Structure of Bacterial cell

Dr. Prosanta Saha

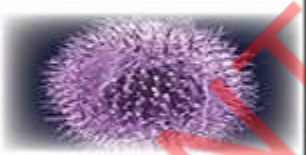
Table 2.1. Summary of the equivalences in Kingdom classification

Linnaeus 1735 2 kingdoms	Haeckel 1866 3 kingdoms	Chatton 1937 2 empires	Copeland 1956 4 kingdoms	Whittaker 1969 5 kingdoms	Woese et al. 1977 6 kingdoms	Woese et al. 1990 3 domains
(not treated)	Protista	Prokaryota	Monera	Monera	Eubacteria	Bacteria
					Archaebacteria	Archaea
		Eukaryota	Protoctista	Protista	Prostista	
				Fungi	Fungi	
Vegetabilia	Plantae		Plantae	Plantae	Plantae	Eukarya
Animalia	Animalia		Animalia	Animalia	Animalia	

SIX KINGDOMS


ARCHAEOBACTERIA

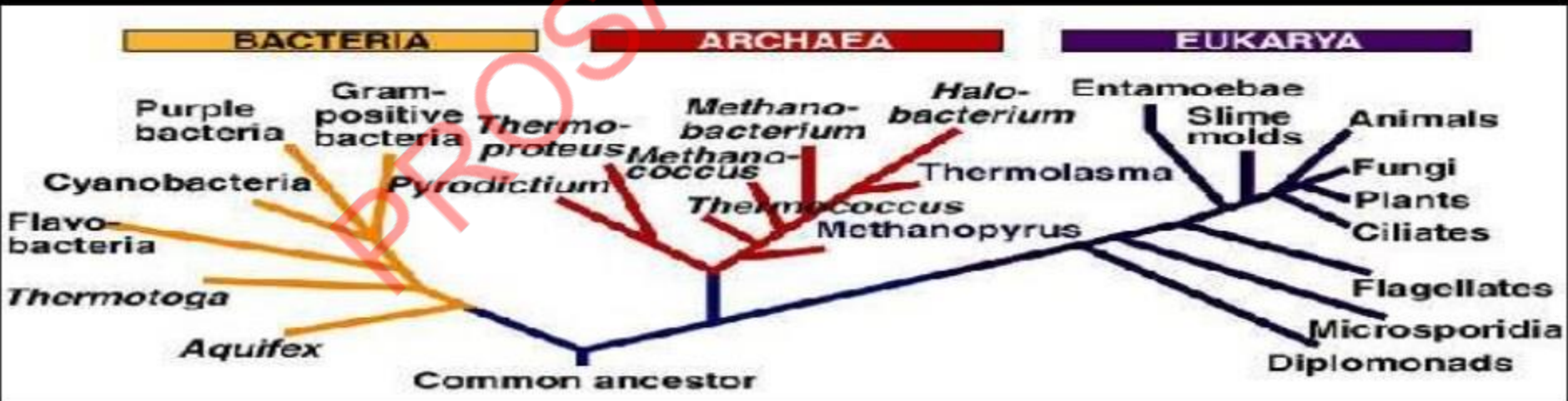

EUBACTERIA


PROTOCTISTA


FUNGI


PLANTAE


ANIMALIA



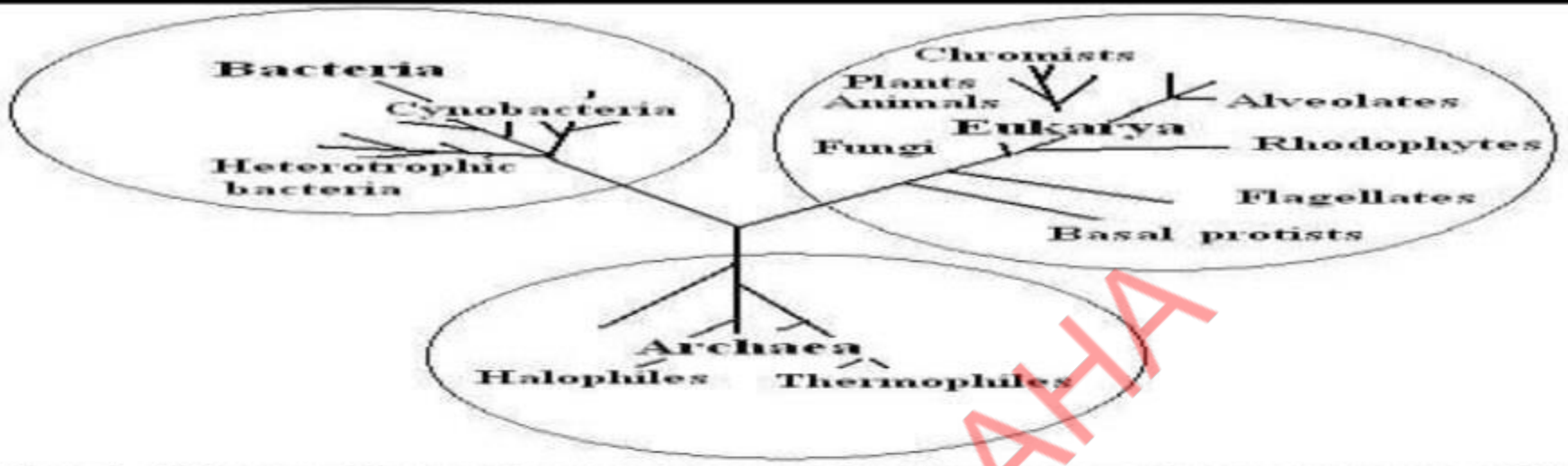
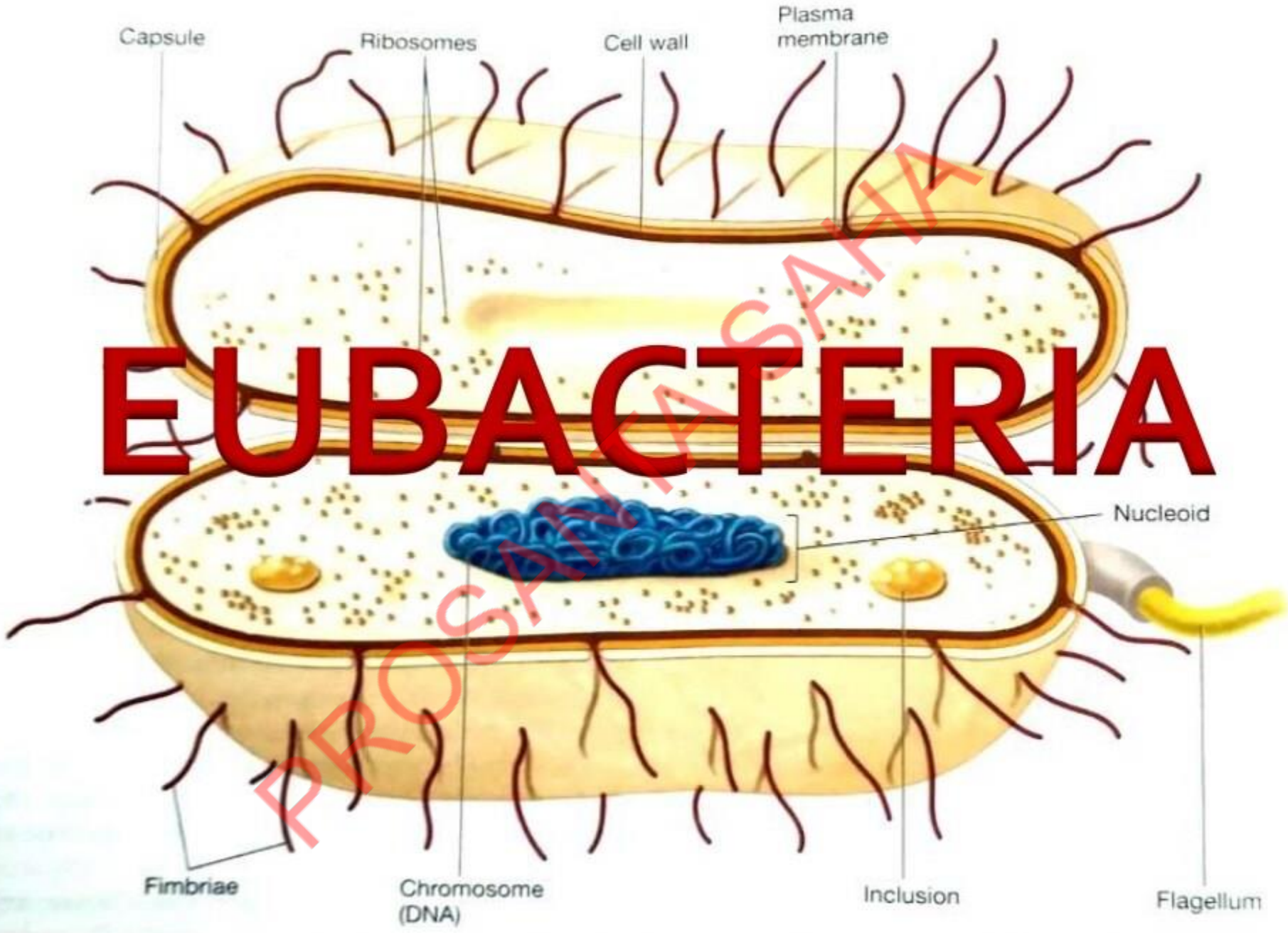


Fig 1. Three Domain system of living organism proposed by Carl Woese

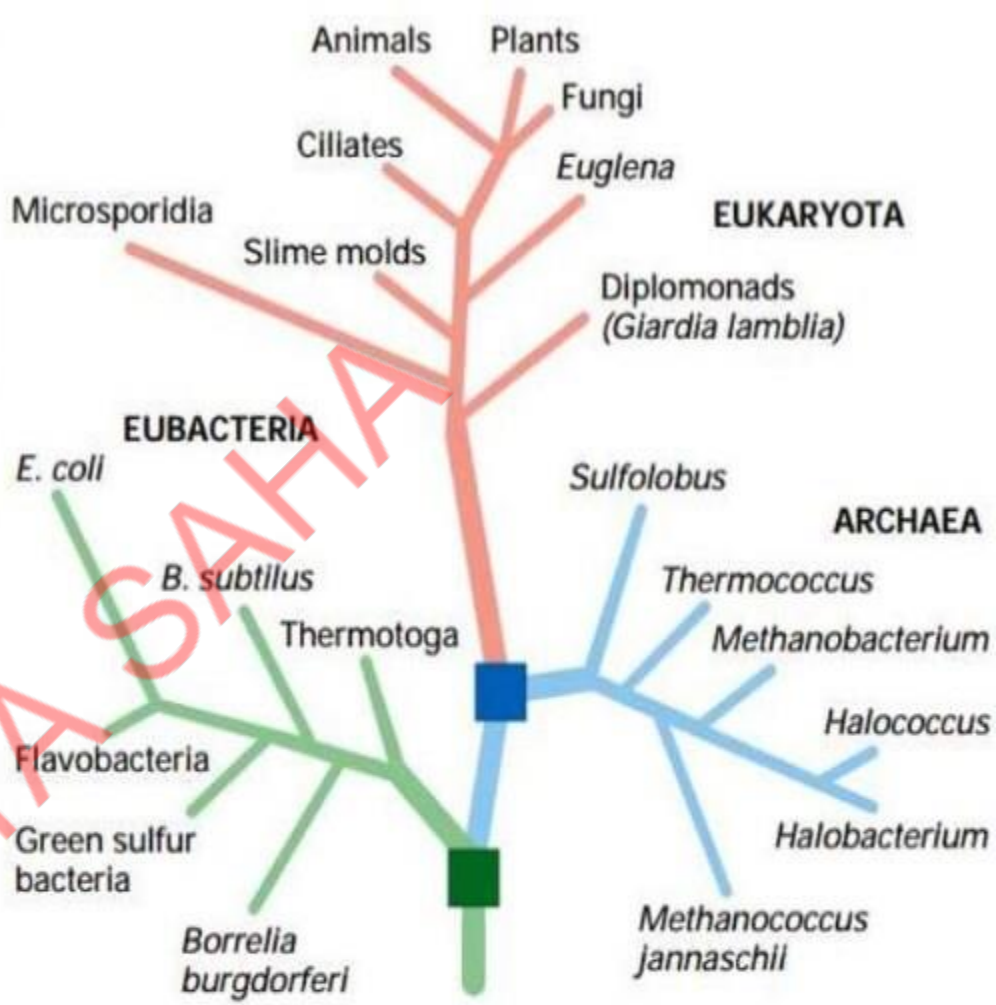
Domain	Bacteria	Archaea	Eukarya			
Kingdom	Eubacteria	Archaebacteria	Protista	Fungi	Plantae	Animalia
Cell Type: Prokaryotic or Eukaryotic?	Prokaryotic	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell Structures: Cell Wall or Chloroplast?	Cell Walls with peptidoglycan	Cell Walls without peptidoglycan	Cell walls of cellulose in some; some have chloroplasts	Cell Walls of chitin	Cell Walls of cellulose; chloroplasts	No cell walls or chloroplasts
Number of Cells: Unicellular or Multicellular?	Unicellular	Unicellular	Most Unicellular; some colonial; some multicellular	Most multicellular; some unicellular	Most multicellular; some green algae unicellular	Multicellular
Mode of Nutrition: Heterotroph or Autotroph?	Heterotroph or Autotroph	Heterotroph or Autotroph	Heterotroph or Autotroph	Heterotroph	Autotroph	Heterotroph
Examples: Type of organism?	*Streptococcus, Escherichia coli*	Methanogens, halophiles	*Amoeba, Paramecium,* Slime Molds, Giant Kelp	Mushrooms, Yeast	Mosses, Ferns, Flowering Plants	Sponges, Worms, Insects, Fishes, Mammals

EUBACTERIA



INTRODUCTION

- The study of bacteria is known as bacteriology a branch of microbiology.
- Eubacteria are the simplest, the smallest and the most successful prokaryotic microorganisms.
- Eubacteria were among the first life forms to appear on Earth.
- The Eubacteria are single celled organisms that reproduce by simple division, i.e. binary fission.
- Most are free living and contain the genetic information, energy-producing and biosynthetic systems necessary for growth and reproduction.



▲ **FIGURE 1-3 All organisms from simple bacteria to complex mammals probably evolved from a common, single-celled progenitor.** This family tree depicts the evolutionary

Introduction

- All bacteria are unicellular organisms that reproduce by binary fission.
- Most bacteria are capable of independent metabolic existence and growth, but species of Chlamydia and rickettsia are obligately intracellular organism.
- Bacterial cells are extremely small and are most conveniently measured in microns (10^{-6} m).
- Bacterial cells are usually between 0.4 and 1.5 micro meter in short diameter.

GENERAL CHARACTERISTICS OF EUBACTERIA

- Cosmopolitan
- Microscopic in nature
- Size: 0.5-1.0µm
- Unicellular
- Prokaryotic type of cellular organization
- They may be Autotrophic, Heterotrophic and Saprophytic.
- Motile Bacteria may possess flagella.
- Cell wall is made up of Peptidoglycan.
- All cell organelles are absent(except Ribosomes)
- Ribosomes are abundant (70S).
- Mesosomes are present.
- Chlorophyll pigments, if present, are located within involuted cytoplasmic membranes.
- Binary fission is the common method of multiplication.
- True sexual reproduction is absent.

Distribution:

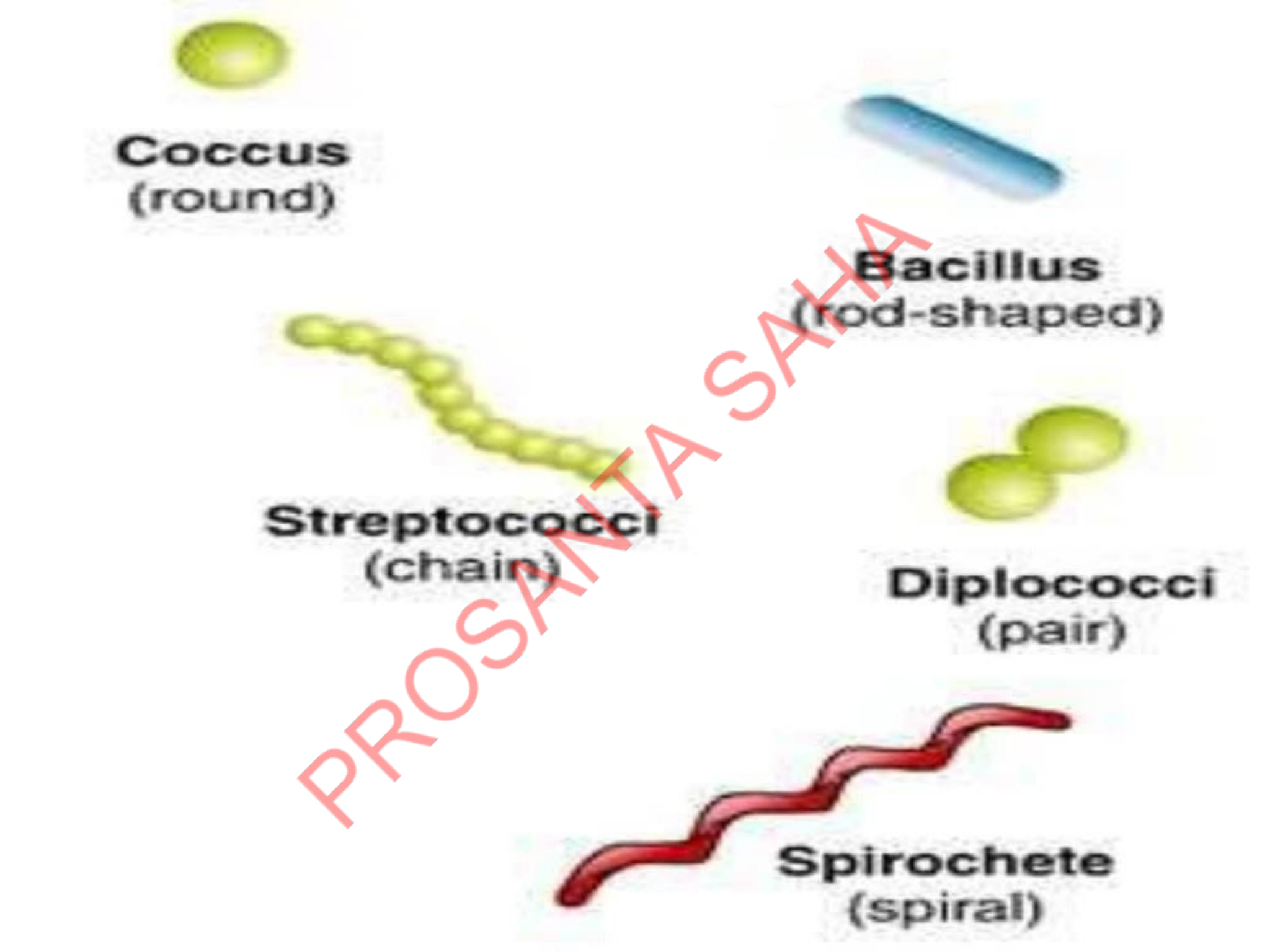
Exists everywhere….!!!!!!!

Apart from normal Environmental conditions…..

- Occur in atmosphere to an height of about 6 KM & on the sea floor 5 KM below the mean sea level.
- Exist in Hot springs.
- Can survive below Freezing point of water.
- Tolerate to pH range from 0-11 .
- Can tolerate Pressure of 3000-6000 atm.
- Exist as Free living, Parasitic and Symbiotic.

Cell Morphology

- Bacteria have characteristic shape. The common microscopic morphologies are :
  - spherical or ovoid (cocci)
  - rod –shaped (bacilli)
  - comma shaped (vibrio)
  - spiral (spirillum and spirochete)
- Some cocci characterristically grouped in pairs or chains; some form grapelike clusters of sperical cells; some round cocci form cubic packets.
- Bacterial cell of other species grow separately .
- The microscopic appearance is therefore valuable in classification and diagnosis.



Shape of Eubacteria

Depending on their shape, bacteria are classified into several varieties :

1. **Cocci:** Cocci (from kokkos meaning berry) spherical, or nearly spherical.

2. **Bacilli:** Bacilli (from baculus meaning rod) relatively straight, rod shaped (cylindrical) cells.

3. **Vibrios:** Vibrios are curved or comma-shaped rods and derive the name from their characteristic vibratory motility.

4. **Spirilla:** Spirilla are rigid spiral or helical forms.

5. **Spirochetes:** Spirochetes (from speira meaning coil and chaite meaning hair) are flexuous spiral forms.

6. **Mycoplasma:** Mycoplasma are cell wall deficient bacteria and hence do not possess a stable morphology. They occur as round or oval bodies and interlacing filaments.

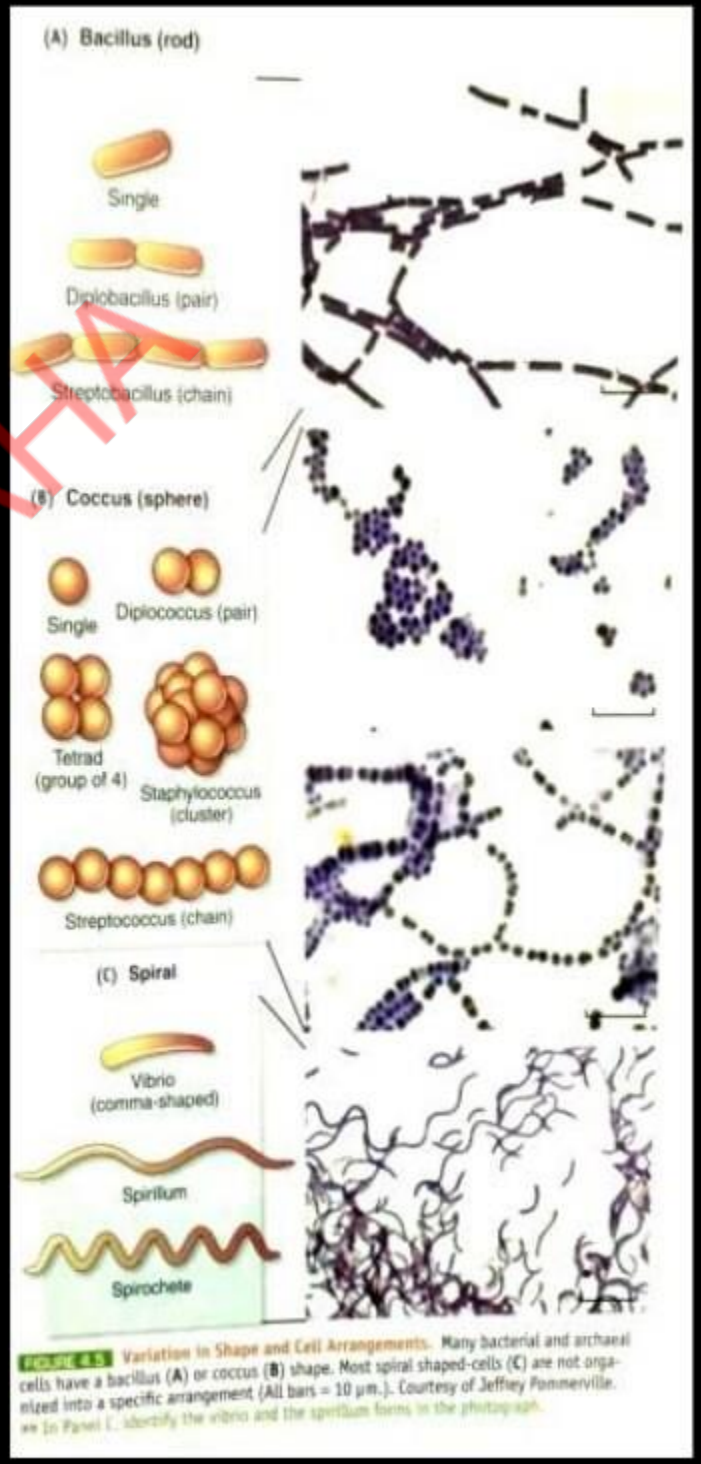


FIGURE 4.5 Variation in Shape and Cell Arrangements. Many bacterial and archaeal cells have a bacillus (A) or coccus (B) shape. Most spiral shaped-cells (C) are not organized into a specific arrangement (All bars = 10 μm.). Courtesy of Jeffrey Pommerville.

Arrangement Of Eubacteria

(*i*) **Coccus Forms :** There are several groups of cocci based on the number and arrangement of cells.

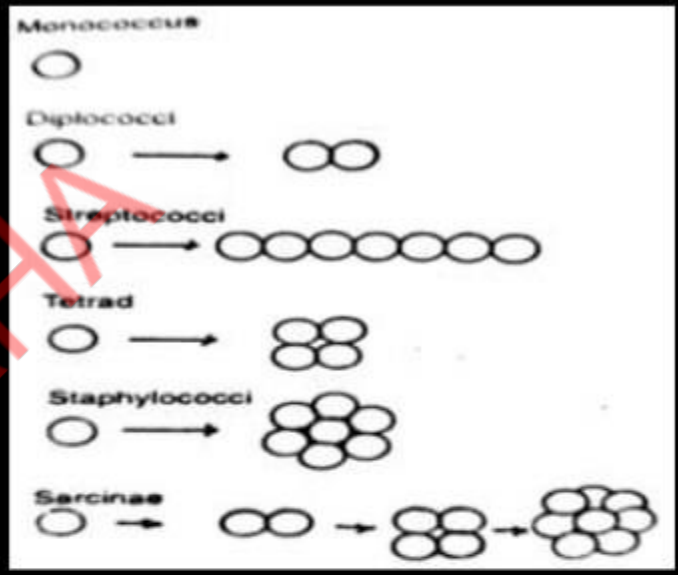
(*a*) **Diplococcus :** Cells divide in one plane and get attached permanently in pairs.

(*b*) **Streptococcus :** Cells divide in one plane and remain attached to form a linear chain of cells.

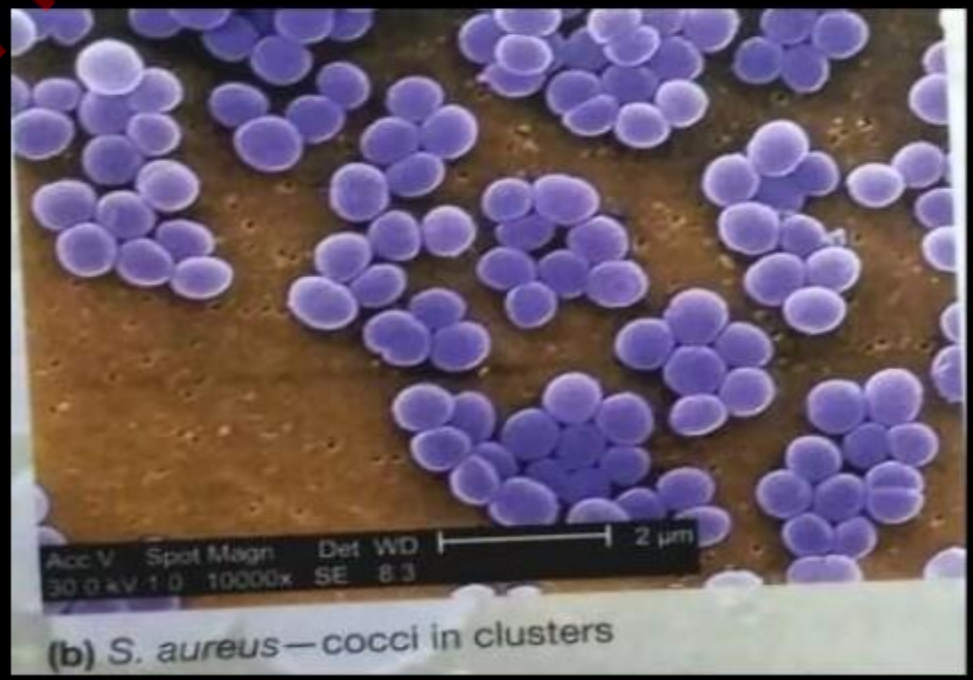
(*c*) **Tetracocci :** Cells divide in two planes and form groups of four cells.

(*d*) **Straphylococci :** Cells divide in three planes in an irregular pattern producing bunches of cocci.

(*e*) **Sarcinae :** Cells divide in three planes in regular pattern producing bunches of cocci.




(a) *S. agalactiae*—cocci in chains



(b) *S. aureus*—cocci in clusters

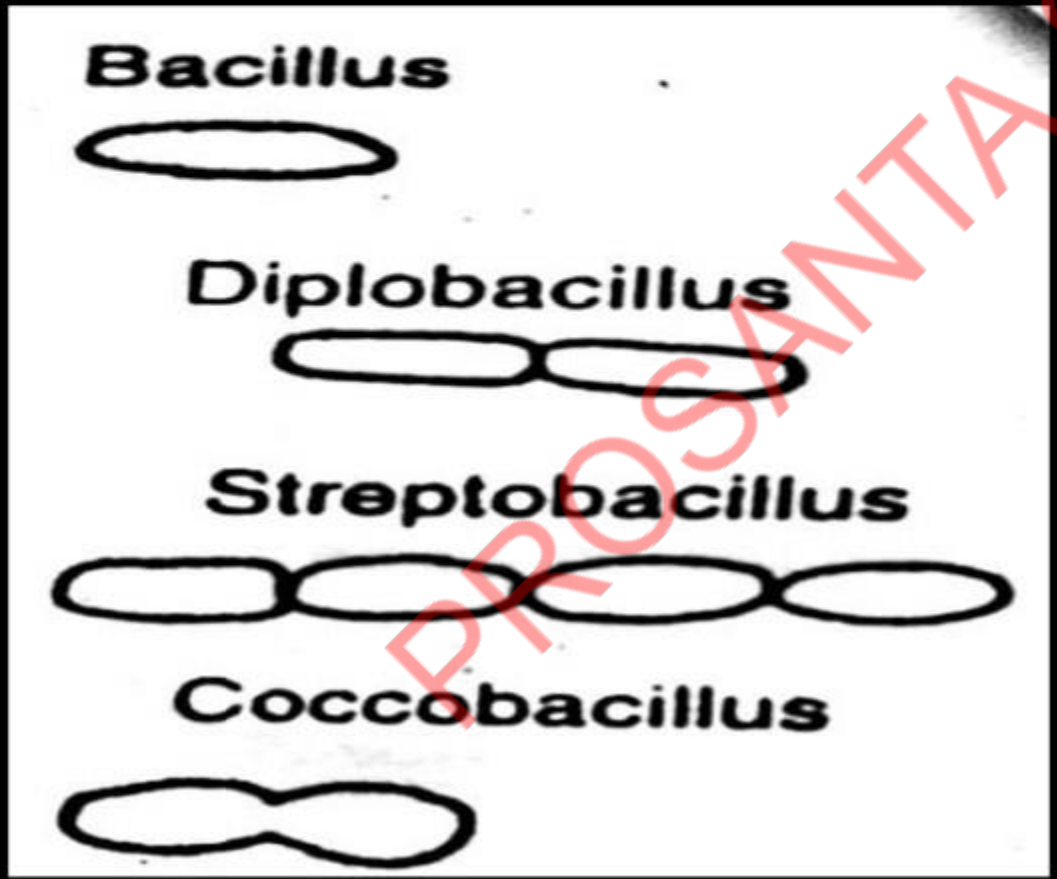
(*ii*) Forms of Bacillus : There are a few groups of bacilli unlike cocci as the former divide across their short aries.

(*a*) Monobacillus : The single elongated cells freely present in nature are monobacillus.

(*b*) Diplobacillus : After division the cells remain adhered and appear in paired form.

(*c*) Streptobacillus : After division the cells remain attached in chains appearing like straws.

