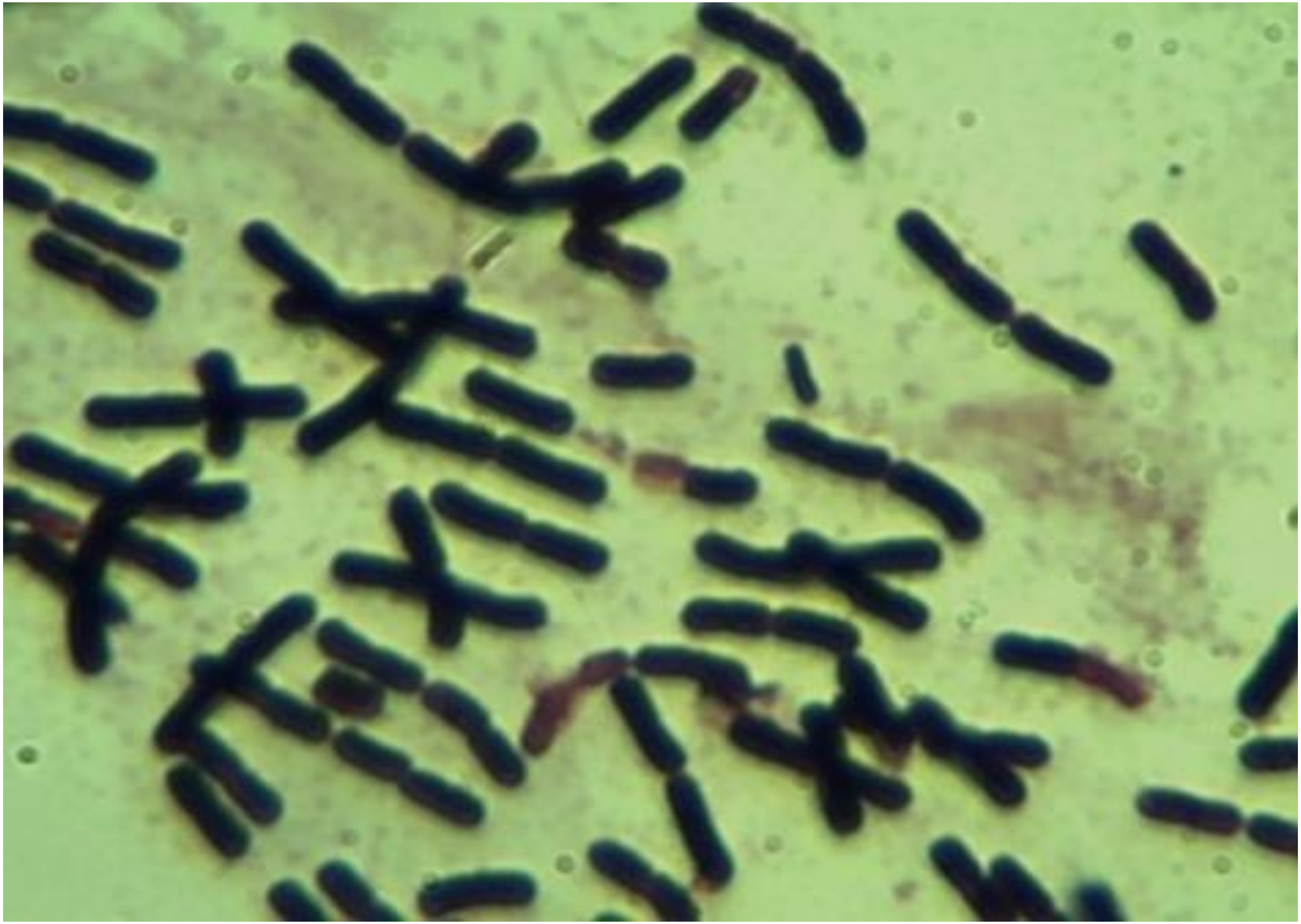
6. Biodegradation of Insecticides and Pesticides: Chemical insecticides and herbicides are having adverse effects on the environment. They remain in soil for a long time. Bacteria are useful in the bio decomposition of these pesticides. For example, 2,4-D is decomposed by Achromobacter and Corynebacterium. DDT (Dichlorodiphenyltrichloroethane)is decomposed by Aerobacter. Paraquant the weed killer degraded by Corynebacterium and Clostridium.

7. Genetic Engineering: Genetic Engineering may be defined as the manipulation of DNA outside and organism for the purpose of constructing new strains with altered properties. It is considered as one of the most exciting areas of biology. Human insulin, human growth hormones, antibiotics and enzymes can be produced without much cost by application of genetic engineering.

Lacto Bacillus

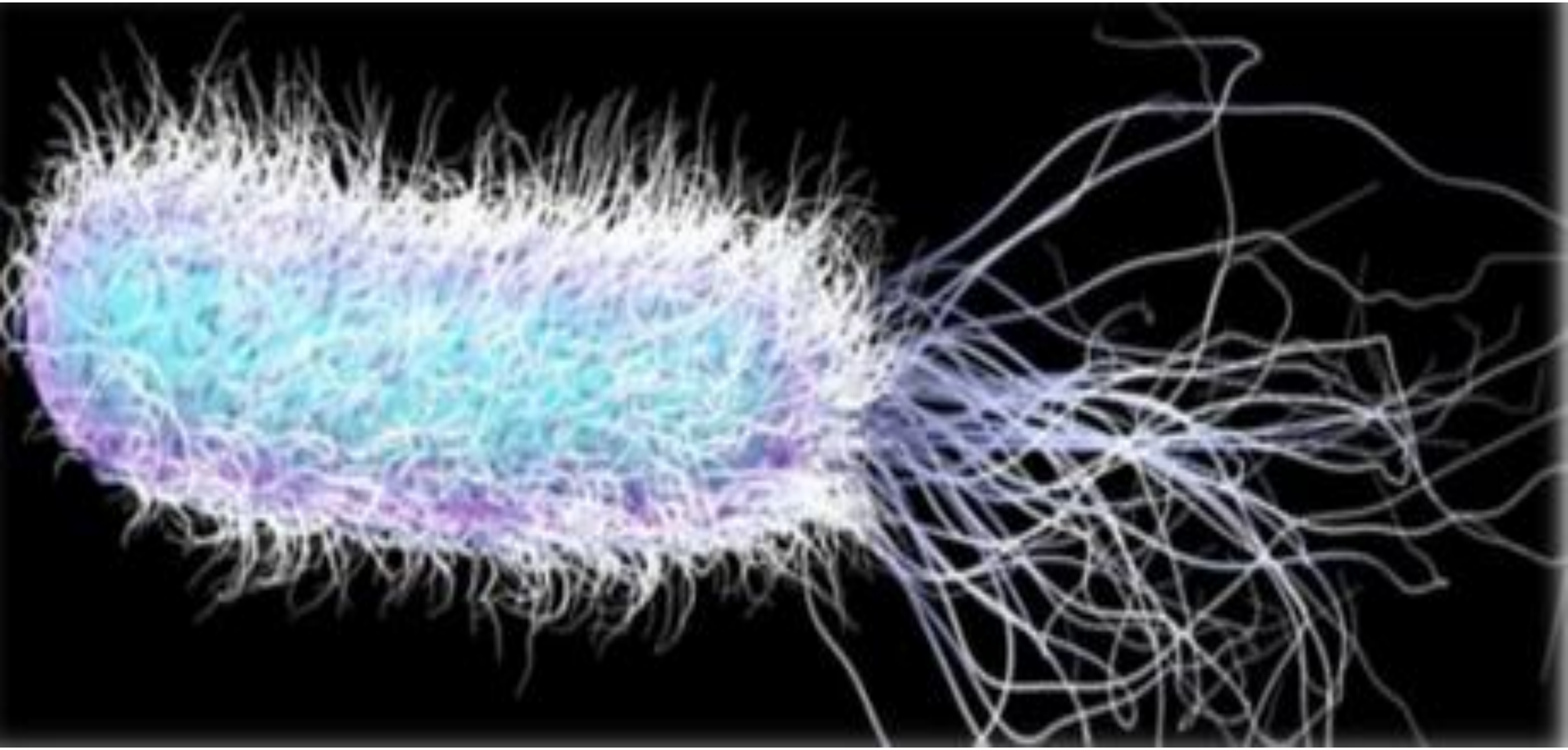


Clostridium tetani



Clostridium butyricum

Clostridium butylicum



Pseudomonas

Harmful Bacteria

1. **Spoilage of Food**: Many bacteria grow on food stuffs. They produce toxic substances which cause food poisoning. Generally stored food stuffs loose their flavour and taste due to growth of bacteria. Such foods are unfit for consumption.

i. **Botulism:** This type of food poisoning is caused by the toxins produced by Clostridium botulinum. These bacteria grow on preserved foods, meat products, canned food stuffs and poultry products. The poison affects the nerves and causes paralysis of pharynx and diaphragm. About 65% of botulism cases terminate in death

ii. **Staphylococcus Poisoning:** Staphylococcus food poisoning is characterized by nausea, vomiting, chills. The bacteria grow on ham(preserved pork meat), poultry products, cream filled bakery products, cheese, milk and salad.

iii. **Salmonella Poisoning:** The symptoms are similar to Staphylococcus poisoning and resembles typhoid fever. They are caused by fecal contamination of cooking foods and partially cooked meat.

iv. **Streptococcus and Bacillus Poisoning:** this is caused by Enterococci and Bacillus cereus. The symptoms are nausea, vomiting, colicky pains and diarrhea. Improper cooking of food is the main cause of this poisoning.

2. Spoilage of Paper: In the paper mills at various stages of paper manufacture bacterial contamination occurs. They destroy materials like cellulose
3. Destruction of Wood: Wood and wood products are degraded by the action of bacteria.
4. Bacterial and Water Pollution: many pathogenic bacteria like Schigella dysenteriae, Vibrio cholerae and Salmonella typhi grow rapidly in stagnant waters. Such water is harmful to health.
5. Reduction of Soil Fertility: Some of the anaerobic soil bacteria like Bacillus denitrificans are abundant water logged soils. They reduce soil nitrates so that free nitrogen escapes into the environment. Such bacteria are called denitrifying bacteria. Soils rich in organic matter also facilitate the liberation of nitrogen into the atmosphere. Ex. B. licheniformis
6. Biological Warfare: Bacteria may be used in biological warfare. Pathogenic bacteria that spread infectious diseases are kept as a kind of weapons and used on enemy country. The strategy is to ensure that enemy’s human, cattle and plant population are destroyed.
7. Diseases in Human Beings: Pathogenic bacteria causes diseases in human, animals and plants. Bacteria produce toxins which are poisonous to the host organism.
   i. Human Diseases caused by Bacteria:
   - Typhoid-Salmonella typhi;
   - Pneumonia- Streptococcus pneumoniae
   - Dysentery- Shigella dysenteriae
   - Cholera- Vibrio cholerae
   - Botulism-Clostridium botulinum
   - Tuberculosis-Mycobacterium tuberculosis
   - Leperosy- Mycobacterium leprae
   - Diarrehoea- Bacillus coli.

8. **Animal Diseases: Bacteria also cause diseases to domestic animals. Ex. Tuberculosis of cattle, Anthrax of sheep, Pneumoniae, Septicemia in cattle and Glanders in sheep, horse and goats.**
9. **Plant Diseases:**
    - **Leaf Blight of Paddy-Xanthomonas oryzae**
    - **Citrus canker-Xanthomonas citri**
    - **Angular leaf spot of cotton- Xanthomonous malvacearum**
    - **Crown gall of apple-Agrobactrium tumefaciens**
    - **Soft rot of Potato and Carrot: Erwinia carotovora**

10. **Control of Bacterial Plant Diseases:**

i. **The eradication of diseased plants**
ii. **Maintaining field sanitation**
iii. **Growing resistant varities**
iv. **Spraying of bordeaux(copper sulphate and calcium oxide in water)**
v. **Application of antibiotics**
vi. **Crop rotation**

Important Plant Diseases

1. Citrus canker: This is one of the most important diseases of all citrus plants. The disease was reported in Japan and now it is known to occur in every citrus growing areas of the world.

Symptoms:

- Citrus canker affects all the aerial parts of the plant such as leaves, twigs and fruits.
- On the leaves canker first appears as a small watery translucent spots of darker green coloured with a raised convex surface.
- The spots first become evident on the lower surface and as the disease advances the surface of the spot becomes white or grayish and look like pustule.
- Finally the pustules rupture exposing a light brown spongy central mass developed in a crater-like formation
- The spots are usually surrounded by a yellow chlorotic halo.
- Older lesions become corky, brown, and with more elevated margins and a sunken center.
- Sunken centers are especially noticeable on fruits
- Severe infection results in defoliation, dieback, deformation of root and premature fruit drop
- The disease is economically important because fruits with canker lesions are not acceptable for fresh market and fetch very little price.

