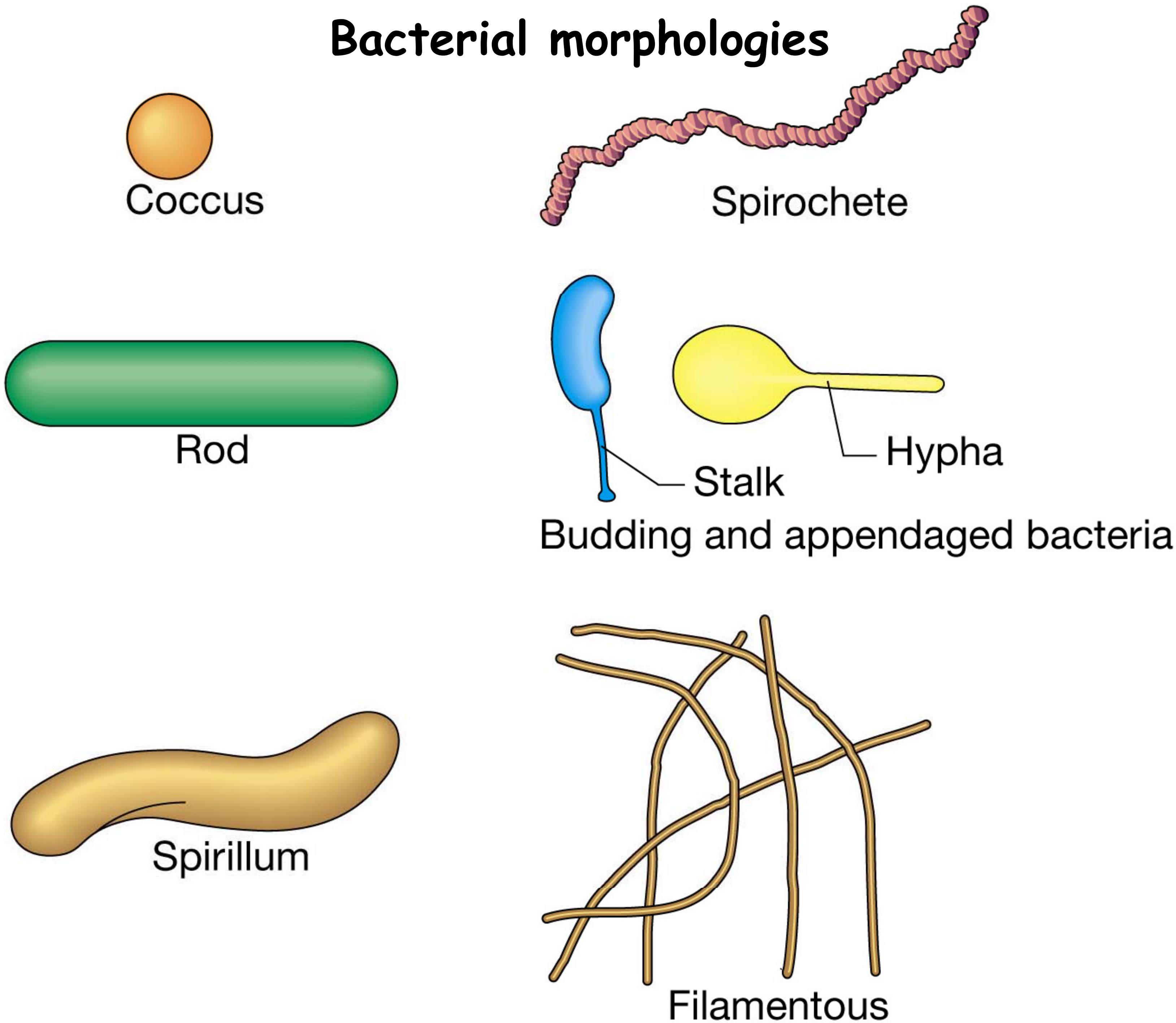
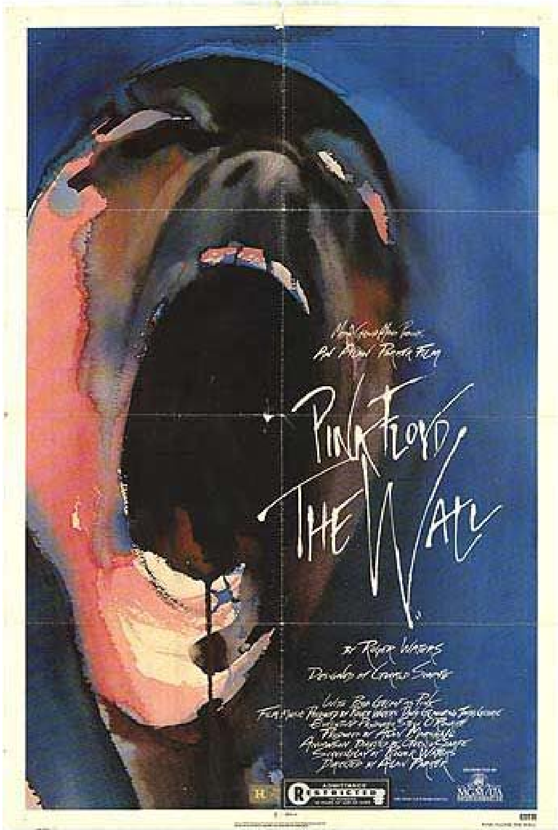
Comparing Bacteria, Archaea and Eucarya

Classification of microbial cellular features:
Variant (or NOT common to all)

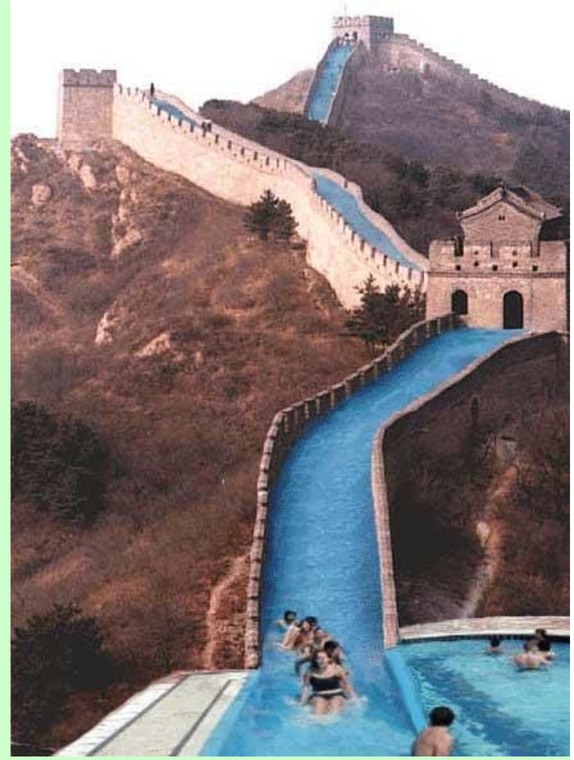
Cell Wall (multiple barrier support themes)
Endospores (heavy-duty life support strategy)
Bacterial Flagella (appendages for movement)
Gas Vesicles (buoyancy compensation devices)
Capsules/Slime Layer (exterior to cell wall)
Inclusion Bodies (granules for storage)
Pili (conduit for genetic exchange)