(*d*) Coccobacillus : The oval cells looking like cocci are called coccobacilli.

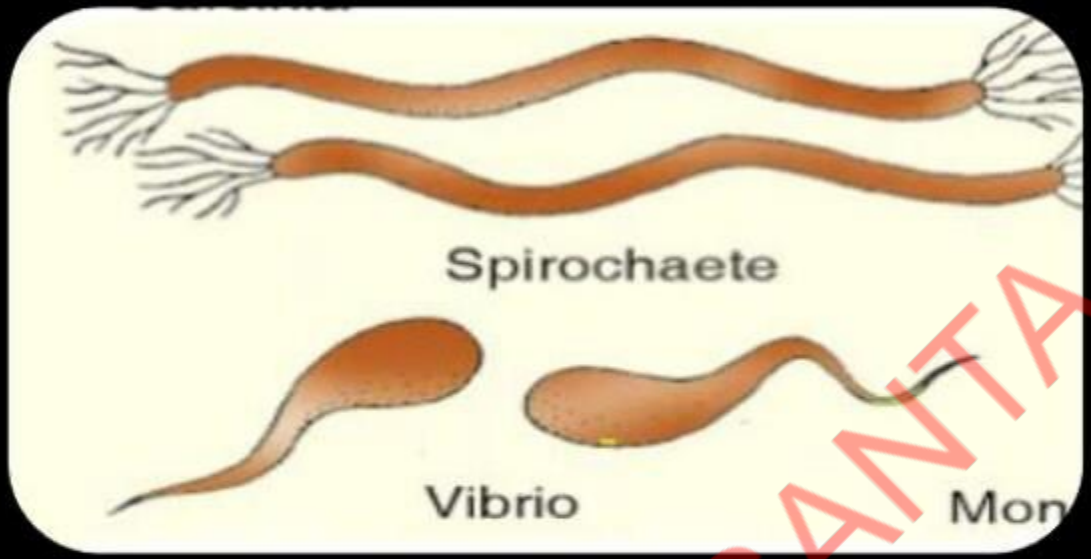


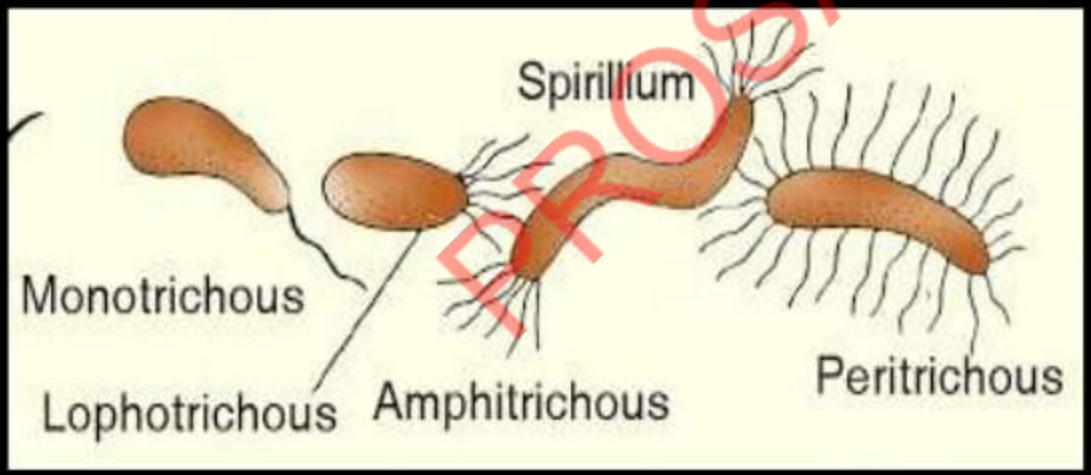
(c) *B. megaterium*—rods in chains

(*iii*) Forms of Spirilli :

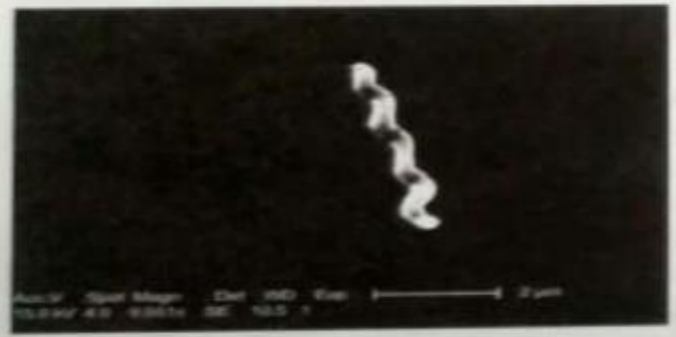
(*a*) Vibrioid : Bacterial cells having less than one complete twist form vibrioid shape e.g. *Vibrio cholerae*.

(*b*) Helical : Cells that have more than one twist form a distinct helical shape e.g. *Spirillum* (with flagella).






(a) *V. cholerae*—comma-shaped vibrios


(b) *C. jejuni*—Spiral-shaped spirillum


(c) *Leptospira interrogans*—a spirochete

(*iv*) Other Forms :

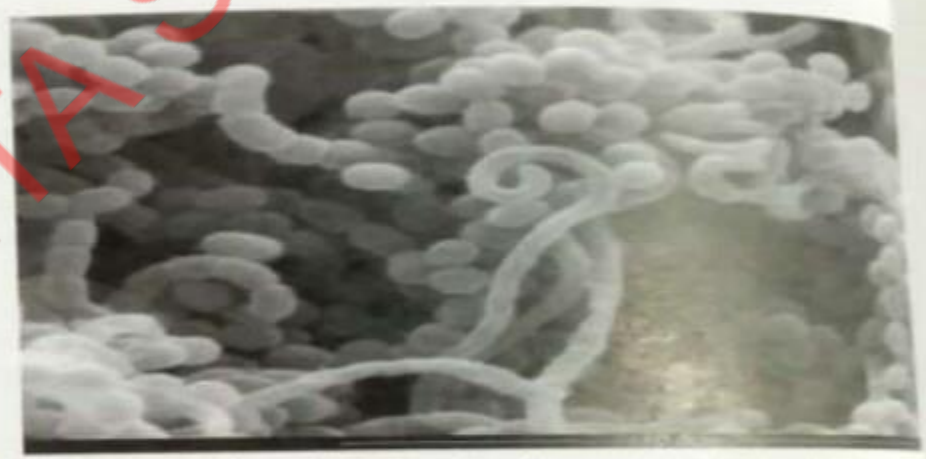
(*a*) Pleomorphic : Of changing forms e.g. *Rhizobium, Mycoplasma,* etc.

(*b*) Trichomes : Cells divide in one plane forming a chain which has much larger area of contact between the adjacent cells e.g. *Baggiatoa, Saprospria.*

(*c*) Palisade : The cells are arranged laterally (side by side) to form a match sticks like structure and at angles to one another e.g. *Corynebacterium diphtheriae.*

(*d*) Hyphae : Some microorganisms form the multicellular, thin-walled, profusely branched filaments called hyphae. The interwoven hyphae are collectively known as mycelium e.g.

(d) *Hyphomicrobium*


(e) *Streptomyces* — a filamentous bacterium


(f) *M. stipitatus* fruiting body

Content

- Introduction
- Cell Morphology
- Structure of bacterial cell
    - 1] Cell Wall
    - 2] Plasma membrane
    - 3] Extracellular (external) structure
    - 4] Intracellular (Internal) structure

Structure of Bacterial cell

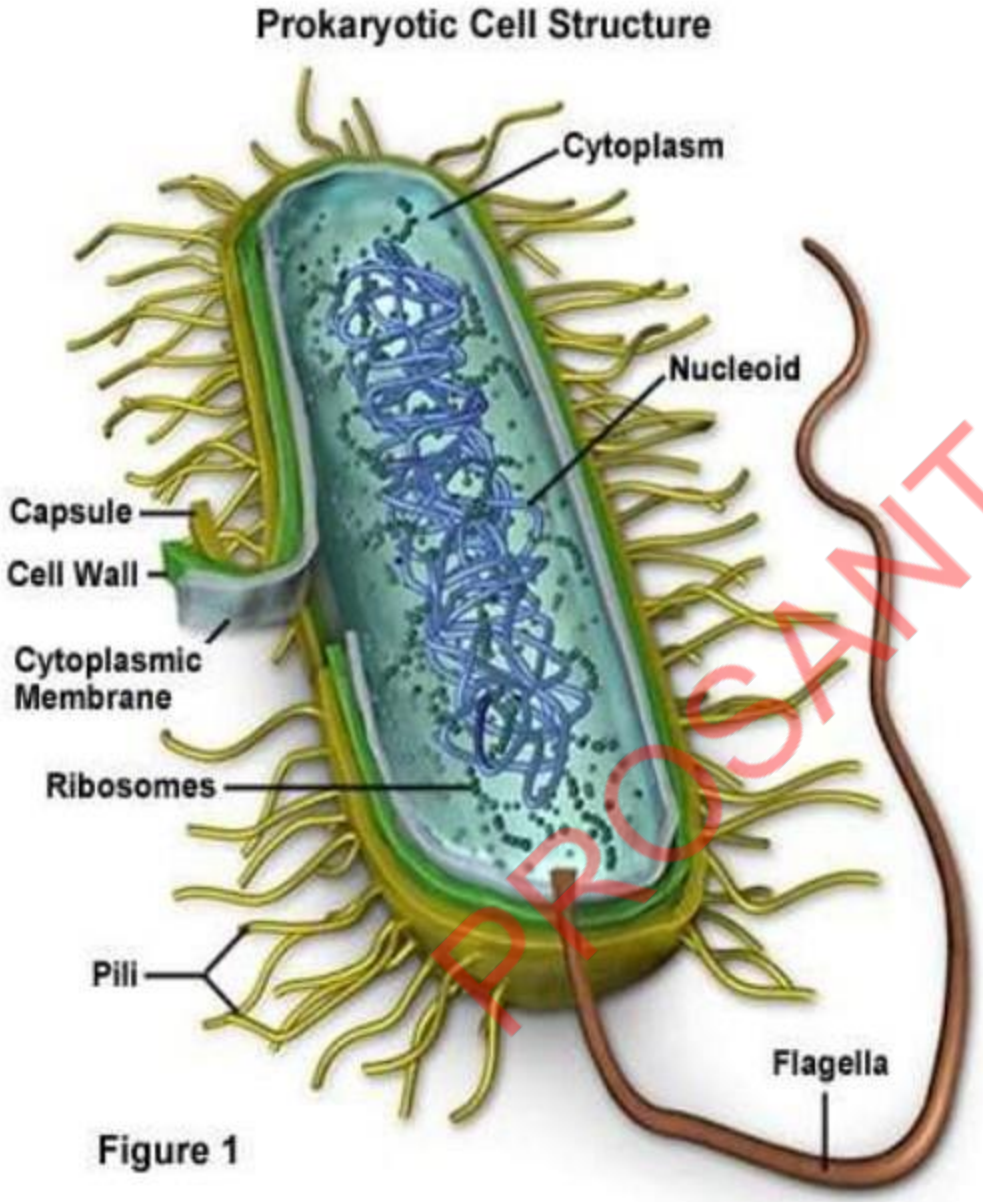
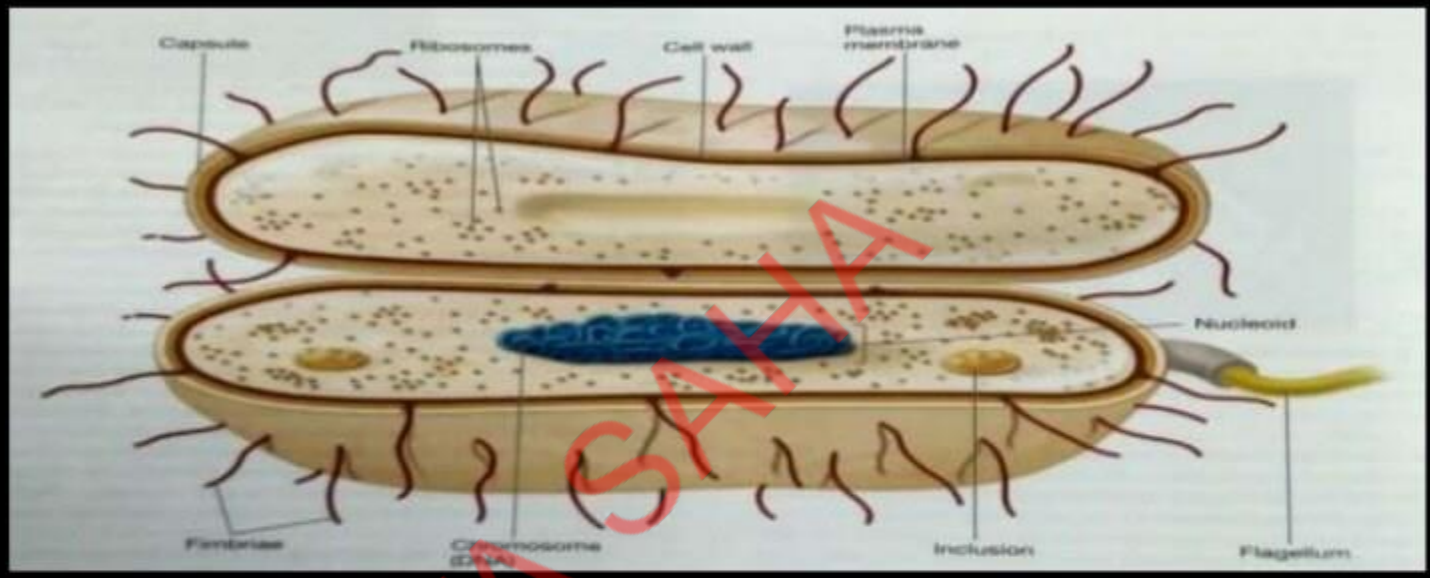


Figure 1

- The protoplast , i.e. the whole body of living material (protoplasm) is bounded paripherally by a very thin, elastic and semipermeable cytoplasmic membrane.
- Outside and colsely covering this lies the rigid ,supporting cell wall, which is porous and relativity permeable.

Ultra-Structure of Eubacterial Cell:

[A] Cellular projection
i) Flagella
ii) Pili
iii) Fimbrae
[B] Protective layers
i) Capsule
ii) Cell Wall
iii) Cell Membrane
[C] Cytoplasm
i) Cytoplasm
ii) Nucleoid
iii) Cytoplasmic Organelles



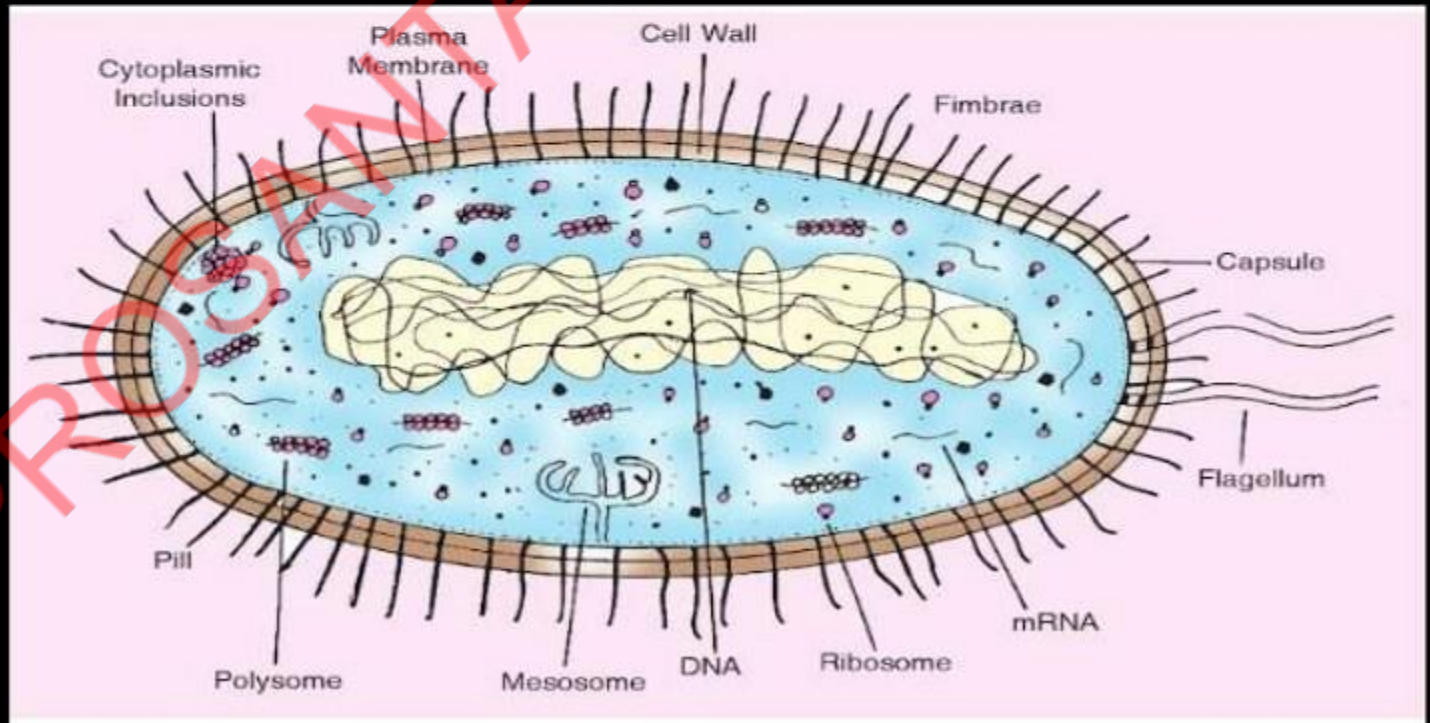
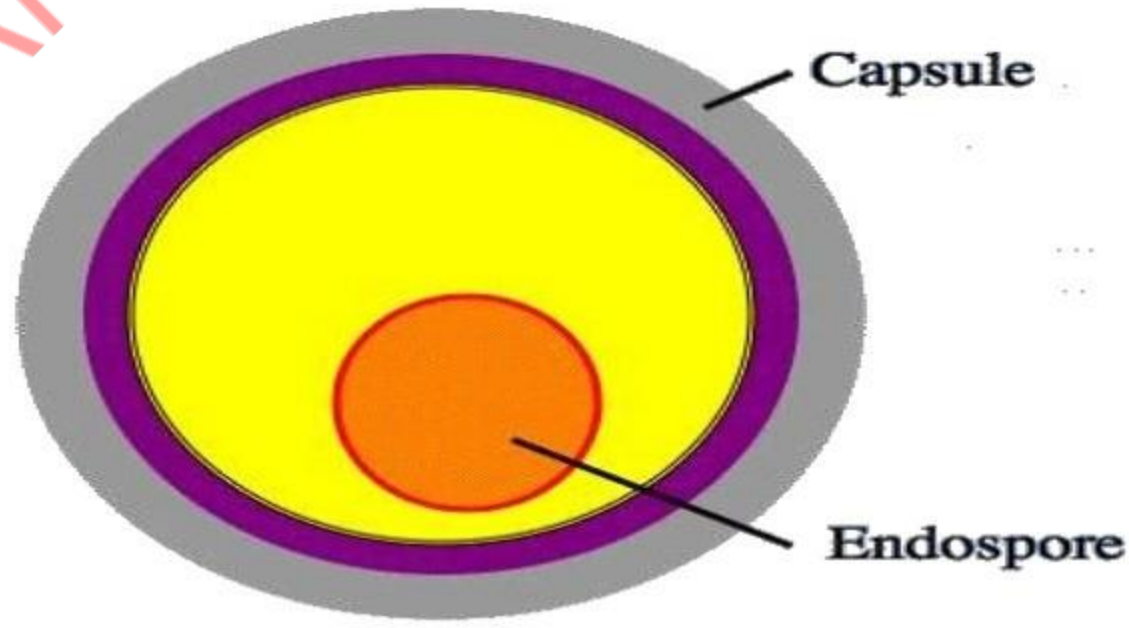


Fig. 4.2 : Structure of a typical bacterial cell (diagrammatic)

•Capsule (Slime layer) :-

- The capsule of most bacteria consists of a polysaccharide.
- The bacteria of a single species can be classified in different capsule serovas or serotype based on the fine chemical structure of this polysaccheride.



i. Capsule or Slime Layer or glycocalyx

Structure:

- Many bacteria synthesize large amount of extracellular condensed polymer.

- well defined polymer layer closely surrounding the cell, is called as capsule as in the *pneumococcus*.

- If the polymer is easily washed off and does not appear to be associated with the cell in any definite fashion, it is referred as a slime layer as in *Leuconostoc*.

- *A glycocalyx is a network of polysaccharide extending from the surface of bacteria and other cells.*
- *Capsules too thin to be seen under the light microscope are called microcapsules.*

Capsulated bacteria: *Streptococcus pneumoniae, several groups of streptococci, Neisseria meningitidis, Klebsiella, Haemophilus influenzae, Yersinia and Bacillus.*

Some bacteria may have both a capsule and a slime layer (for example : Streptococcus salivarius).

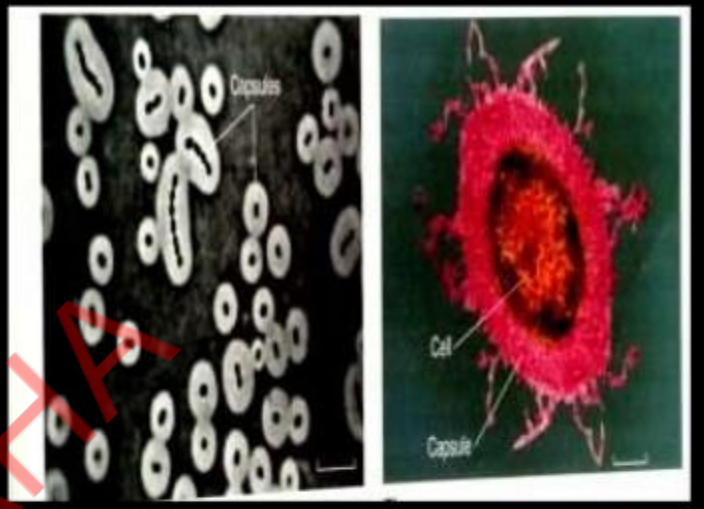
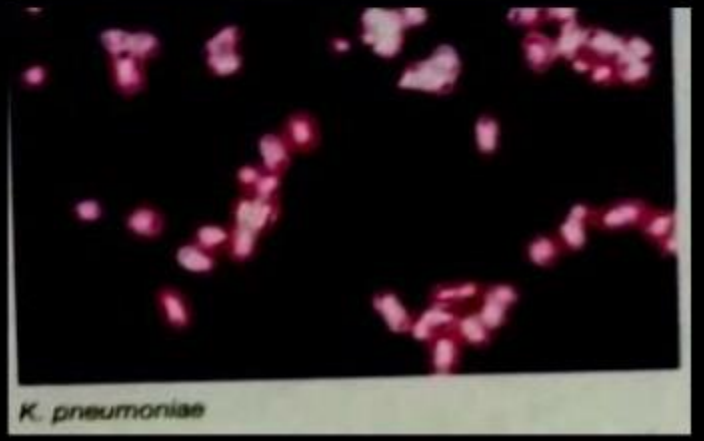


Figure 3.30 Bacterial Glycocalyx. Bacteria connected to each other and to the intestinal wall by their glycocalyxes, the extensive networks of fibers extending from the cells (×17,500).



Composition of capsules and slime layers:

- usually are composed of polysaccharide (for example *pneumococcus)*
- or of polypeptide in some bacteria (for example *Bacillus anthracis and Yersinia pestis).*

FUNCTIONS

Functions of Capsule

i. Virulence factor: Capsules often act as a virulence factor by protecting the bacterium from ingestion by phagocytosis,

ii. Protection of the cell wall: In protecting the cell wall attack by various kinds of antibacterial agents, e.g. bacteriophages, colicines, complement, lysozyme and other lytic enzymes.

iii. Identification and typing of bacteria: Capsular antigen is specific for bacteria and can be used for identification and typing of bacteria.

1] cell wall

- The cell wall encases the protoplast and lies immediately external to the cytoplasmic membrane.
- It is 10-25 nm thick, strong and relatively rigid, though with some elasticity and openly porous , being freely permeable to solute molecules smaller then 10 kDa in mass and 1 nm in diameter
- It shows granular structure and lacks microfibrils.
- Gram Positive and Gram negative bacteria have different type of bacterial cell wall

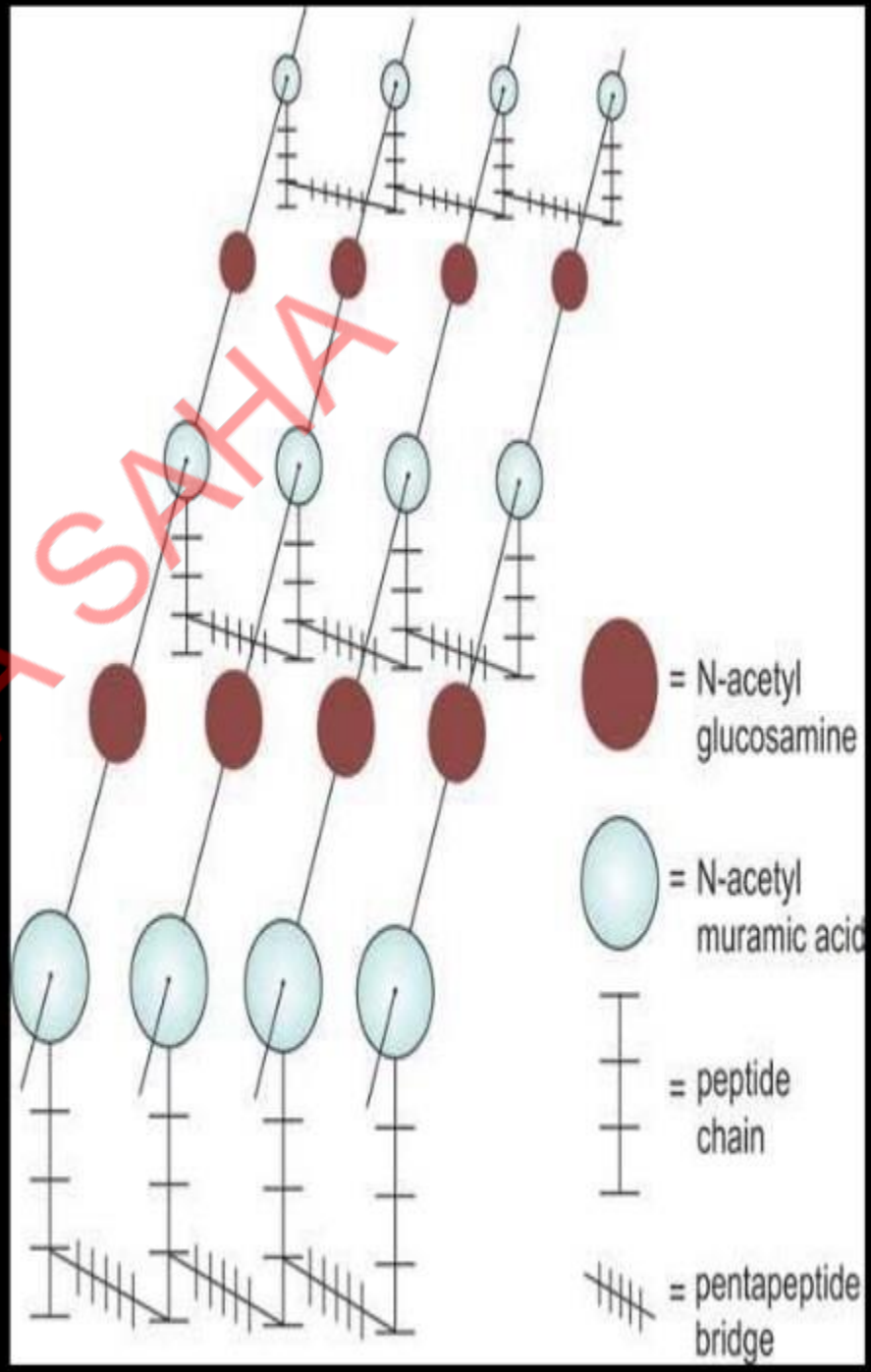
Cell Wall

Structure

- The cell wall is the layer that lies just outside the plasma membrane.
- It is 10-25 nm thick, strong and relatively rigid, though with some elasticity,
- and openly porous, being freely permeable to solute molecules smaller than 10 kDa in mass and 1 nm in diameter.

Functions of the cell wall:

1. To impart shape and rigidity to the cell.
2. It supports the weak cytoplasmic membrane against the high internal osmotic pressure of the protoplasm (ranges from 5 and 25 atm).
3. Maintains the characteristic shape of the bacterium.
4. It takes part in cell division.
5. Also functions in interactions (e.g. adhesion) with other bacteria and with mammalian cells.
6. Provide specific protein and carbohydrate receptors for the attachment of some bacterial viruses.



Chemical Structure of Cell Wall

Chemically the cell wall is composed of mucopeptide (peptidoglycan or murein) scaffolding formed by N-acetyl glucosamine and N-acetyl muramic acid molecules alternating in chains, which are crosslinked by peptide bonds .

Peptidoglycan consists of three parts :

1. A backbone—composed of alternating N-acetylglucosamine and N-acetylmuramic acid.

2. A set of identical tetrapeptide side chains attached to N-acetylmuramic acid.

3. A set of identical pentapeptide cross-bridges.

In all bacterial species, the backbone is the same, however, tetrapeptide side chains and pentapeptide cross-bridges vary from species to species .

Several antibiotics interfere with construction of the cell wall peptidoglycan.