Causal Organism

1. The pathogen responsible for Citrus canker is Xanthomonas citri(X.axonopodis citri)
2. The bacterium is a short rod shaped Gram negative bacterium and has a single polar flagellum
3. It is 1.5 to 2.0 microns long and 0.5 to 0.75 microns rod and aerobic
4. On 2% sucrose peptone agar medium colonies are yellowish and mucoid.
5. The yellow colour is due to Xanthomonadin pigment
6. The optimum temperature for growth is 28 to 30 degree centigrade

Disease Cycle:

1. The inoculum is provided by the diseased twigs and leaves
2. The pathogen enters the host through stomata and wounds. On penetration into the host it multiplies in the inter cellular places dissolves the middle lamella and establishes itself in the cortex
3. Cankerous outgrowths develop within which bacteria multiply and are released with exudations.
4. The disease is chiefly disseminated by wind,rain and insects.

Control Measures

Citrus canker disease can be controlled by the following methods.

1. Exclusion of the pathogen from canker-free citrus producing areas, by enforcement of strict quarantine measures.
2. Eradication of the pathogen by the destruction ofj infected trees.
3. Spraying of neem cake at the rate of 10kg/hectare helps in checking the citrus canker as well as leaf miners.
4. Spraying of antibiotics like Agromycin(Streptomycin sulphate) or Phytomycin at the rate of 500 -1000 ppm affectively checks the spread of the disease.
5. Cultivation of resistant varities(Citrus reticulata) including tangerines, kings, mandarin and satsuma oranges

Canker incidence can be reduced by taking integrated management approach consisting of :

i. Using canker-free nursery stock
ii. Pruning of all the infected twigs, before monsoon and burning them
iii. Periodical spraying of suitable copper-based bactericides along with an insecticide
iv. Taking some precautions to reduce the risk of spread of disease in orchards by sanitation and
v. By evolving canker-resistant varieties suitable to local environmental conditions.

Leaf Blight of Rice

Bacterial leaf blight of rice is widespread in Asia. The disease has been known for a long time in Japan where many studies were carried out.

Symptoms: **In temperate regions, the disease usually becomes noticeable in the field at the heading stage. In severe cases it may appear earlier, but it is rare in the seed bed.**

1. **The earlier symptom of the disease is the appearance of dull greenish water-soaked spots at the margins of fully developed lower leaves.**
2. **As the spots enlarge the leaves turn yellow, dry rapidly and wither.**
3. **The lesions enlarge both in length and width and several lesions coalesce to form straw-brown large lesions or blighted portions.**
4. **The inner margins of the blighted patch is ragged or wavy**
5. **Occasionally, the lesion may extend from the tip downward along the mid rib itself, the leaf margins remaining green.**
6. **On the surface of young lesions, milky or opaque dew drops may be observed in the early morning. These dry up in the form of yellowish, spherical beads which fall down in the field.**
7. **In severely infected fields, the infection may reach the grains. The glumes get discolored and water soaked spots develop on them.**
8. **When the affected leaves are cut and immersed in clear water, a turbid ooze of bacterium, streaming from the vascular bundles can be observed.**

Bacterial Leaf Blight of Rice

Causal Organism

1. The disease is caused by Xanthomonas oryzae. It is a rod shaped bacterium with rounded ends, 1.2x0.8-1µ in size, occurring singly or in pairs.
2. It is Gram negative non-spore forming with a single polar flagella
3. Bacterial cells are surrounded by mucous capsules and joined to form an aggregated mass.
4. Colonies of the bacterium are yellowish on artificial medium due to yellow pigments,

Control Measures:

i. As the diseases is seed borne the seed should be disinfected by soaking in Agromycin and Ceresan followed by hot water treatment for thirty minutes at 52 to 54 degree centigrade will eradicate the bacterium in the seed

ii. Spraying with copper fungicides like Streptomycin is reported to be effective in controlling bacterial blight

iii. Chlorination of irrigation water helps in reducing the spread of the pathogen.

iv. Proper Nitrogen doses results in better growth of the plants and reduces the disease.

v. Cultivation of resistant varieties is always advisable.

Nutrition of Bacteria

On the basis of their mode of nutrition two groups of bacteria can be recognized.

1.Autotrophic bacteria, 2. Heterotrophic bacteria

I. Autotrophic bacteria: Bacteria that can synthesize their own food materials are called autotrophic bacteria. They utilize energy from either sunlight or from chemicals by carrying various metabolic activities. They are further divided into photosynthetic bacteria and chemosynthetic bacteria

1. Photosynthetic Bacteria: These bacteria possess photosynthetic pigments and use light energy as energy source and CO_2 as their main carbon source. Hence these are also called photolithotrophs. In bacterial photosynthesis substance other than water act as hydrogen donor and as a result oxygen is not evolved as byproduct.

Photoautotrophic bacteria are divided into types:

A. Green Sulphur Bacteria: These are small non-motile rod shaped bacteria which are anaerobic. The photosynthetic pigment is Chlorobium chloroquin located in chlorosomes. These bacteria contain bacterial chlorophyll b, c, d or e in addition to bacterial chlorophyll a. these bacteria use H_2S or other reduced inorganic sulphur compounds as electral donor. Elemental Sulphur is formed as byproduct in photosynthesis. These bacteria differ from purple bacteria by the absence of the enzyme ribulose disphosphate carboxilase. Therefore, they are unable to fix CO_2 via RuBP cycle :

$$6CO_2+12H_2S \rightarrow C_6H_{12}O_6+6H_2O+12S$$

Ex. Chlorobium chlorochromatium

B. Purple Sulphur Bacteria

These bacteria contain bacterial chlorophyll a and they fix CO_2 via C_3 cycle and utilize reduced suplphur compounds as energy source. Ex. Chromatium, Thiospirillum

$$2CO_2+H_2S+2H_2O \xrightarrow[\text{Bacterial chlorophyll}]{\text{Light}} 2(CH_2O)+H_2SO_4$$

C. Purple Non-Sulphur Bacteria:

These are motile bacteria and belong to the follow Rhodospirillaceae. The photosynthetic pigment bacterial chlorophyll a. These bacteria do not use sulphur compound. Instead they depend on organic acids and alcohols.

$$\underset{\text{Propioic acid}}{CO_2+12CH_3\,CHOHCH_3} \rightarrow C_6H_{12}O_6+\underset{\text{Acetone}}{12CH_3COCH_3}+6H_2O$$

2. Chemosynthetic Bacteria: Several groups of soil and aquatic bacteria utilize inorganic compounds as well as elemental suplhur, hydrogen or carbon monoxide as electron or hydrogen donors. These are non photosynthetic but autotrophic bacteria. They derive energy from oxidation of inorganic compounds for the synthesis of their food. This mode of life with inorganic hydrogen donors is called chemolithotrophy. All these bacteria assimilate their carbon from CO_2 by fixation via C_3 cycle.

Types of Chemosynthetic Bacteria

A. **Sulphur Bacteria:** These bacteria occur in sulphur containing terrestrial and aquatic environments. They derive energy by oxidation of reduced sulphur compounds. Ex. Beggiatoa, Thiobacillus thiooxidans,

$$H_2S + 1/2O_2 \rightarrow S + H_2O$$

B. **Iron Bacteria:** These bacteria oxydize ferrous compounds to ferric compounds and the releases energy is utilized in the synthesis of organic compounds.

$$4\,Fe^{2+} + 4H^{+} + O_2 \rightarrow 4Fe^{3+} + 2H_2O$$

The ferric ion is deposited as insoluble ferric hydroxide. The overall reaction is as follows.

$$2Fe(HCO_3)_2 + O_2 + H_2O \rightarrow 2Fe(OH)_3 + 4CO_2 + energy$$

The important iron bacteria are Thiobacillus ferroxidans, Thiobacillus thiooxidans, Leptothrix ochrea, Gallionella. These bacteria form natural coloniesj in acid waters of iron ore mines, which contain metal sulphides as well as iron pyrites (FeS_2)

C. Hydrogen Bacteria

Many species of chemoautotrophic bacteria have the ability to grow with molecular hydrogen. They oxidize molecular hydrogen and in this process water and energy are obtained.

$$2H_2+O_2 \rightarrow 2H_2O$$

Pseudomonas saccharophila, (Gram negative), Nocardia opaca, Mycobacterium(Gram positive)

D. Nitrifying Bacteria

These are soil-borne obligate autotrophs. They oxydize ammonia to nitrate and play an important role in N_2-cycle. The conversion of ammonia to nitrate is known as nitrification. This process occurs in two steps, each step is carried out by a very specialized group of bacteria.

Nitrosomonas

$$2NH_3+3O_2 \xrightarrow{\text{Nitrosomonas}} 2HNO_2+2H_2O+78\text{K Cal.energy}$$

Nitrobcacter

$$2HNO_2+O_2 \xrightarrow{\text{Nitrobcacter}} 2HNO_3+21.6\text{K.Cal energy}$$

The nitrifiers are gram-negative bacteria, that collectively placed in the family Nitrobacteriaceae.

II. Heterotrophic Bacteria

These bacteria can not utilize CO2 as a sole source of carbon and require organic compounds for their main carbon source. Depending upon the source of energy, these bacteria are of two types.

A. Phto-heterotrophs(Photoorganotrophs): these bacteria obtain enerfy from sunlight but carbon is derived from organic compounds eg. Chloroflexus, Heliobacter, Chlororium

B. B. Chemo-heterotroophs(Chemoorganotroophs): These bacteria derive both carbon and energy from organic compounds. These are divided into three types-parasites, saprophytes and symbionts

i. Parasites: They depend on their living organisms like plants, animals and human beings. They cause diseases in the host. So they are called Pathogenic bacteria. Most of the human disease like typhoid, tuberculosis, pneumonia, cholera, plague, cankers, fire blight of the beans etc.

ii. Saprpphytes: Bacteria obtaining their food from decaying organic matter are now as saprophytic bacteria. Some saprophytic bacteria cause decomposition of dead plants and animals. The anaerobic break down of proteins is called putrefaction. Several bacteria are useful in fermentation, tanning of leather and retting of fibres. Several free living soil bacteria are useful in nitrogen fixation.

iii. Symbiotic Bacteria: some bacteria live in close association with other organisms(plant and animals) in such a way that both the concerned organisms receive mutual benefit from this association. This is called symbiosis. For ex.Rhizobium living in the rood nodules of leguminous plants fix free atmospheric nitrogen into nitrogenous compounds which are utilized by the plants. The bacteria inahabiting intestine of man animals are good examples of symbiotic bacteria . The enzymes secreted by these bacteria are helpful in the digesiton cellulose and in return obtain their food from the host. Eg.E.Coli,Lactobacilli,

Bacteria General Characters

1. Bacteria are very small microscopic, unicellular organisms.
2. They were first observed by A. Van Leewenhock(1676) and named as ‘animalcules’
3. The term bacteria was used by Ehrenberg(1838)
4. They show typical prokaryotic characters and resemble both plants and animals.
5. Based on the level of organization and mode of reproduction R.H. Whittaker(1969) included bacteria and cyanobacteria under kingdom Monera.
6. Monera is divided into two divisions-Schizomycophyta which includes bacteria and Myxomycophyta which includes cyanobacteria
7. Carl Woese proposed three domains- Archaea, Bacteria and Eukarya . Bacteria, Cyanobacteria and Actinomycetes are kept in the domain of Bacteria.
8. Bacteria are omnipresent, found in all possible habitats
9. Most of the bacteria have heterotrophic mode of nutrition and live as Saphrophytes, parasites and symbionts.Some bacteria are autotrophic
10. They are unicellular and morphologically simple of all the living organisms
11. The cells may be spherical, cylindrical or curved rods.
12. The cell wall of bacteria is rigid and made up of two types of polymers-amino acid sub units and saccharide sub units. Cellulose is absent

13. Bacterial cell is prokaryotic. A well organized nucleus is absent.

14. Chlorophyll pigments are located within cytoplasmic membranes. Plastids are absent

15. In the cytoplasm are present 70s ribosomes.

16. Other organals like endoplasmic reticulum, golgi bodies, lysosomes, mitochondria and vacuoles are absent.

17. Binary fission is the most common method of reproduction.

18. True sexual reproduction is absent. However recombination of genetic material occurs by conjugation, transformation and transduction.