Bacterial morphologies

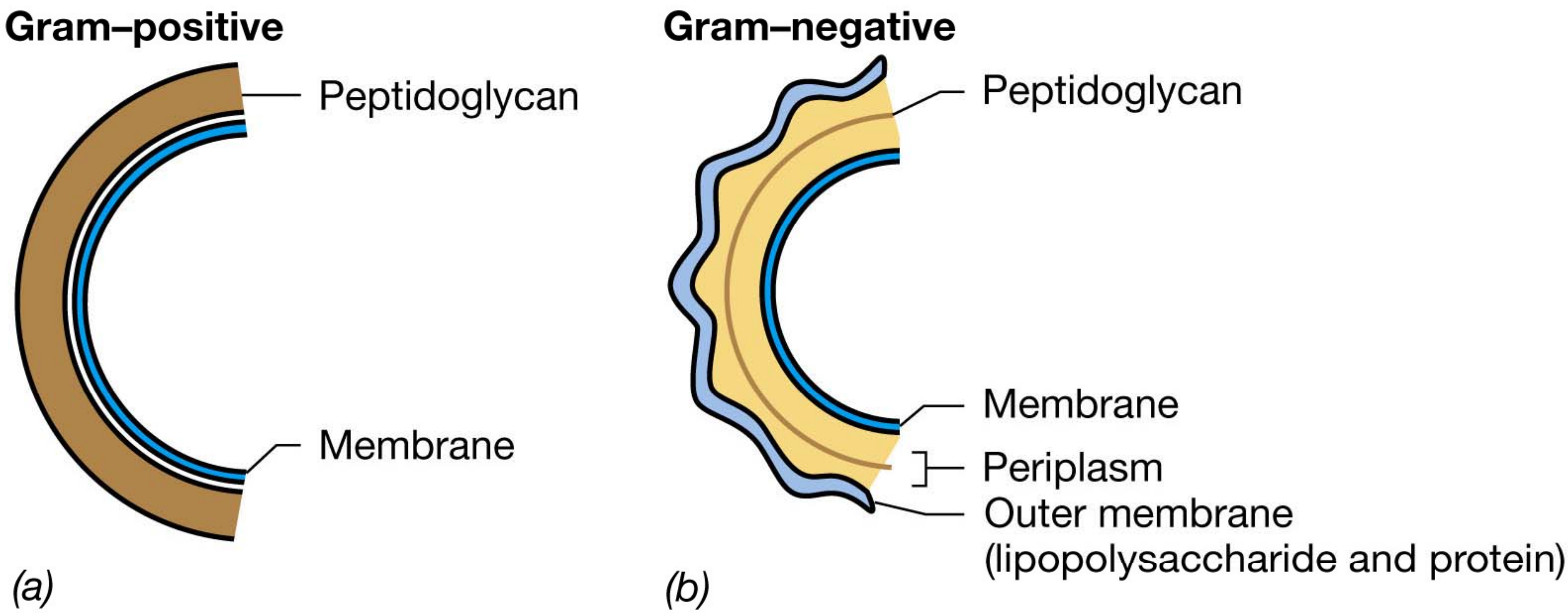




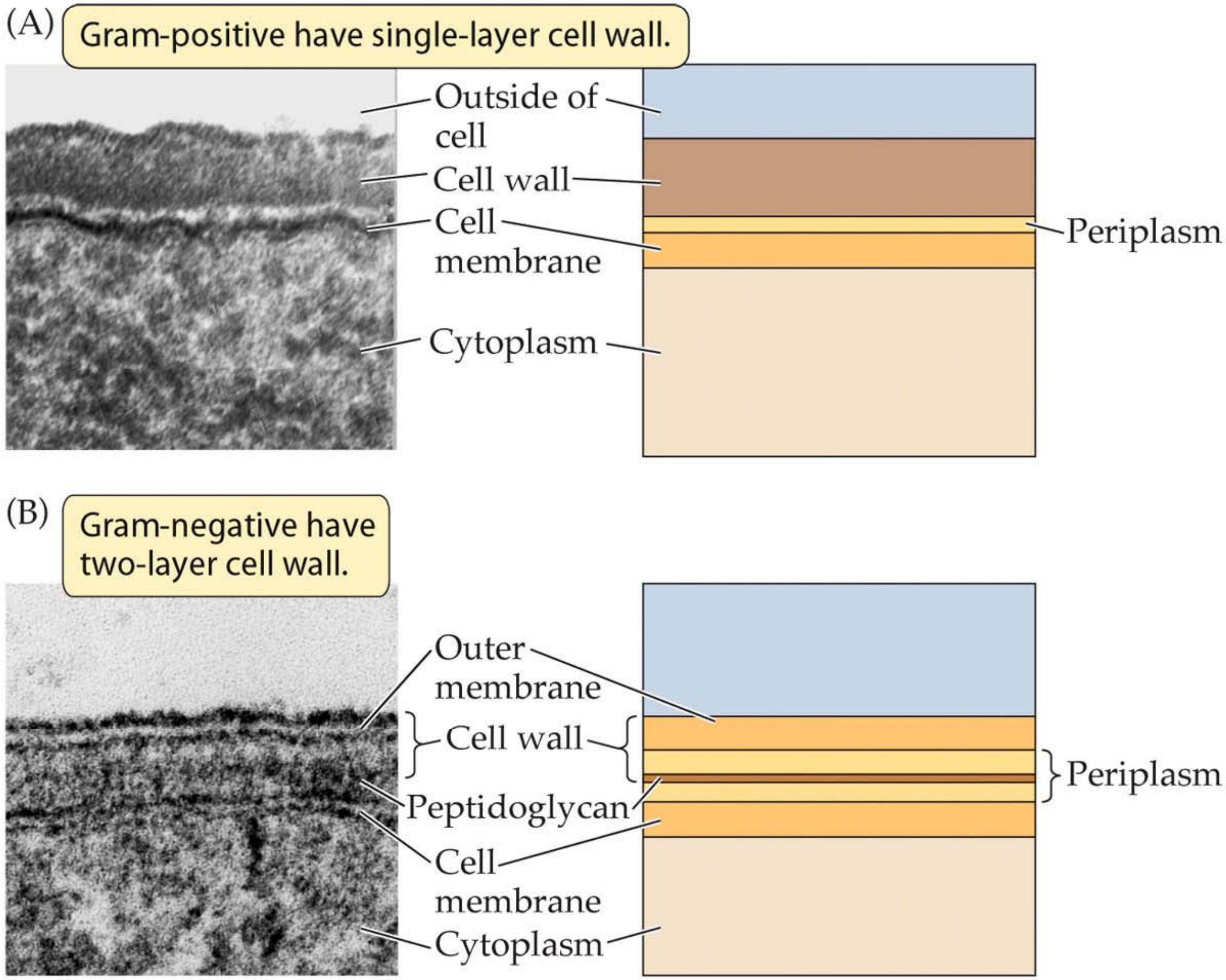
Famous Walls



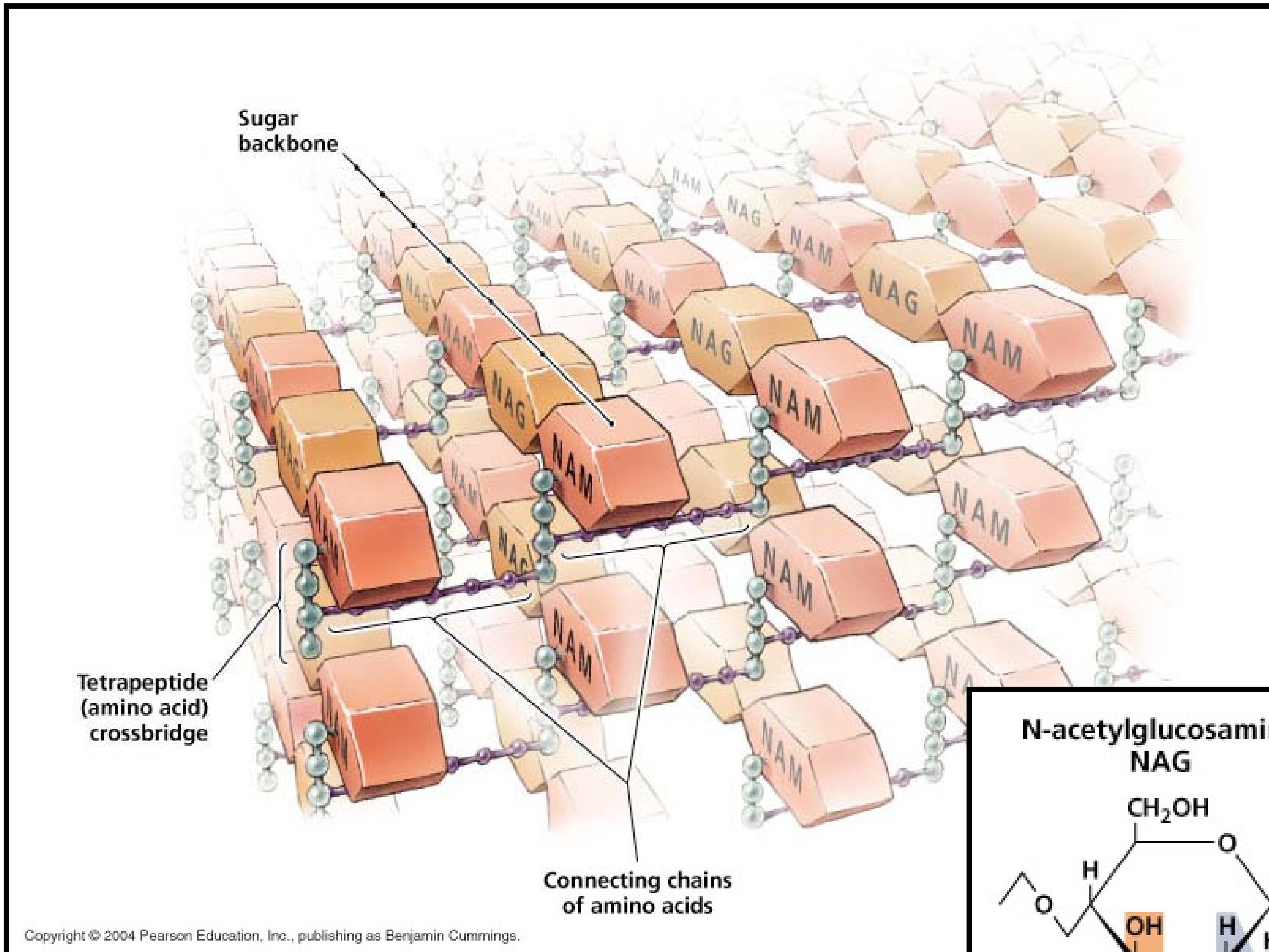
Cell walls of *Bacteria*

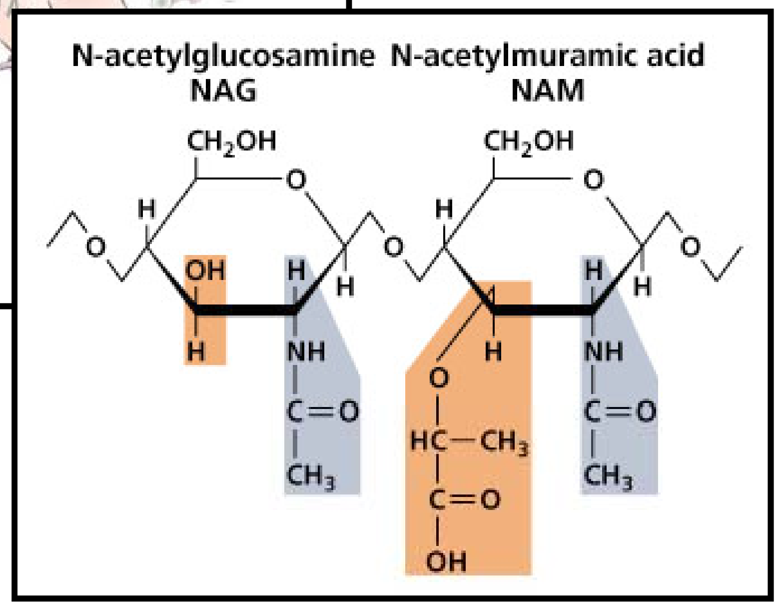