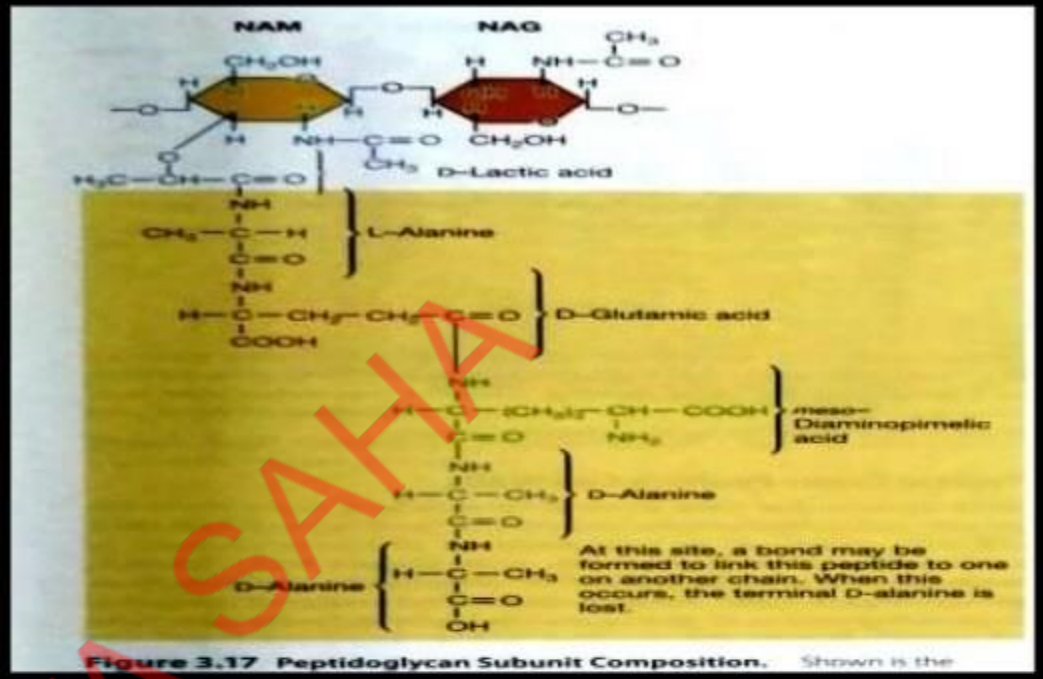
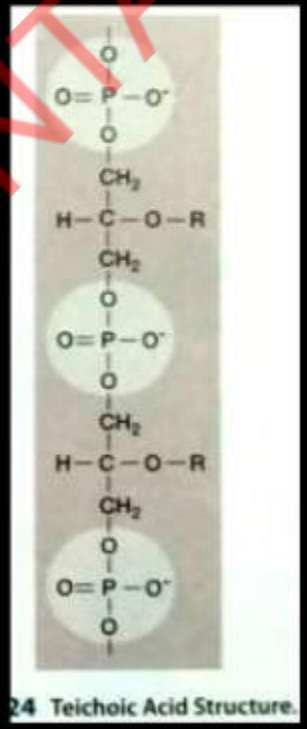
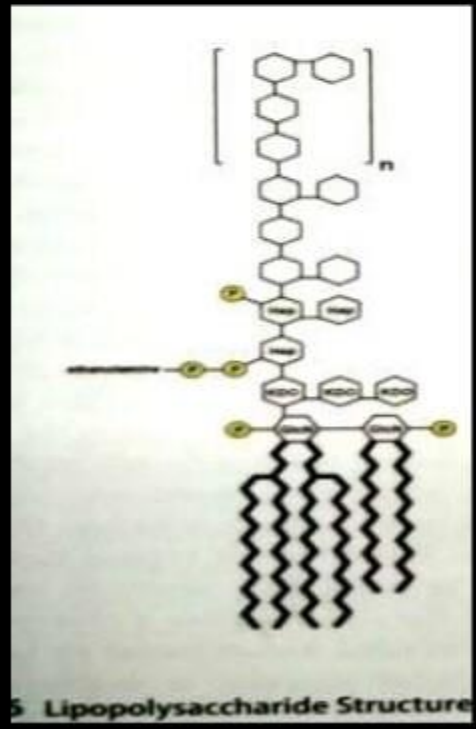


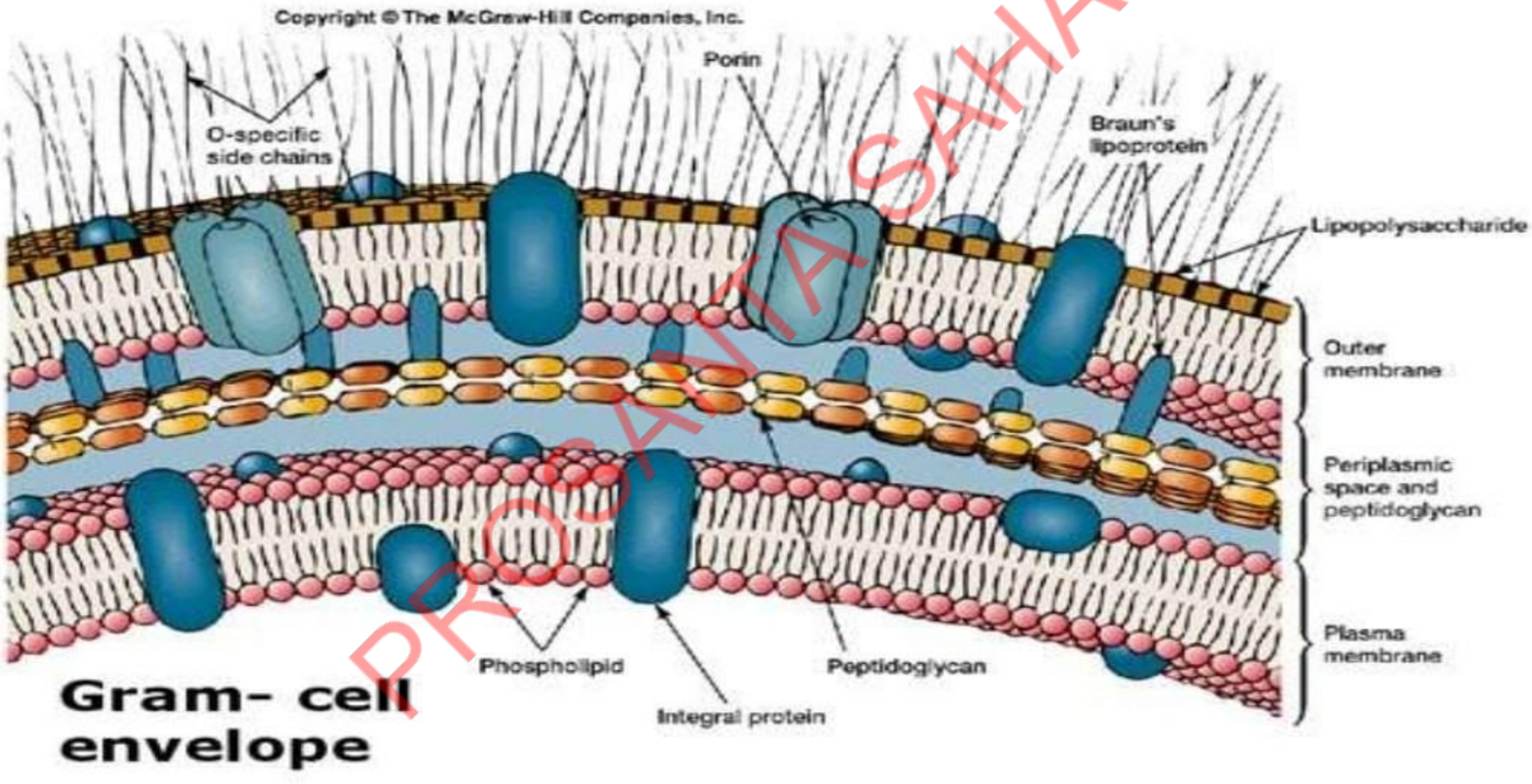
Figure 3.17 Peptidoglycan Subunit Composition. Shown is the


24 Teichoic Acid Structure.


5 Lipopolysaccharide Structure


(a) Porin trimer

➢Structure of cell wall



Gram Stain

Principle of staining technique:

Primary stain:- Crystal Violet

Mordant(fixes the dye):- Iodine

Decolorizing agent:- Alcohol/Acetone

Counter stain:- Safranin

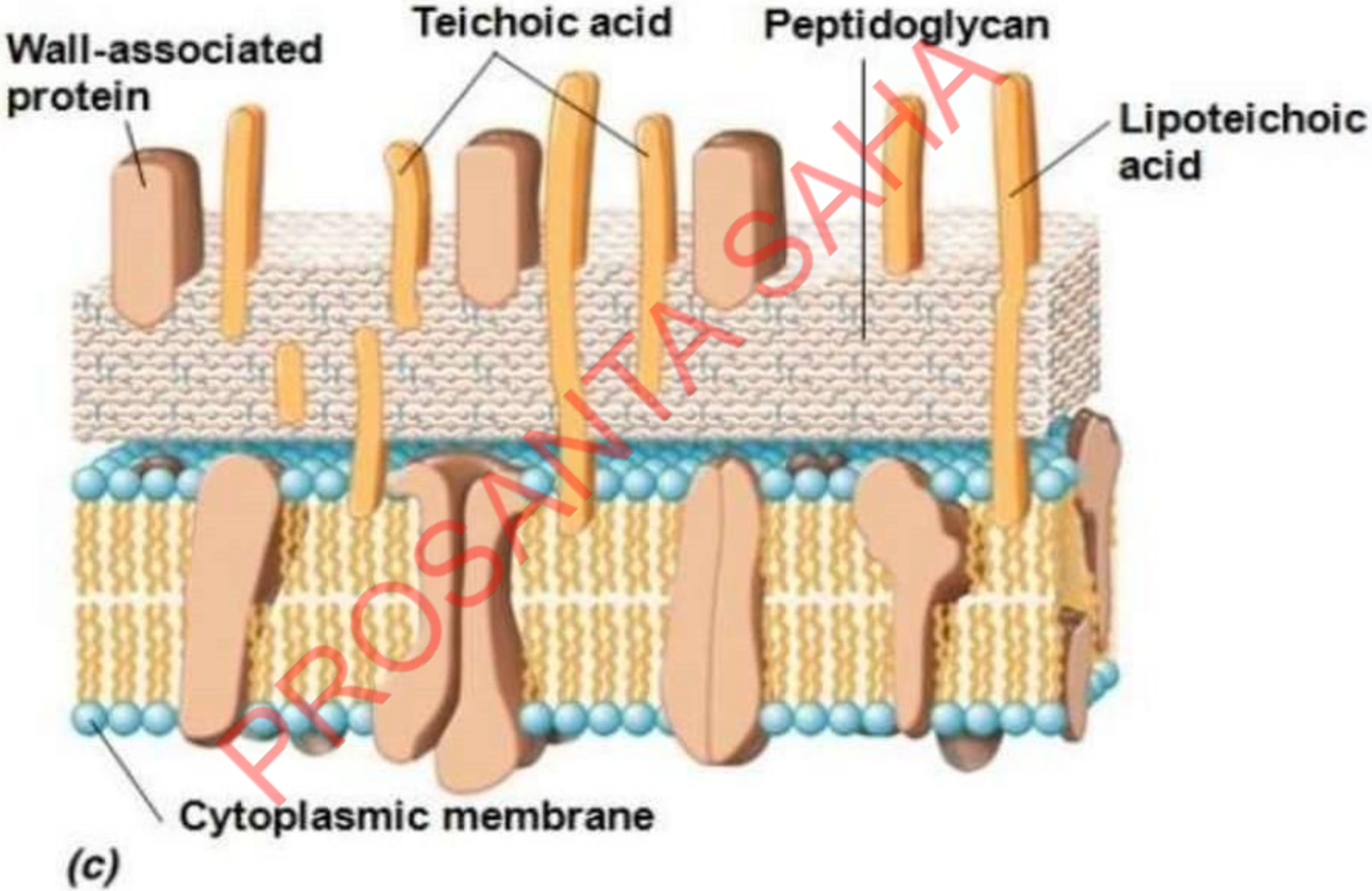
❑ Gram positive cell wall :-

- The Gram positive type wall is relatively thick (about 30-100 nm) and it generally has a simple, uniform appearance under the electron microscope.
- Some 40 – 80 % of wall is made of tough, complex polymer , peptidoglycan .
- In this type of wall the sacculus consists of multilayered peptidoglycan which, during growth, develops by the "inside–to-outside" mechenism.

continue.....

- Covalently bound to peptidoglycan are compounds such as tichoic acid : typically ,substituted polymers glycerol phosphate or ribitol phosphate.
- In some bacteria (e.g. *mycobacterium*) the wall contains lipids, while in others (strains of *streptococcus*) it contains carbohydrates.
- The composition of the wall can vary with growth condition ; for example in *Bacillus* , the availability of phosphate affects the amount of cell wall teichoic acids.

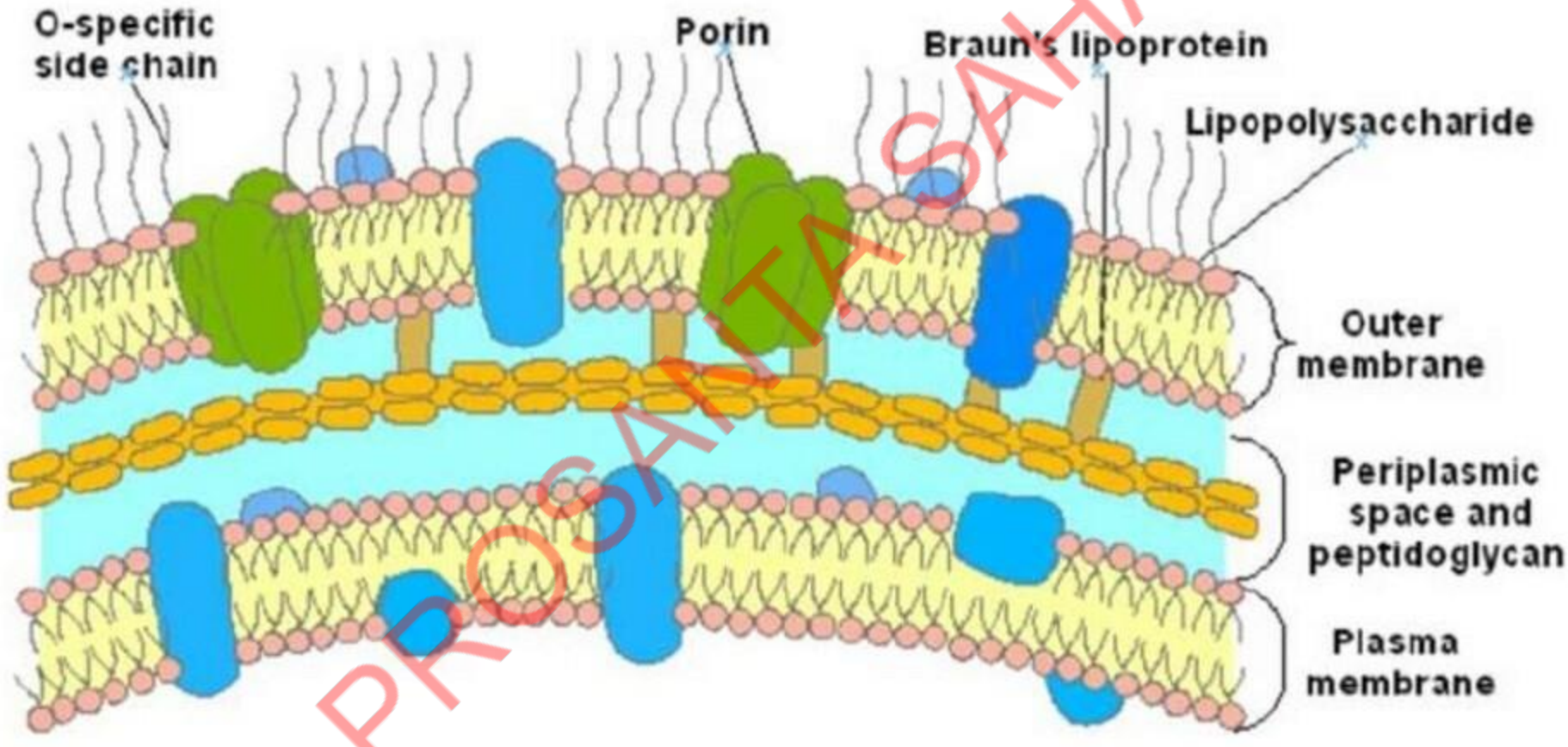
Gram positive cell wall



❑Gram negative cell wall :-

- The cell walls of Gram-negative bacteria are more chemically complex, thinner and less compact.
- Peptidoglycan makes up only 5 – 20% of the cell wall, and is not the outermost layer.
- The peptidoglycan of Gram-negative bacteria is located between the plasma membrane and an outer, LPS membrane.
- This LPS membrane is similar to the plasma membrane, but is less permeable and is composed of lipopolysaccharides (LPS).

Gram negative cell wall



The typical Gram-positive cell envelope

The typical Gram-negative cell envelope

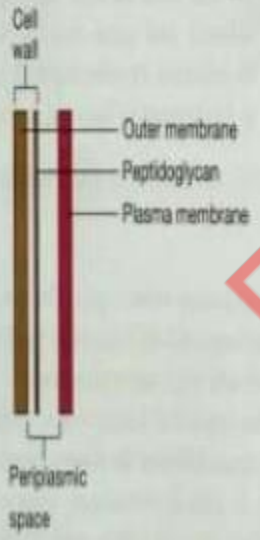
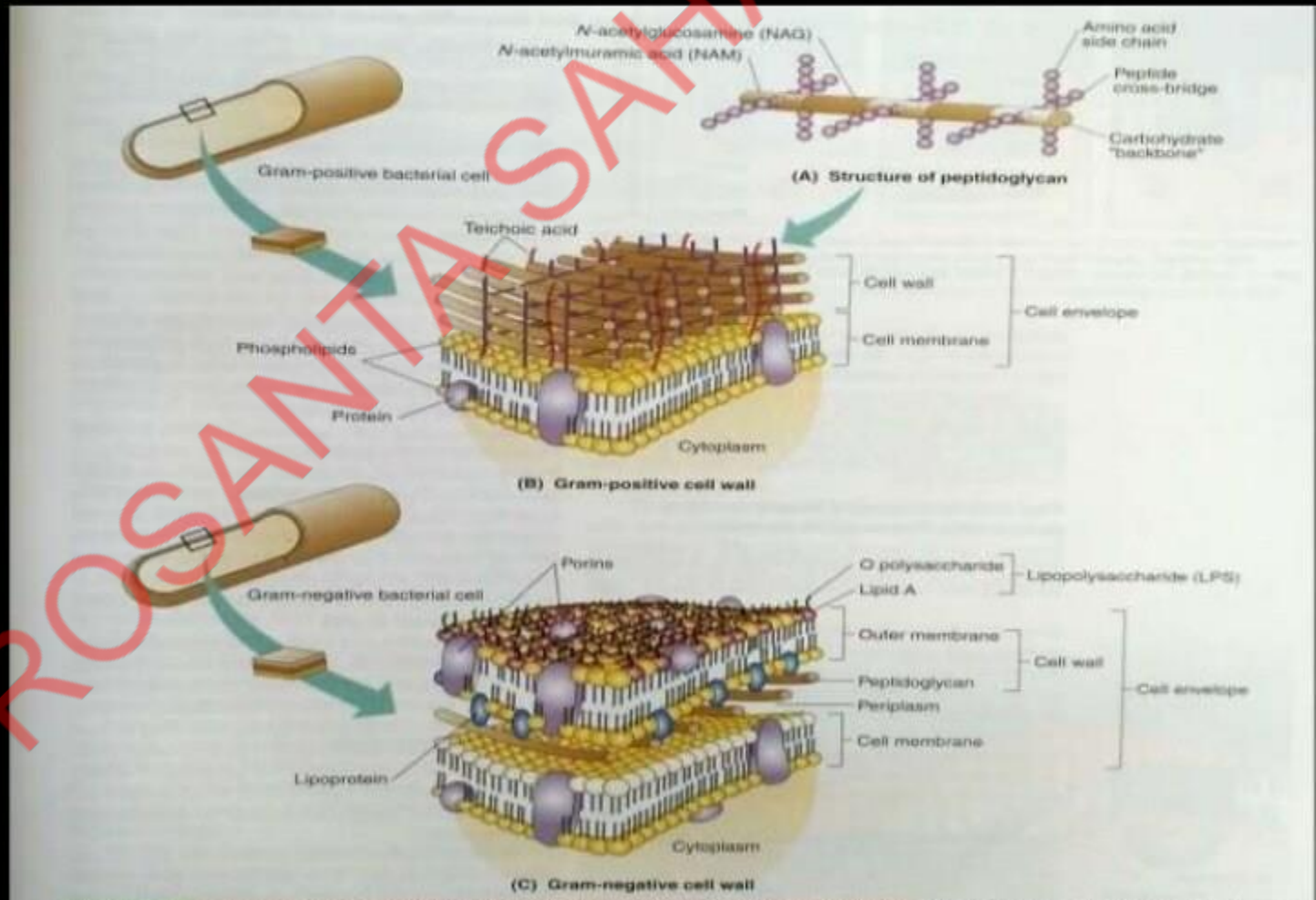


Table 3.2: Comparison of cell walls of gram-positive and gram-negative bacteria

Characteristic	*Gram-positive*	*Gram-negative*
1. Thickness	Thicker	Thinner
2. Peptidoglycan	Thick layer (16-80 nm)	2 nm (thin layer)
3. Teichoic acid	Present	Absent
4. Variety of amino acids	Few	Several
5. Aromatic and sulfur containing amino acids	Absent or scant	Present
6. Lipids	Absent or scant	Present
7. Porin proteins	Absent	Present
8. Periplasmic region	Absent	Present

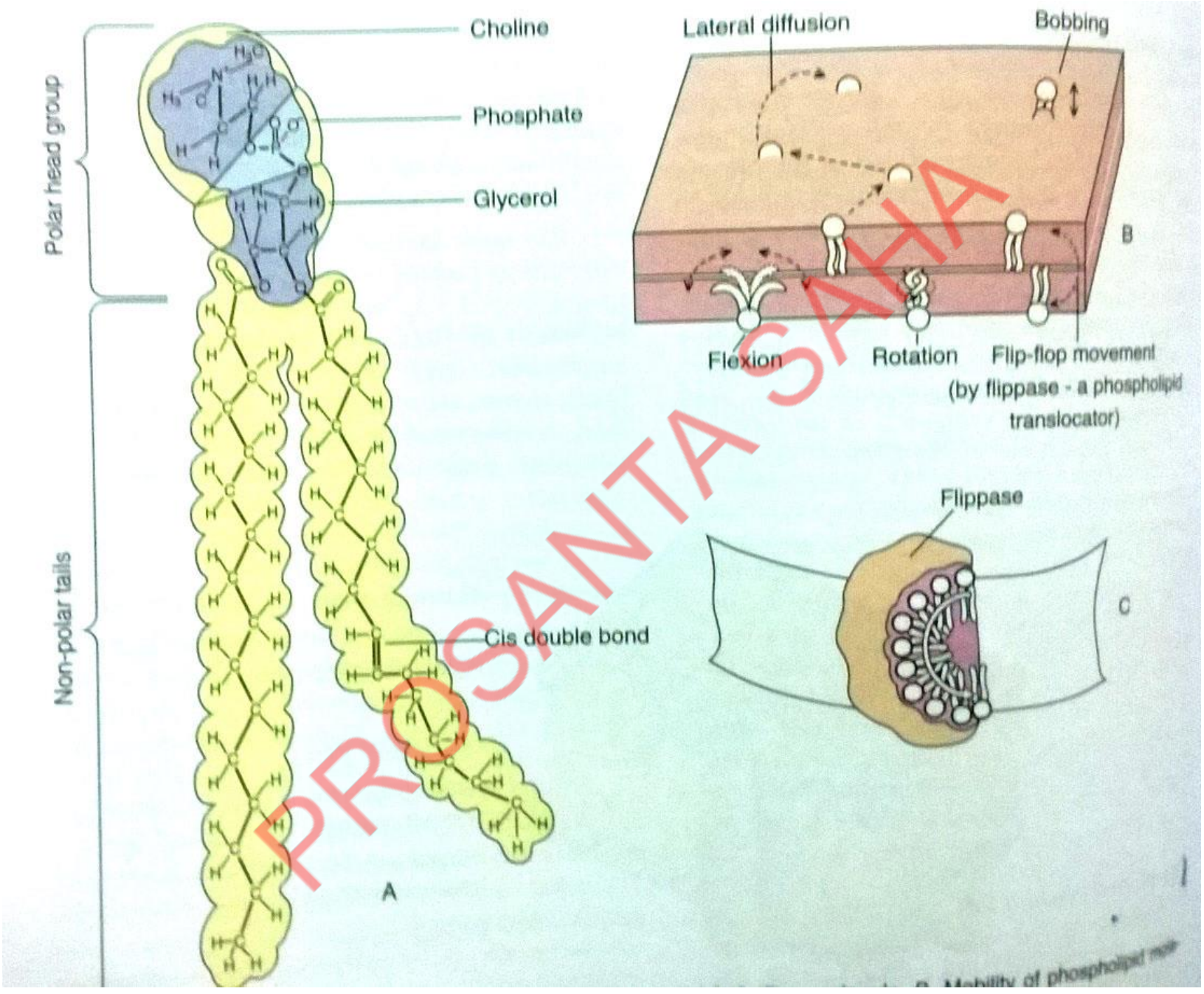


A Comparison of the Cell Walls of Gram-Positive and Gram-Negative Bacterial Cells. (A) The structure of peptidoglycan is shown as units of NAG and NAM joined laterally by amino acid cross-bridges and vertically by side chains of four amino acids. (B) The cell wall of a gram-positive bacterial cell is composed of multiple peptidoglycan layers combined with teichoic acid molecules. (C) In the gram-negative cell wall, the peptidoglycan layer is much thinner, and there is no teichoic acid. Moreover, an outer membrane overlies the peptidoglycan layer such that both comprise the cell wall. Note the structure of the outer membrane in this figure. It contains porin proteins and the outer half is unique in containing lipopolysaccharide.

2) Plasma membrane :-

- Plasma membranes in bacteria are composed of phospholipids contain a polar group attached to a 3 carbon glycerol back bone.
- They are also two fatty acid chains dangling from the other carbons of glycerol.
- The phosphate end of the molecule is ***hydrophilic*** and is attracted to water.
- The fatty acids are ***hydrophobic.***
- Membrane also contain protein.

Lipid structure and movement



Cytoplasmic (Plasma) Membrane

Structure:

- **The cytoplasmic (plasma) membrane limits the bacterial protoplast.**
- **It is thin (5-10 nm thick), elastic**and can only be seen with electron microscope.

- It is a typical "**unit membrane", composed of phospholipids and proteins.**

- **Lipid molecules are arrayed in a double layer with their hydrophilic polar regions externally aligned and in contact with a layer of protein at each surface.**

Chemically, the membrane consists of lipoprotein with small amounts of carbohydrate.

With the exception of *Mycoplasma*, *bacterial cytoplasmic membrane lacks sterols.*

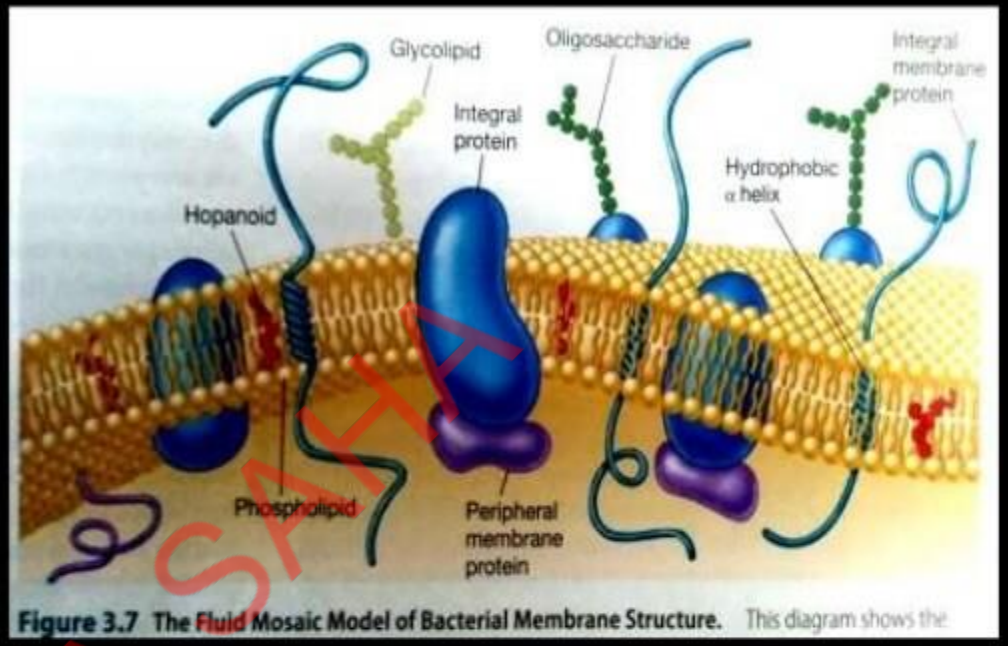


Figure 3.7 The Fluid Mosaic Model of Bacterial Membrane Structure. This diagram shows the

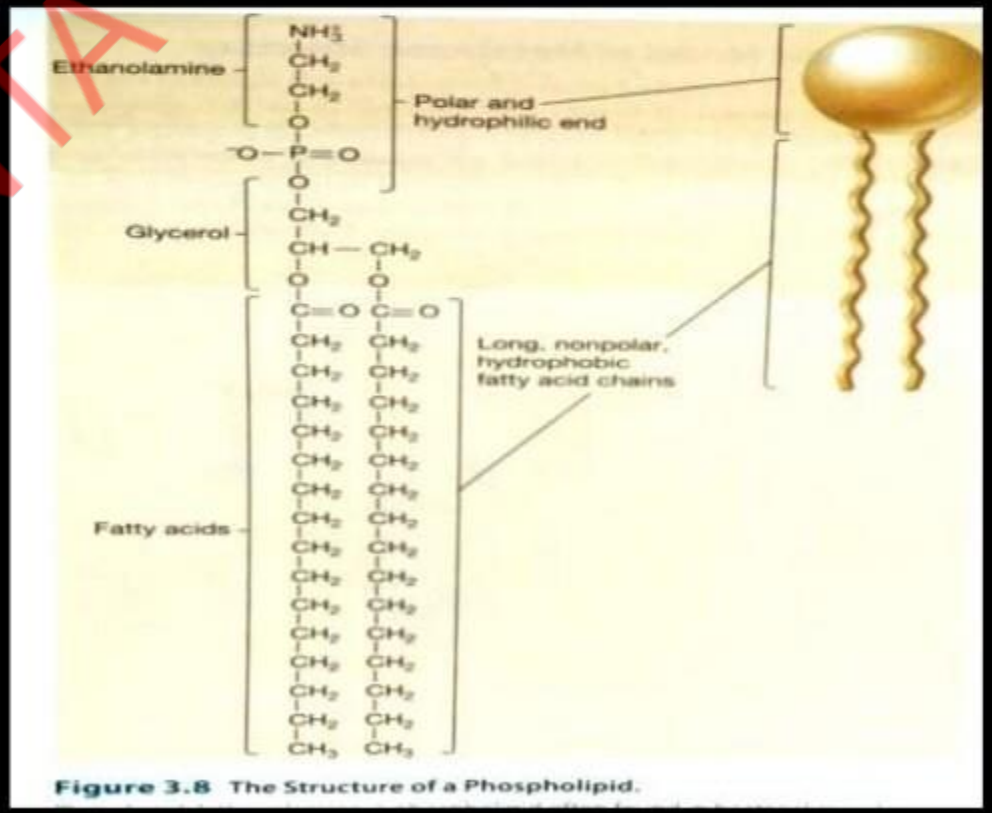


Figure 3.8 The Structure of a Phospholipid.