19. The motile bacteria posses one or more flagella composed of 8 parallel chains of flagellin molecules arranged helically along the axis to give hollow tube

20. Some gram negative bacteria posses minute hair-like cytoplasmic appendages known pili. They help in attachment of bacterial cells during conjugation

Occurrence and Habitat:

1. Bacteria are ubiquitous and occur in all natural habitats.
2. They can withstand great extremes of temperature, moisture, acidity and salinity
3. Bacteria are present abundantly in soil with moisture, nutrients and suitable temperature for their growth
4. They are carried from soil to air along with dust particles.
5. They are found in fresh waters of rivers, ponds, reservoirs and lakes and also in saline waters of oceans and seas.
6. They thrive well in hot water springs(75^0C) and also survive below freezing points in the Atlantic ice
7. Many species of bacteria are free living and others are symbiotic, parasitic or saphrophytic

Habit:

1. **Size:**

   i. Bacteria are vary small microscopic organisms. The diameter of coccus bacteria ranges from 0.5 to 2.5µ and bacilli are 0.4 to 15µ in diameter.

   ii. Epulopiscium fishelesoni is the huge bacterium that lives in the intestines of brown surgeon fish measures about 600x80µ

2. **Shape** : Bacteria are unicellular with rigid cell wall which determines the shape of the cell. Three types of shapes are recognized.

   i. Bacillus or rod -shaped bacteria: Bacillus bacteria are rod shaped or cylindrical, may be motile or non-motile, about 10µ in length and 1.5µ in diameter. The bacillus may be solitary(Monobacillus-ex.Pseudomonas,Clastridium)may form pairs (Diplococcus-Corynobacterium diptheriae) or chains(Streptobacillus-Bacillus tuberculosis)

ii. Coccus or spherical bacteria:

1. **The spherical are called Cocci bacteria measures 0.5 to 1.25 μ in diameter**
2. **They are non-motile atrichous**
3. **On the basis of arrangement and number of cells in a cluster the cocci are classified into six groups**
   - **i. Monococcus(one cell). Ex.Micrococcus luteus**
   - **ii Diplococcus(two cells). Ex.Diplococcus pneumoniae**
   - **iii. Streptococcus(long chains): Ex. Streptococcus lactis**
   - **iv. Staphylococcus(irregular group of many spherical bacteria): Staphylococcus albus**
   - **v. Tetracoccus(group of four cells): Ex. Neisseria**
   - **vi. Sarcina(cubical arrangement of eight cells): Ex.Sarcina lutea**

iii. Spiral or Helical bacteria: These are slightly larger and elongated spiral rods

- **i. Vibrio: These are curved rods resembling comma and are called comma bacteria with single flagellum and 10μ in length and 1.5 to 1.7μ in width.Ex.Vibrio cholerae**
- **ii. Spirillum:They look like helix and measure 15 μ in length and 1.5 μ in width. They are motile with one or more flagella at each pole.Ex. Spirillum volutans**
- **iii. Spirochaete: These bacteria are spiral shaped but lack rigid cell wall, flexible and motile. Ex.Treponema**

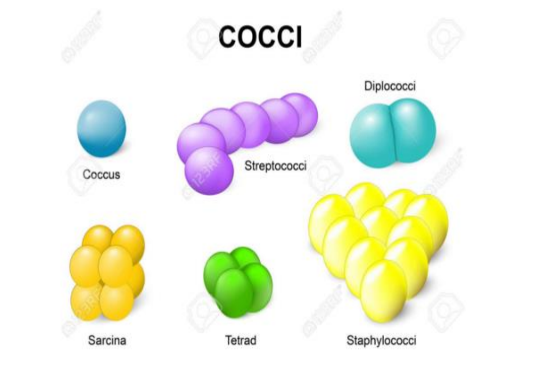
iv. Other forms:

i. Pleomorphic: Some bacteria change their shape and size temporarily in response to changes in the surrounding environment. As such a single bacterium may occur in more than one shape in its life cycle. Ex.Acetobacter, Rhizobium.

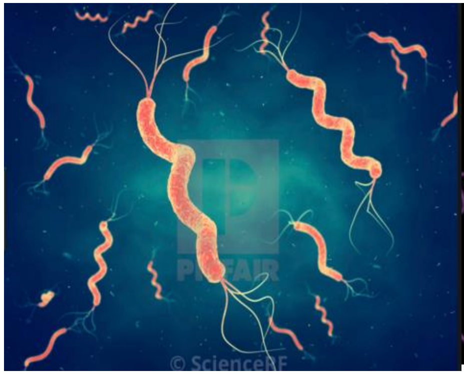
ii. Trichomes: Cells divided in one plane forming a chain of cells surrounded a sheath is called trichomes. Ex.Beggiatoa

iii. Hyphae: Some bacteria form mult-icellular thin walled branched filaments called hyphae. These filamentous bacteria are called actinomycetes. Ex.Streptomycin, Mycobacterium.

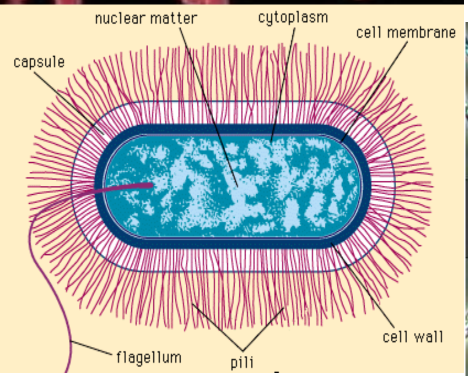
Bacillus

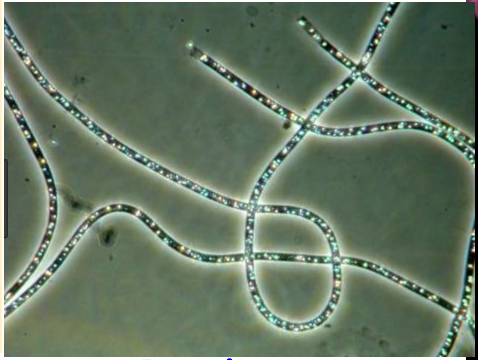


Spirillum



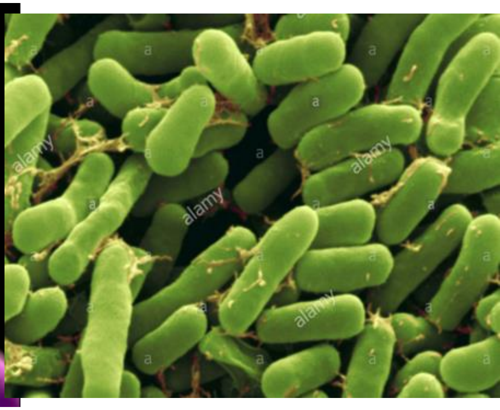
Vibrio



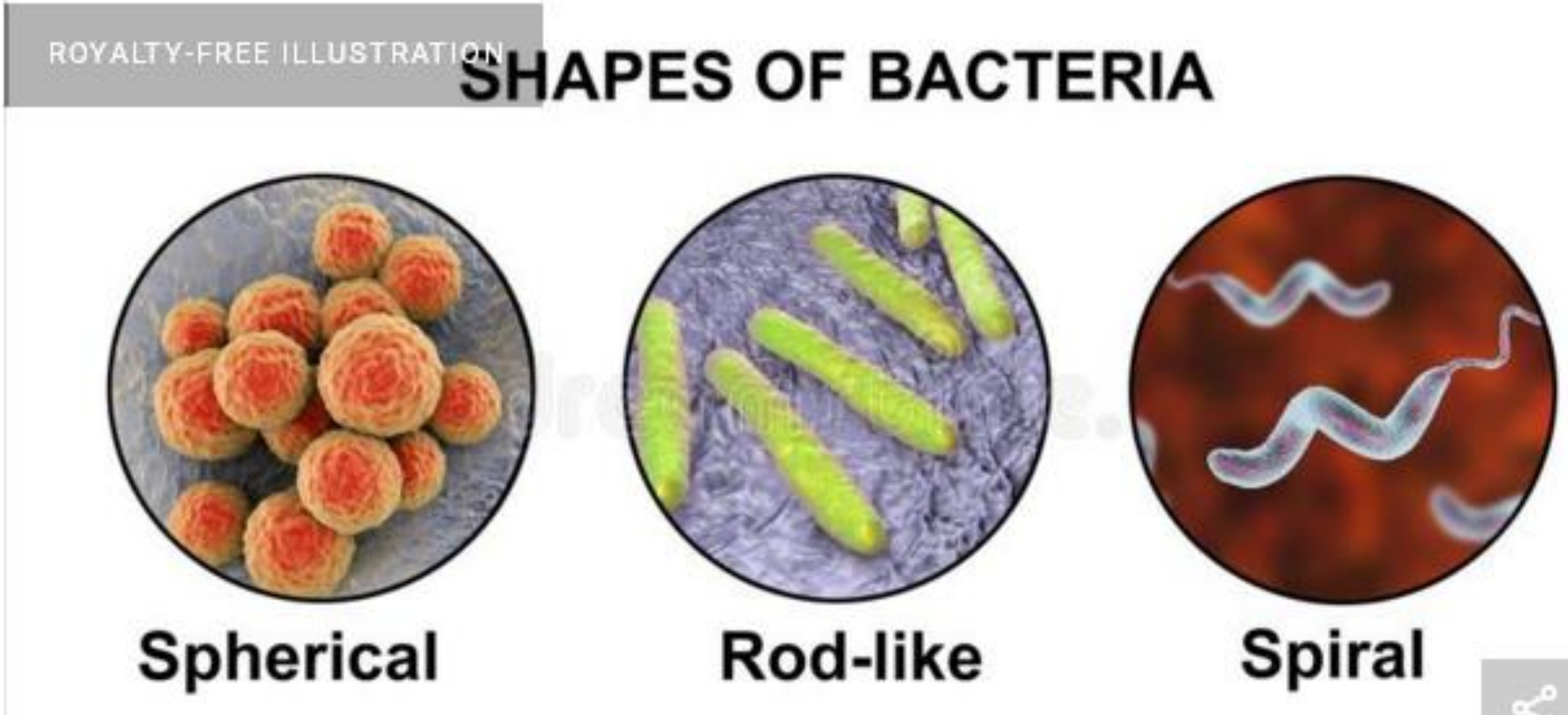


Beggiaota

Acetobacter



Rhizobium


ROYALTY-FREE ILLUSTRATION
SHAPES OF BACTERIA
Spherical
Rod-like
Spiral

Staining of Bacteria-Gram staining

1. Christian Gram in 1884 devised a differential staining procedure. This differentiate two kinds of bacteria-Gram positive and Gram negative bacteria. This procedure is called Gram-staining technique

Steps in Gram Staining:

Step 1: A thin smear of bacterial cells is prepared on a glass slide.To the smear crystal violet solution is applied for 30 seconds.

Step 2: The slide is gently rinsed in clean water and then an iodine solution is applied for thirty seconds. This in turn is rinsed off with clean water. If the slide is observed under microscope all cells would be deeply stained and appear blue purple.

Step 3: 95% Ethyl alcohol or acetone is applied for 30 seconds and this is repeated until all the thickest parts of the smear have ceased to give off the dye. This usually takes twenty seconds to one minute. The smear is immediately rinsed with clean water.

The differential feature of the stain becomes apparent now. Microscopic examination reveals that some bacterial cells retained the violet iodine combination even after alcohol wash. These bacteria are called Gram positive bacteria.

Some other bacterial cells lost the stain after the treatment with alcohol. They are called Gram negative bacteria.

Then a counter stain is applied to the bacterial smear. The counter used is generally Eosin(red), Safranin(red). Each of these colours is taken by Gram negative species and the cells appear in pink colour.

- **This differential reaction of two types of bacteria to crystal violet-iodine stain is due to the different amounts of lipids present in their cell wall.**
- **The Gram negative bacteria have relatively high lipid content in their cell walls. The alcohol dissolves the lipids which allows the leakage of crystal violet-iodine complex.**
- **The Gram positive bacteria on the other hand have less lipids and hence less susceptible to the action of alcohol.**

Bacterial Smear

↓

Crystal violet(Purple dye-Bacteria take a violet stain)
(one minute)

↓

Rinse with water

↓

Few drops of Iodine(All bacteria dark violet or purple)

↓

Rinse with water

↓

Wash the slide with 90% ethyl alcohol and with water

↓

↓	↓
Bacteria colourless	**Bacteria retain colour (Gram-Positive)**
↓	
Counter stain with Safranin	
↓	
Bacteria appear pink (Gram-negative)	

Differences between Gram-negative and Gram-positive bacteria

Gram-negative	Gram-positive
1. Cell wall is heterogeneous, more complex and multi-layered	1. Cell wall is homogeneous, amorphous and single layered
2. Peptidoglycan layer is thina(10-15 nm) and constitutes not more than 5-10% of the total dry weight of the cell	2. Peptidoglycan layer is thick(25-30nm) and constitutres 20-40% of the total weight of the cell
3. Peptide inter bridges are usually absent.	3. Peptide inter bridges are present
4. Teichoic acid is absent	4. Teichoic acid is present
5. These are phototrophic, chemo lithoautotrophic or chemo organotrophic	5. These are usually chemo-organo-hterotrophs
6. These may be motile or non-motile	6. These are mostly motile
7. Appendages like pili and fimbriae are present.	7. Generally appendages are absent
8. These cannot form endospores eg. E.coli, Pseudomonas, Rhizobium, Vibrio	8. Some of the members form endospores eg. Bacillus, Clostridium, Micrococcus, Streptococcus

Structure of Bacterial Cell

The bacterial cell shows a typical prokaryotic cell structure. It is enclosed by three layers.