Cell wall structure



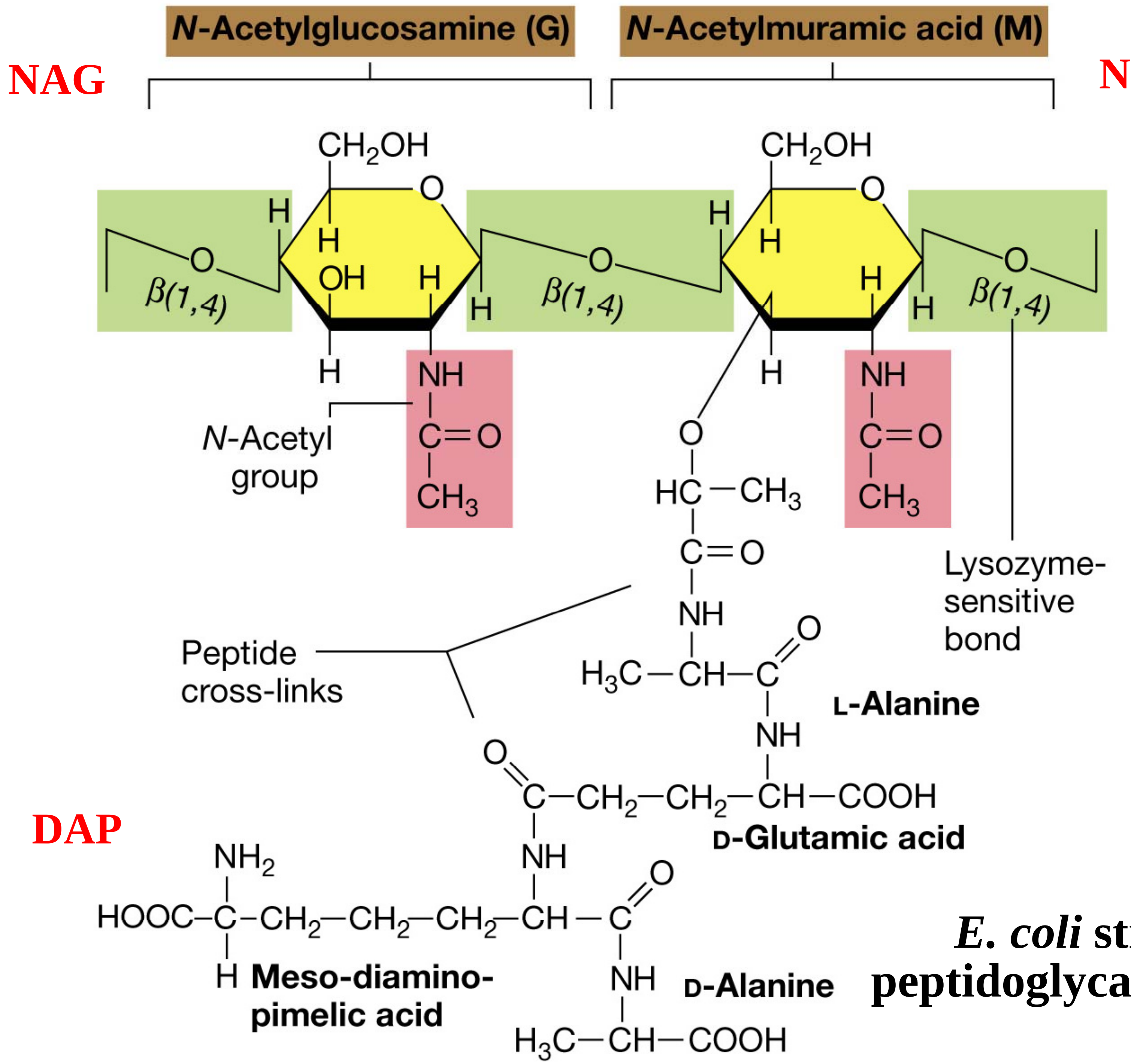
Peptidoglycan





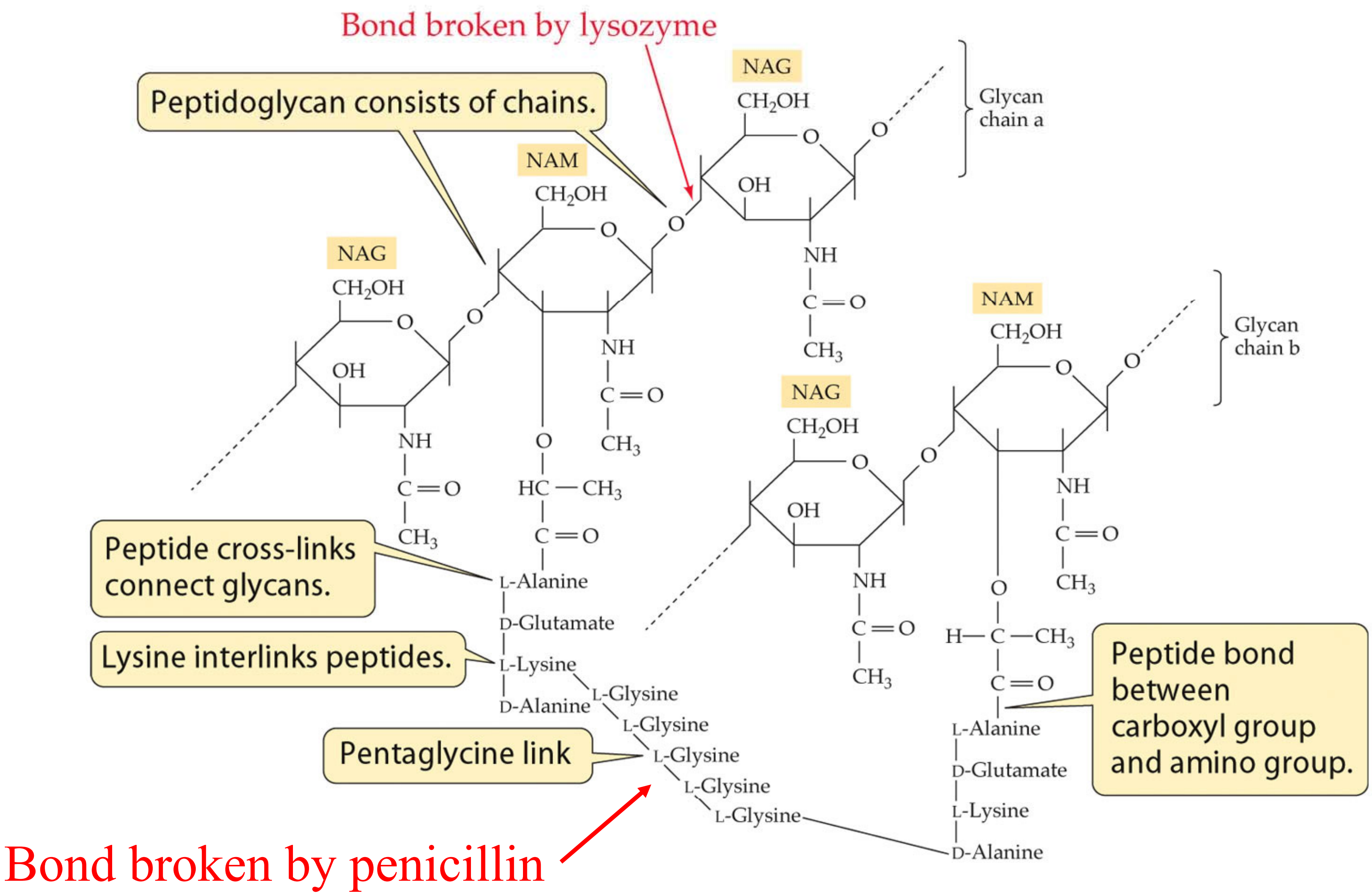
Constant: glycan (NAM and NAG), β-1,4 glycosidic linkages horizontally