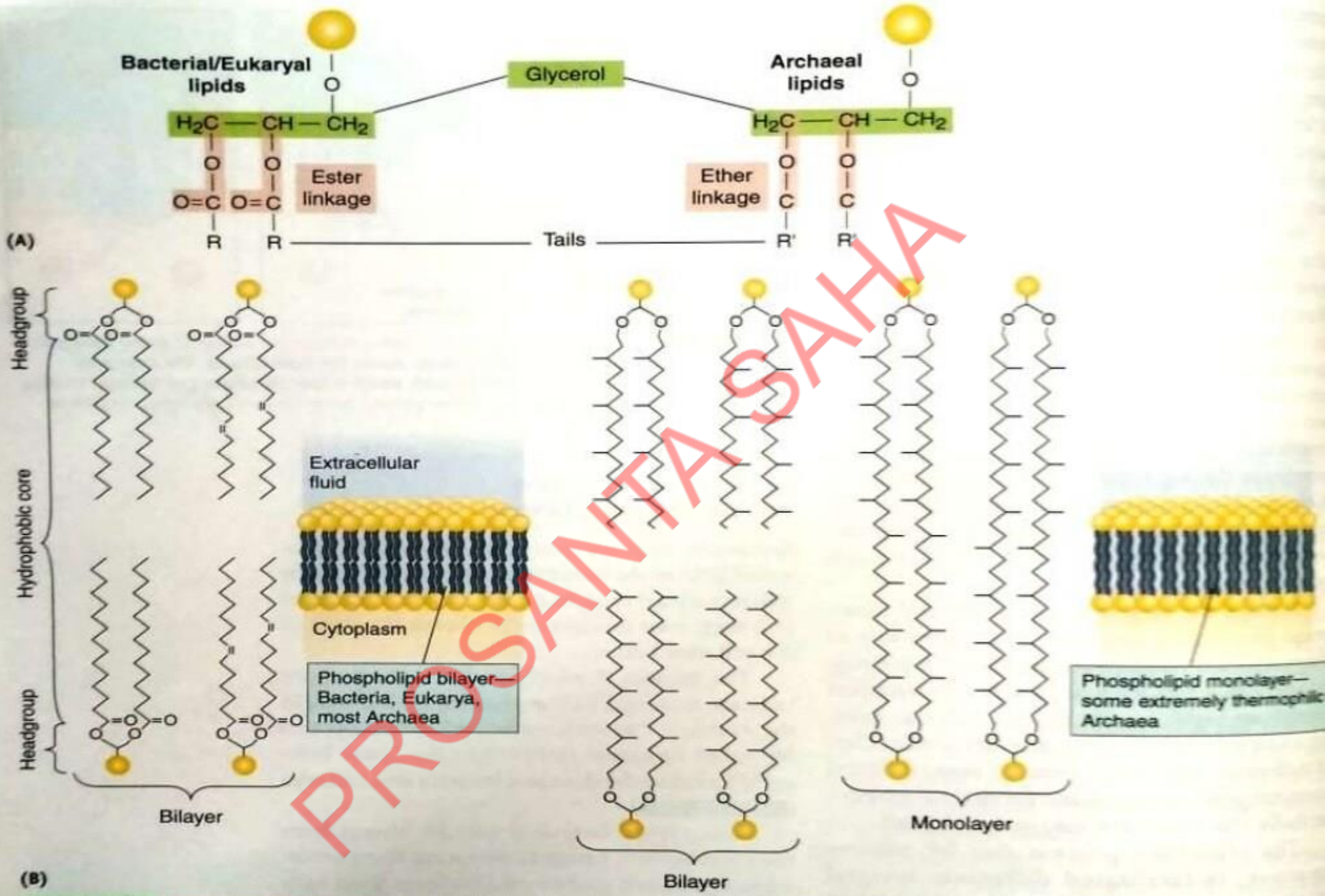


FIGURE 4.17 Structure of Cell Membranes. **(A)** Bacterial and eukaryotic cell membranes involve an ester linkage joining the glycerol to the fatty acid tails (R) while archaeal membranes have an ether linkage to the isoprenoid tails (R′). **(B)** Bacterial and eukaryal membranes form a bilayer while archaeal membranes may be a bilayer or a monolayer. »» What identifies an ester linkage from an ether linkage?

Functions of Plasma membrane

i. **Semipermeable** membrane—controlling the inflow and outflow of metabolites to and from the protoplasm.

ii. **Housing enzymes**—involved in outer membrane synthesis, cell wall synthesis, and in the assembly and secretion of extracytoplasmic and extracellular substances.

iii. **Housing many sensory and chemotaxis proteins** that monitor chemical and physical changes in the environment.

iv. **Generation of chemical energy (i.e, ATP).**

v. **Cell motility.**

vi. **Mediation** of chromosomal segregation during replication.

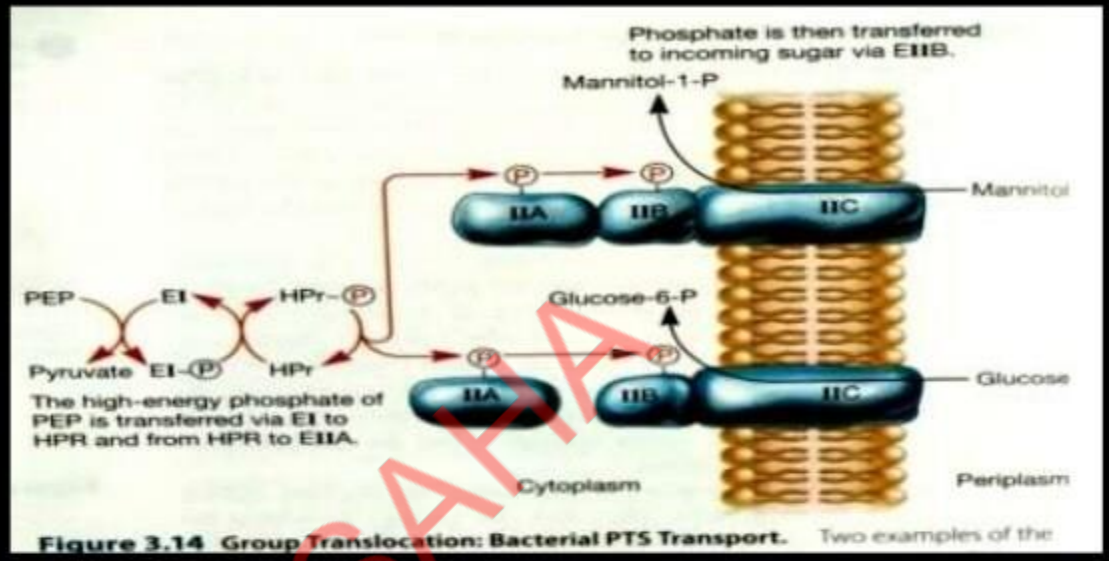


Figure 3.14 Group Translocation: Bacterial PTS Transport. Two examples of the

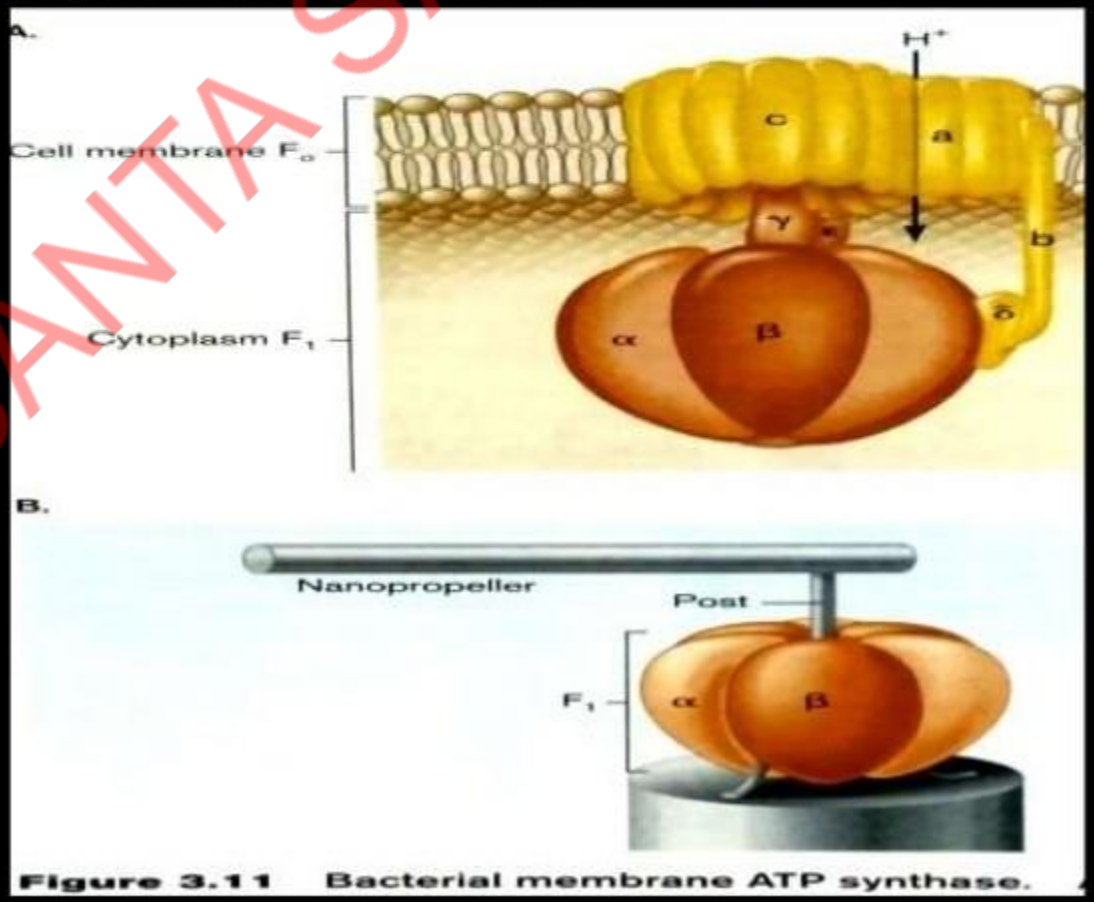
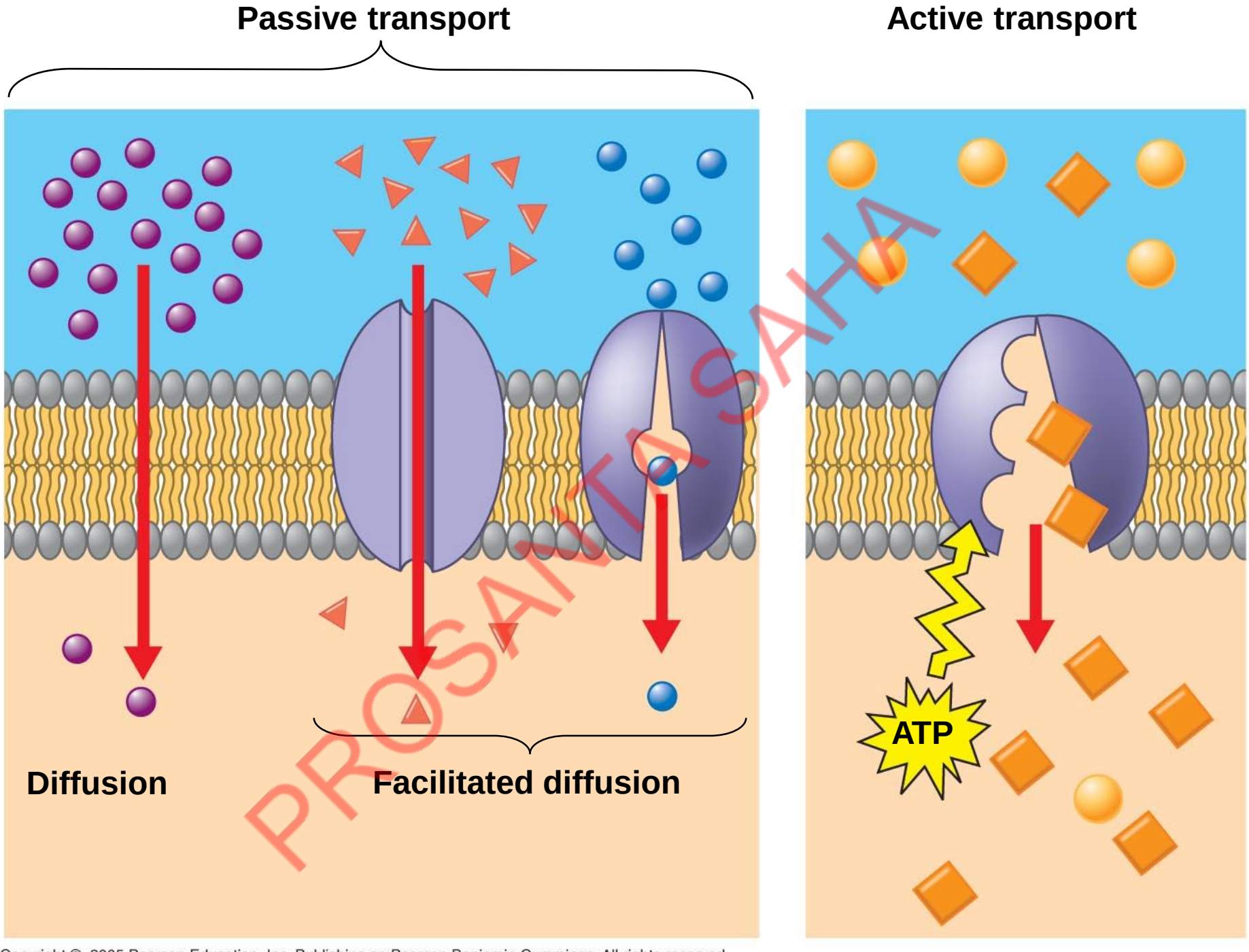
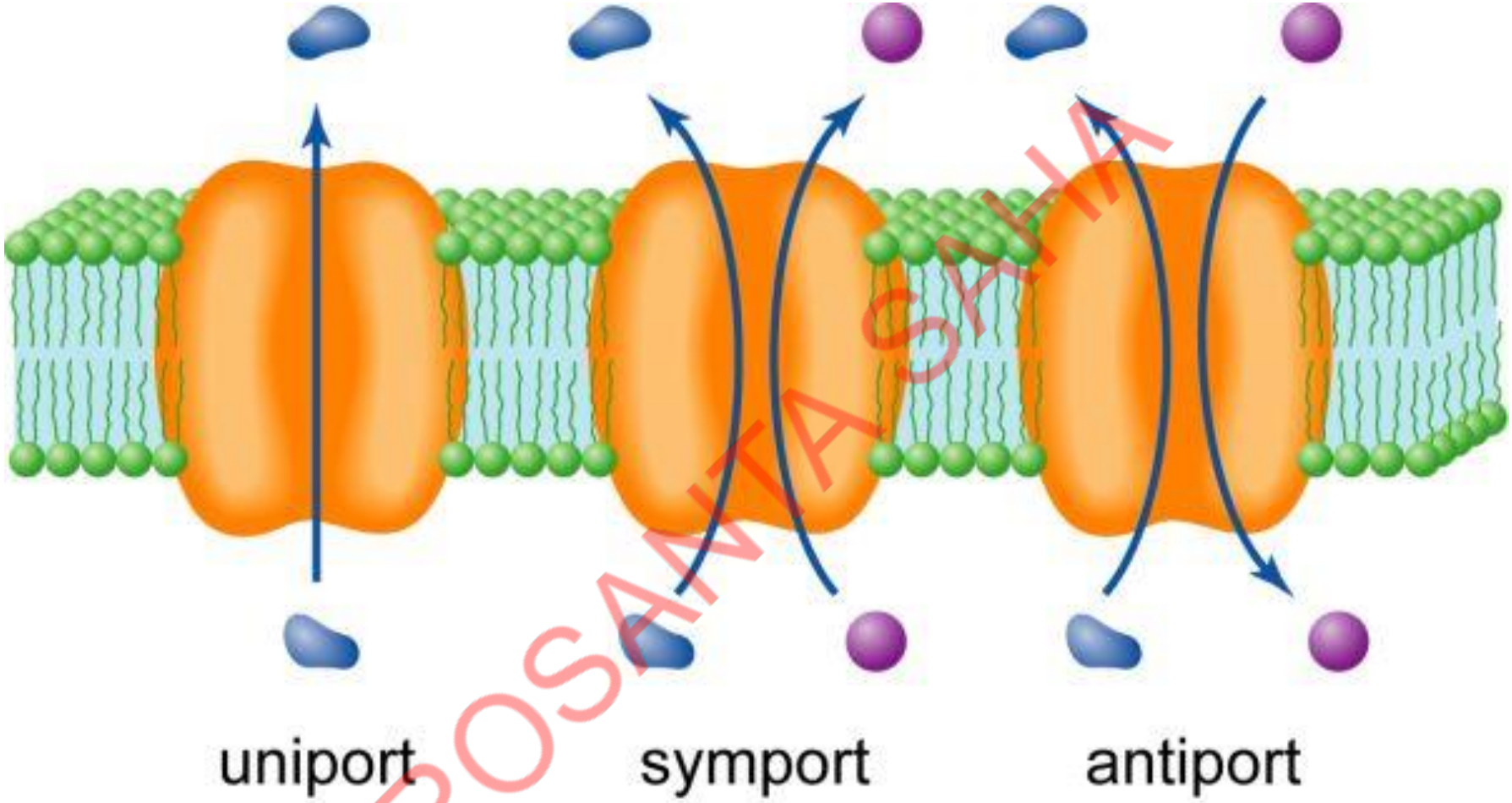


Figure 3.11 Bacterial membrane ATP synthase.

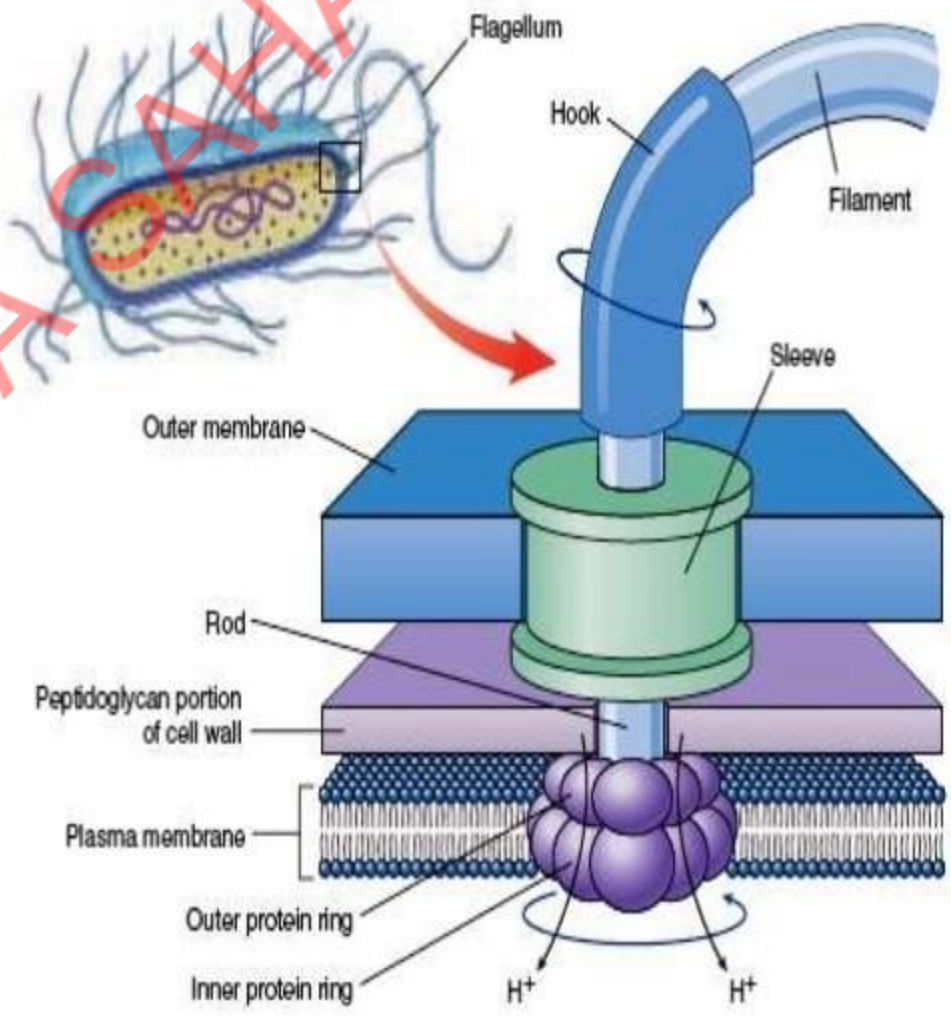




•Flagella : -

- The flagella are made up of a class of linear protein call flagellins .
- Flagella which arise at verious points on the cell surface.
- Flagellated bacteria are described as

monotrichous, lophotricho u or petritrichous. Its depending on how the flagella are arranged.



Arrangement/Types

The number and location of flagella are distinctive for each genus.

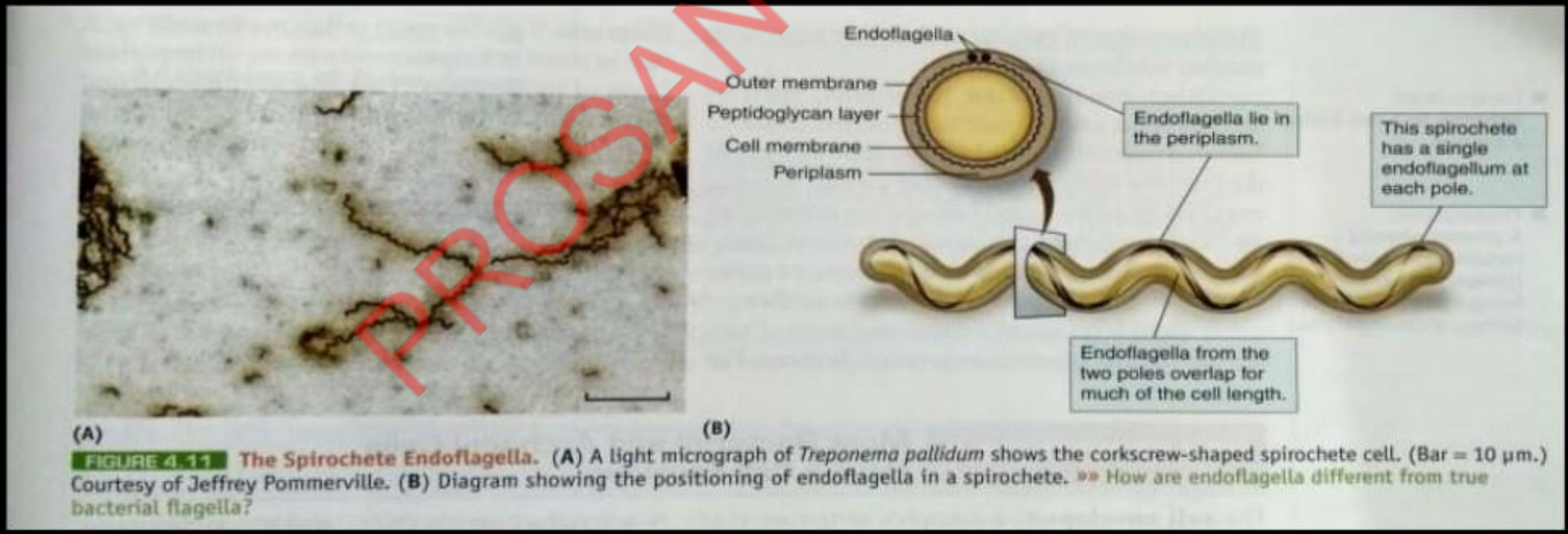
There are four types of flagella arrangement:

- Monotrichous—Single polar flagellum (e.g. *Cholera vibrio*).
- Amphitrichous—Single flagellum at both ends (e.g. *Alcaligenes faecalis*).
- Lophotrichous—Tuft of flagella at one or both ends (e.g. spirilla).
- Peritrichous—Flagella surrounding the cell (e.g. Typhoid bacilli).

(a) *Pseudomonas*—monotrichous polar flagellation

(b) *Spirillum*—lophotrichous flagellation

(c) *P. vulgaris*—peritrichous flagellation



(A) (B)

FIGURE 4.11 **The Spirochete Endoflagella.** (A) A light micrograph of *Treponema pallidum* shows the corkscrew-shaped spirochete cell. (Bar = 10 µm.) Courtesy of Jeffrey Pommerville. (B) Diagram showing the positioning of endoflagella in a spirochete. »» How are endoflagella different from true bacterial flagella?

ii. Flagella

Motile bacteria, except spirochetes, possess one or more unbranched, long, sinuous filaments called flagella, which are the organs of locomotion.

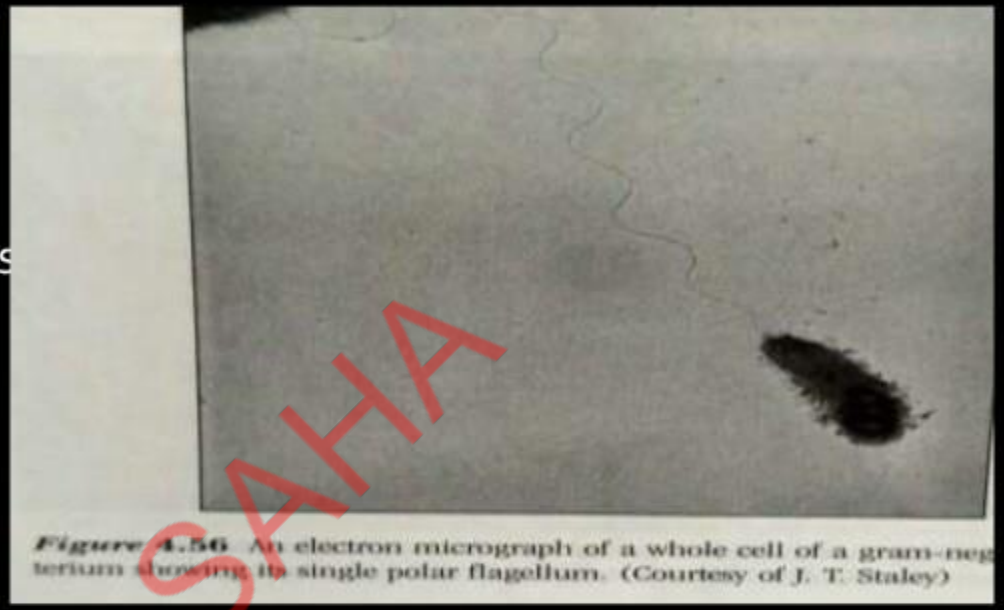


Figure 4.56 An electron micrograph of a whole cell of a gram-neg terium showing its single polar flagellum. (Courtesy of J. T. Staley)

Structure:

.3-20 µm long, hollow, helical filaments, usually several times the length of the cell.
.of uniform diameter (0.01-0.013 µm) and terminate in a square tip.
. originates in the bacterial protoplasm
. extruded through the cell wall.

Composition :

Flagella consists of largely or entirely of a protein, flagellin, belonging to the same chemical group as myosin, the contractile protein of muscle.

Part of flagellum:

Each flagellum consists of three parts .
i. Filament
ii. Hook
iii. Basal body.

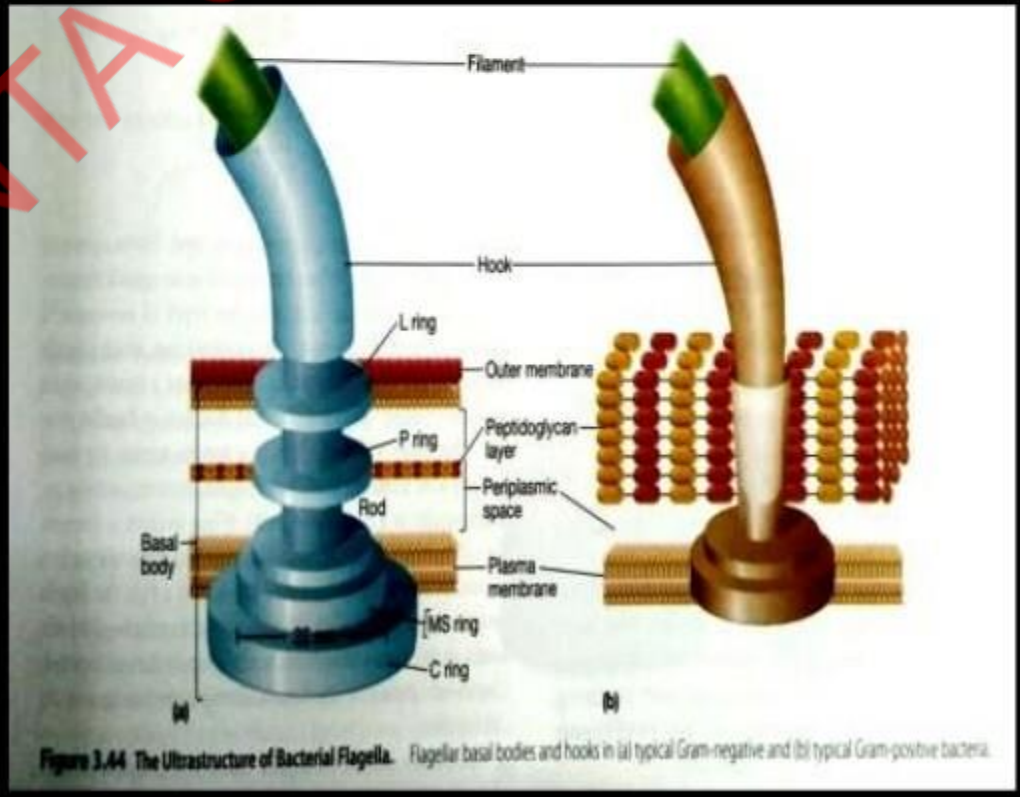


Figure 3.44 The Ultrastructure of Bacterial Flagella. Flagellar basal bodies and hooks in (a) typical Gram-negative and (b) typical Gram-positive bacteria.

Functions of flagella

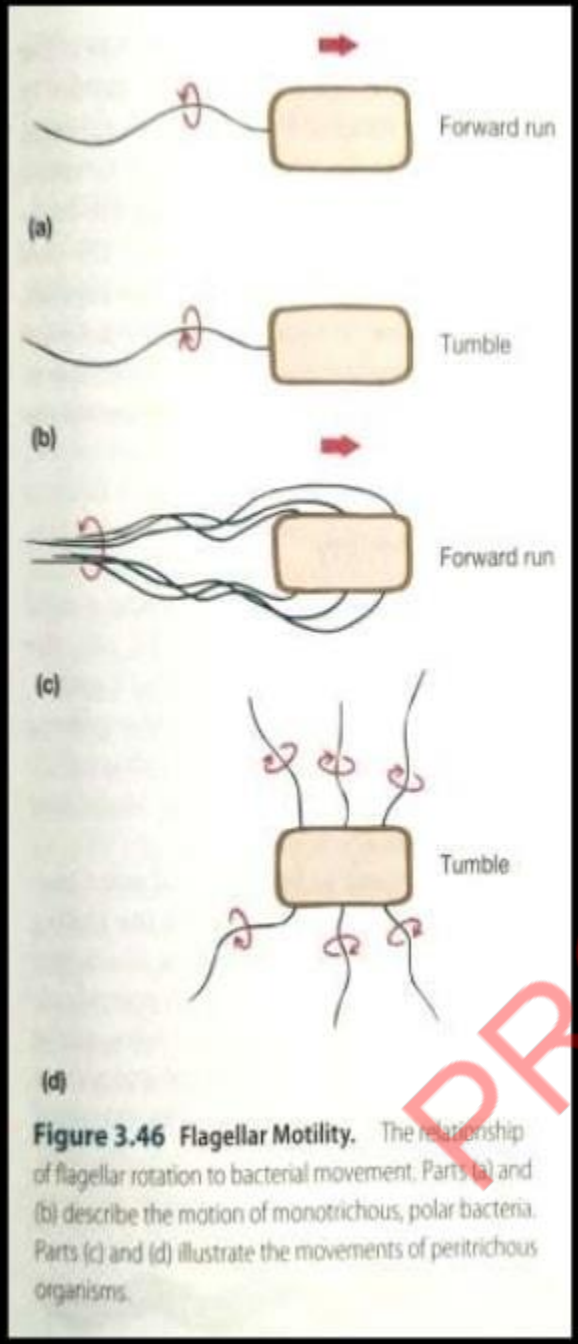


Figure 3.46 Flagellar Motility. The relationship of flagellar rotation to bacterial movement. Parts (a) and (b) describe the motion of monotrichous, polar bacteria. Parts (c) and (d) illustrate the movements of peritrichous organisms.