1. **The outermost layer-slime layer**
2. **The middle layer-cell wall**
3. **The innermost layer-cytoplasmic membrane**

   I. **slime layer-glycocalyx-** **It is the gelatinous layer present on the outer surface of the cell wall.**

- **It is made up of either polysaccharide or polypeptide or both. It forms a viscous layer and loosely attached to the cell wall**
- **When nitrogenous substances are also present along with polysaccharides and firmly attached to the cell wall the slime layer is called capsule.**
- **The presence of capsule is often associated with the virulence of the pathogenic organism.**
- **The slime layer/capsule protects the bacterial cell from desiccation, antibodies and phagocytosis by the white blood cells**

   II. Cell Wall

- **Beneath the capsule and external to plasma membrane the rigid cell wall is present.**
- **It varies in thickness from 50 to 100 A°**
- **Bacterial cell wall consists peptidoglycan or murein which is heteropolymer made up of N-acetylglucosamine(NAG) and N-acetylmuramic acid(NAM)**
- **NAG and NAM are linked by 1, 4 β glycosidic bonds.**
- **A tetrapeptide side chain containing 4 amino acids is attached to each NAM**
- **The amino acids of these peptides are L-alanine, D-glutamine,L-lysine or Diamynopimelic and D-alinine.**

- The parallel tetrapeptide side chains are linked by pentaglycin peptide cross bridge that contains five amino acids. Due to extensive cross linking the peptidoglycan becomes a rigid macromolecule of the cell wall
- The cell wall also contains other chemicals such as Teichoic acid, Protein Polysaccharides and Lipoproteins and Lipopolysaccharides.
- The outer membrane has small channels of special of protein called porins. The porins serve as pores for the entry of small molecules of nutrients and allows secretion of extracellular enzymes such as proteases, pectinases and aminases.
- In the cell wall of Gram positive bacteria present Techioc acid. Techoic acids are hydrophylic, flexible and linear molecule. Ex. Bacillus, Streptococcus
- In the cell wall of Gram negative bacteria Techoic acid is absent(Rhizobium)

Functions of the cell wall:

1. Peptidogylcan provides structural integrity to the cell by forming a rigid layer in the outer membrane
2. The matrix proteins act as receptors sites for bacteriophages and bacteriocins
3. The cell wall protects bacteria against destruction by osmotic pressure

III. Cytoplasmic Membrane/Plasma Membrane:

1. Inner to the cell wall a semi permeable cytoplasmic membrane is present which is about 75A° units thick. Chemically it is composed of double layers of phospholipid molecule
2. The globular proteins are embedded in the lipid layerThe cell membrane is an important center of metabolic activities.
3. It acts as a selective barrier for the penetration of water soluble molecules and waste products.The cytoplasmic membrane also contains the enzymes involved in respiration and synthesis of capsular and cell wall material
4. It is the site of ATP synthesis and center for the control of flagellar motility

Mesosomes: Mesosomes are the invaginations formed in the plasma membrane. These structures comprise vesicles, tubules. Mesosomes are common Gram positive bacteria and they increase the surface area of the membrane. They are considered the sites of cell respiration. During cell division they play a role in the cross wall formation and DNA replication

IV. Cytoplasm and Cytoplasmic Inclusions:

1. The bacterial cytoplasm is complex miture of carbohydrates, proteins, lipids, inorganic ions and water(80%)
2. Cytoplasm is thick and transparent.
3. The organic material is stored in the form of glycogen,volutin granules and poly-β-hydroxybutyrate(PHB)
4. Organelles like Mytochondria, endoplasmic reticulum, centrosome, golgi bodies and Chloroplast are absent

Nuclear Material: Bacterial cells contain the nuclear material consisting of a single long circular double stranded DNA molecule devoid of histone proteins and introns. The DNA has approximately $5x10^9$ base pairs and a molecular weight of about $3x10^9$ daltons.Nuclear membrane, nucleolus, nucleoplasm are absent

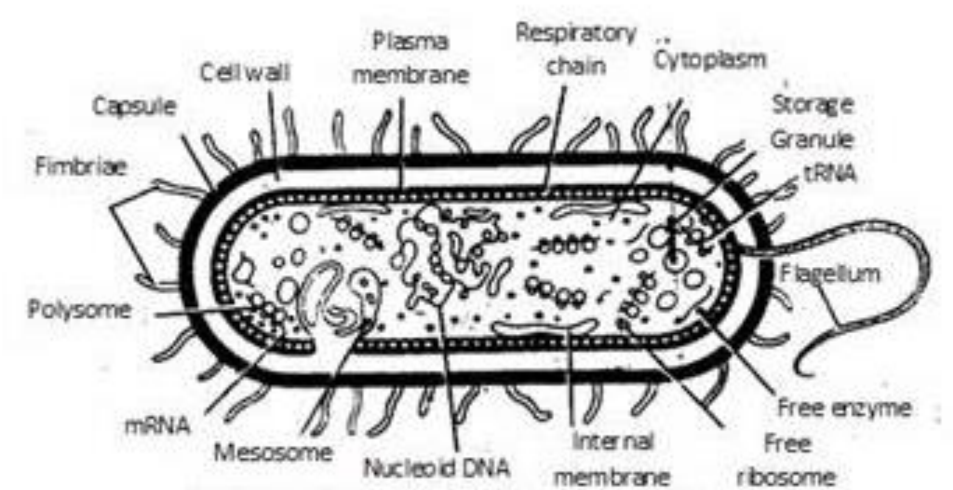
Plasmids:

i. Bacterial cell also contains some extra chromosomal hereditary material called plasmid.
ii. The plasmids may be defined a small circular cells replicating and double stranded DNA molecule present in the bacterial cell

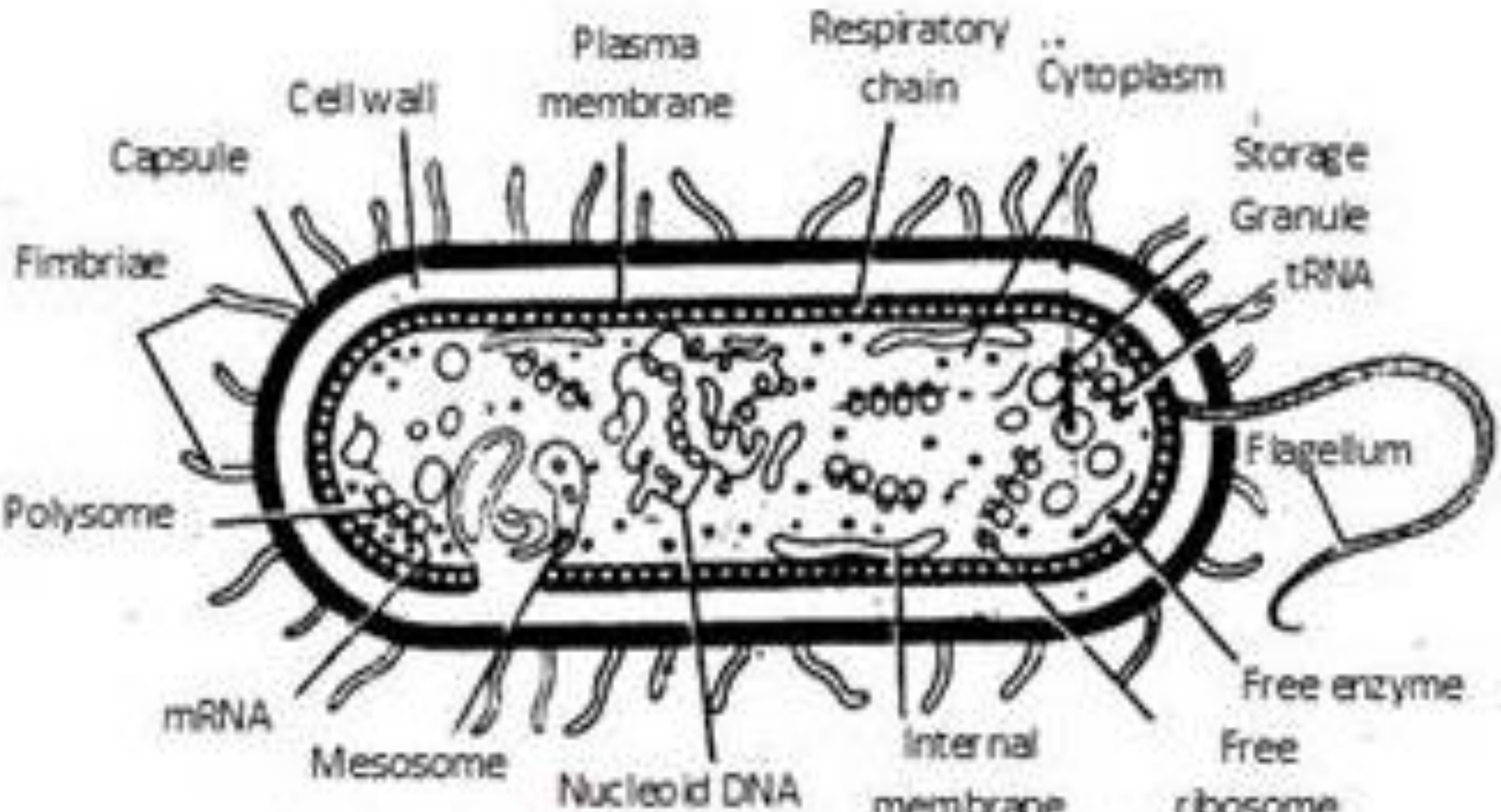
Ribosomes: Ribisomes are the sites of protein synthesis. They are found freely distributed in the cytoplasm. Bacterial ribsosomes are 70S type and consist of two sub units-50S and 30S. The 50S sub unit consists of 5S and 23S rRNA and 34 proteins. Whereas, 30S sub unit consists 16S rRNA and 21 proteins.

V. **Flagella:** The motile bacterium possess a flagellum. The flagellum is hair – like surface appendage emerging from the cell wall. It is of 20 to 30 nm in diameter and 15μ long. Flagella are absent in *coccus* bacteria. The flagella helps in locomotion.

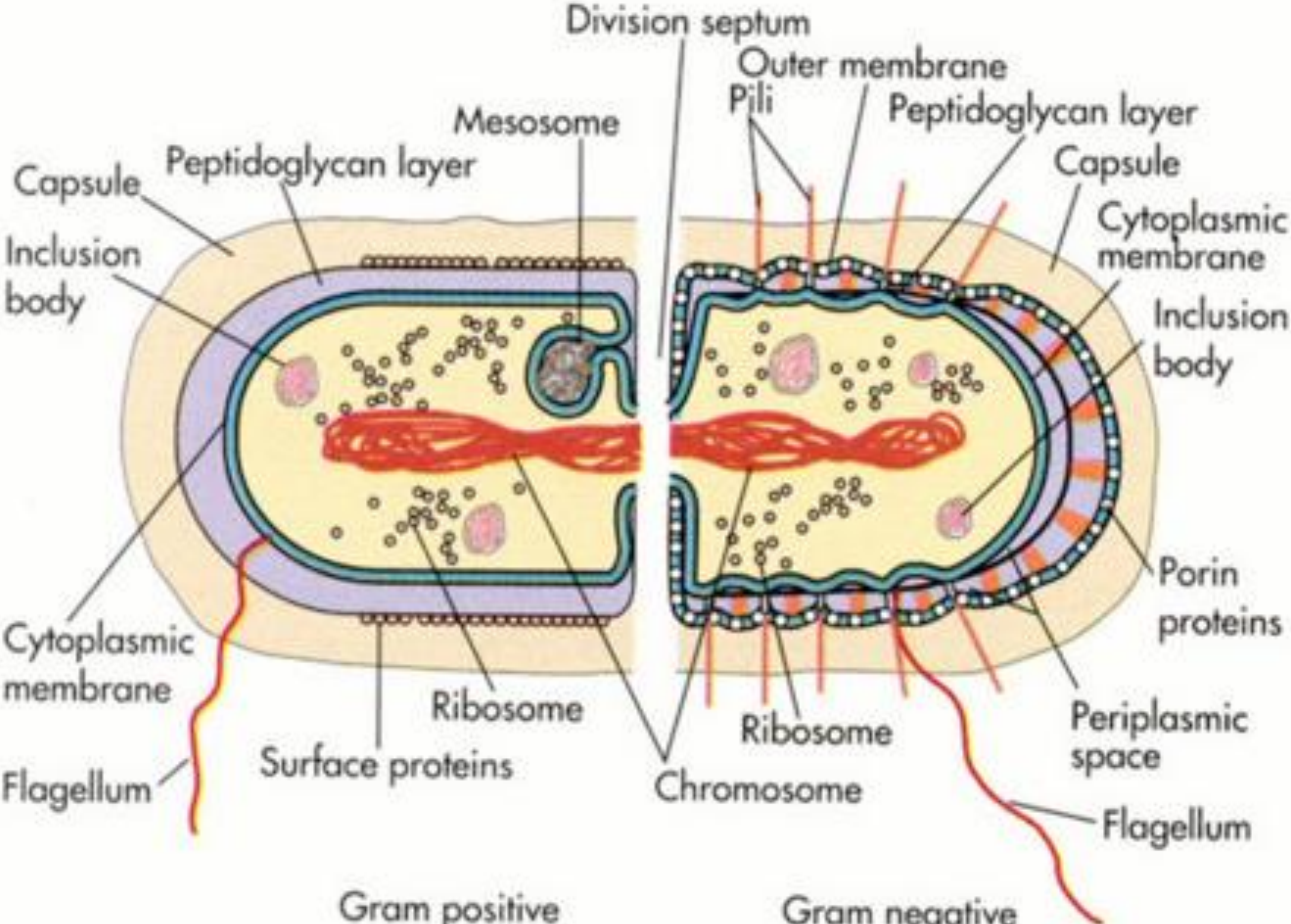
VI. **Pili-Fimbriae:** Many Gram negative possess minute hair-like appendages extending outwards from the surface of the cell wall. These are called Pili or fimbriae. Bacteria containing fimbriae are called fimbriate bacteria. The length of Pili is 3 to 10nm and diameter is 30 to 50 A^{o} ·Pili are made up of a special type of protein called Pilin which consists of about 163 amino acids. Pili helps in attachment of the bacterial cell to the substrate and also in conjugation.