Variable: type of peptide bridge, connects sheets vertically

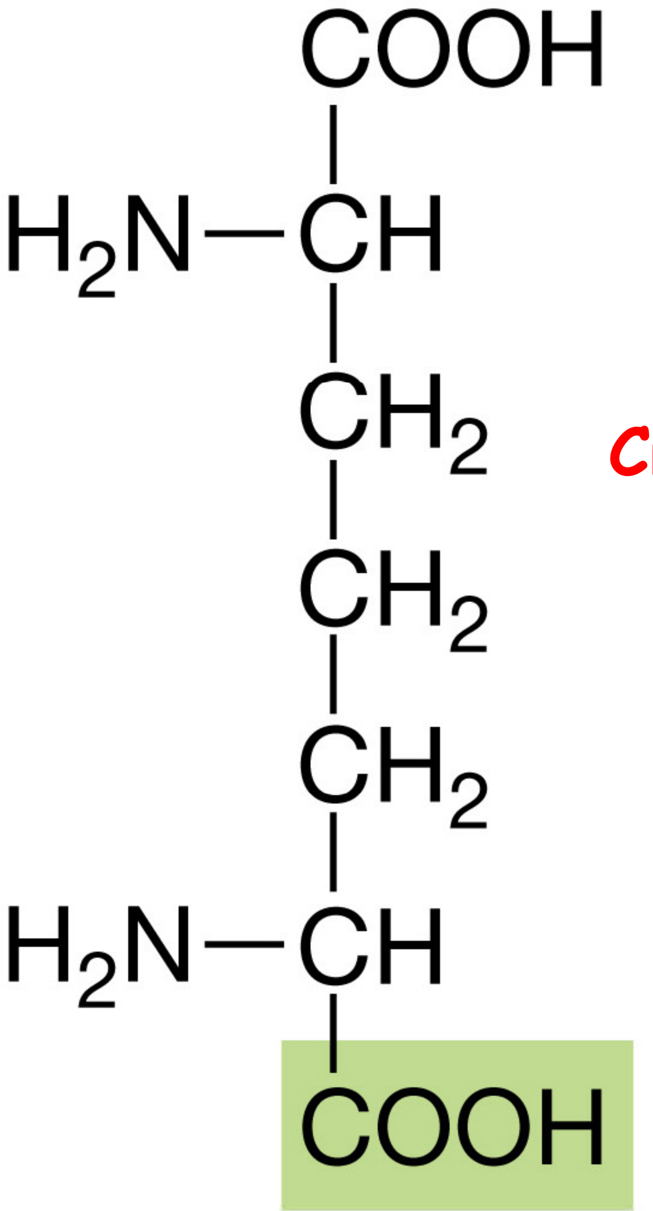


***E. coli* structure of peptidoglycan aka murein**

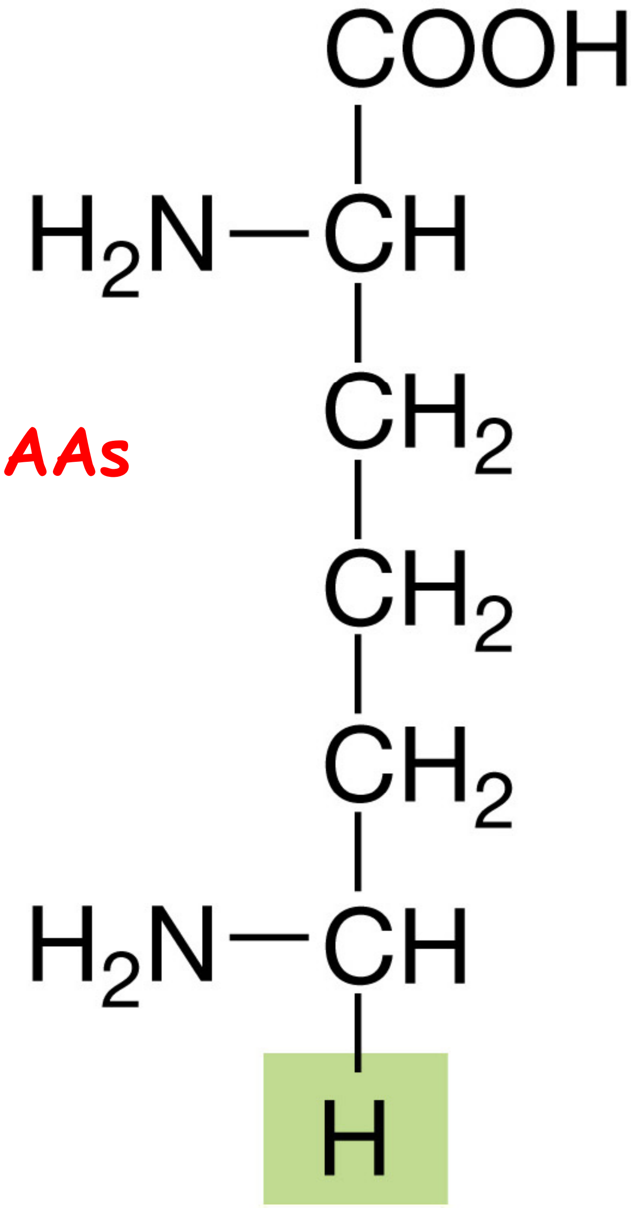
Peptidoglycan of a gram-positive bacterium