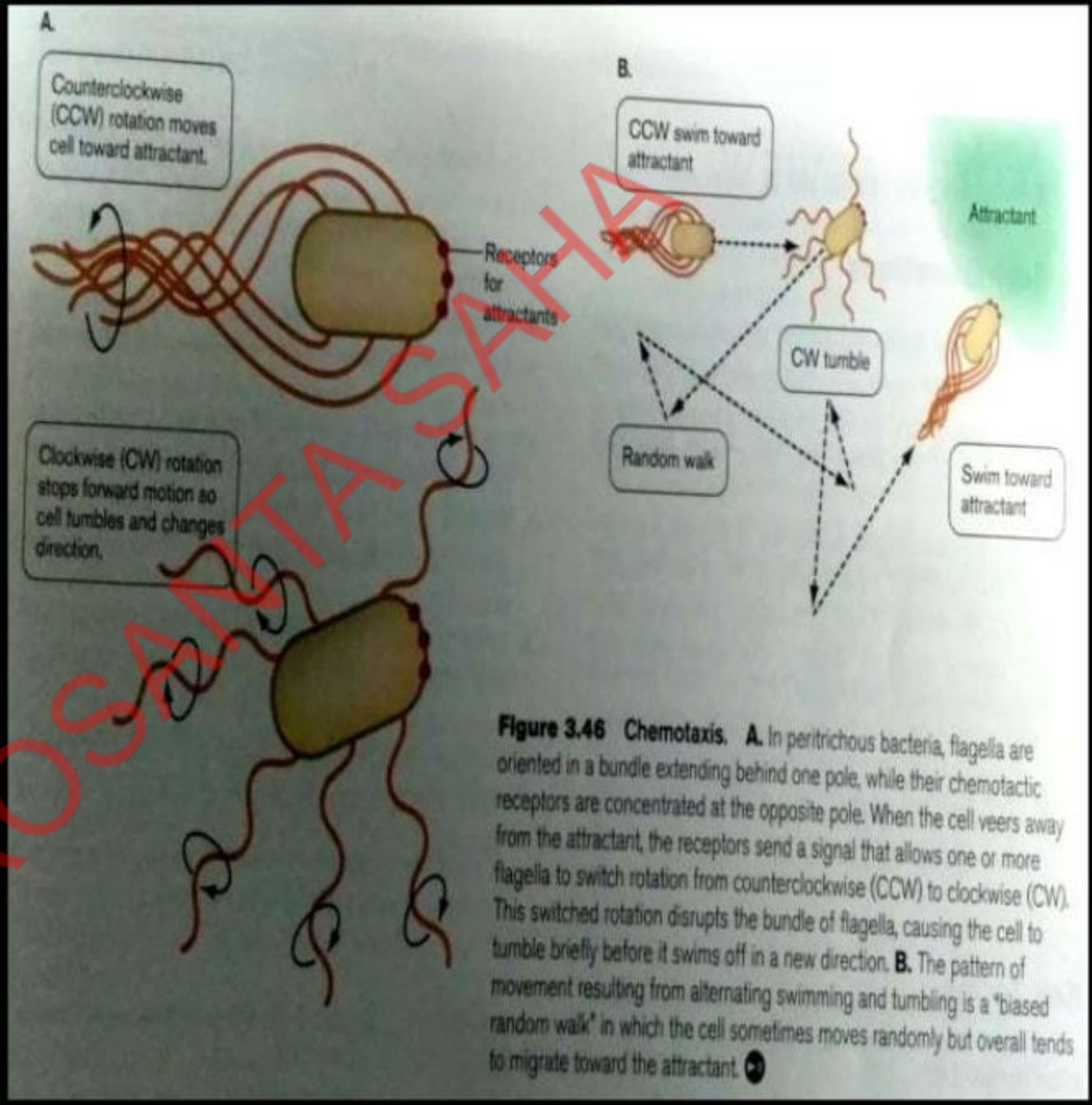


Figure 3.46 Chemotaxis. **A.** In peritrichous bacteria, flagella are oriented in a bundle extending behind one pole, while their chemotactic receptors are concentrated at the opposite pole. When the cell veers away from the attractant, the receptors send a signal that allows one or more flagella to switch rotation from counterclockwise (CCW) to clockwise (CW). This switched rotation disrupts the bundle of flagella, causing the cell to tumble briefly before it swims off in a new direction. **B.** The pattern of movement resulting from alternating swimming and tumbling is a "biased random walk" in which the cell sometimes moves randomly but overall tends to migrate toward the attractant.

3) Extracellular structure

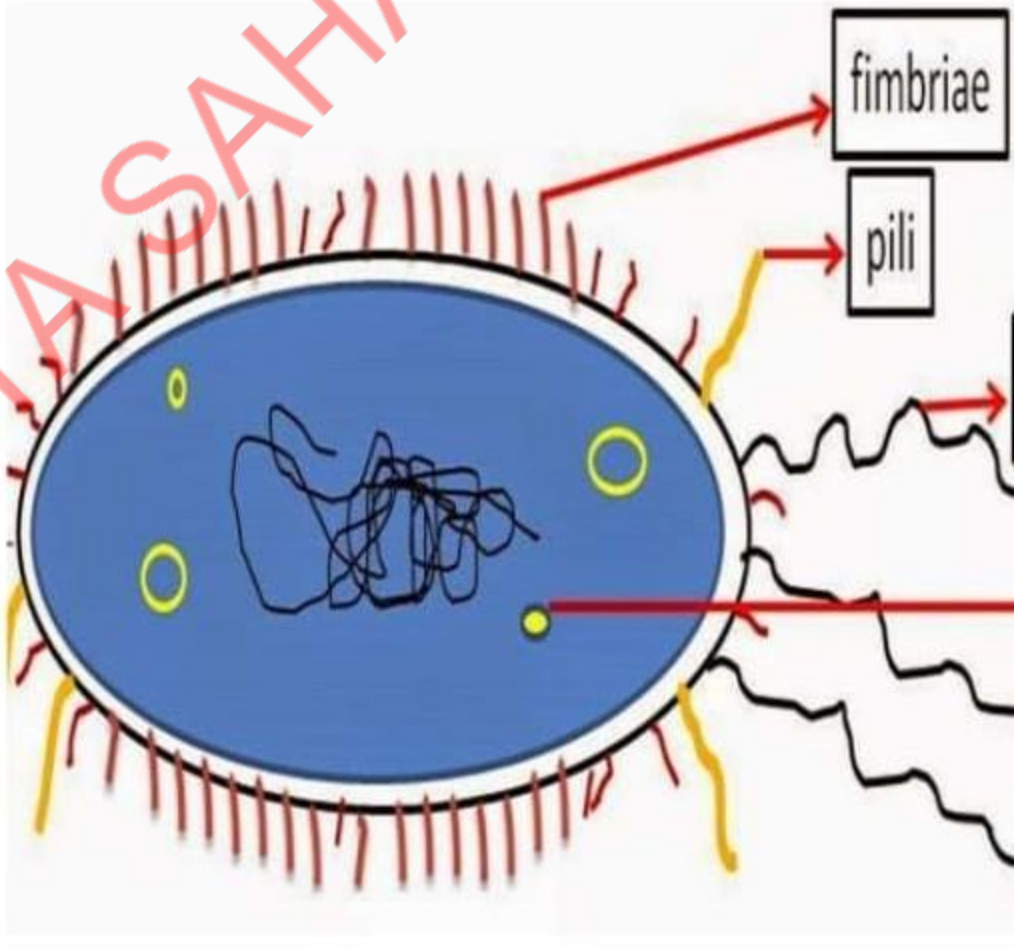
- **i) fimbriae or Pili :-**

✓ fimbriae or pili are elongated or hair like proteinaceous structures which project from the cell surface.

✓ they are specifically on those gram negative cell.

✓ Fibriae are typically 2 – 3 nm in diameter and from 0.1 micrometer to several micrometer in length .

✓ They may occur all over the cell or may be localized



iii. Fimbria or Pili

Structure and synthesis:

short, fine, hair like surface appendages called fimbriae or pili depending on their function.

•They are shorter and thinner than flagella (0.1 to 1.5 µm in length and uniform width between 4 and 8 nm) and emerge from the cell wall.

•Single cells have been seen to be covered with as few as 10 fimbriae to as many as 1000.

• They occur in non-motile, as well as in motile strains.

•They originate in the cytoplasmic membrane

• composed of structural protein subunits termed pilins like flagella.

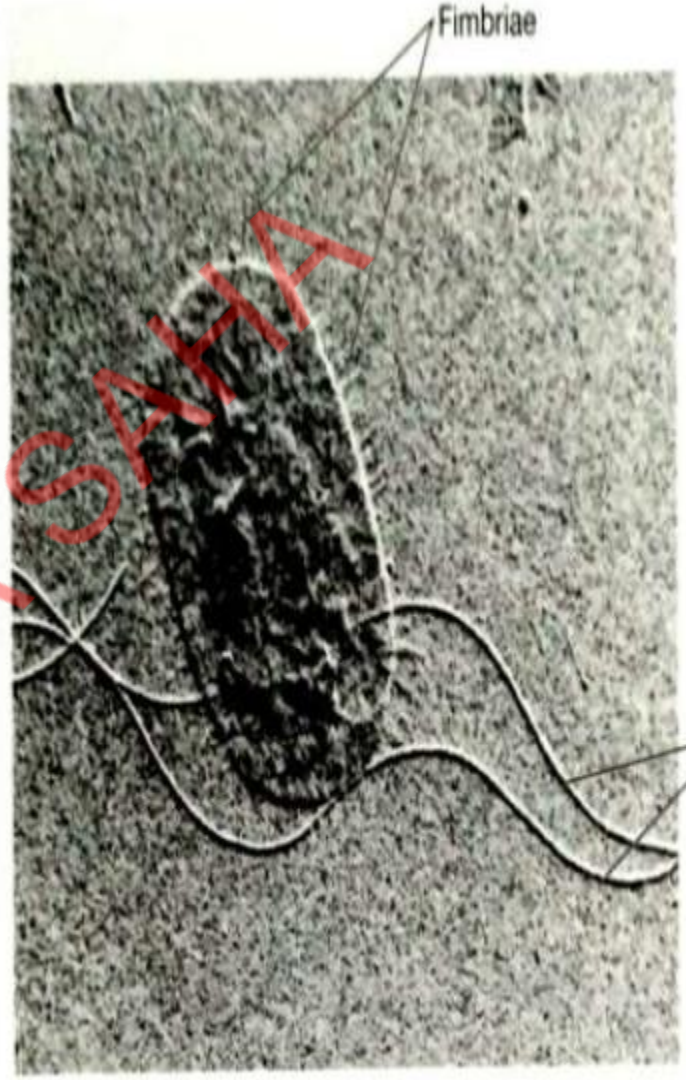


Figure 3.42 Flagella and Fimbriae. The long flagella and numerous shorter fimbriae are evident in this electron micrograph of the bacterium *Proteus vulgaris* (×39,000).

Functions of Pili

Two classes can be distinguished on the basis of their function:

ordinary pili and sex pili.

A. Ordinary (common) pili:

function as organs of adhesions that allow attachment of a bacterial cell to other cells or surfaces ,help in holding them in nutritionally favorable microenvironments.

B. Sex pili:

- ❑ are longer and fewer in number than other fimbriae
- ❑ are genetically determined by sex factors or conjugative plasmids
- ❑ appear to be involved in the transfer of DNA during conjugation.
- ❑ found on 'male' bacteria , help in the attachment of those cells to 'female' bacteria

Spinae: Rigid & tubular appendages found in some Gram Positive bacteria.

- ❖Formed of a single molecule of protein 'Spinin'
- ❖Helps the bacterium to resist Salinity, pH. temperature etc.

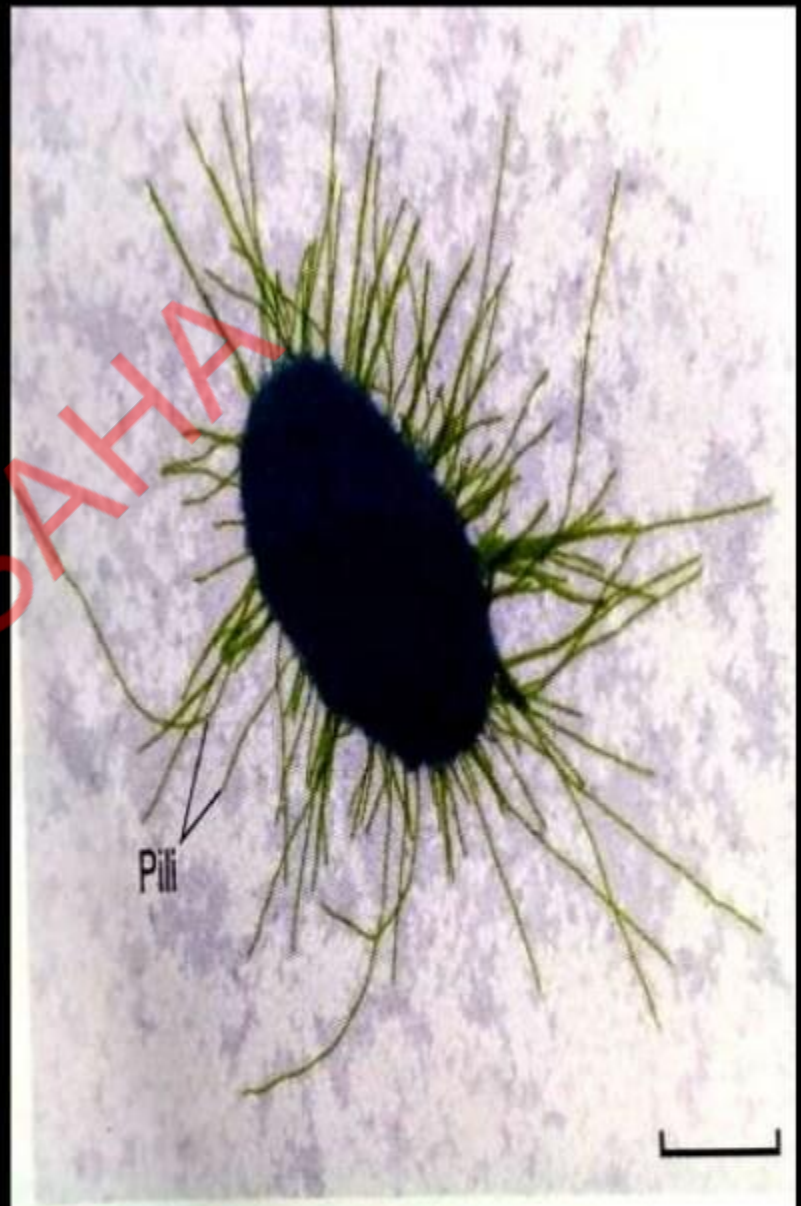


FIGURE 4.8 Bacterial Pili. False-color transmission electron micrograph of an *Escherichia coli* cell (blue) with many pili (green). (Bar = 0.5 µm.) © Dennis Kunkel

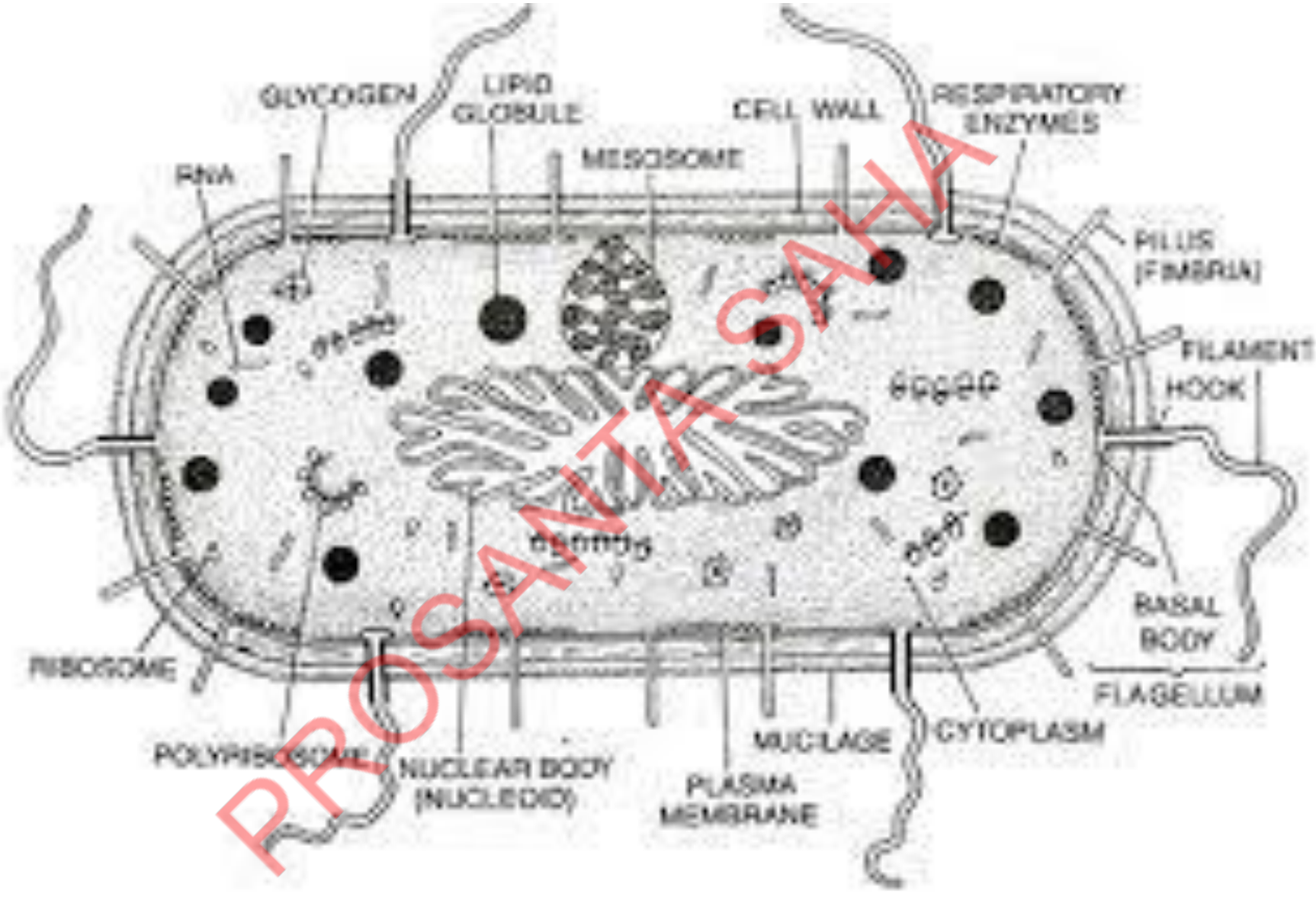
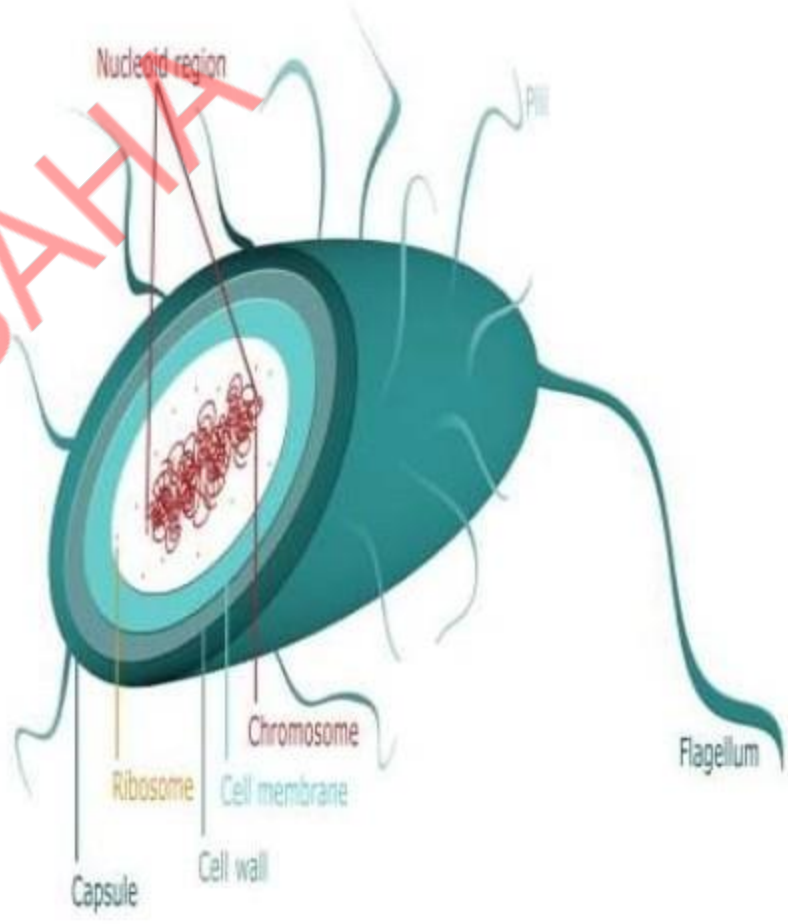


Fig. 8.9. Cell structure under electron microscope (Plasmid and volutin granules not shown).

•Nucleoid

- The nucleoid is a region of cytoplasm where the chromosomal DNA is located.
- It is not a membrane bound nucleus, but simply an area of the cytoplasm where the strands of DNA are found.
- Most bacteria have a single, circular chromosome that is responsible for replication, although a few species do have two or more.
- Smaller circular auxiliary DNA strands, called plasmids, are also found in the cytoplasm.



NUCLEOID IN EUBACTERIA

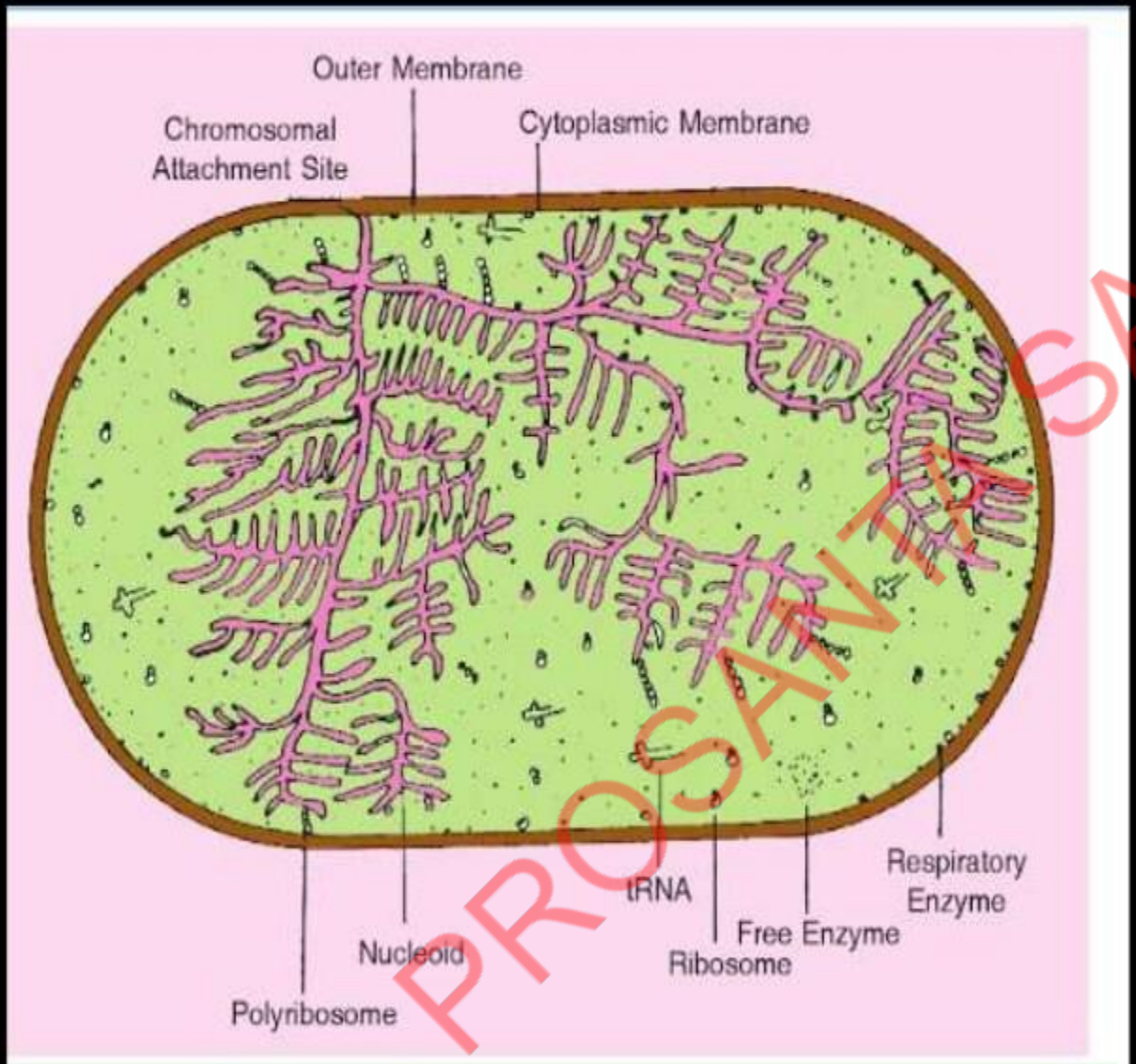
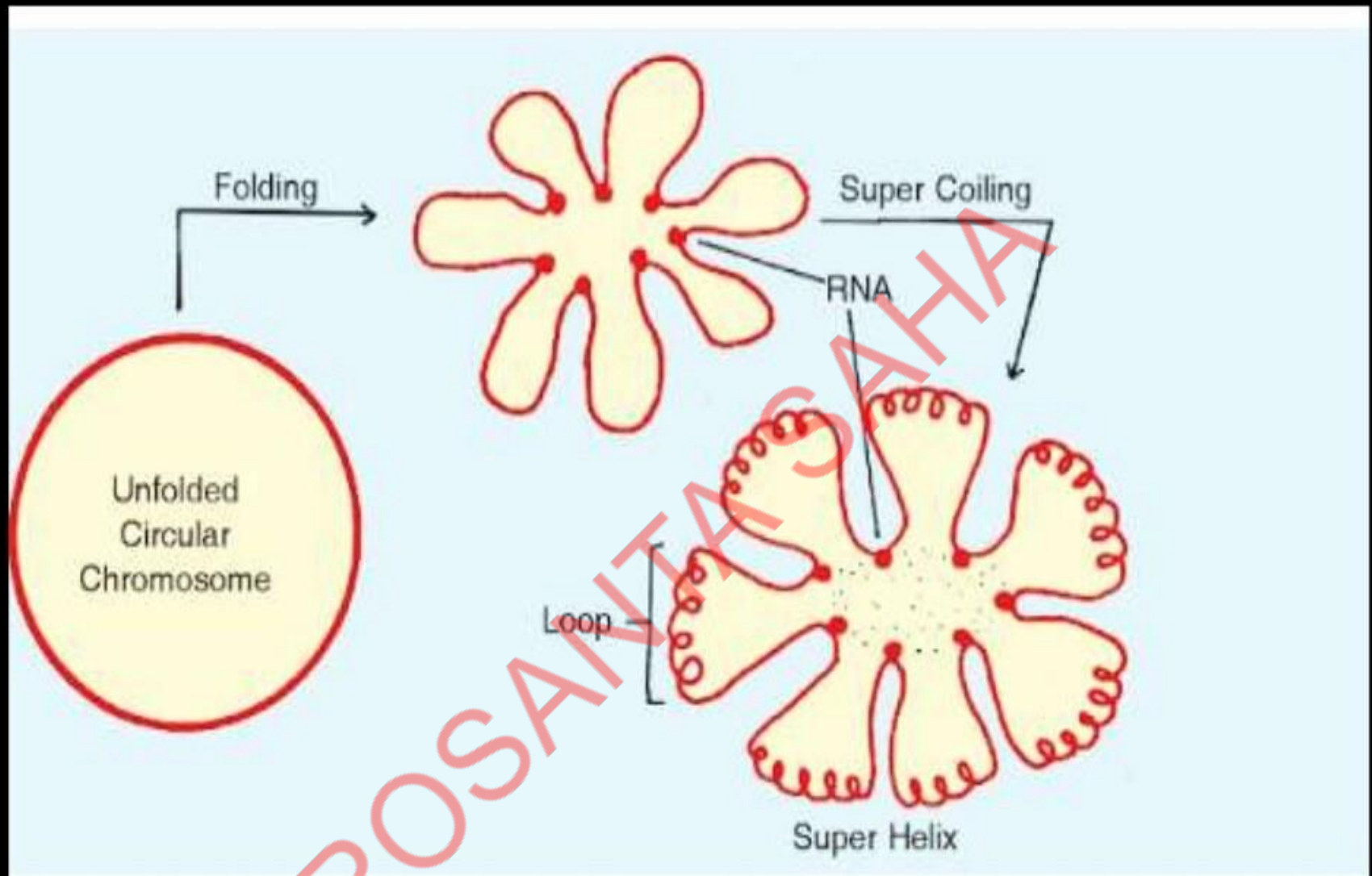
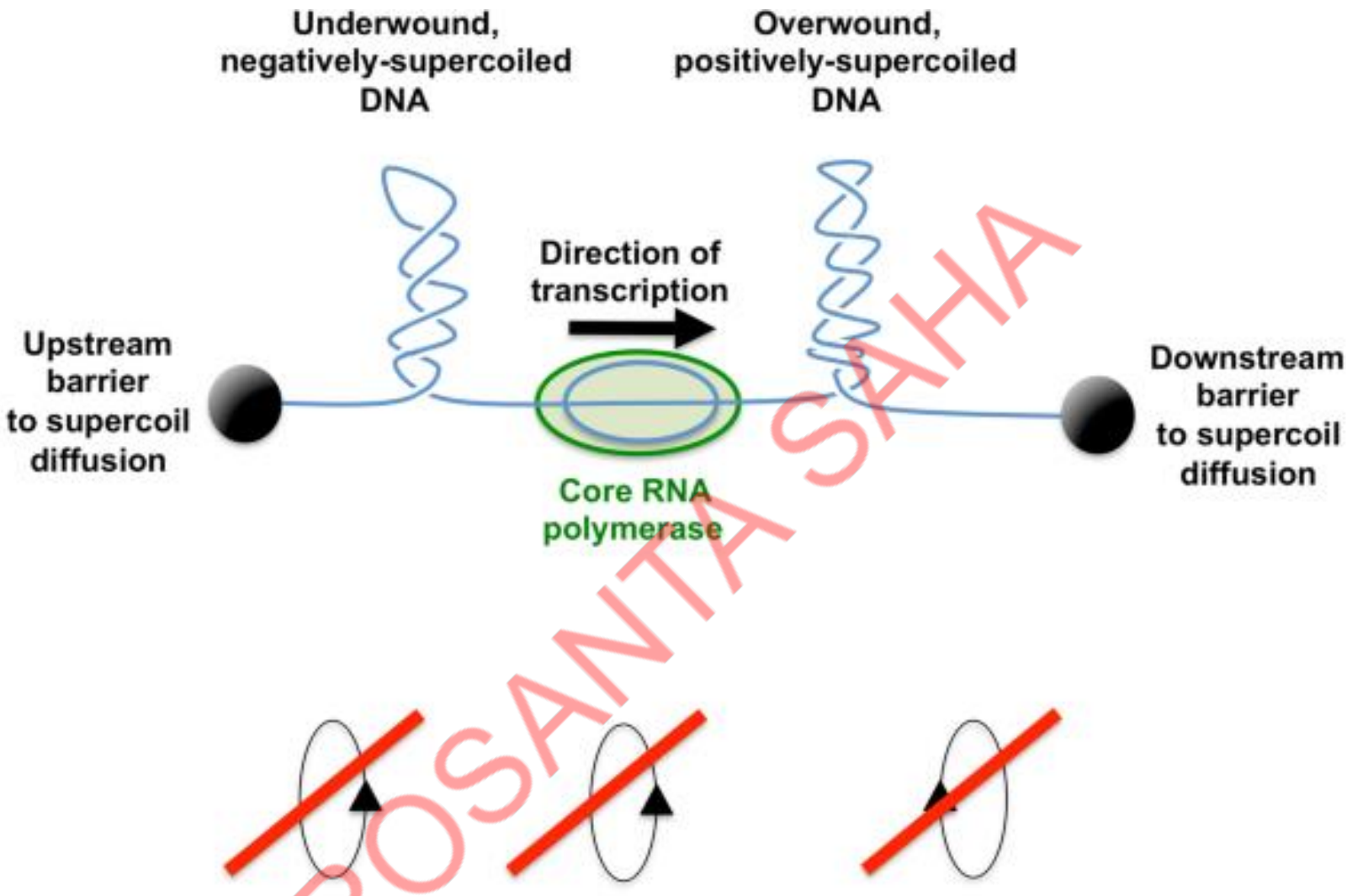


Fig. 4.20 : A cell of ***E.coli*** showing nucleoid in centre and the other cell components (diagrammatic)

Figure 3.28 Nucleoid organization. The nucleoid forms approximately 50 loops of chromosome called domains, which radiate from the center (shown shaded). Within each domain, the DNA is supercoiled and partly compacted by DNA-binding proteins (shown in green).