Electron microscope structure of a bacterium cell



Electron microscope structure of a bacterium cell



Division septum
Outer membrane
Pili
Mesosome
Peptidoglycan layer
Capsule
Peptidoglycan layer
Capsule
Cytoplasmic membrane
Inclusion body
Inclusion body
Cytoplasmic membrane
Porin proteins
Ribosome
Ribosome
Periplasmic space
Surface proteins
Chromosome
Flagellum
Flagellum
Gram positive
Gram negative

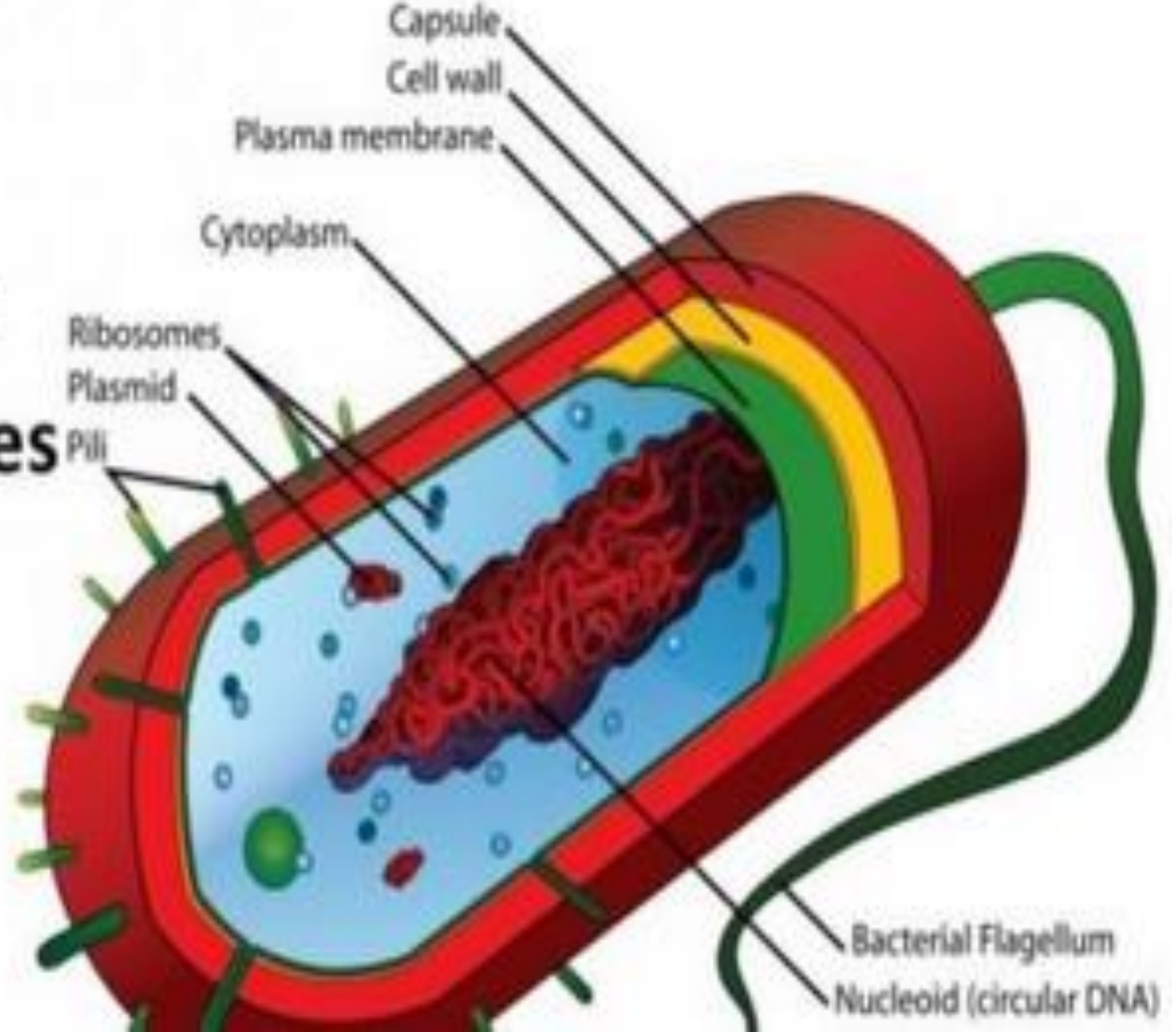
Structure of Bacteria

Essential structure

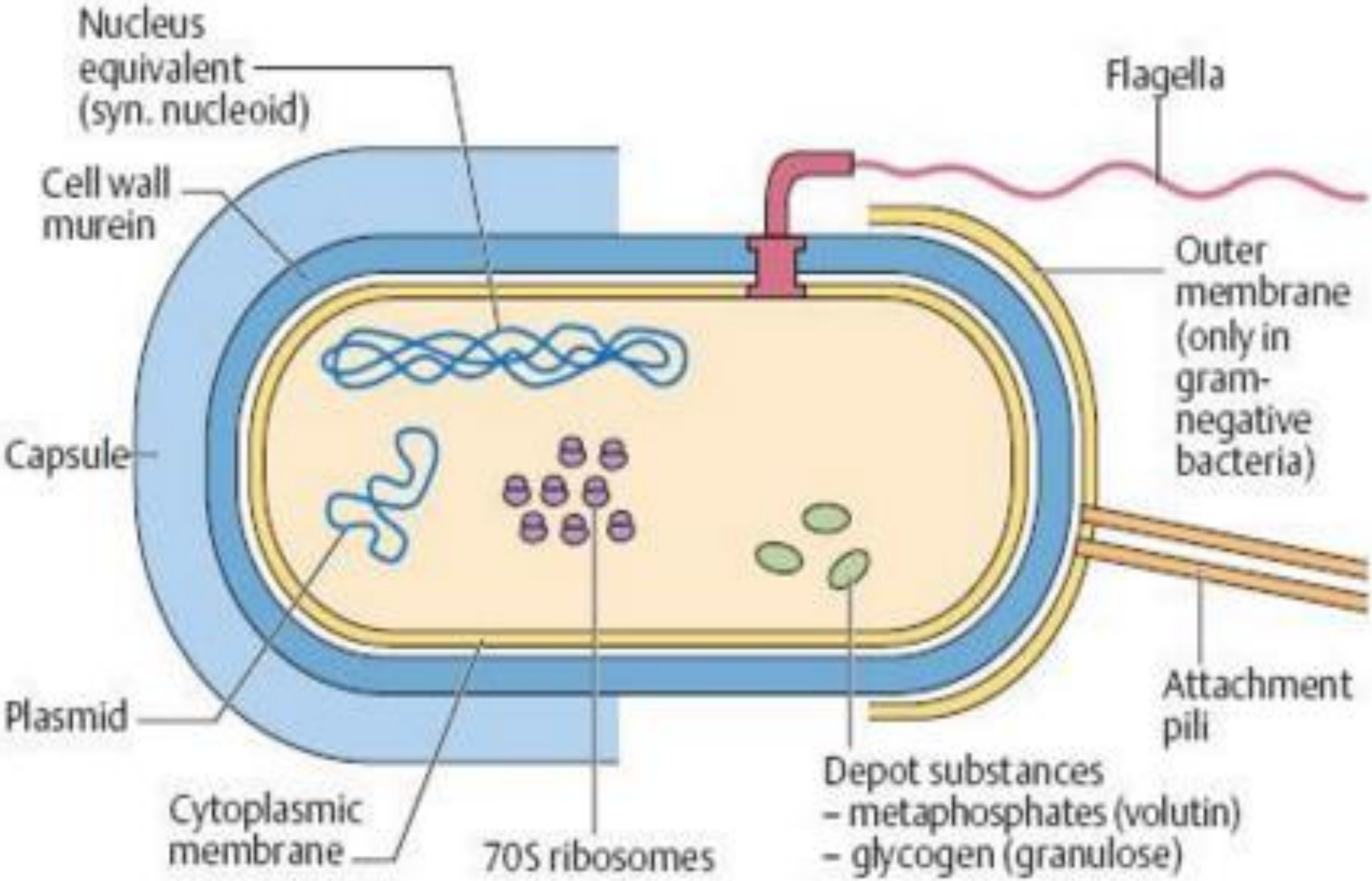
- Cell wall
- cell membrane
- Cytoplasm
- Nuclear material