Crossing linking AAs

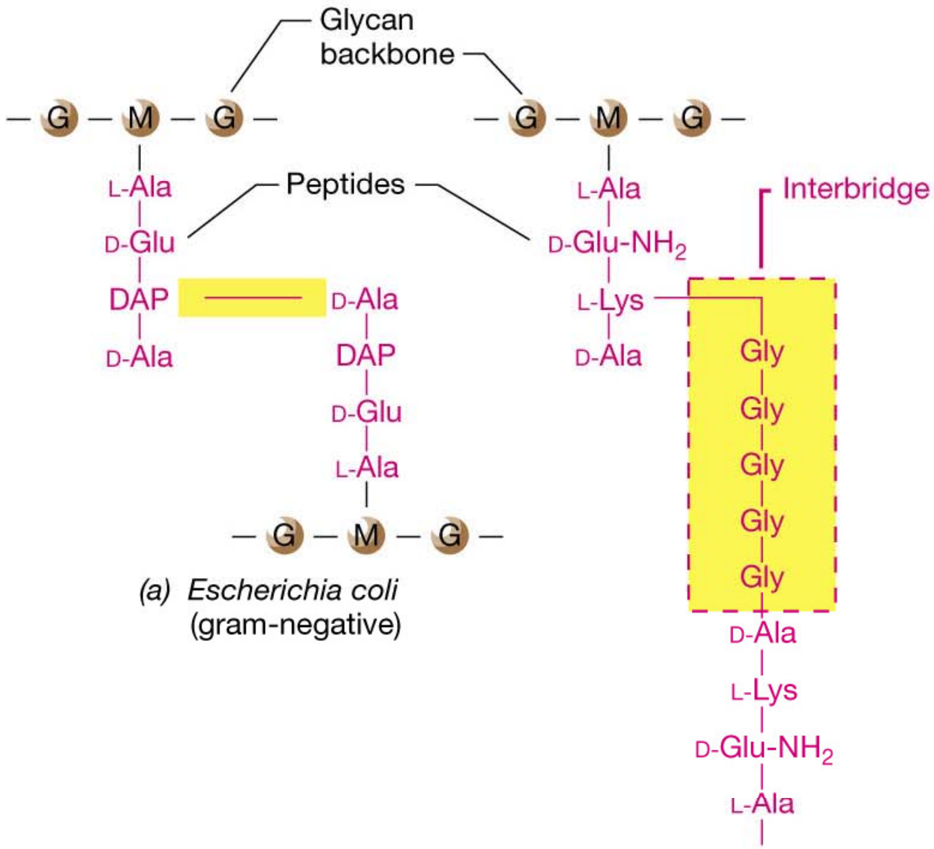


(a) DAP or Diaminopimelic acid



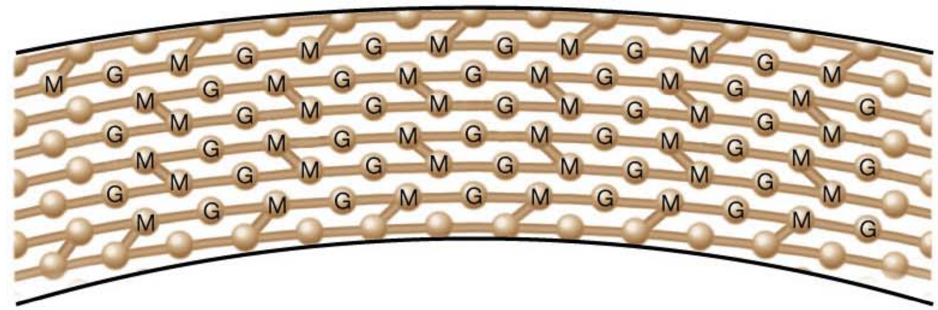
(b) Lysine

Overall structure of peptidoglycan



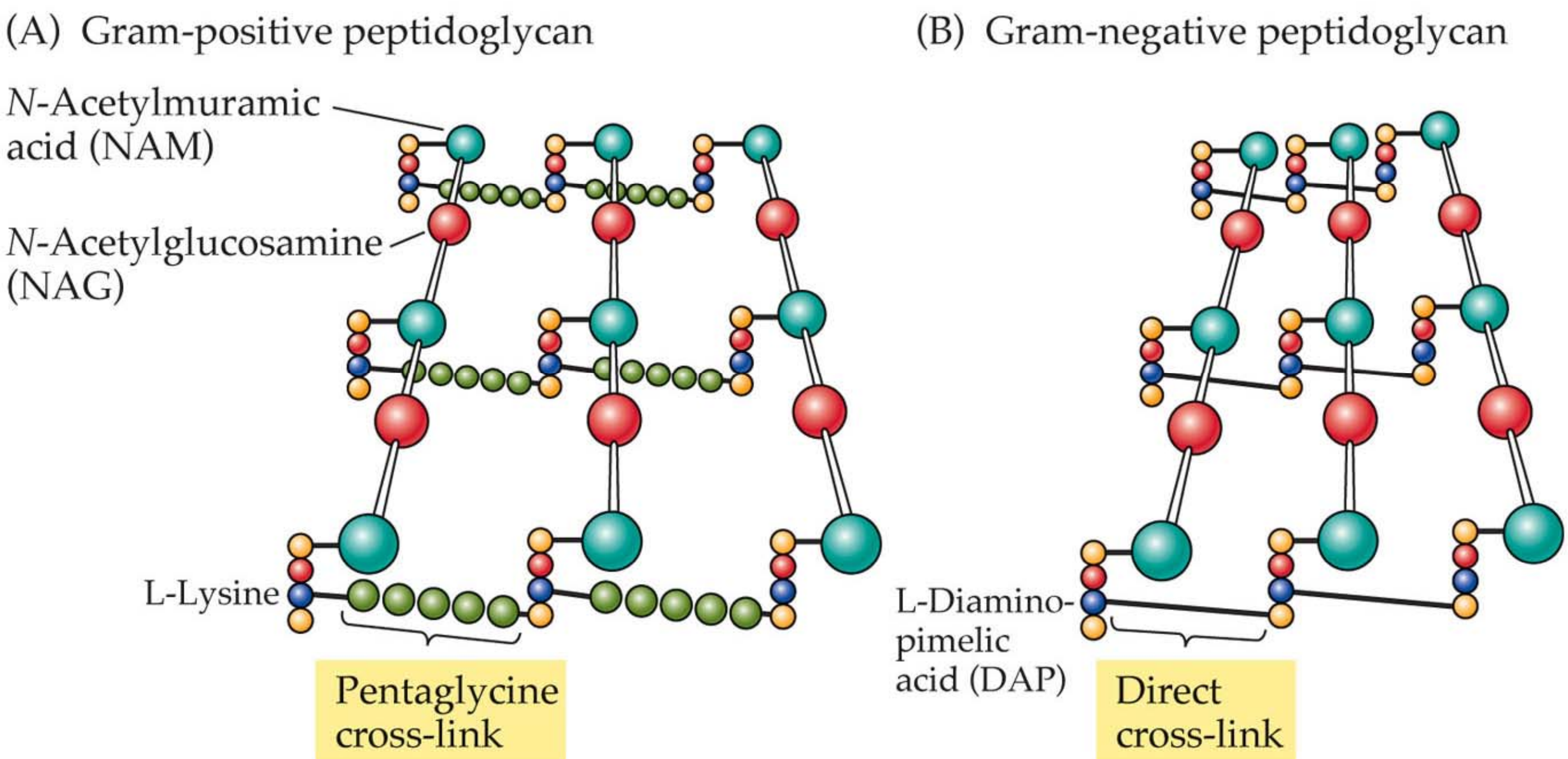
(a) *Escherichia coli* (gram-negative)

(b) *Staphylococcus aureus* (gram-positive)