A model representing the process of folding and super coiling of bacterial chromosome (based on Worcel and Burgi, 1972).

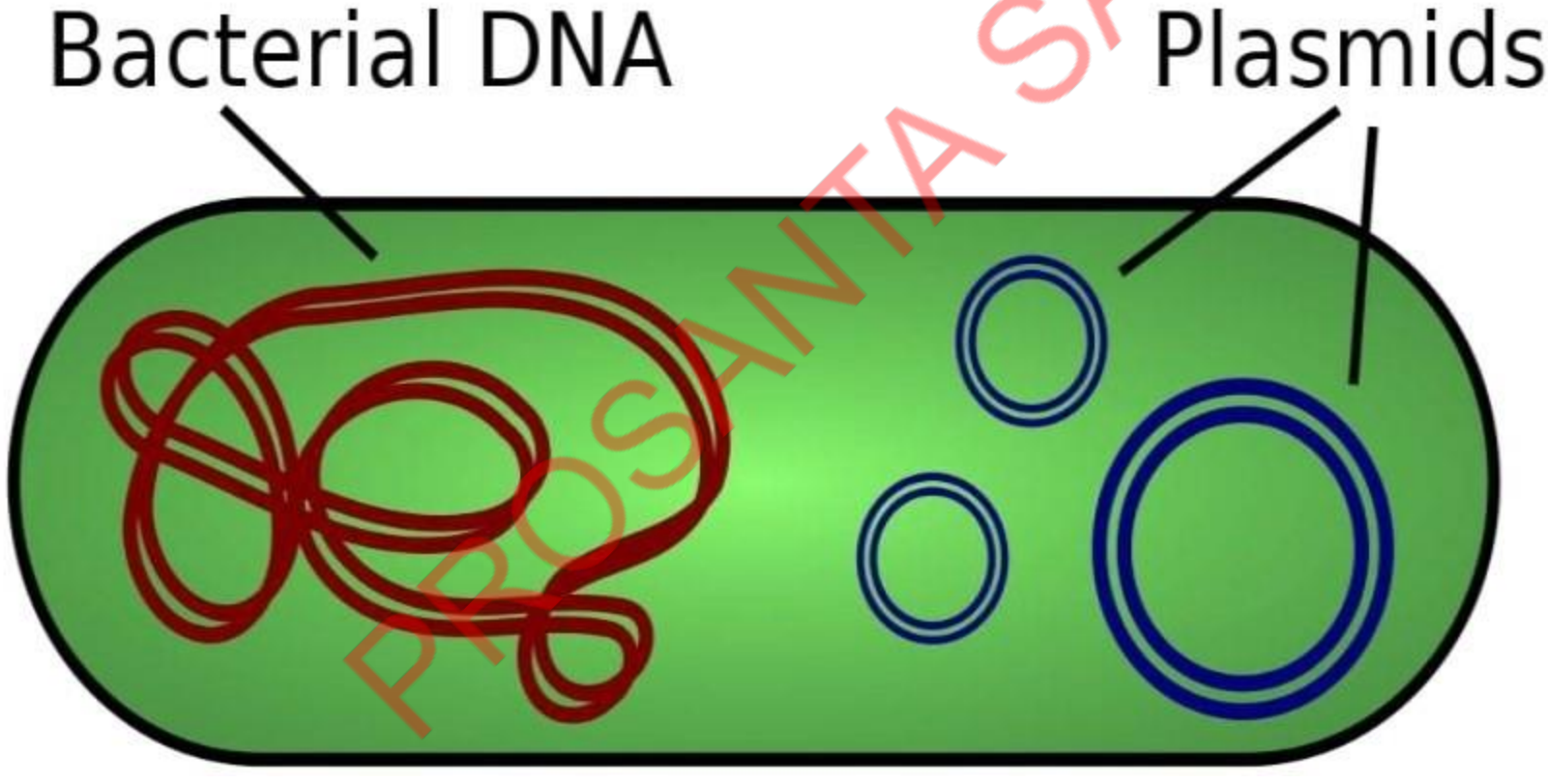


Rotational diffusion of the negatively-supercoiled DNA (left), of the positively-supercoiled DNA (right) or rotation of the transcription complex (centre) around the DNA to unjam the elongation complex is forbidden in this system. Topoisomerase activity is needed to remove the accumulated supercoils.

4)Intracellular structure

- **Plasmids :-**
- The term plasmid was first introduced by the American molecular biologist *Joshua lederberg* in 1952.
- A plasmids is a short usually circular and double stranded segment of DNA .
- That is found in the cytoplasm separate from the main bacterial chromosome.
- Their size veries from 1 kbp to over 100 kilobase pare.

- **Plasmids are capable of autonomous replication.**
- **Plasmids can transfer genes from one cell to other cell.**



PLASMIDS IN EUBACTERIA

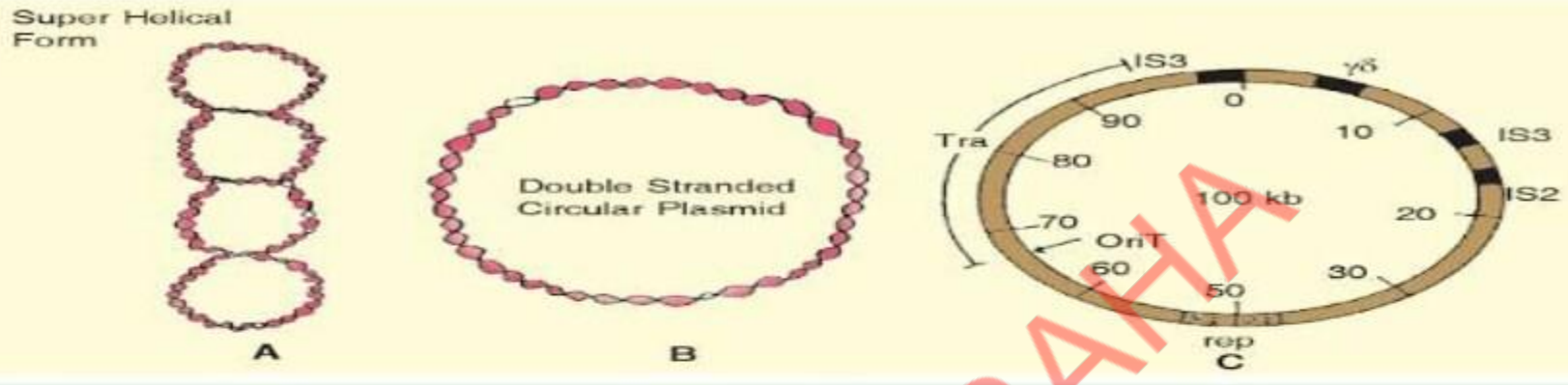


Fig. 4.22 : Plasmid. A, super helical form; B, double stranded circular form; C, F-plasmid.

Table 4.4 : Some important types of plasmids

Type	*Representative*	*Hosts*	*Size(kb)/ (Number)*	*Features*
Fertility factor	F factor	*E.coli, Salmonella Citrobacter*	95-100 (1-3)	Sex pilus, Conjugation
R plasmids	RP4	*Pseudomonas* and other Gram-negative bacteria	54 (1-3)	Sex pilus, conjugation Amp^r, Kan^r, Neo^r, Tet^r
	R100	*E.coli, Shigella Salmonella, Proteus*	90 (1-3)	$Chlo^r$, $Stre^r$, Tet^r, Hg^r
	pSJ23a	*S. aureus*	36	Pen^r, Hg^r, $Gent^r$, Kan^r, Neo^r, Ery^r
Col plasmids	ColE1	*E.coli*	9 (10-30)	Colicin E1 production
	ColE2	*Shigella*	10-15	Colicin E2
Virulence plasmids	Ent (P307)	*E.coli*	83	Enterotoxin production
	Col V-K30	*E.coli*	2	Siderophore for iron uptake
Metabolic plasmids	CAM	*Pseudomonas*	230	Camphor degradation
	SAL	*Pseudomonas*	56	Salicylate degradation
	TOL	*P. putida*	75	Toluene degradation
	P5P4	*Pseudomonas*	—	2,4-dichlorophenoxy acetic acid degradation
		E.coli	—	Lactose degradation

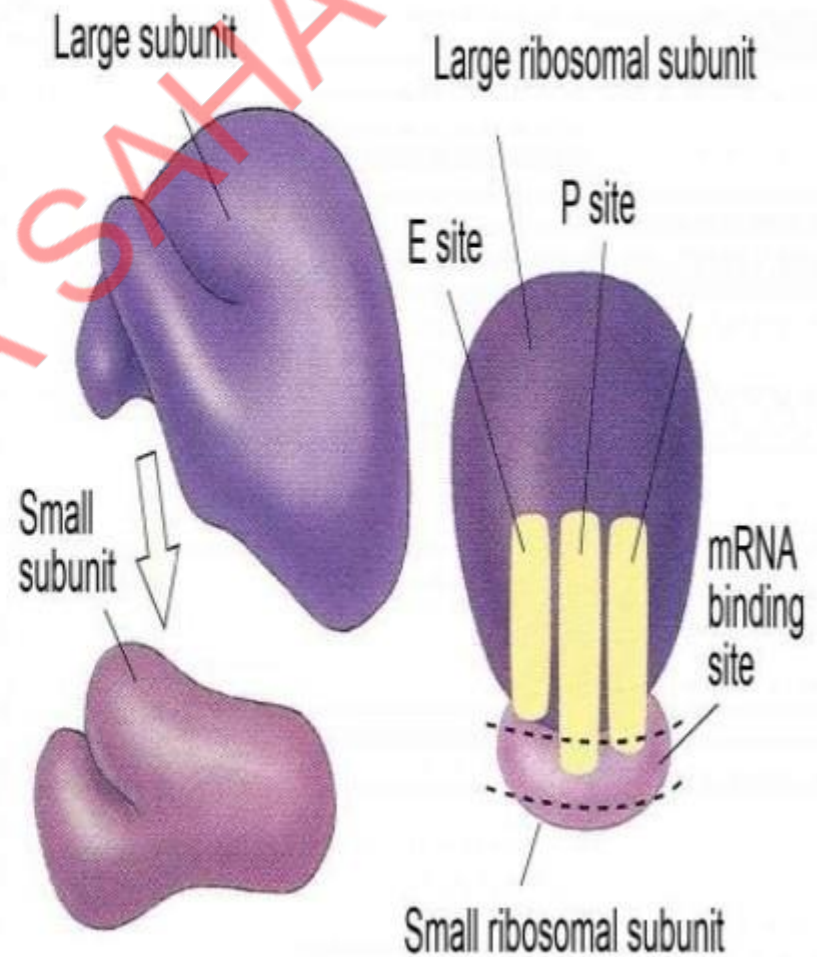
Source : Based on Prescott *et al.* (1996)

• Ribosomes :-

- The cytoplasm contains a large number of solute low and high molecular weigh substunce.
- RNA and approximately 20,000 Ribosomes/cell.
- Bacteria have 70S Ribosomes comprising 30S and 50s subunit.

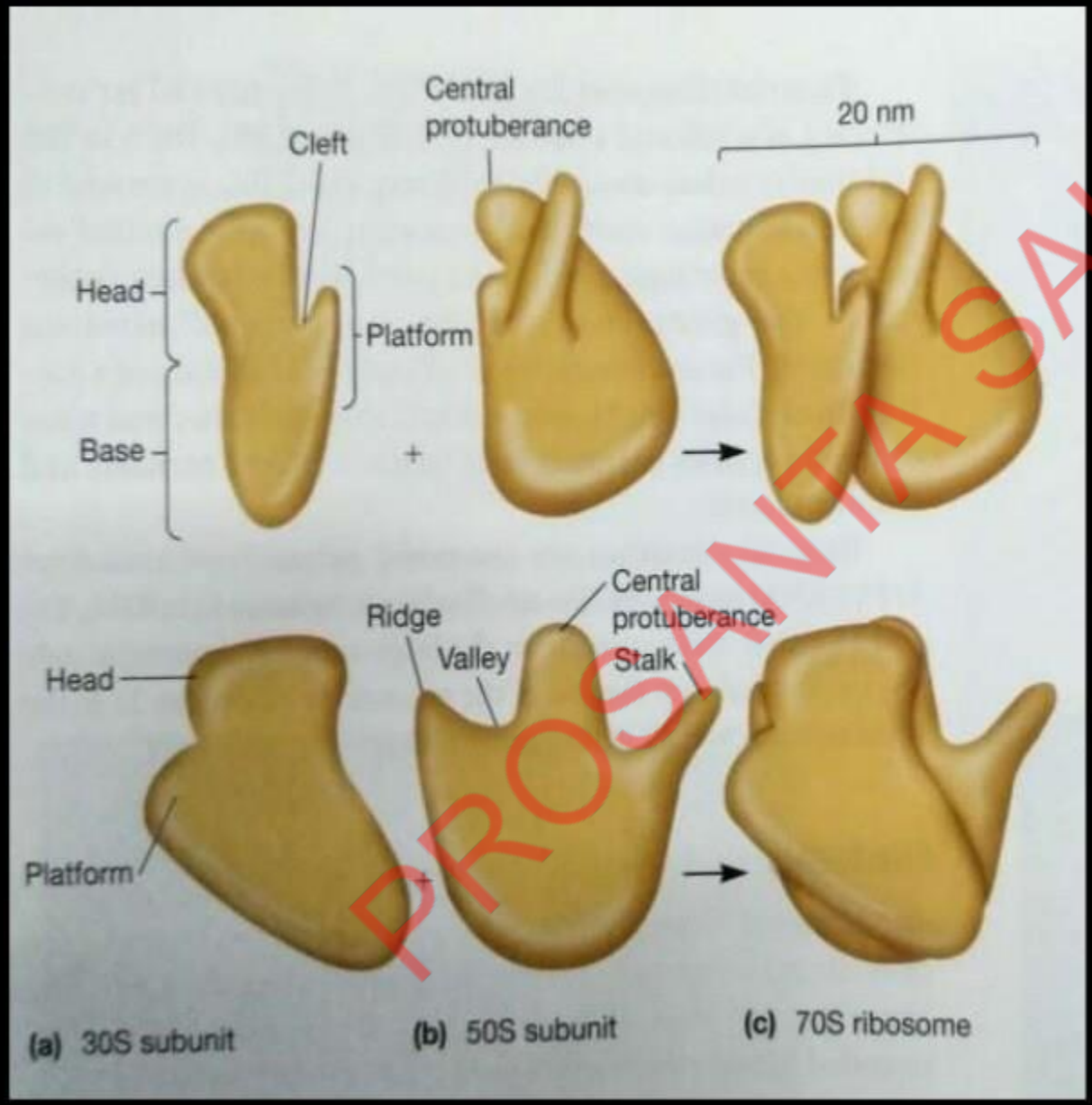
• Function :-

- Ribosomes as the organelles for protein synthesis.



EUBACTERIA RIBOSOME

: Three dimensional model of ***E.coli*** ribosome shown in two different orientation (A and B) (after Lake, 1981)



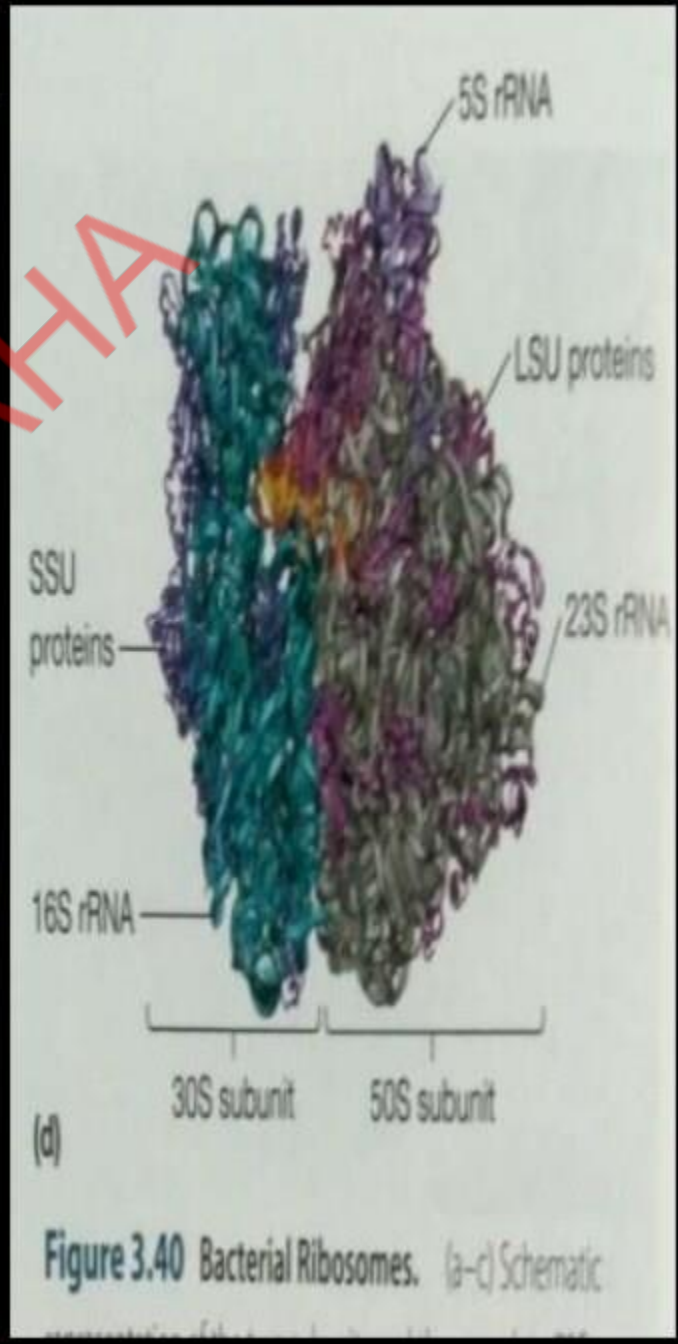
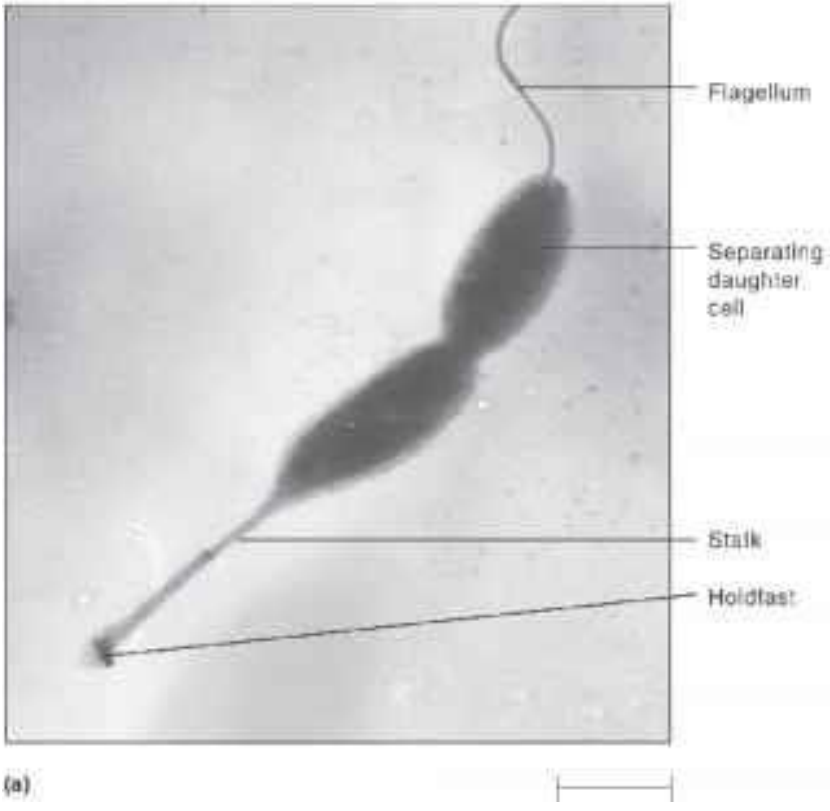
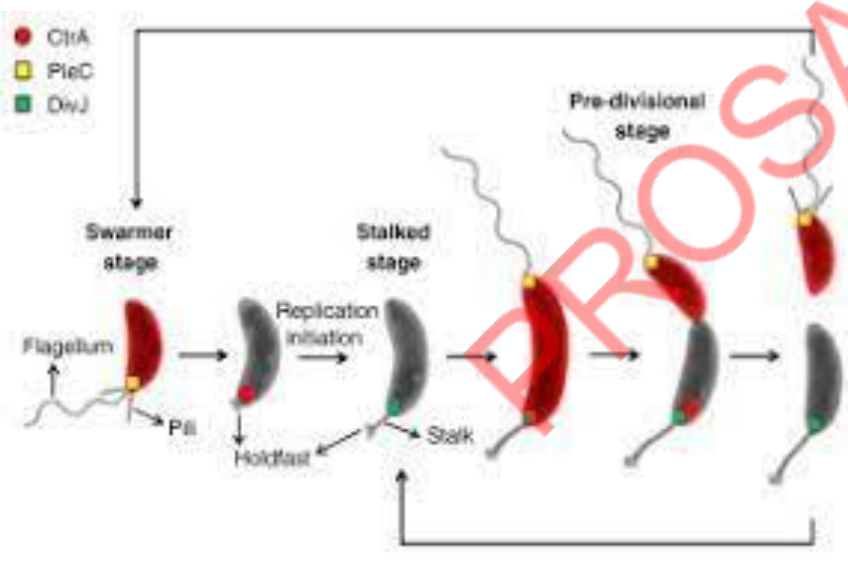


Figure 3.40 Bacterial Ribosomes. (a–d) Schematic

Prostheca





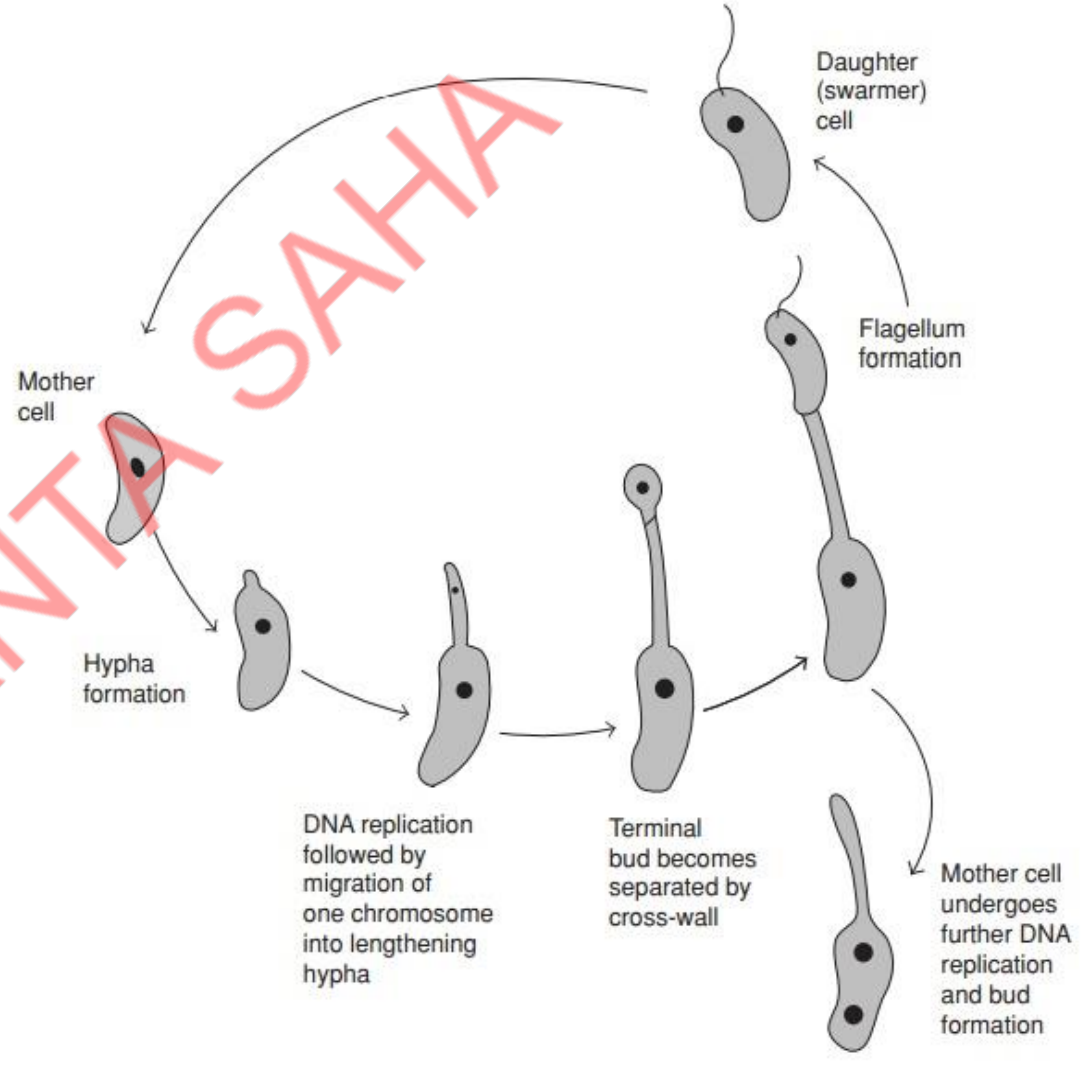


Figure 7.6 The budding bacteria: reproduction in *Hyphomicrobium*. Before reproduction takes place, the vegetative cell develops a stalk or hypha, at the end of which a bud develops. This produces a flagellum, and separates to form a motile swarmer cell

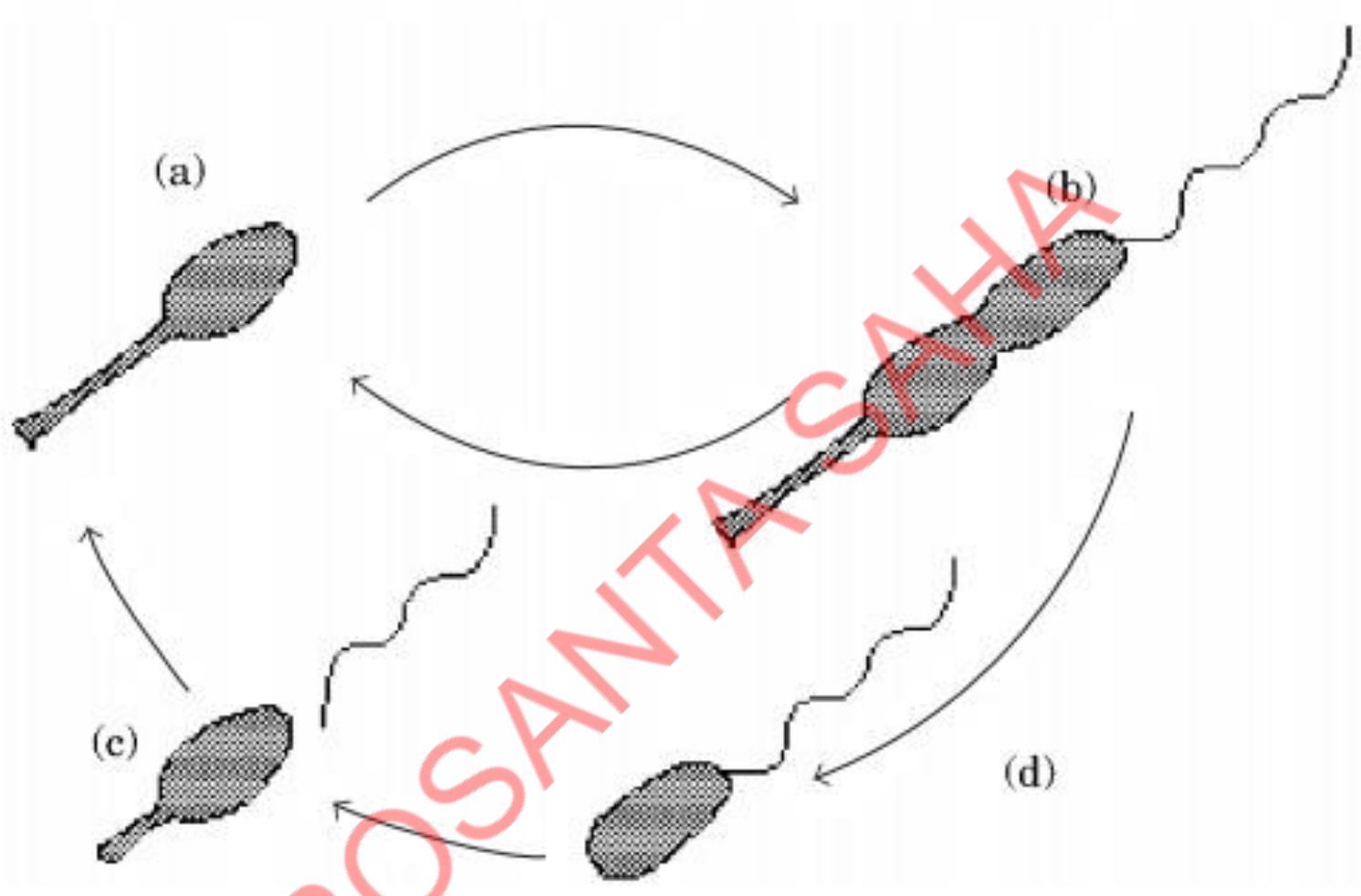
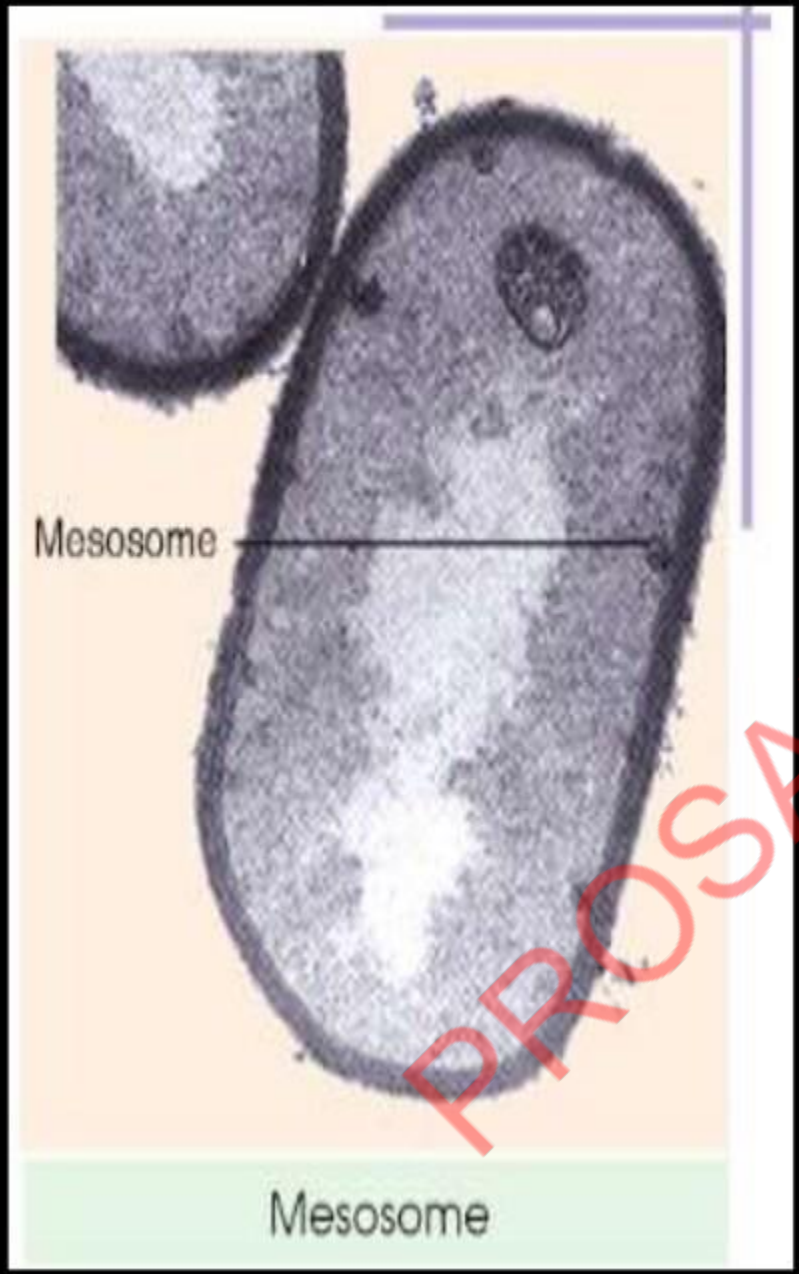