Particular structures

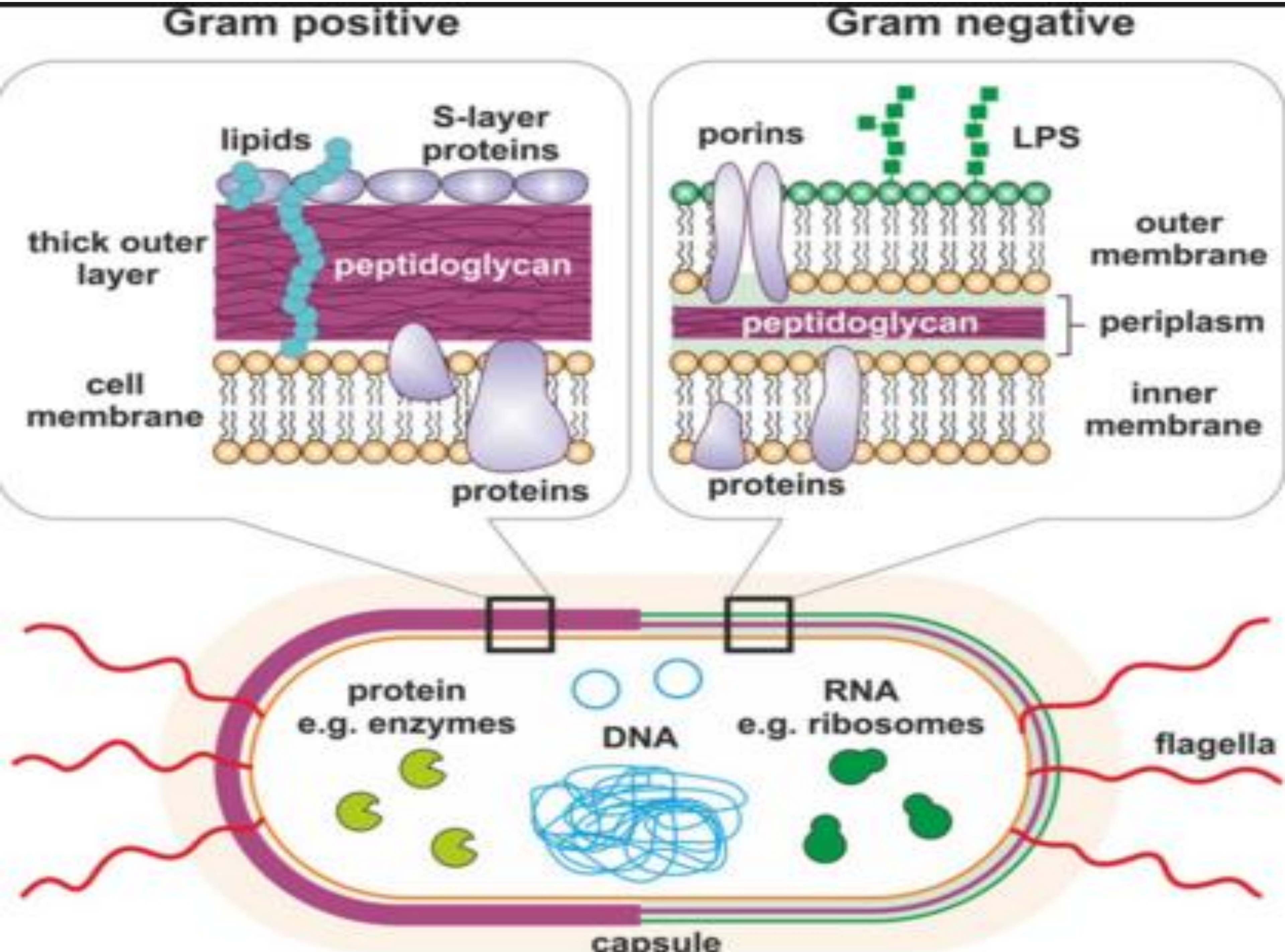
- Capsule
- flagella
- pili
- Spore



Basic Bacterial Cell Structure



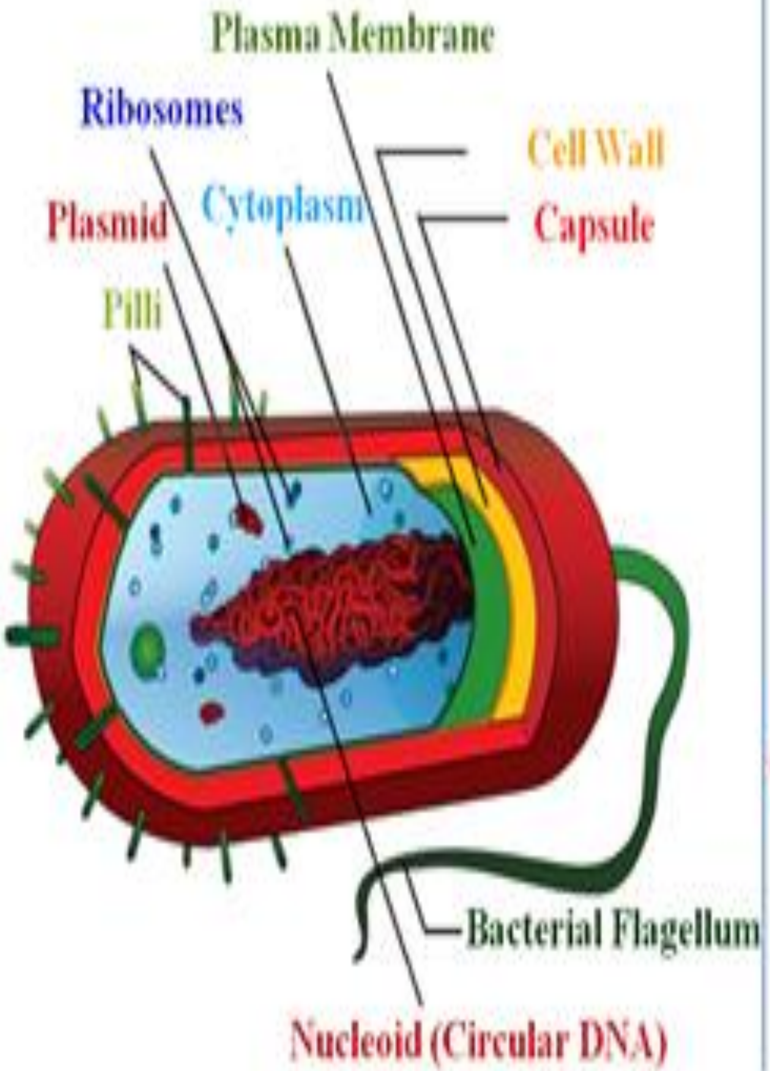
All bacteria have the same basic structure (not to scale).



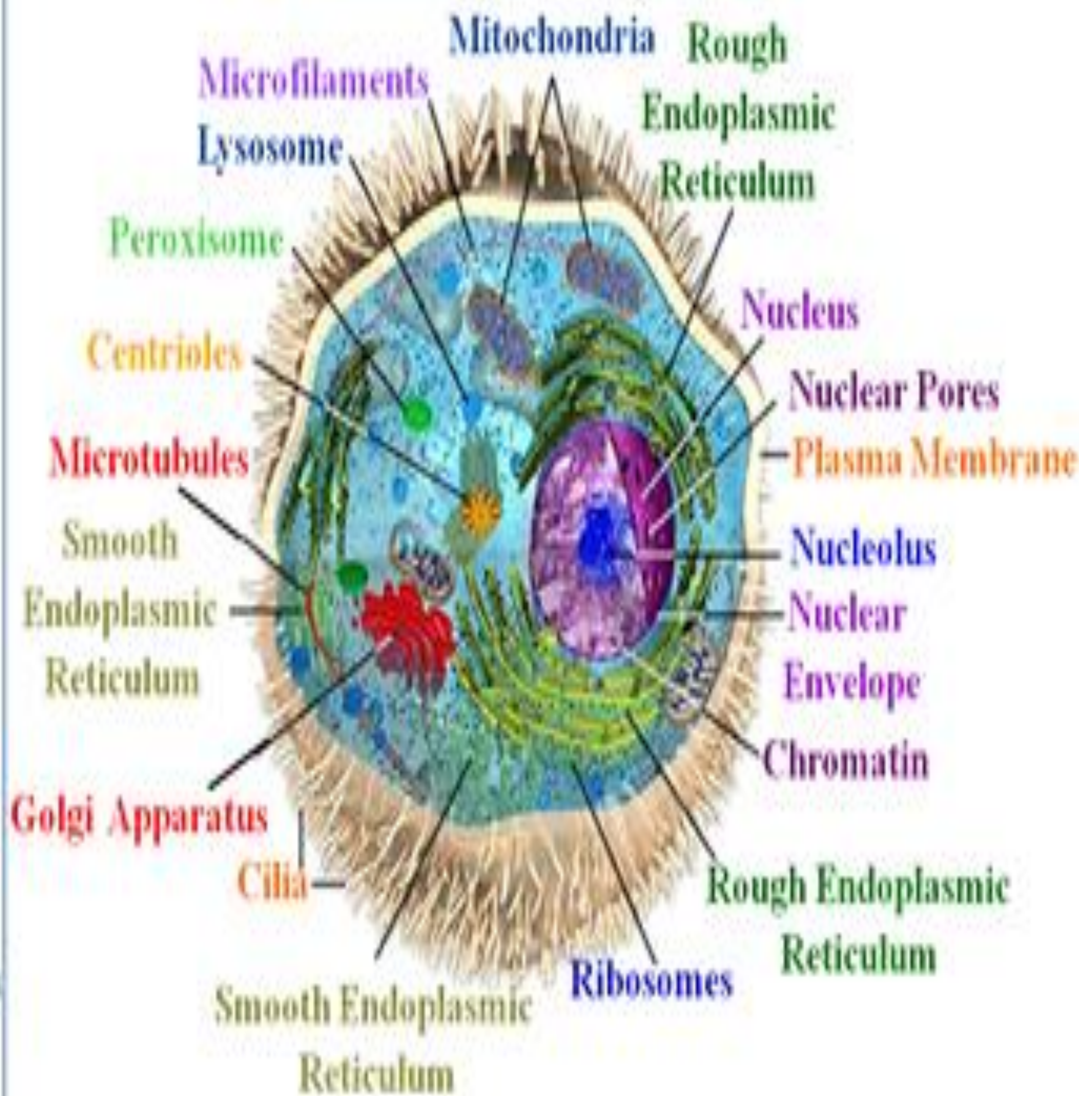
Gram positive
Gram negative
lipids
S-layer proteins
thick outer layer
peptidoglycan
cell membrane
proteins
porins
LPS
outer membrane
peptidoglycan
periplasm
inner membrane
proteins
protein e.g. enzymes
DNA
RNA e.g. ribosomes
flagella
capsule

Structures of Prokaryotic and Eukaryotic Cells

Structure of a Prokaryotic (Bacterium) Cell



Structures of Eukaryotic (Mammalian) Cells



Plasmids

1. Bacterial cells contain extra chromosomal hereditary materials which are called plasmids. The plasmids may be defined as a small circular self replicating and double stranded DNA molecule present in bacterial cell in addition to bacterial chromosome.
2. It replicates independently during the cell division and inherited by both of daughter cells
3. The number of plasmids ranges from 1 to 100 or more per bacterial cell
4. A plasmid contains 5 to 100 genes that control several biological functions.
5. Plasmids exhibit certain properties like toxigenecity and drug resistance.
6. They are transmitted to daughter cells during binary fission.
7. Plasmids are the circular DNA molecules of about 2 to 500 kb(kilobase)
8. In resting stage DNA helix twists in right hand direction at every 400 to 600 base pairs and forms super coils.

Types of Plasmids: **On the basis of function plasmids are divided into several types.**

I. F-Plasmids:

i. These plasmids play major role in conjugation of bacteria.

ii. F-plasmid is a circular ds-DNA molecule of 99 to 159 base pairs.

iii. There are two sites for replication in the DNA molecule.

a) rep genes-responsible for regulation of DNA replication

b) Transposable elements(IS3,Tn 1000, IS3,and IS2 genes involved in its ability to function as episome(plasmids integrated with bacterial chromosome during replication)

c) tra genes:the tra region consists of tra genes which promote transfer of plasmids during conjugation

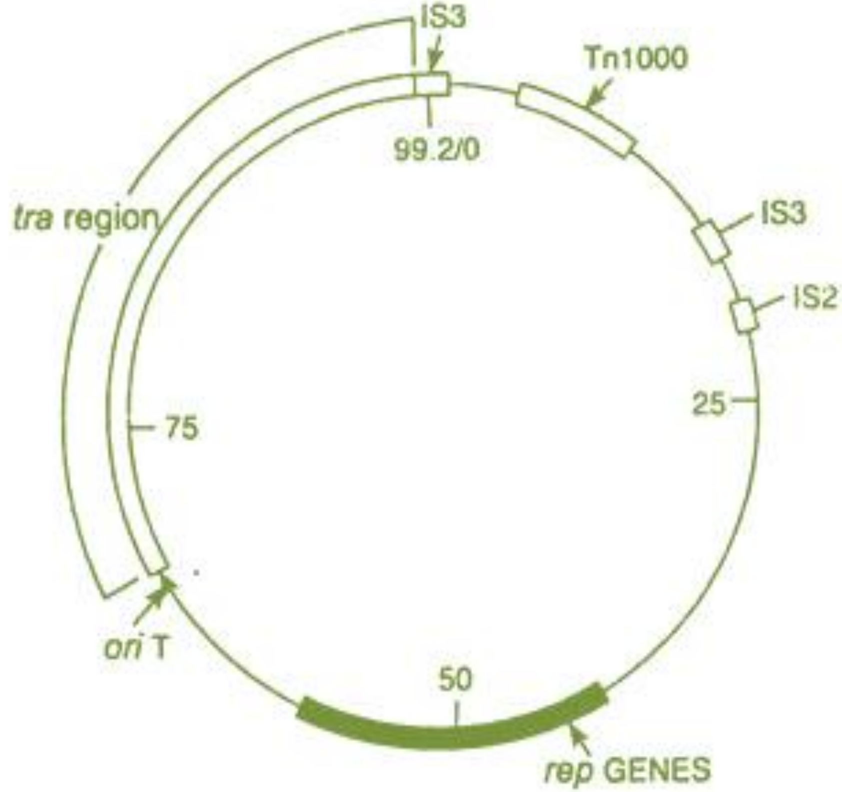


FIG. 5.31. Genetic map of the F (fertility) plasmid of *Escherichia coli*. *tra* region contains *tra* genes involved in conjugative transfer; *Ori* T sequence is the origin of transfer during conjugation; transposable element region responsible for functioning as episome, and; the *rep* genes regulate DNA replication.

A detailed knowledge of transposable elements is useful in understanding the structure and behavior of plasmid genomes. ... When a transposable elementcontains one or more accessory genes that encode a marker (such as antibiotic resistance, toxins, or virulence factors), they are called transposons.

II. R-Plasmids:

i. These are the most widespread and well studied group of plasmids. They provide resistance to antibiotics and various other growth inhibitors. Hence these are called resistant plasmids.

ii. Many of R plasmids are conjugative and possess drug resistant genes as transposable elements.

iii. They play important role in medical microbiology as they spread through natural populations during conjugation.

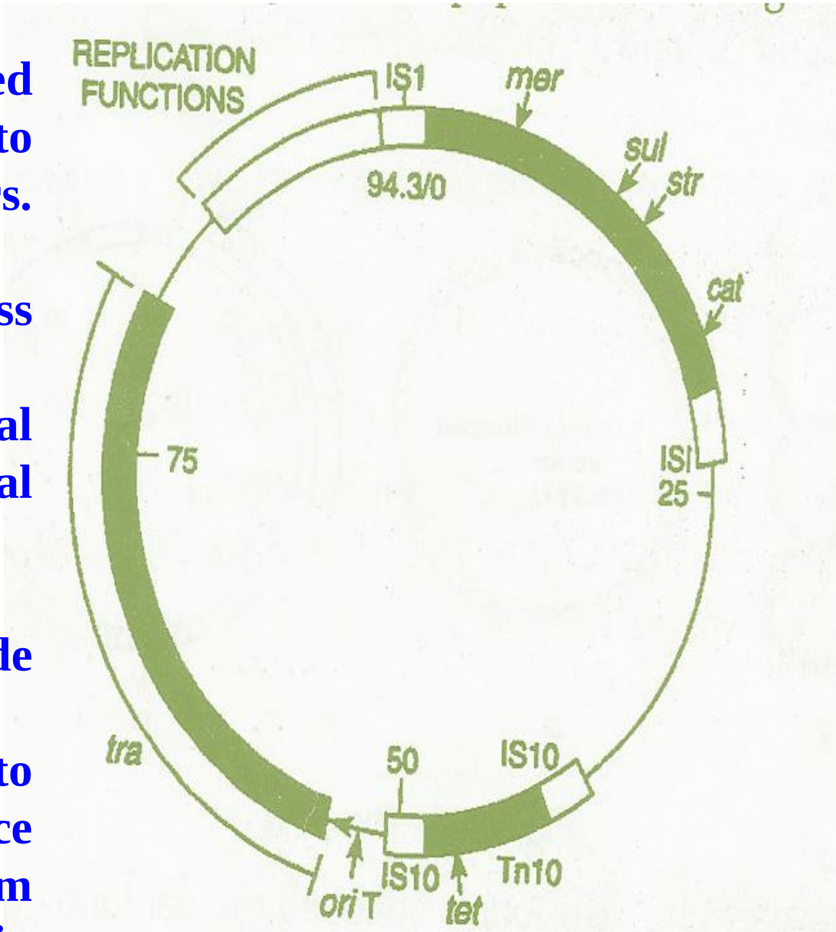
III. Virulence Plasmids:

i. These plasmids contain genes that provide pathogenicity on the host.

ii. They make the bacaterium more pathogenic to resist host defense mechanism and produce toxins.ex. Ti-plasmids of Agrobacterium tumefaciens induce crown gall disease in angiospermic plants.