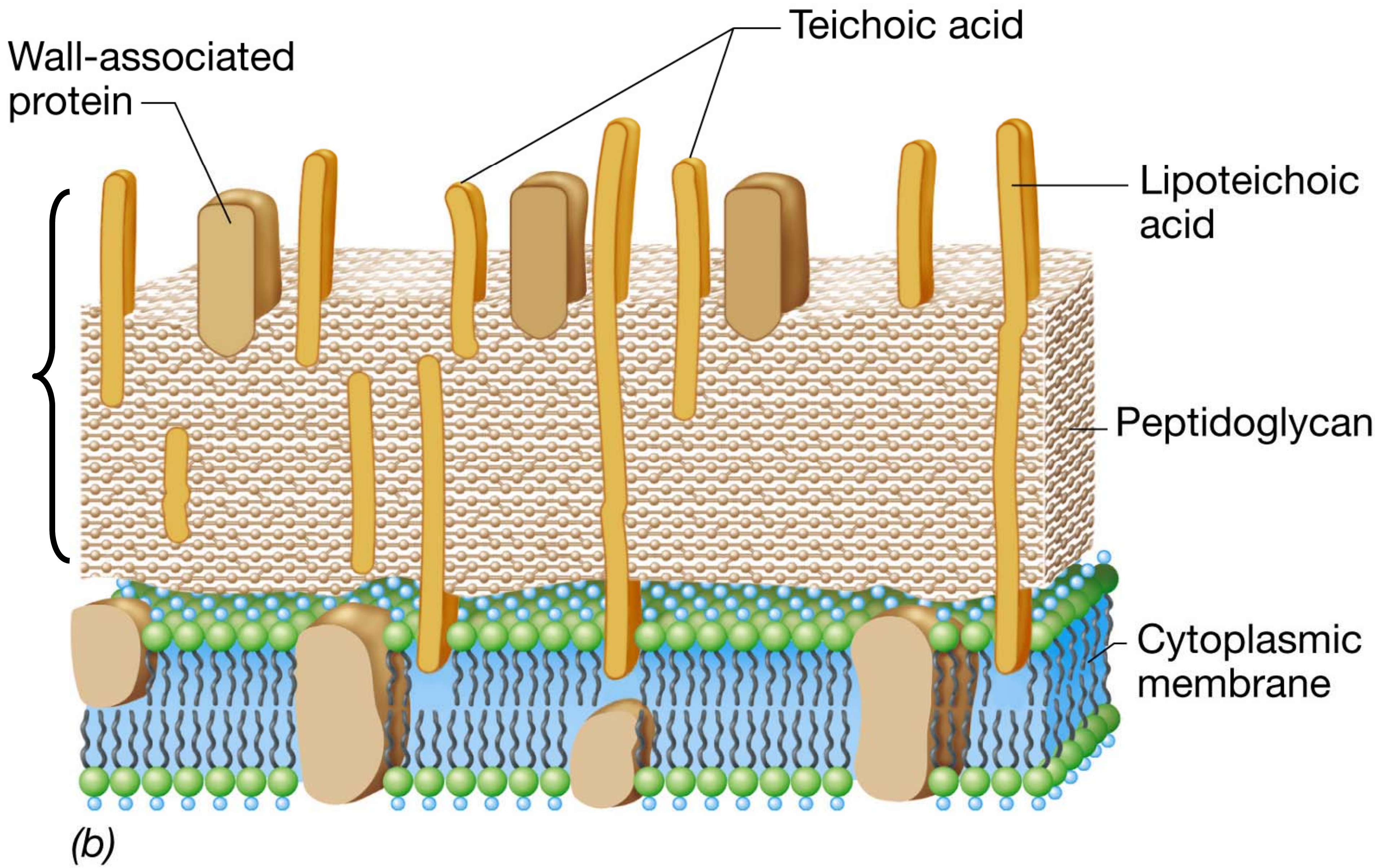


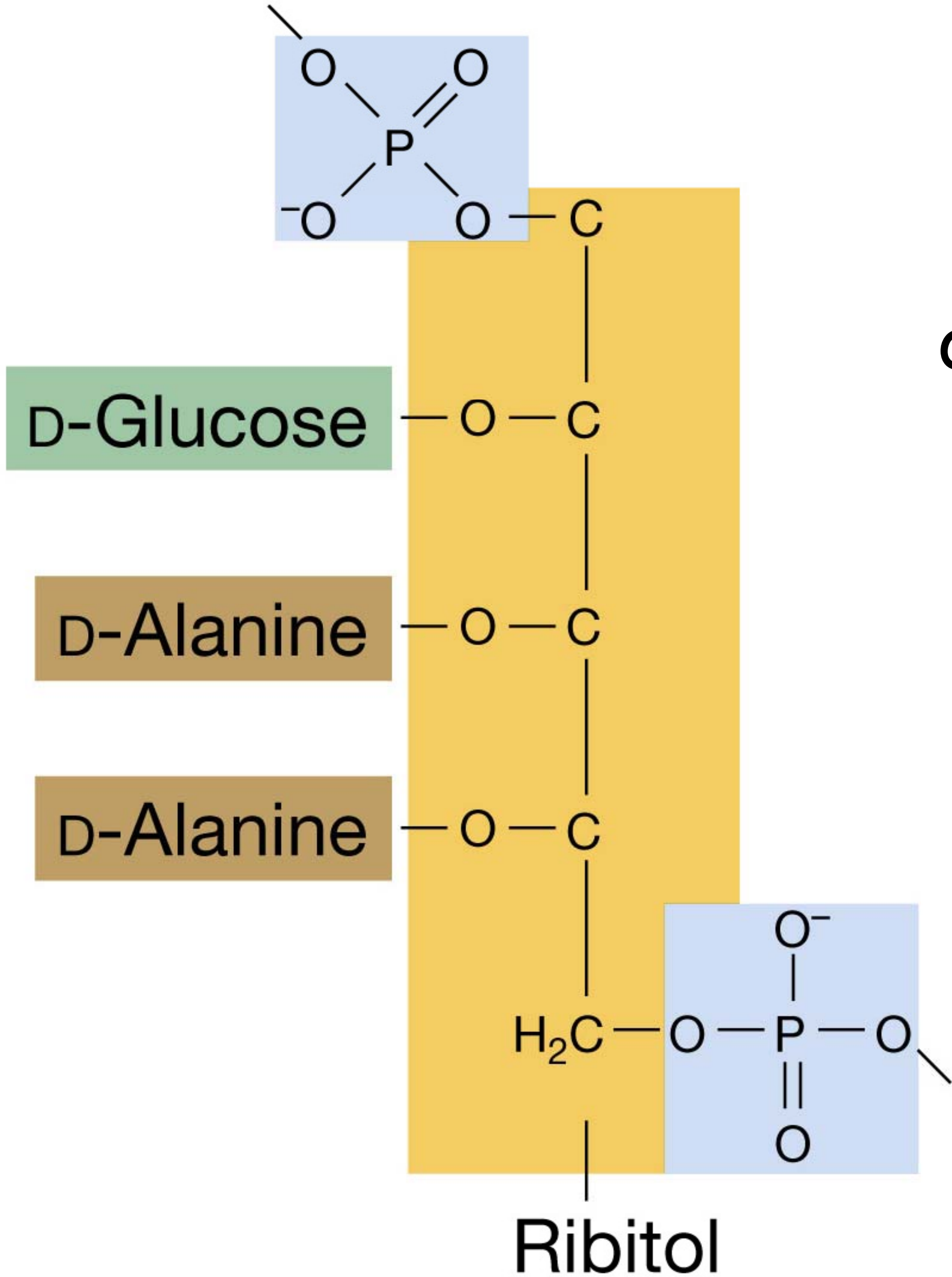
(c)

Cell walls of gram-positive and gram-negative bacteria



Summary diagram of the gram-positive cell wall





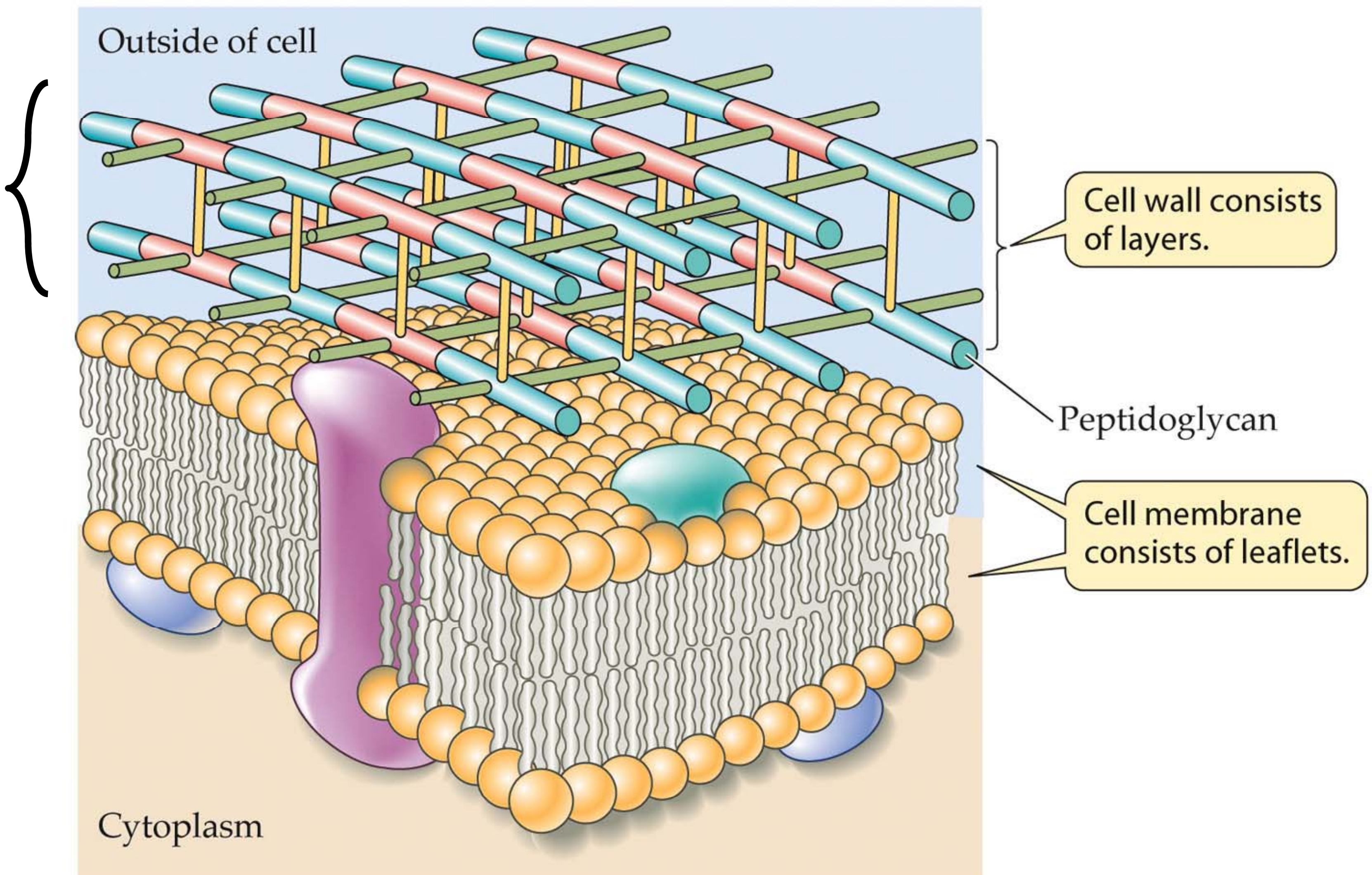
(a)

Teichoic acids and the overall structure of the gram-positive cell wall

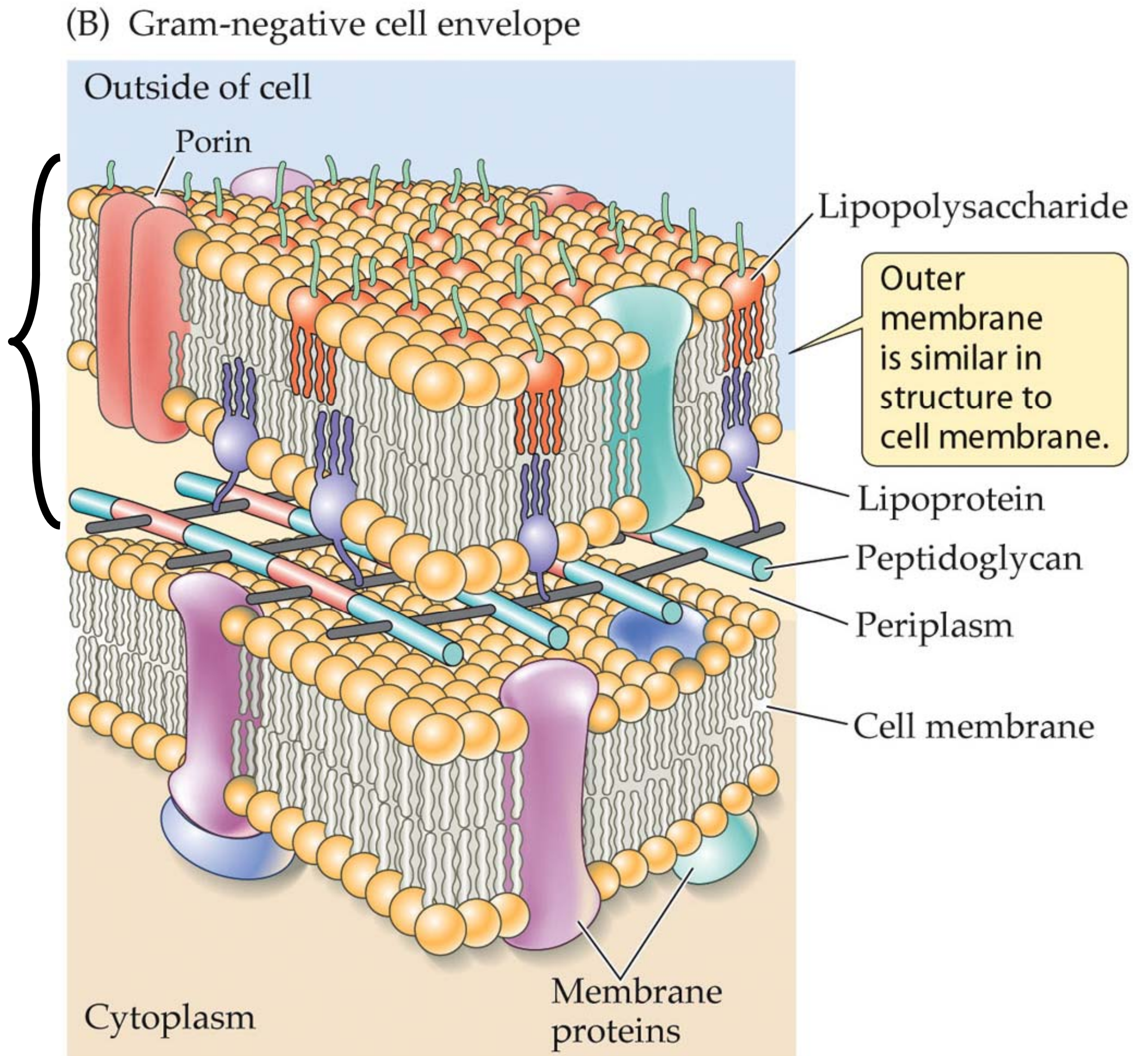
- repeating units of this structure
- negatively charged, contribute to negative charge of cell surface
- found in wall, membrane, and capsule
- may be covalently attached to membrane lipids