Figure 7.5 The life cycle of *Caulobacter*, a stalked bacterium. The stalked 'mother' cell attaches to a surface by means of a holdfast (a). It grows in length and develops a flagellum (b), before undergoing binary fission. The flagellated swarmer cell swims away (c), and on reaching a suitable substratum, loses its flagellum and develops a stalk or prostheca (d). Reproduced by permission of Dr James Brown, North Carolina State University

MESOSOME IN EUBACTERIA



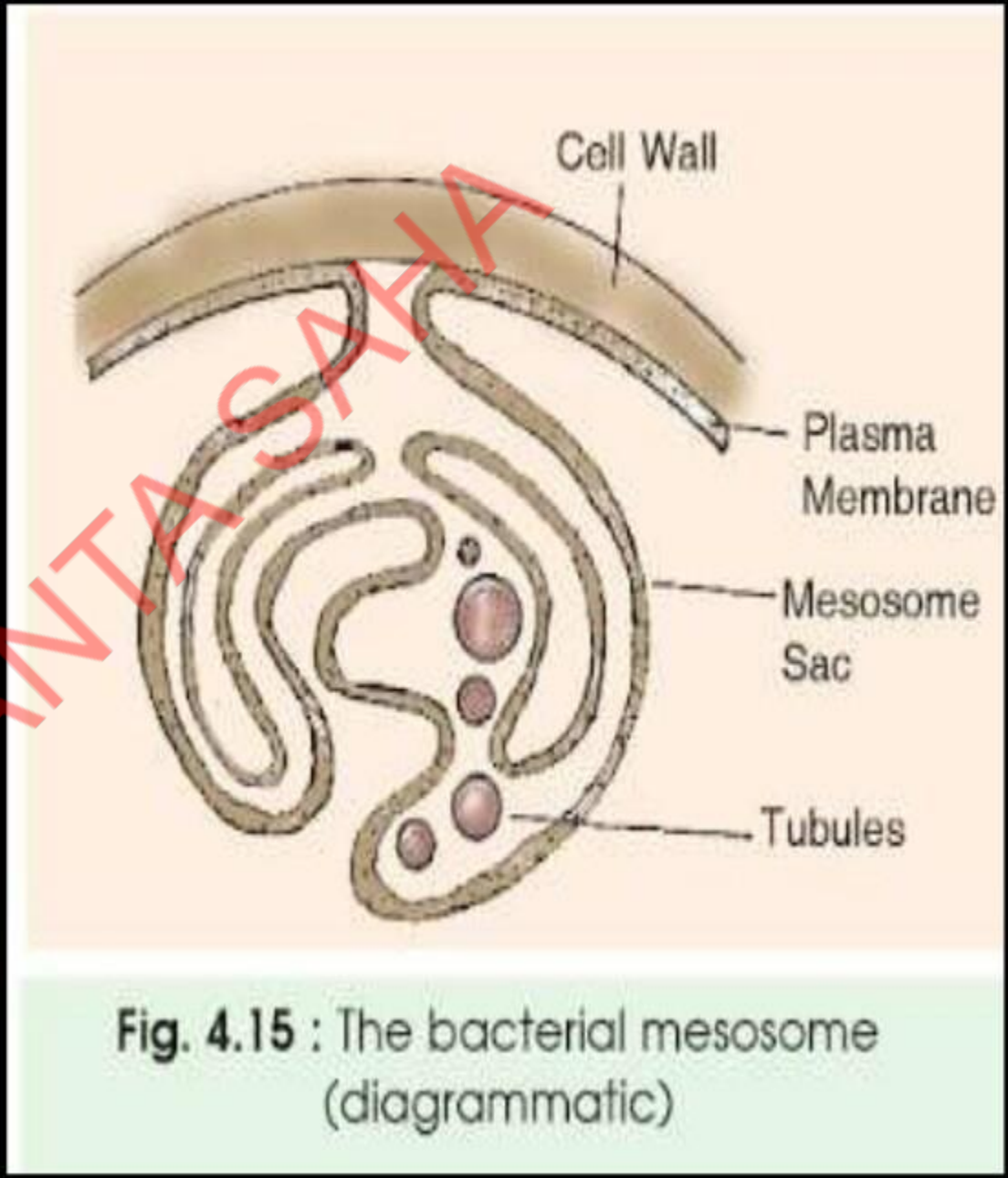


Fig. 4.15 : The bacterial mesosome (diagrammatic)

Mesosome

- **Convoluted or multilaminated** membranous bodies.
- Develop by **complex invagination of the cytoplasmic membrane** into the cytoplasm.

Function

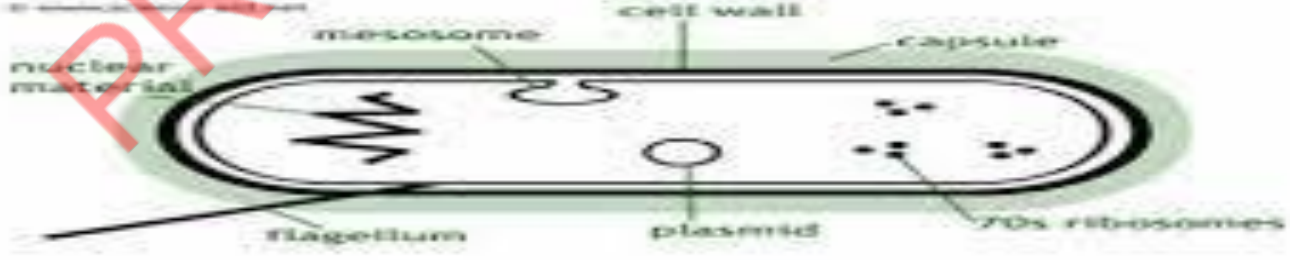
(1)Compartment of DNA at cell division and at sporulation.

(2)Are principal sites of **respiratory enzymes** (analogous to the mitochondria of the eukaryotic cell)

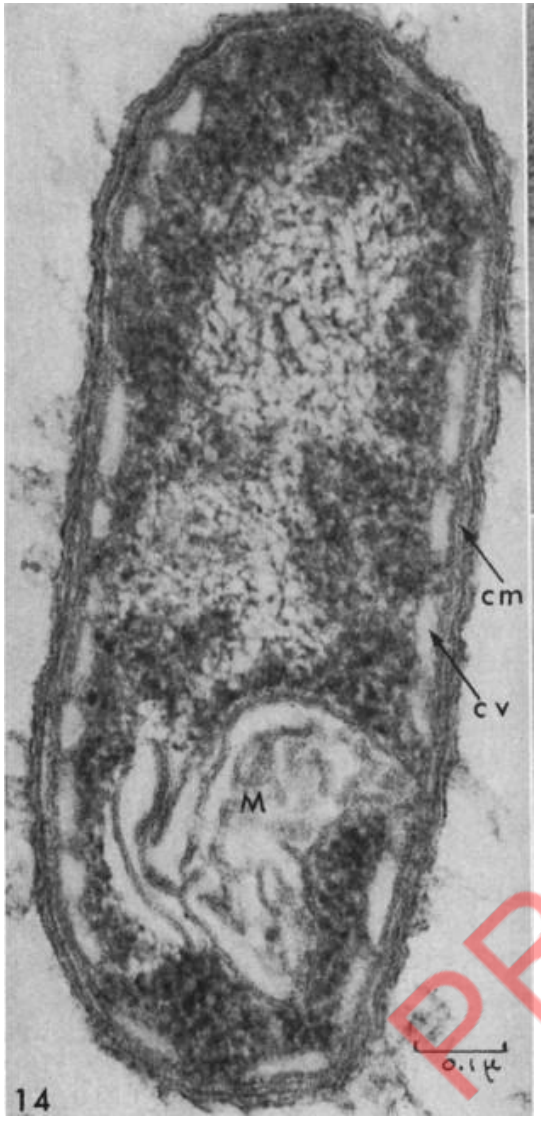
Mesosomes are the infoldings of cell membrane, which
(i) are present in both prokaryotic and equkaryotic cells.
(ii) help in cell wall formation, DNA replication and respiration.
(iii) increase the surface area of plasma membrane.

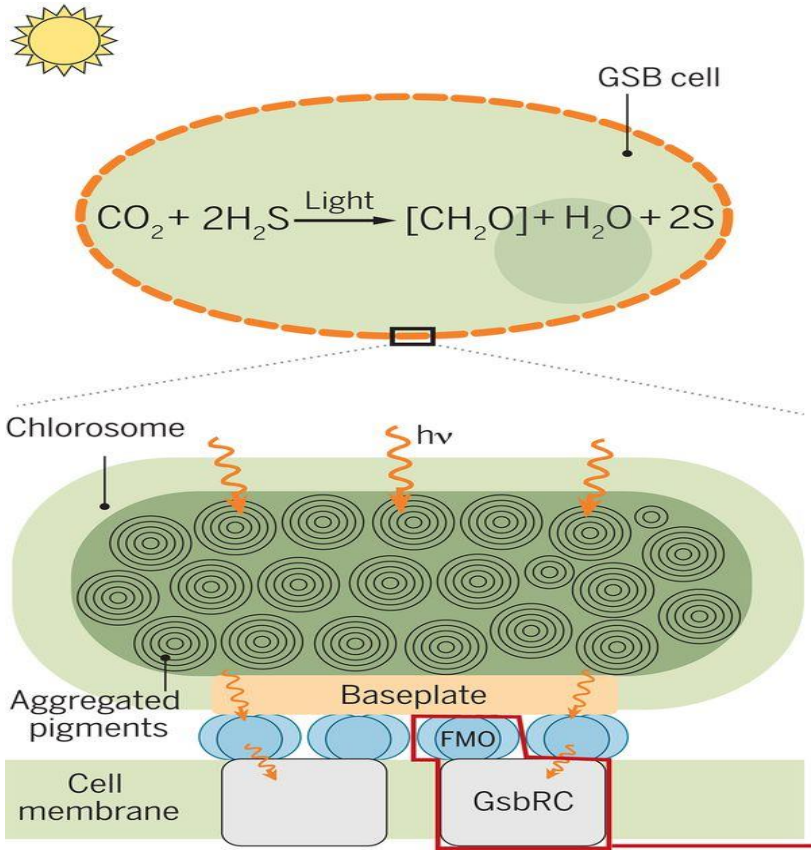
Mesosomes

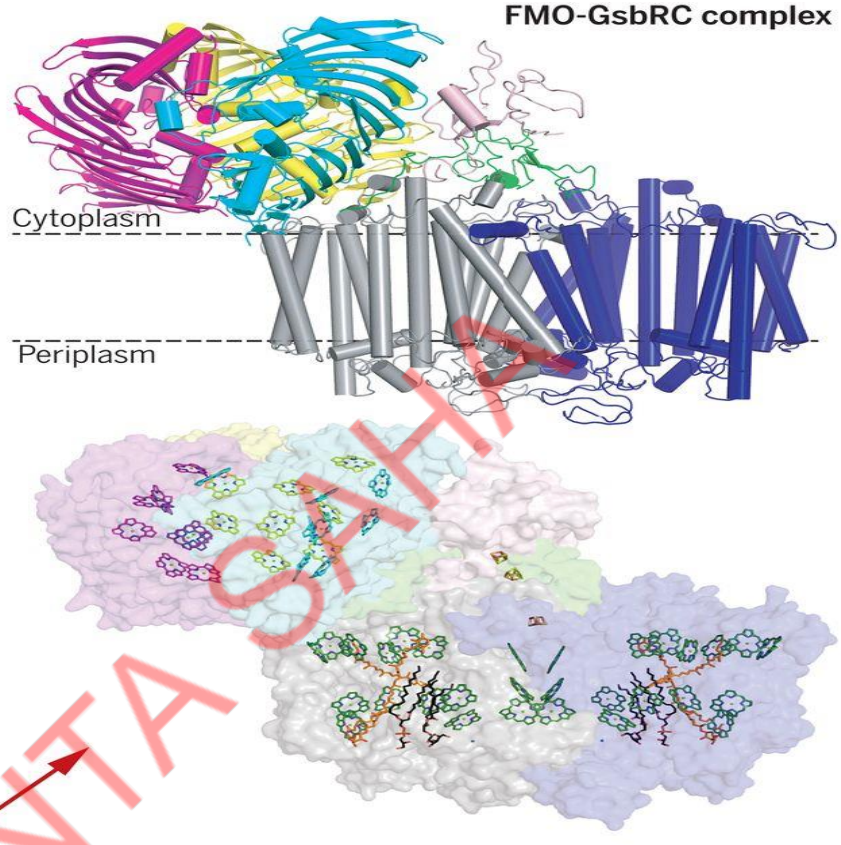
Mesosomes are folded invaginations in the plasma membrane of bacteria that are produced by the chemical fixation techniques used to prepare samples for electron microscopy. Although several functions were proposed for these structures in the 1960s, and are no longer considered to be part of the normal structure of bacterial cells.

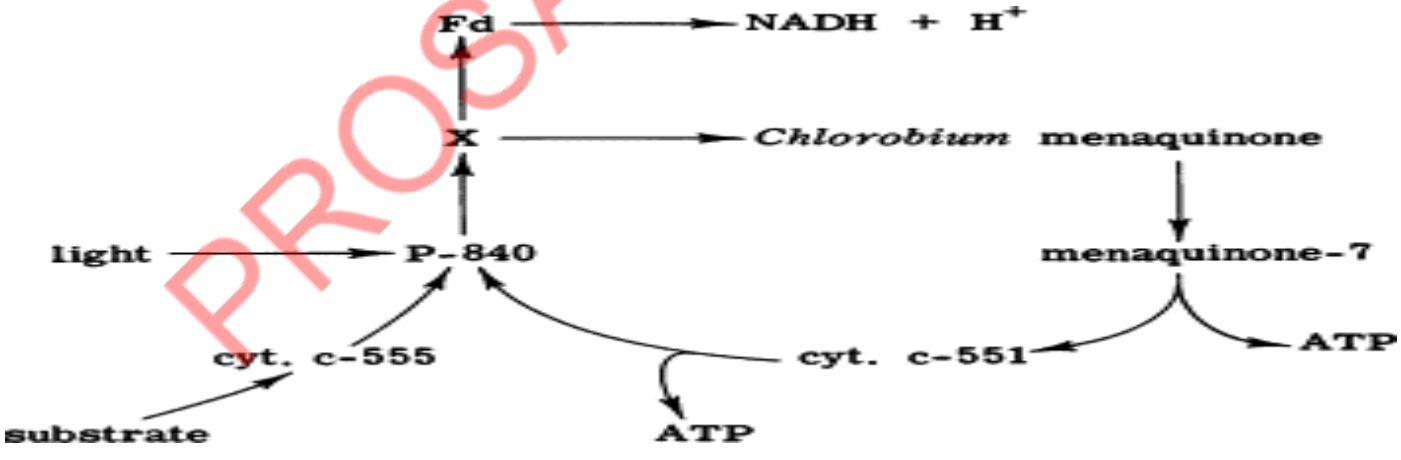


Magnetosome and Chlorobium vesicles

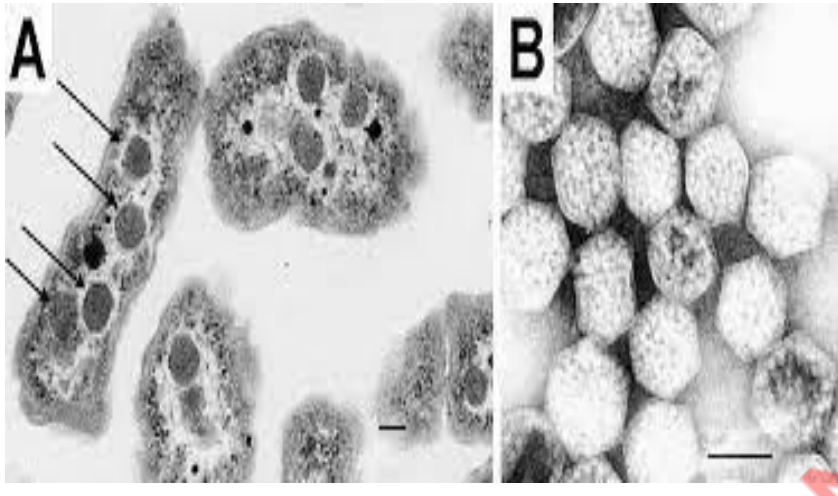


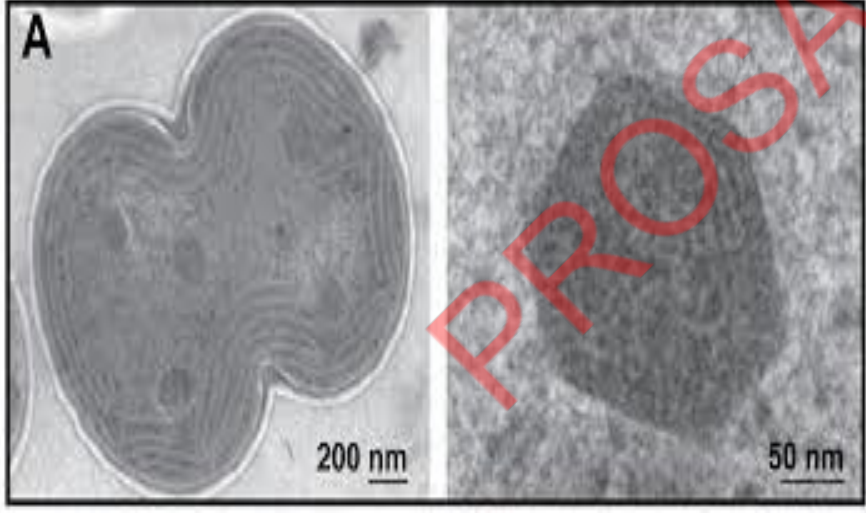


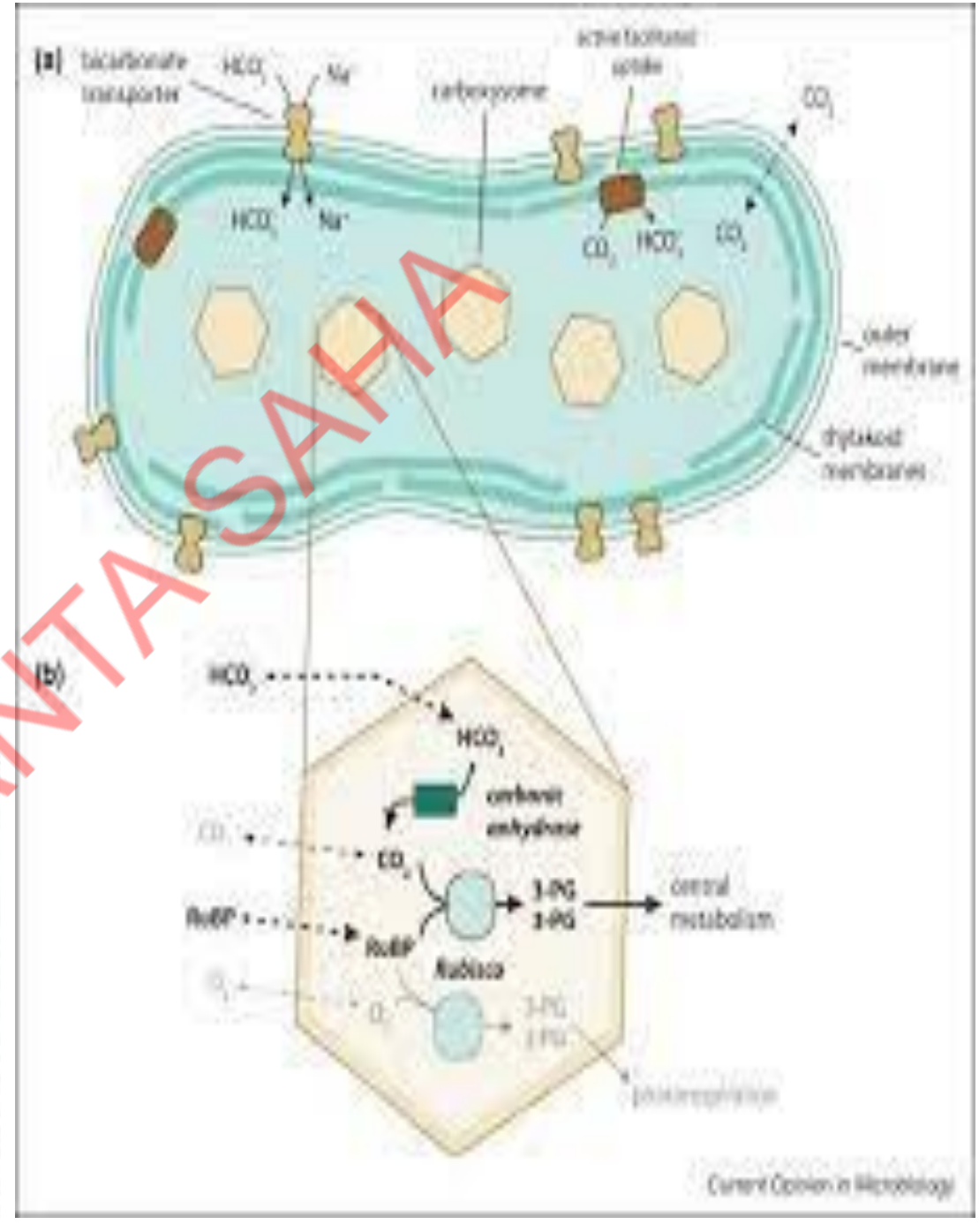




Carboxysomes







CARBOXYSOMES IN EUBACTERIA

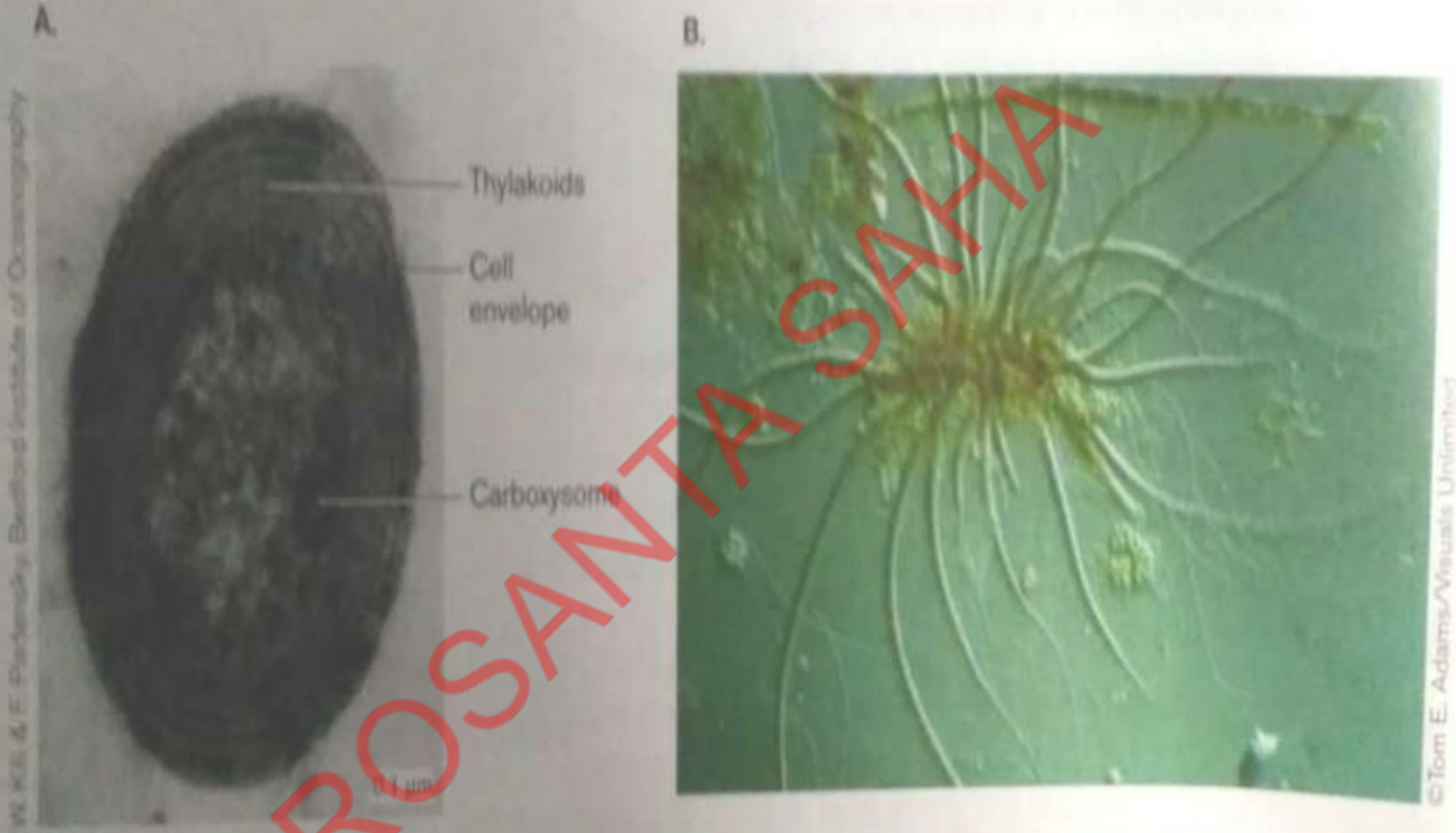
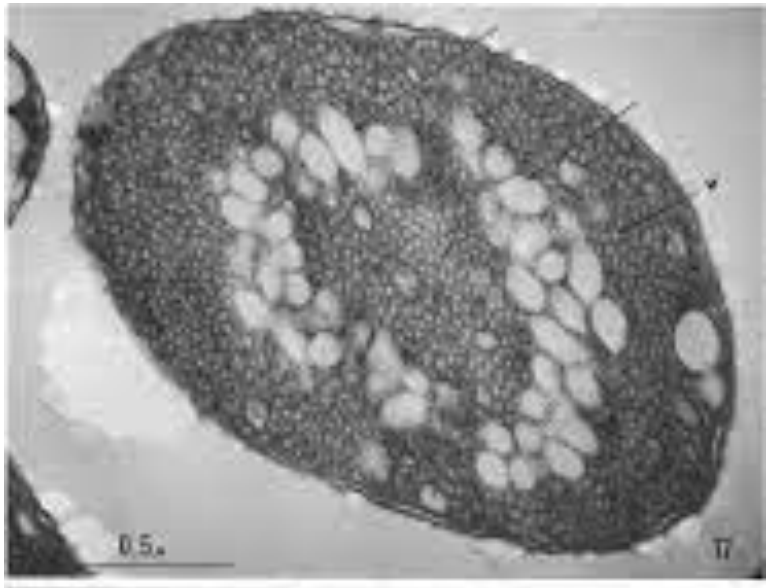
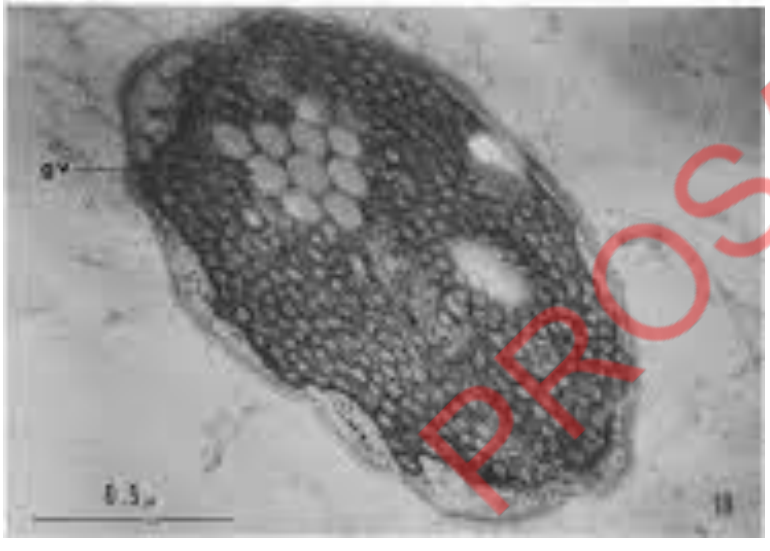


Figure 3.39 Organelles of phototrophs. **A.** The marine phototroph *Prochlorococcus marinus* (TEM). Beneath the envelope lie the photosynthetic double membranes called thylakoids. Carboxysomes are polyhedral, protein-covered bodies packed with rubisco enzyme for CO_2 fixation. **B.** Filaments (chains of cells) of the cyanobacterium *Planktothrix*. Gas vesicles provide buoyancy, enabling the phototroph to remain at the surface of the water, exposed to light.