IV. Col Plasmids:

i. These plasmids carry genes that provide ability to the host bacterium to kill other bacteria by secreting bacteriocins-a type of proteins.



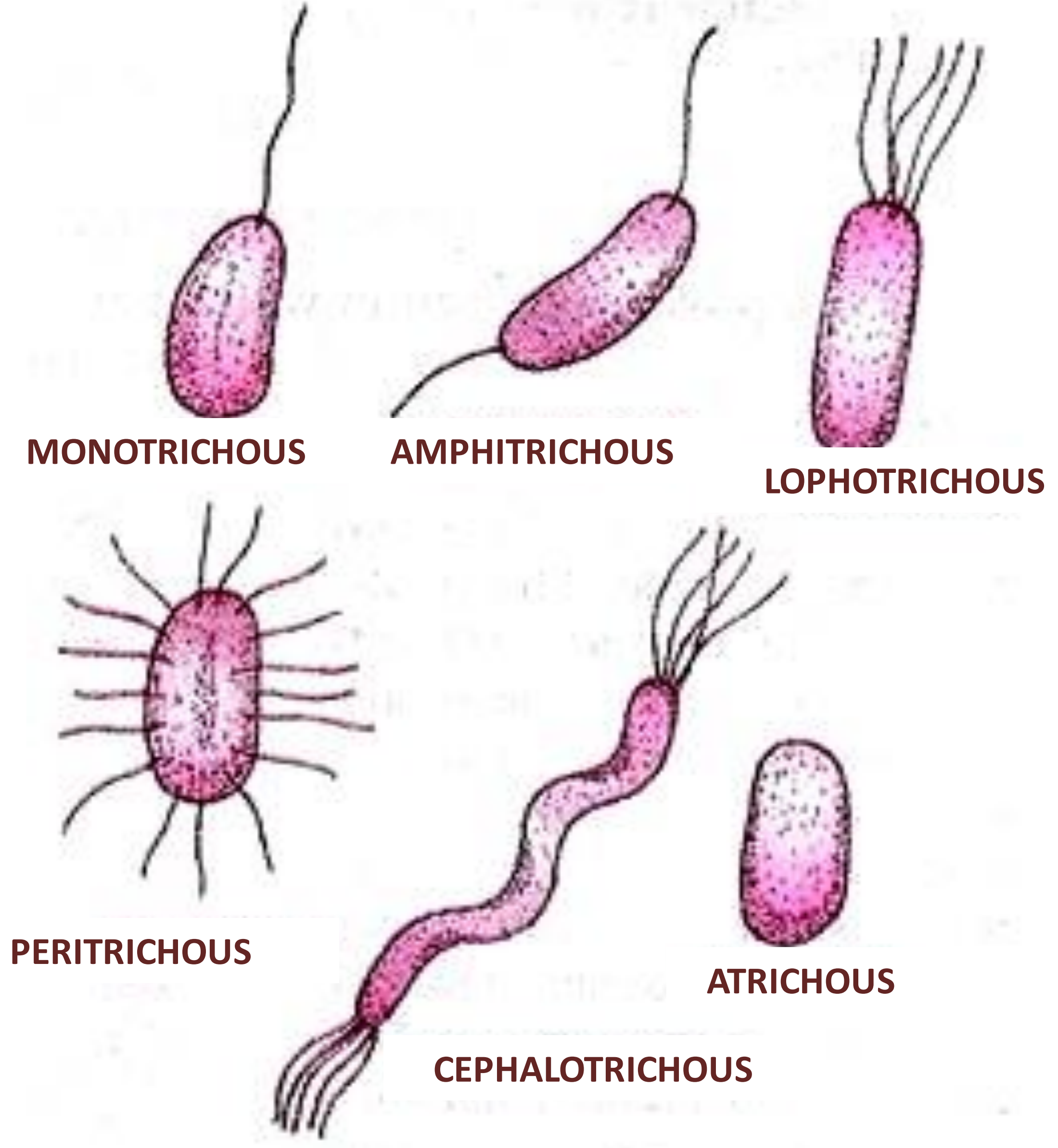
cat-Chloramphenicol resistance gene
str-Streptomycin resistance gene
sul-Sulfonamide resistance gene
mer-Mercury ion resistance gene
IS-Insertion sequences
tra-tra genes which promote transfer of plasmid during conjugation
Ori T-It is the origin of transfer of plasmid during conjugation

V. Flagella:

1. The motile bacterium possesses a flagellum(Plural:flagella).
2. The flagellum is a hair like, surface appendage emerging from the cell wall.
3. It is of 20-30 nm in diameter and 15µm long.
4. Flagella are characteristic of all spiral bacteria and they also occur in some bacillus bacteria.
5. Coccus bacteria are, however, devoid of flagella and are non-motile(Atrichous)

The number and position of flagella vary in different species. The arrangement may be –

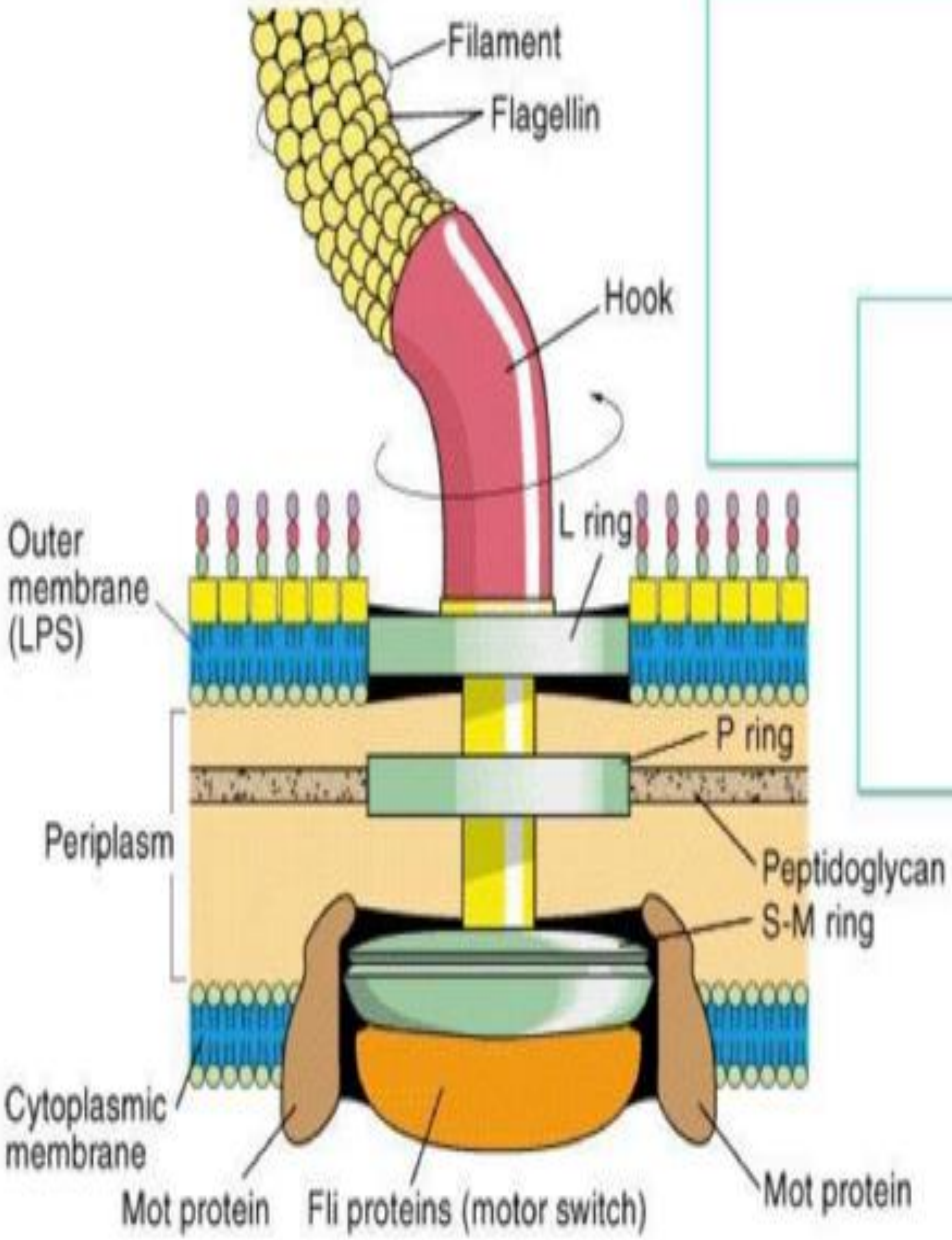
i. **Monotrichous:** A single flagellum is present at one endo of the cell. Eg. Virbri cholerae
ii. **Lophotrichous:** A group of flagell is present at one end of the cell.eg. Spirillum voluntans
iii. **Amphitrichous:** One flagellum occurs at both ends of the cell. Ex.Nitrosomonas sp.
iv. **Cephalotrichous:** Two or more flagella occur at both ends of the cell. Ex. Pseudomonas sp
v. **Peritrichous:** Cell surface is evenly surrounded by several flagella.ex. Proteus vulgaris, Bacillus typhosus.



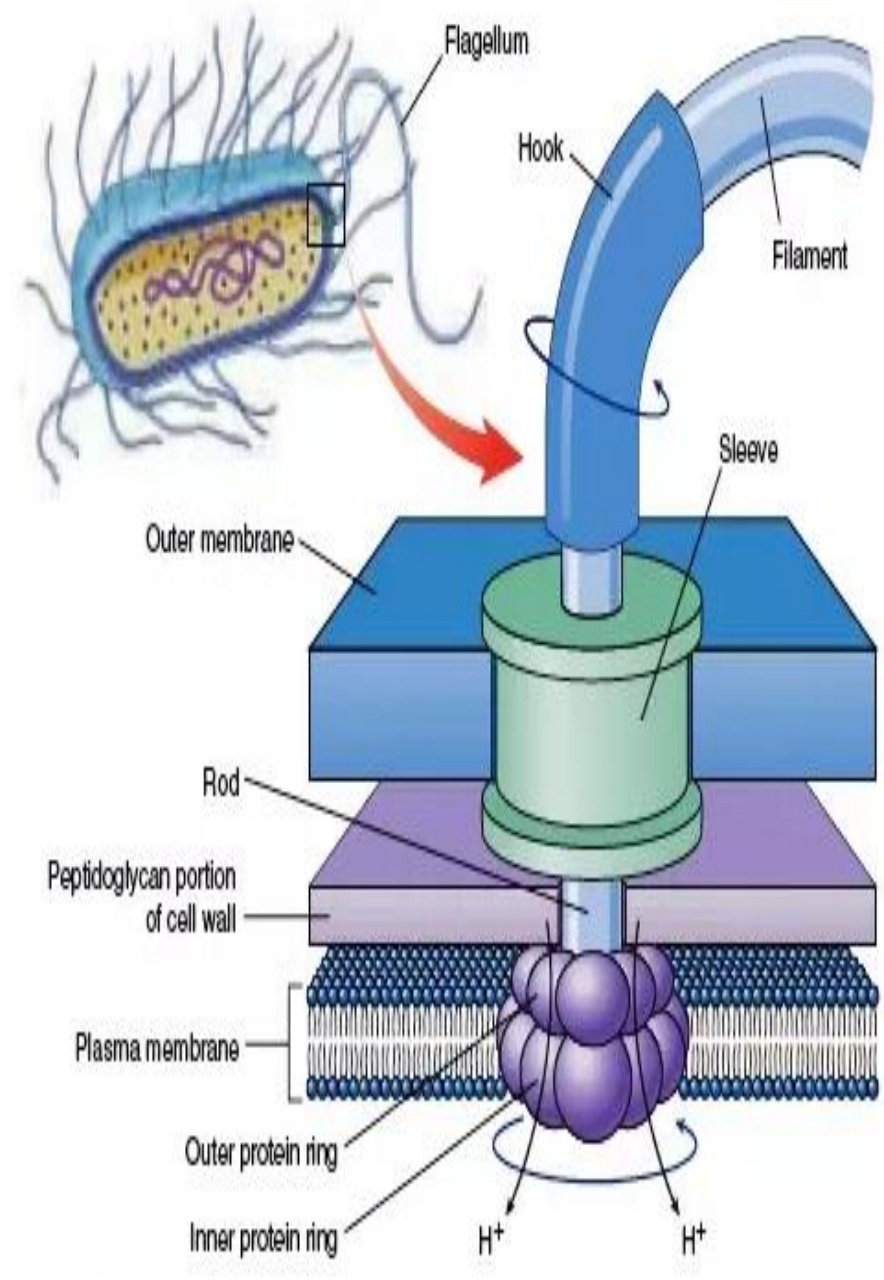
Flagellation Types in Bacteria

Structure of Flagella

1. The structure and function of bacterial flagella have been described by Simon et.al in 1978
2. A flagellum consists of three basic parts-the basal body, the hook and the filament
3. The basal body attaches the flagellum to the cell wall and plasma membrane. It is composed of small central rod inserted into a series of rings.
4. In Gram negative bacteria two pairs of rings-the proximal(outer) and the distal(inner) are connected by a central rod
5. The outer pair of rings i.e.L-ring(Lipopolysaccharide ring) and P-ring(Peptidoglycan ring) are attached to the respective polysaccharide and peptidoglycan layer of the cell wall
6. The inner pair of rings i.e. M-ring(Membrane ring) and S-ring(Super membrane ring) are attached with the cell membrane.
7. In Gram positive bacteria only the distal(inner) pair of rings is present. The S-ring is attached to the inner side of thick peptidoglycan layer and M-ring is attached to the cell membrane.