Cell envelopes of *Bacteria*

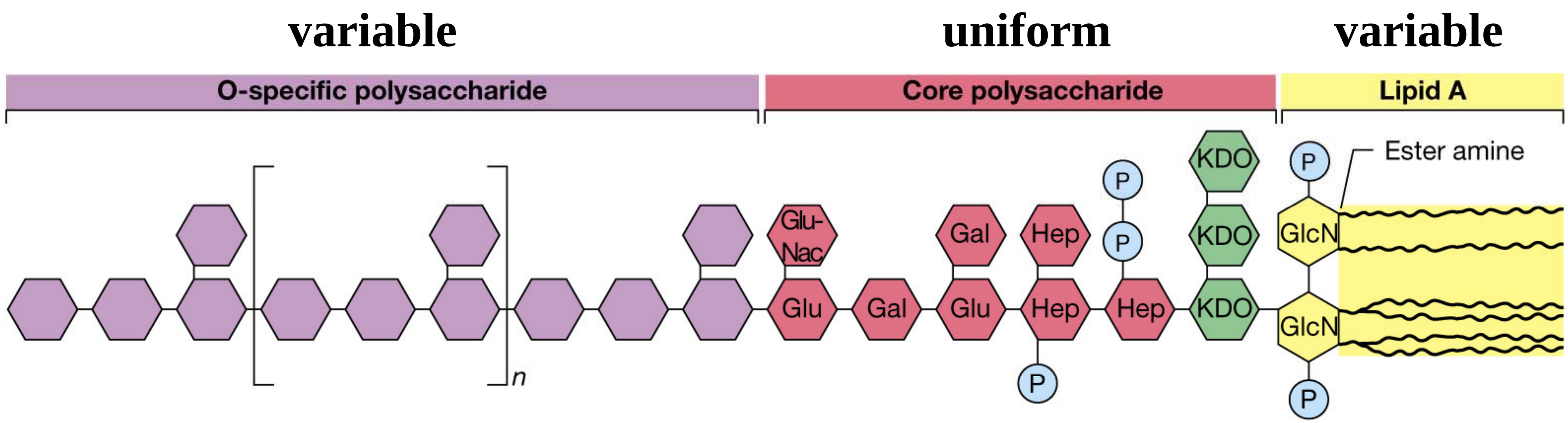
(A) Gram-positive cell envelope



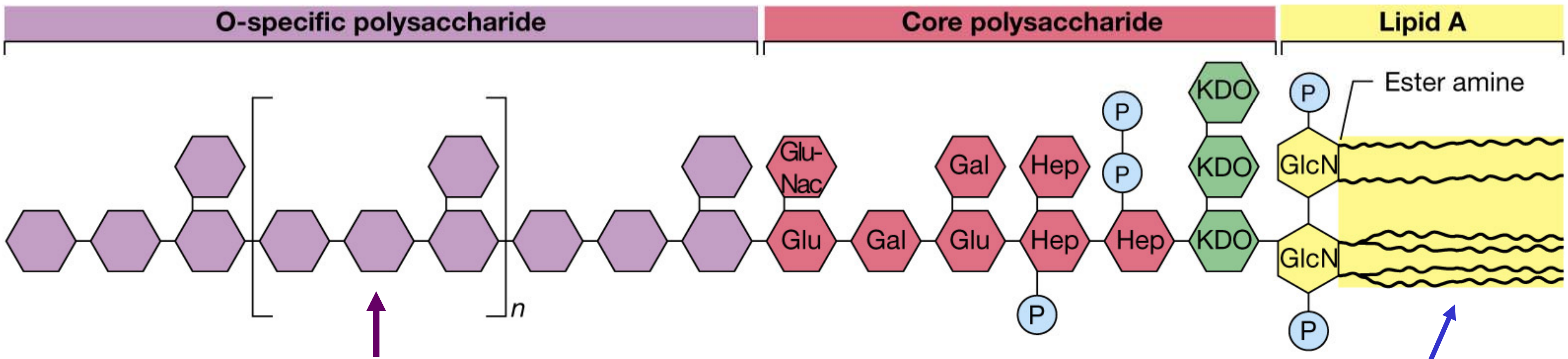
Cell envelopes of *Bacteria*



Structure of the lipopolysaccharide of gram-negative *Bacteria*



LPS chemical structure varies by species



-Hydrophilic, so exclude hydrophobic molecules like antibiotics and bile salts.

-Can be toxic

-Serve as an "epitope" or "antigen"

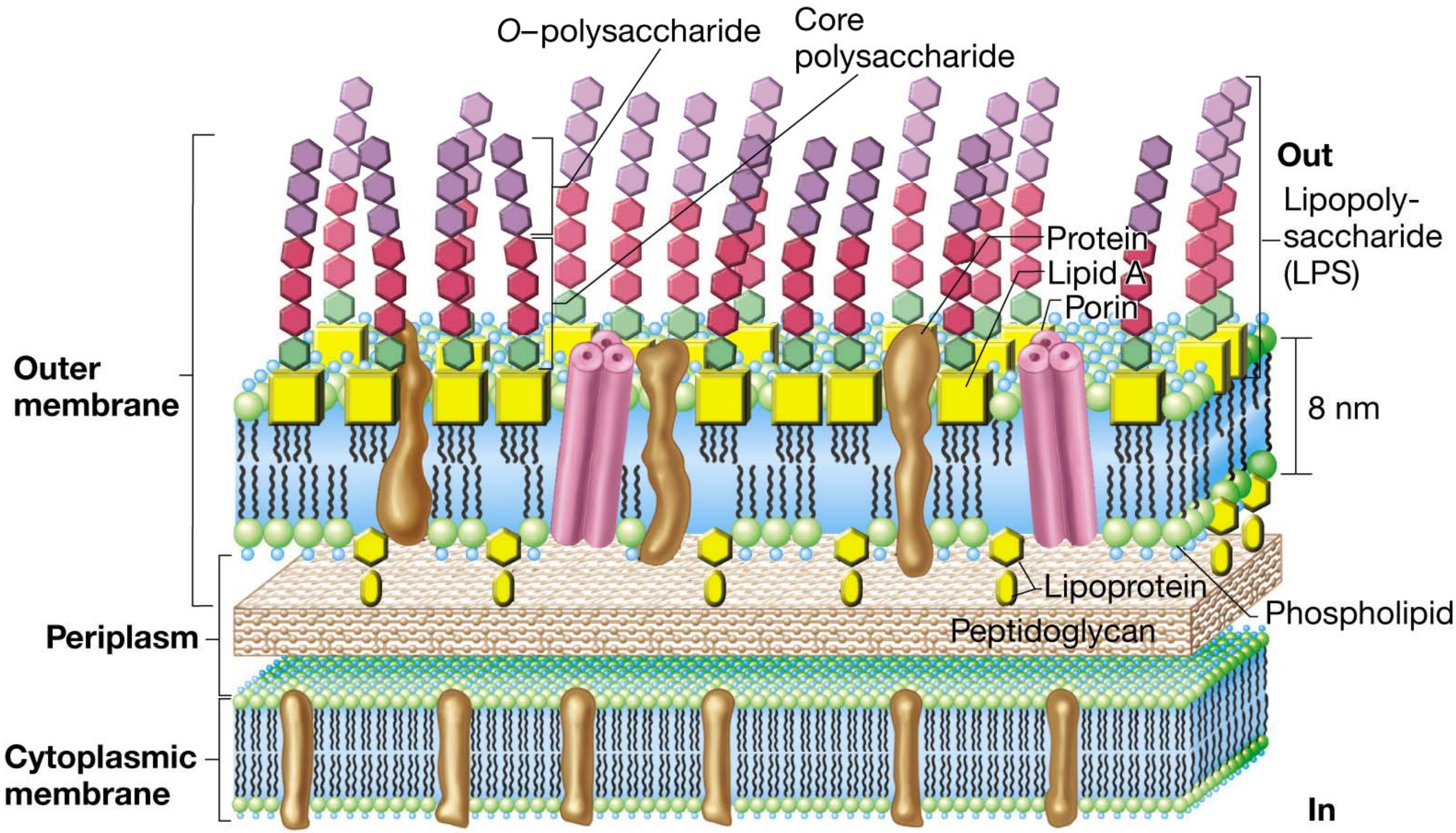
-Antibodies to intact cells' O-antigen are VERY strain-specific.