Gas vacuoles



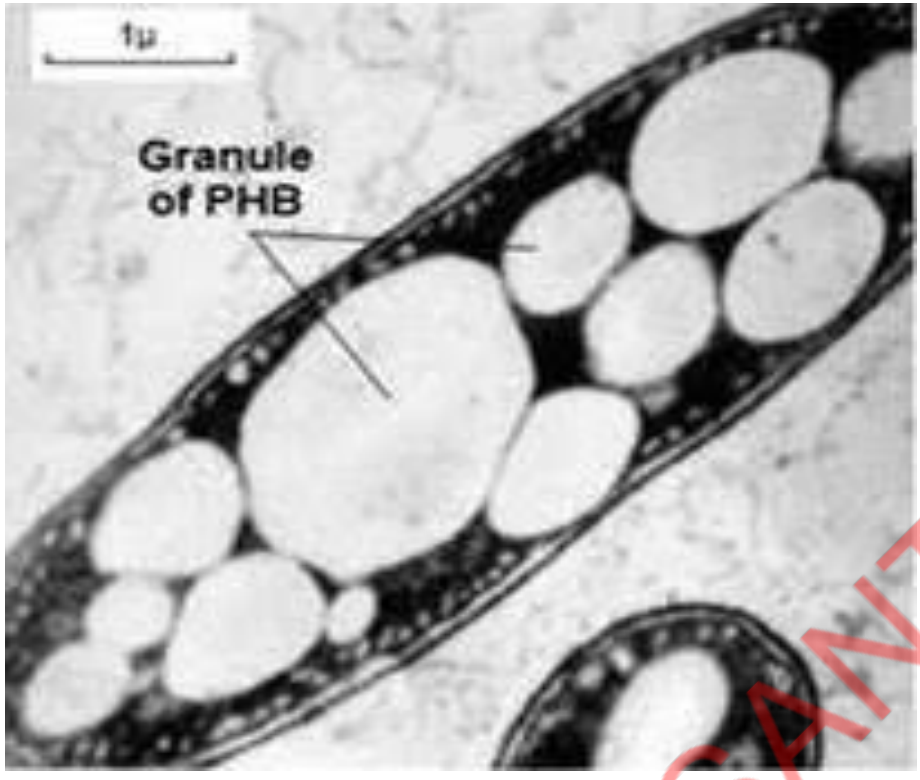


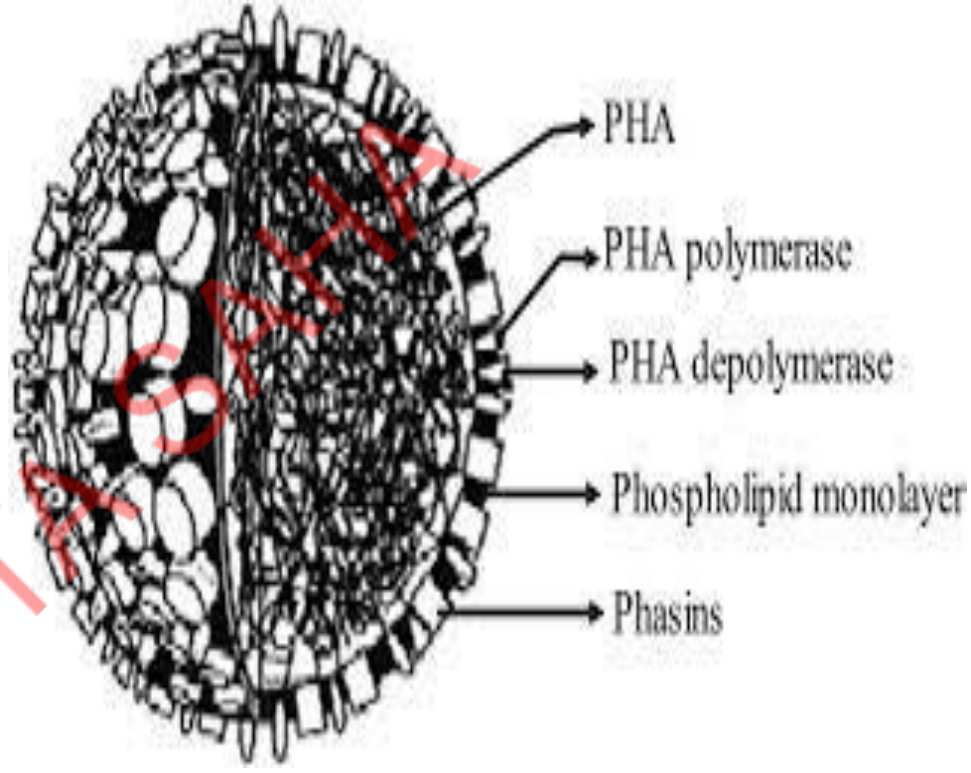
Gas vacuoles (blue)

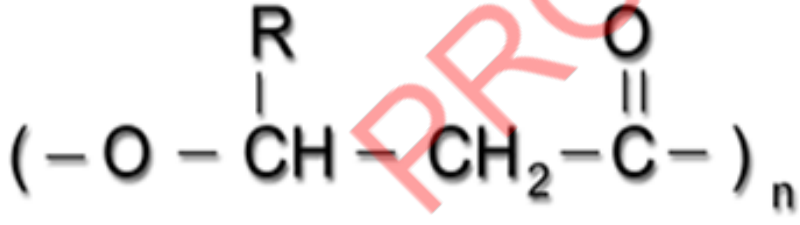
and storage granules (red)
in the cyanobacterium
Microcystis

The formation of gas vacuoles by aquatic bacteria provides a mechanism for adjusting the buoyancy of the cell.Many aquatic cyanobacteria use their gas vacuoles to move up and down in the water column.

Polyhydroxy alkanoates







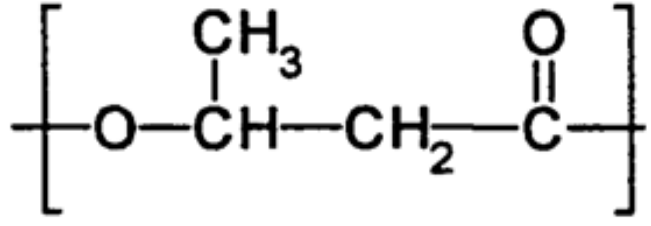
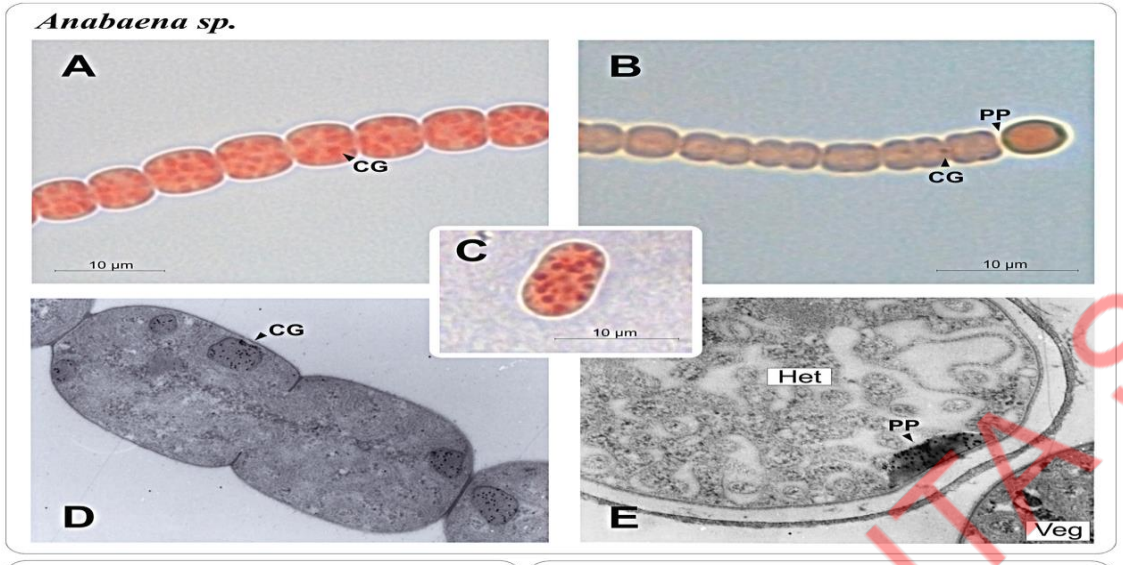


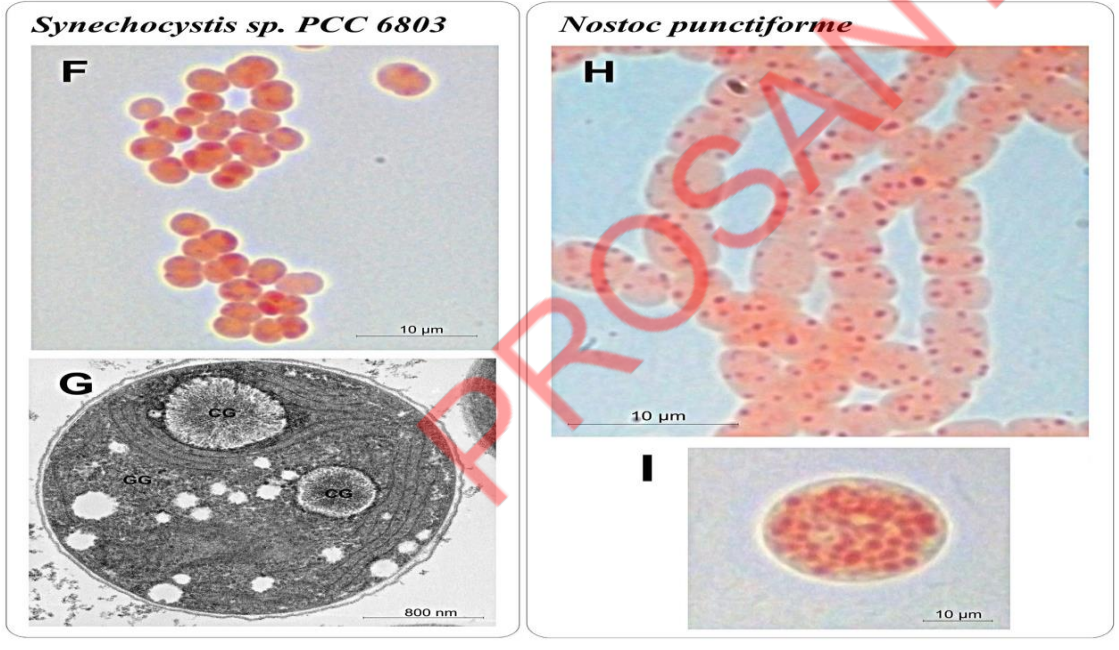
Figure 2 : a) Chemical structure of PHA **b) Chemical structure of PHB**

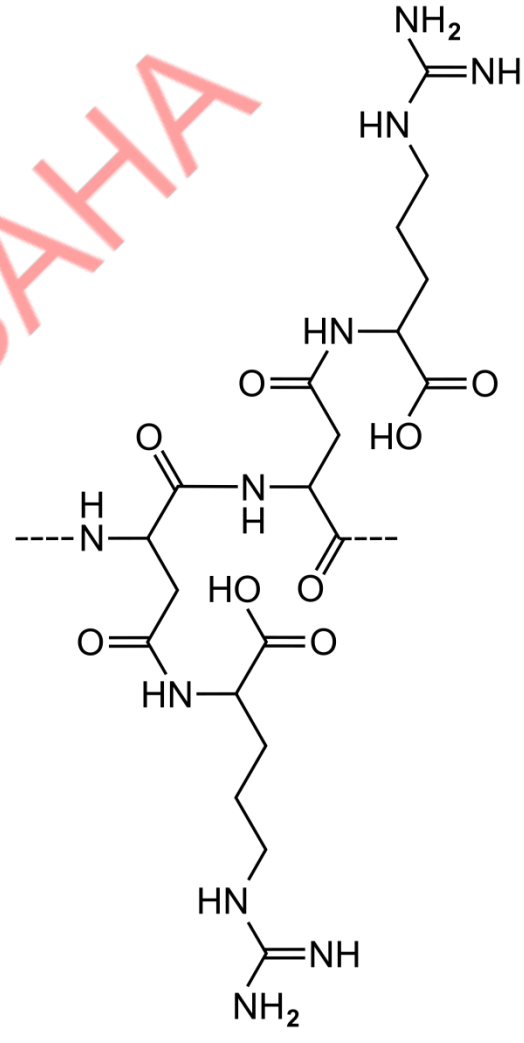
Volutin granules

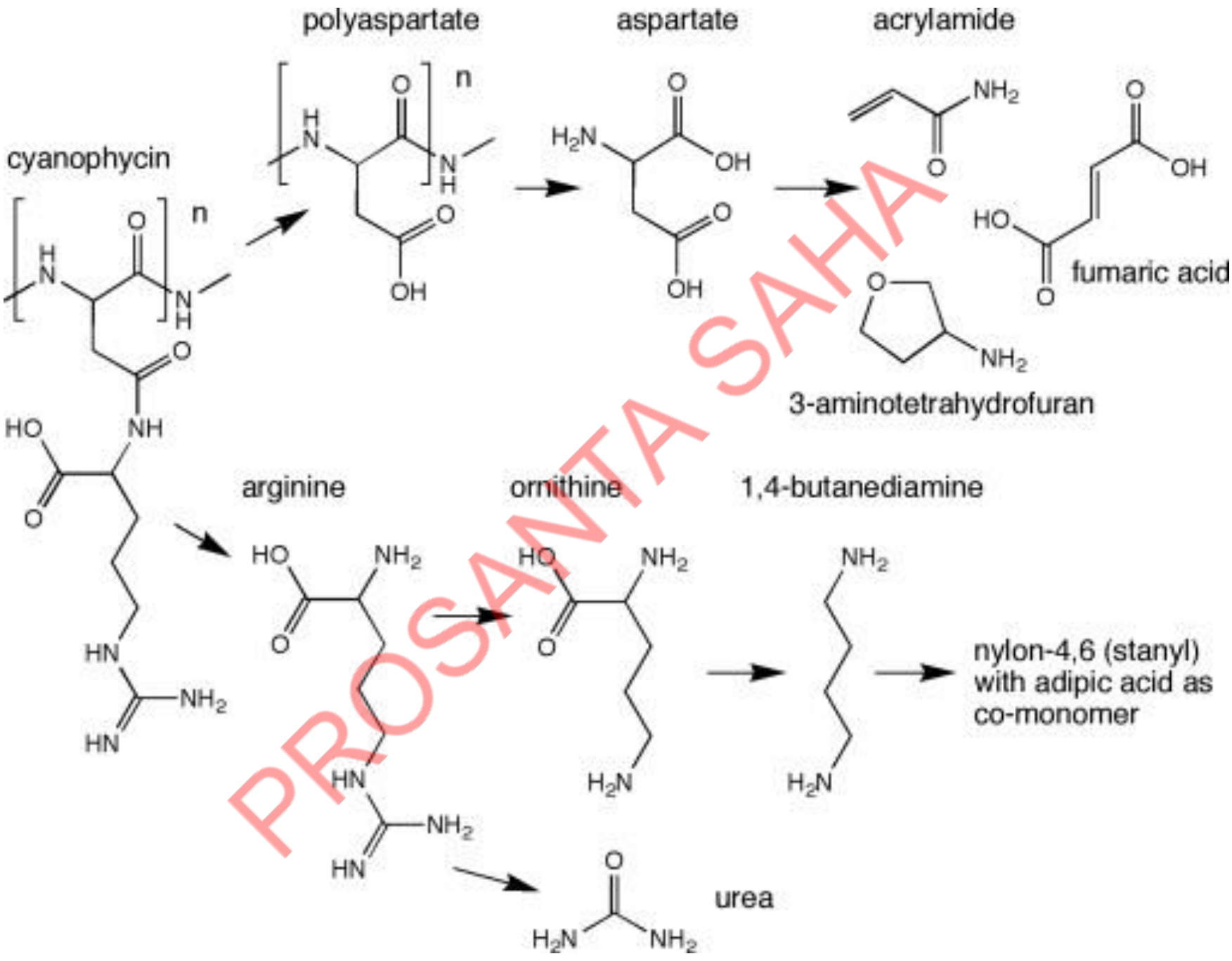
- Also called as Volutin / Babes-Ernst granules.
- Highly refractive , strongly basophilic bodies consisting of polymetaphosphate .
- Appear reddish when stained with Polychrome Methylene blue.
- Special staining like Albert's or Neisser's demonsrate granules more Clearly.
- Characteristic of diphtheria bacilli.

Cyanophycin granules

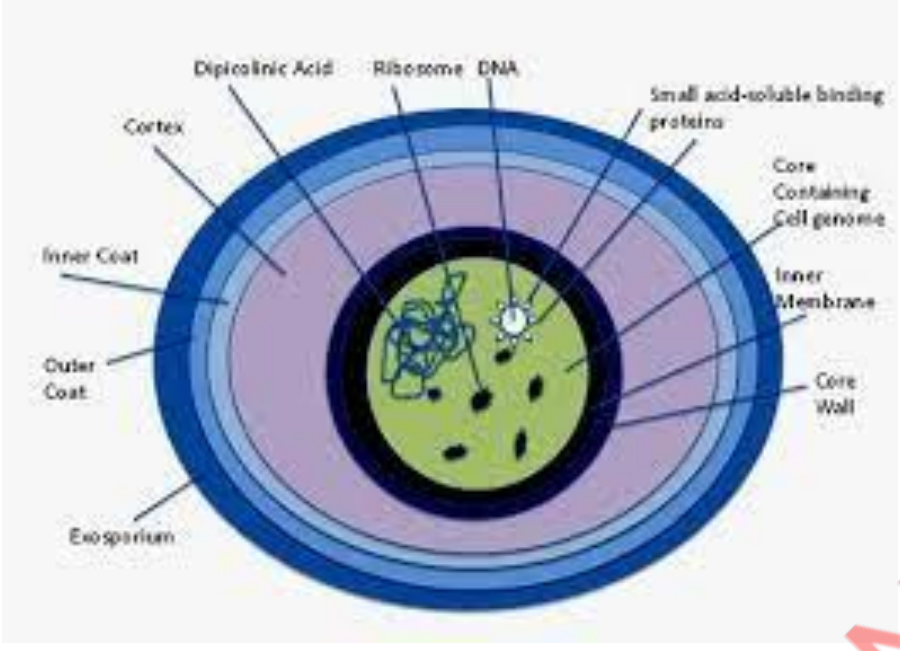


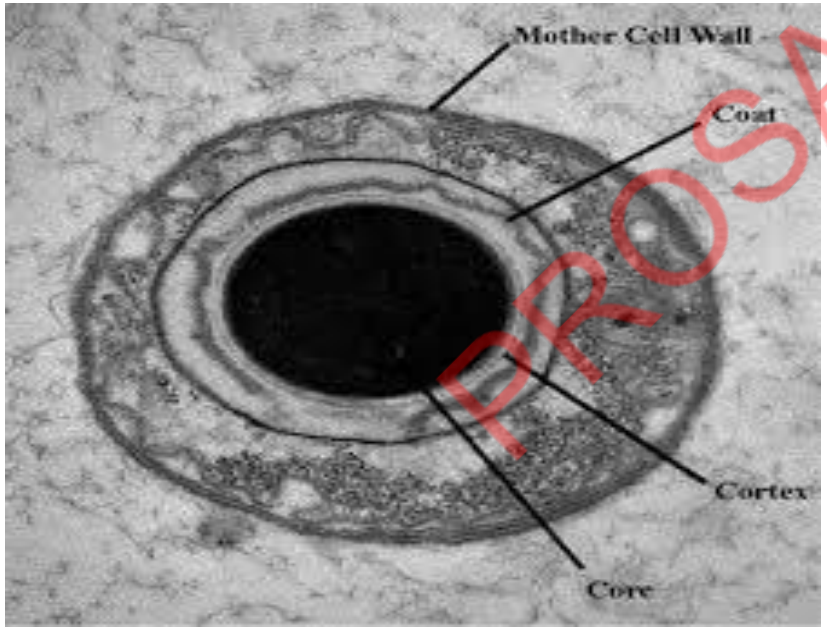


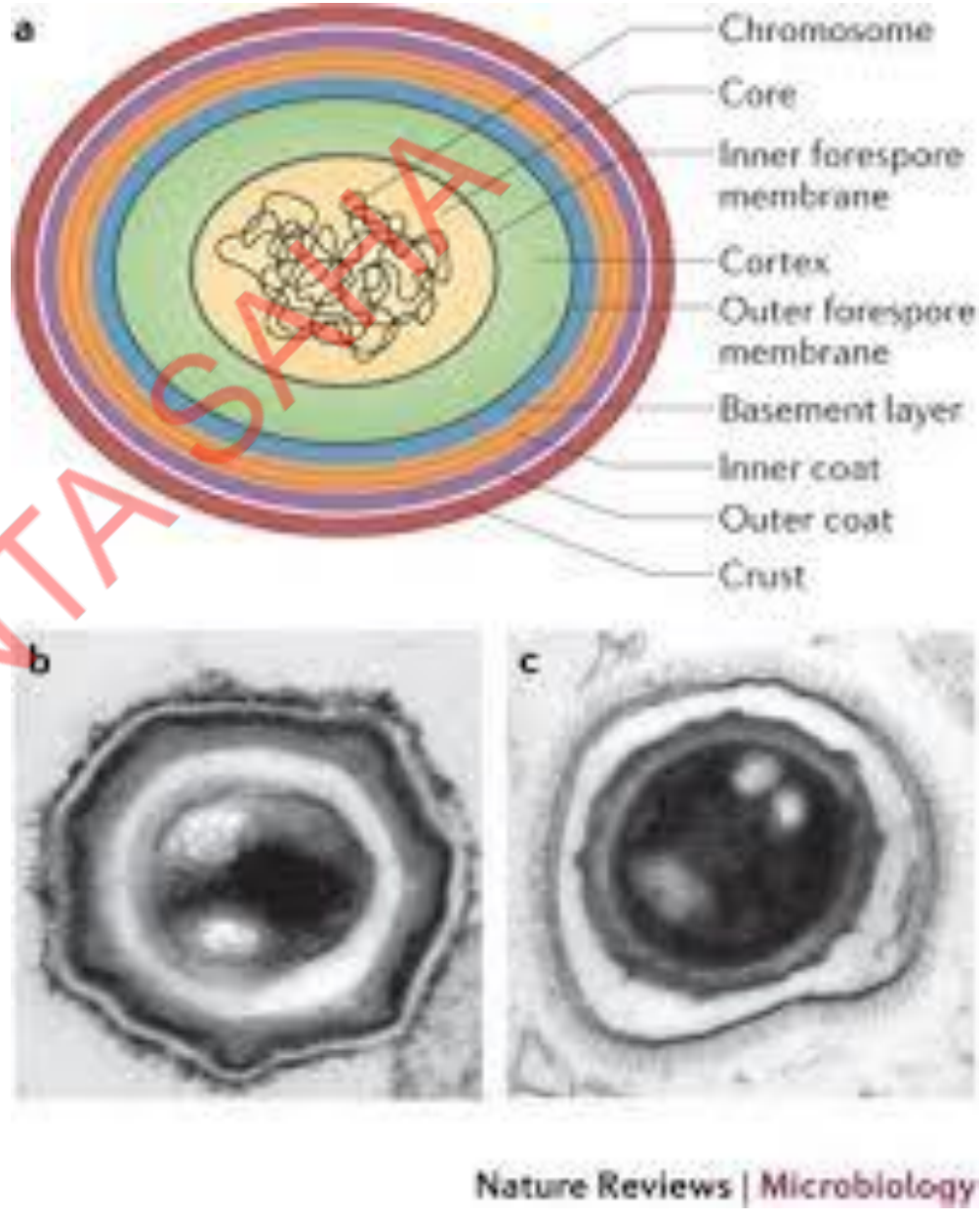




Endospore

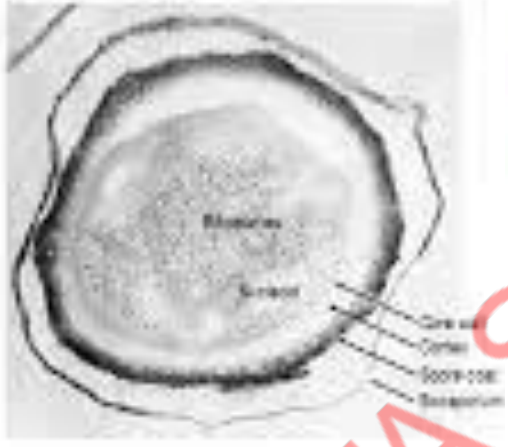


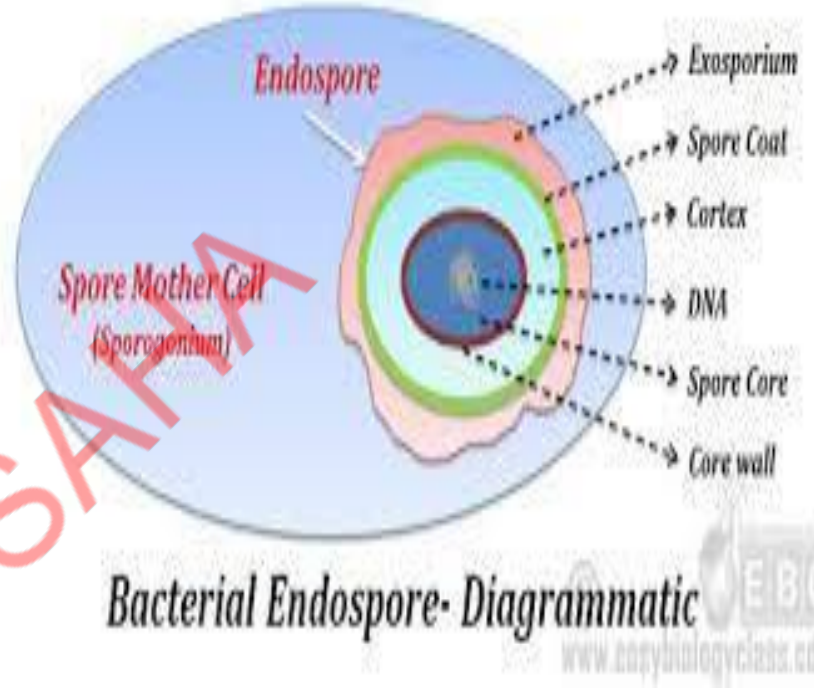


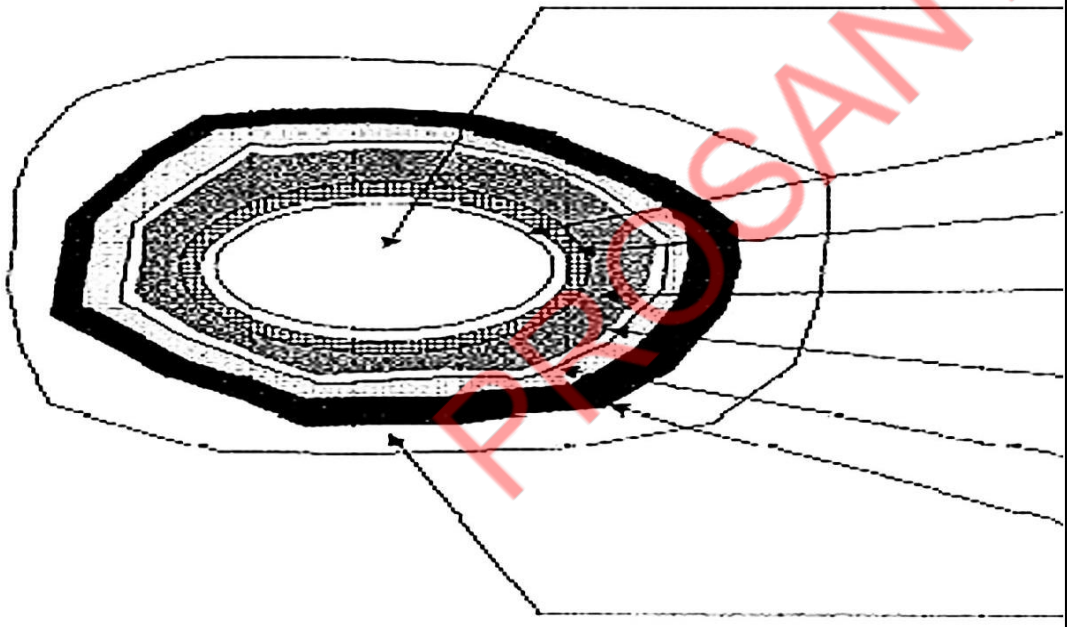


The Bacterial Endospore

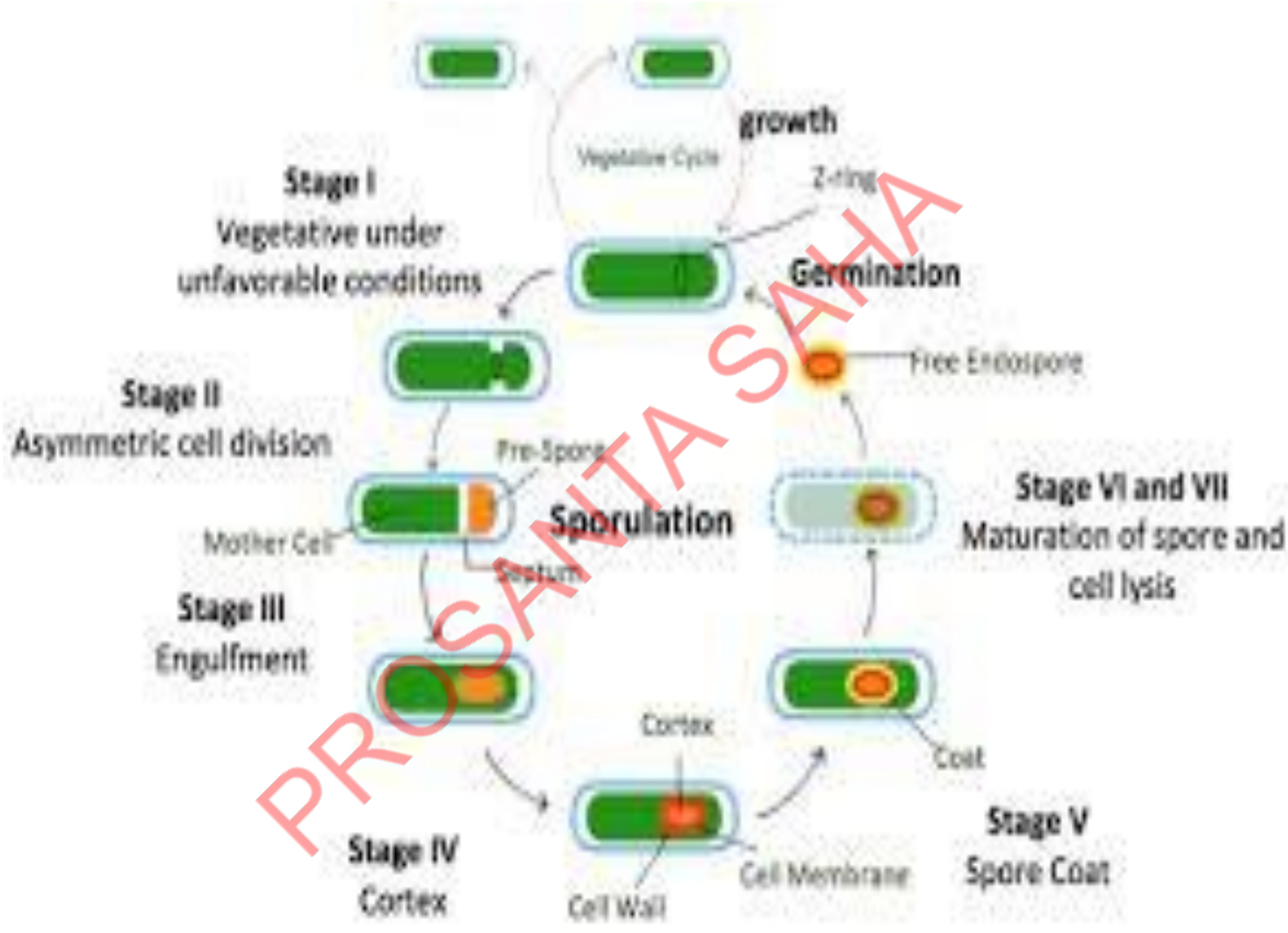
- The spore often is surrounded by a thin, delicate covering called the exosporium
- A spore coat lies beneath the exosporium, is composed of several protein layers, and may be fairly thick.
- The coat also is thought to contain enzymes that are involved in germination







Core	DNA, RNA, Proteins, SASPs, DPA, Ca^{2+}
Inner membrane	Lipid/Protein
Germ cell wall	Peptidoglycan
Cortex	Modified peptidoglycan
Outer membrane	Lipid/Protein
Inner spore coats	Proteins
Outer spore coats	Proteins
Exosporium	Proteins



THANK YOU