8. The hook is present outside the cell wall and connects the filament to the basal body. It consists of different proteins.
9. The outermost long hair like structure of the flagellum is called filament. It is made up globular proteins called flagellin
10. The flagellin molecules are arranged in several chains that intertwine and form a helix around a hollow core.
11. Unlike Eukaryotes the filaments are not covered by a membrane or sheath and do not show 9+2 type of arrangement



Reproduction in Bacteria

1. Bacteria reproduce mainly by asexual methods and therefore they have dominant haploid phase in their life-cycle
2. They do not have sex organs or gametes but they definitely show genetic recombination i.e. exchange of genetic materials

Asexual Reproduction

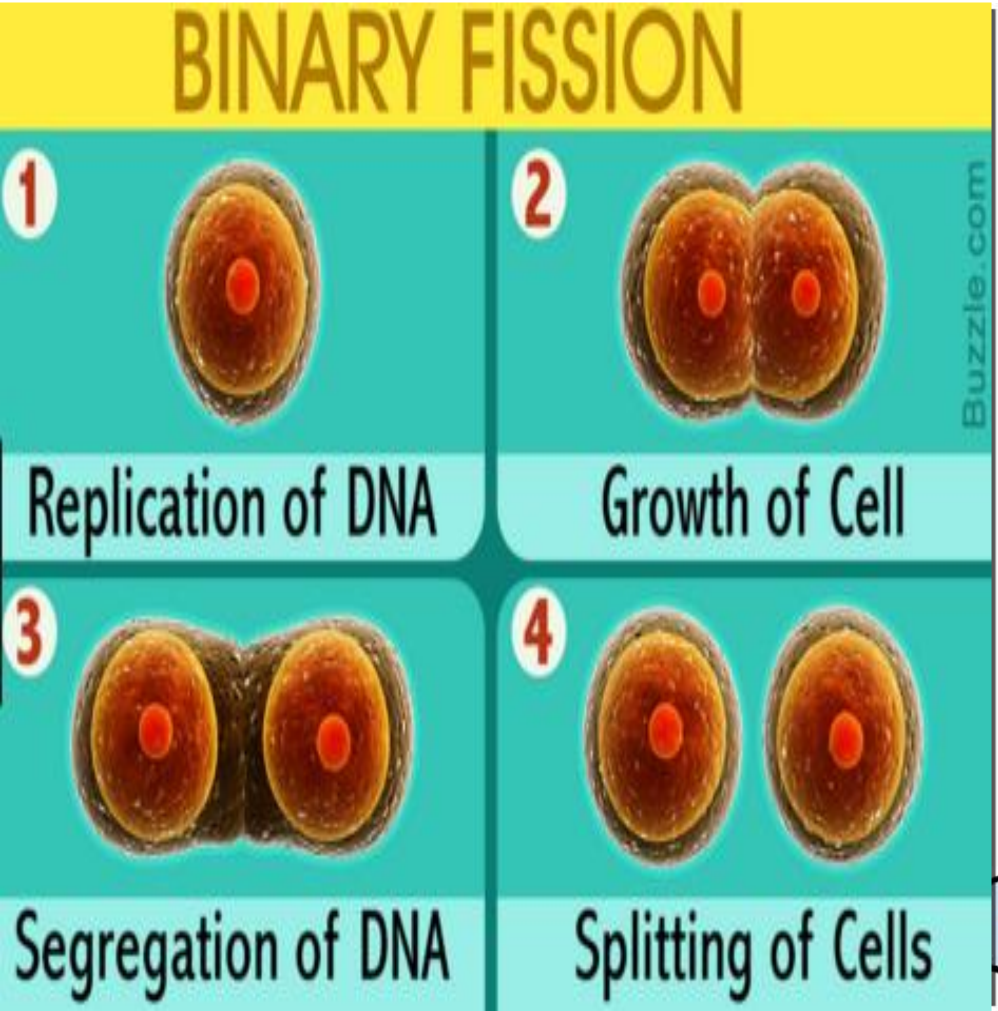
Asexual reproduction in bacteria takes place by the following methods.

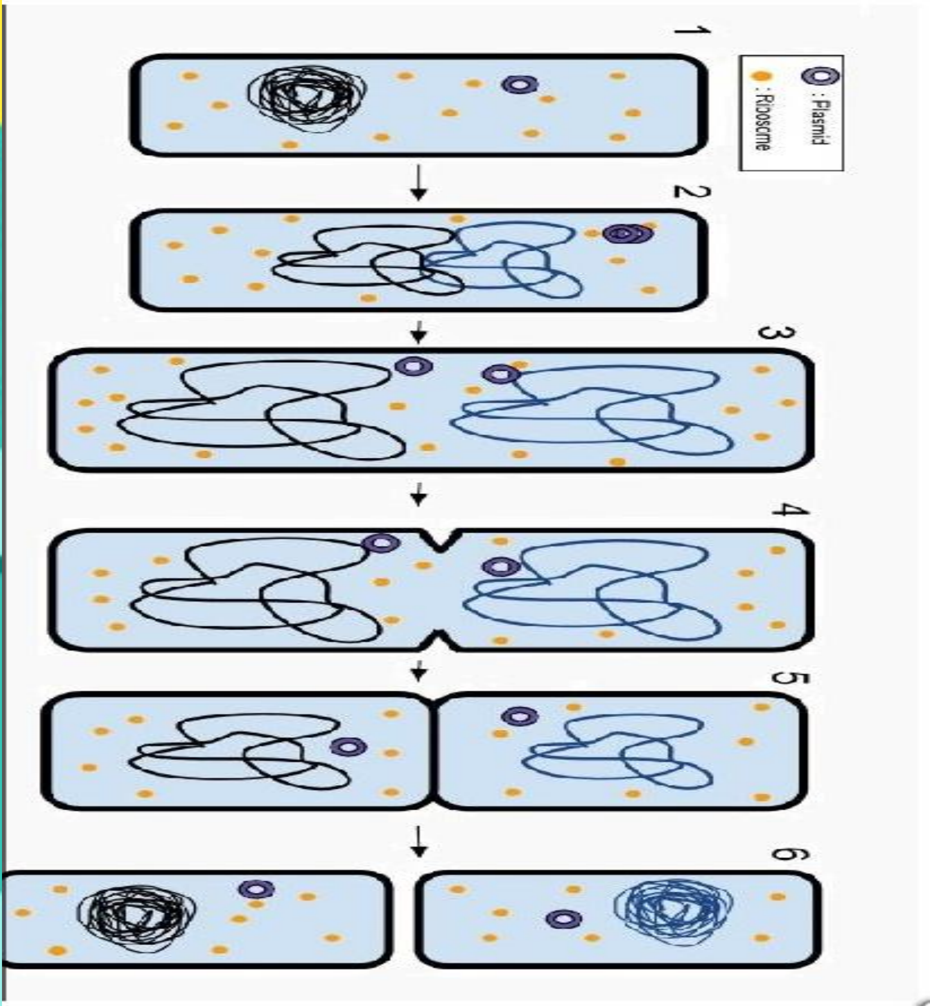
I. Binary Fission:

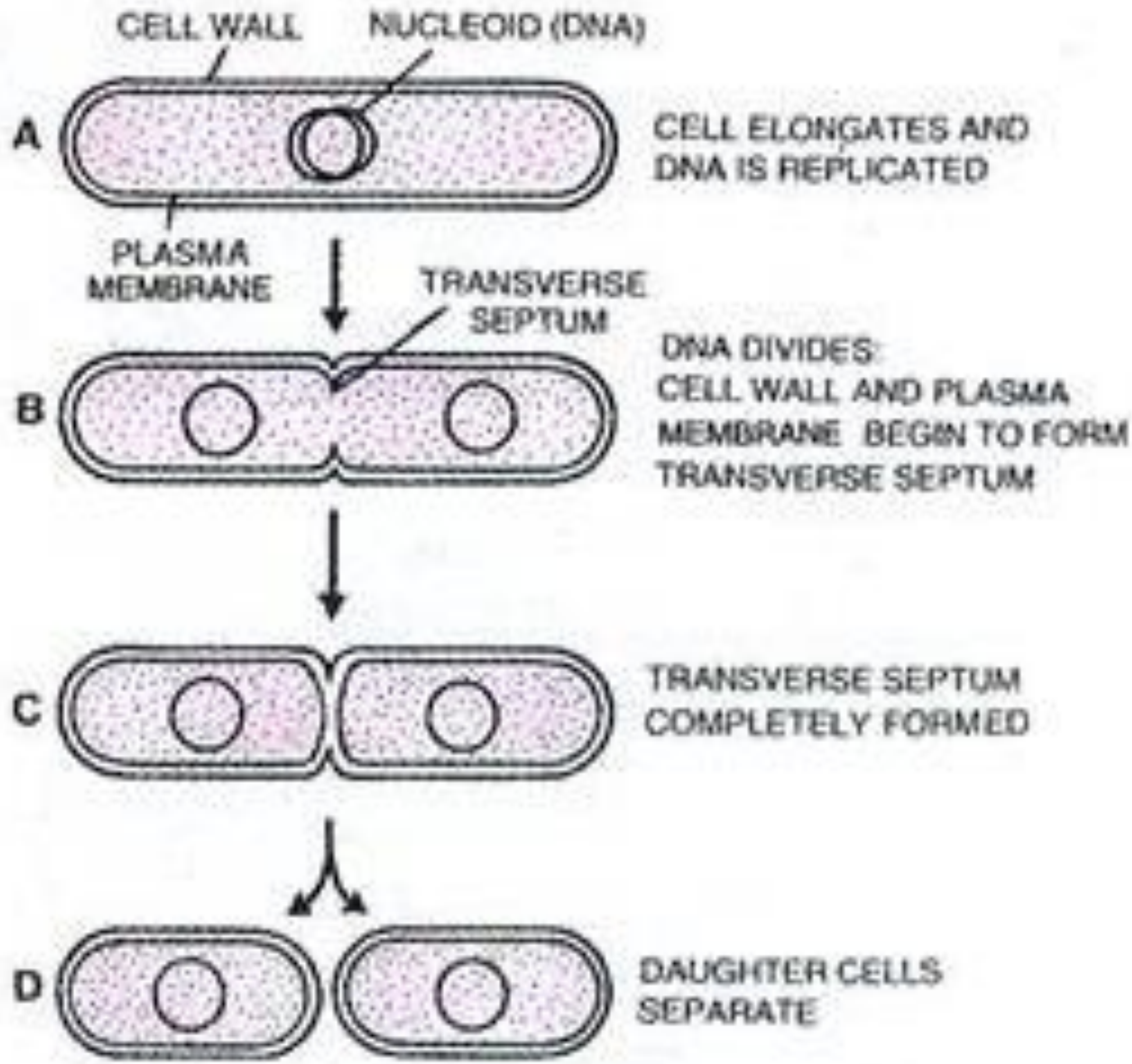
1. It is the simplest and most common method of multiplication in bacteria
2. Under favorable conditions, the cell divides into two daughter cells by a transverse wall. This is called binary fission.
3. During cell division, the cell elongates and there is division of nuclear material(DNA). It is followed by the distribution of DNA
4. The cytoplasmic membrane grows into the centre of the cell resulting in a transverse septum.
5. Then the cell wall on both sides grows inward towards the centre of the cell forming a cross wall.
6. The daughter cells are separated by cleaving along the length of the septum

7. Process of binary fission is very rapid. Bacterial cells may undergo fission for every 20-30 minutes under favorable conditions. Within 6 hours approximately 2,50,000 cells may be formed from a single bacterium. The time required for a cell to divide by binary fission is called *doubling time* or *generation* time.

8. Fission is characteristic of all types of bacteria and that is why they have been placed in the class Schizomycetes(Schizo=split or cut, mycetes=fungi: split, cut or fission fungi)







Binary fission in bacteria.

Fig07.15

1. A young cell at early phase of cycle

2. A parent cell prepares for division by enlarging its cell wall, cell membrane, and overall volume. Midway in the cell, the wall develops notches that will eventually form the transverse septum, and the duplicated chromosome becomes affixed to a special membrane site.

3. The septum wall grows inward, and the chromosomes are pulled toward opposite cell ends as the membrane enlarges. Other cytoplasmic components are distributed (randomly) to the two developing cells.

4. The septum is synthesized completely through the cell center, and the cell membrane patches itself so that there are two separate cell chambers.

5. At this point, the daughter cells are divided. Some species will separate completely as shown here, while others will remain attached, forming chains or doublets, for example.