-Embedded in lipid layer.

-"Endotoxin", causes fever and shock in mammals if released from membrane (when bacteria lyse)

-Free (whole) LPS also triggers host defense by binding a receptor in macrophages

The gram-negative cell wall

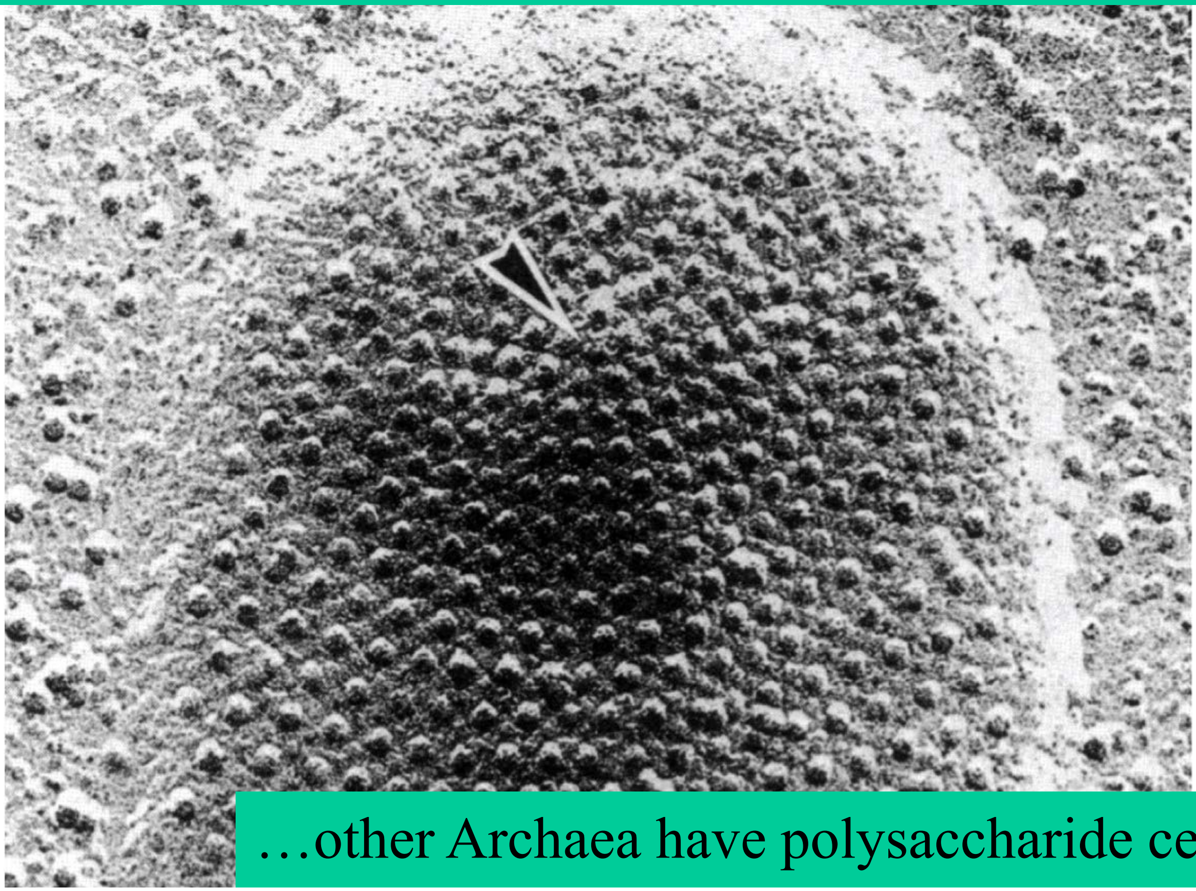


Cell walls of *Archaea:*

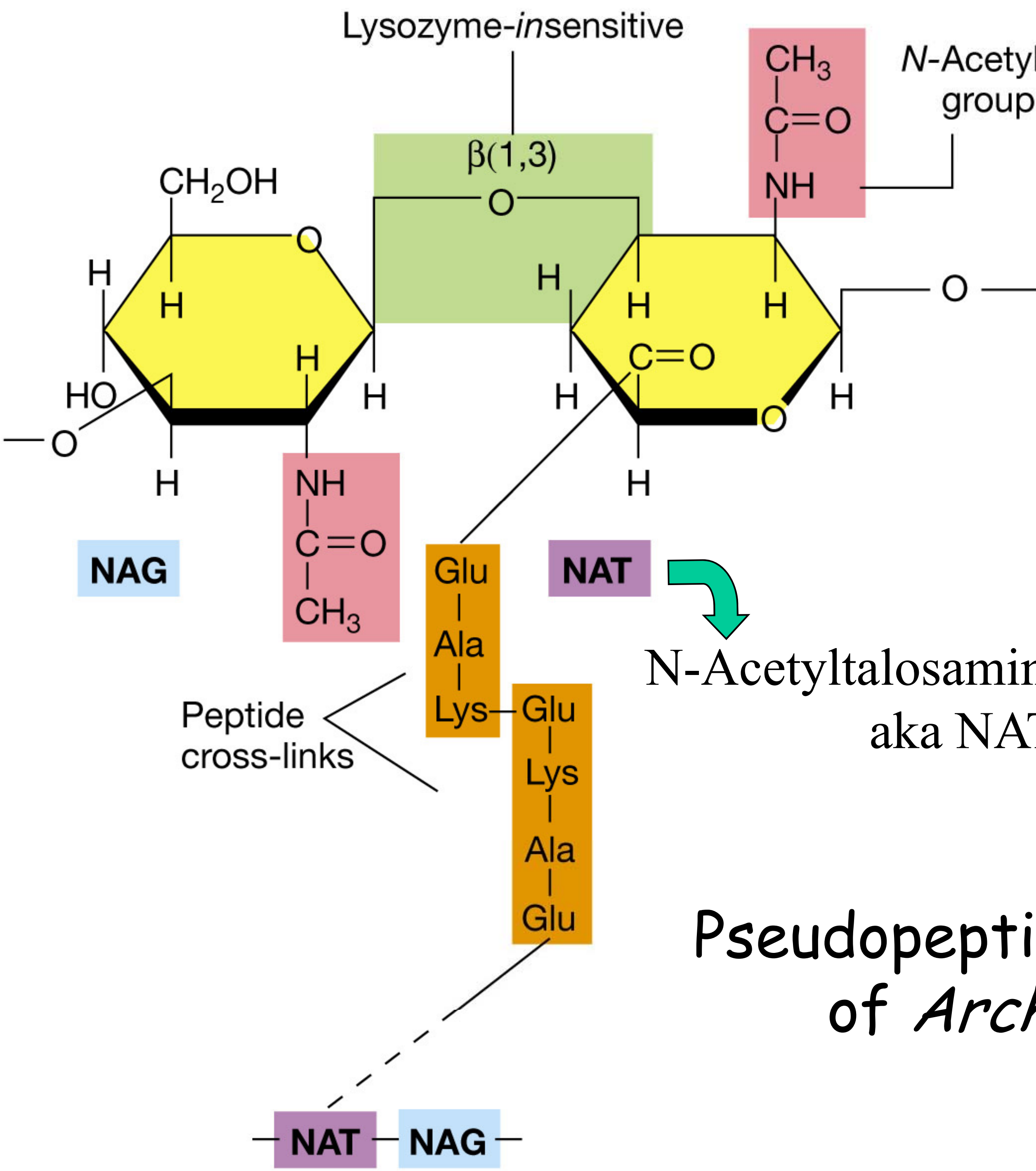
Some *Archaea & Bacteria* have a protein jacket outside the membrane called the "paracrystalline surface layer" or S-layer.

The S-layer sometimes serves as cell wall for *Archaea.*

It is a selective sieve, allowing the passage of low-molecular-weight substances while excluding large molecules and structures.



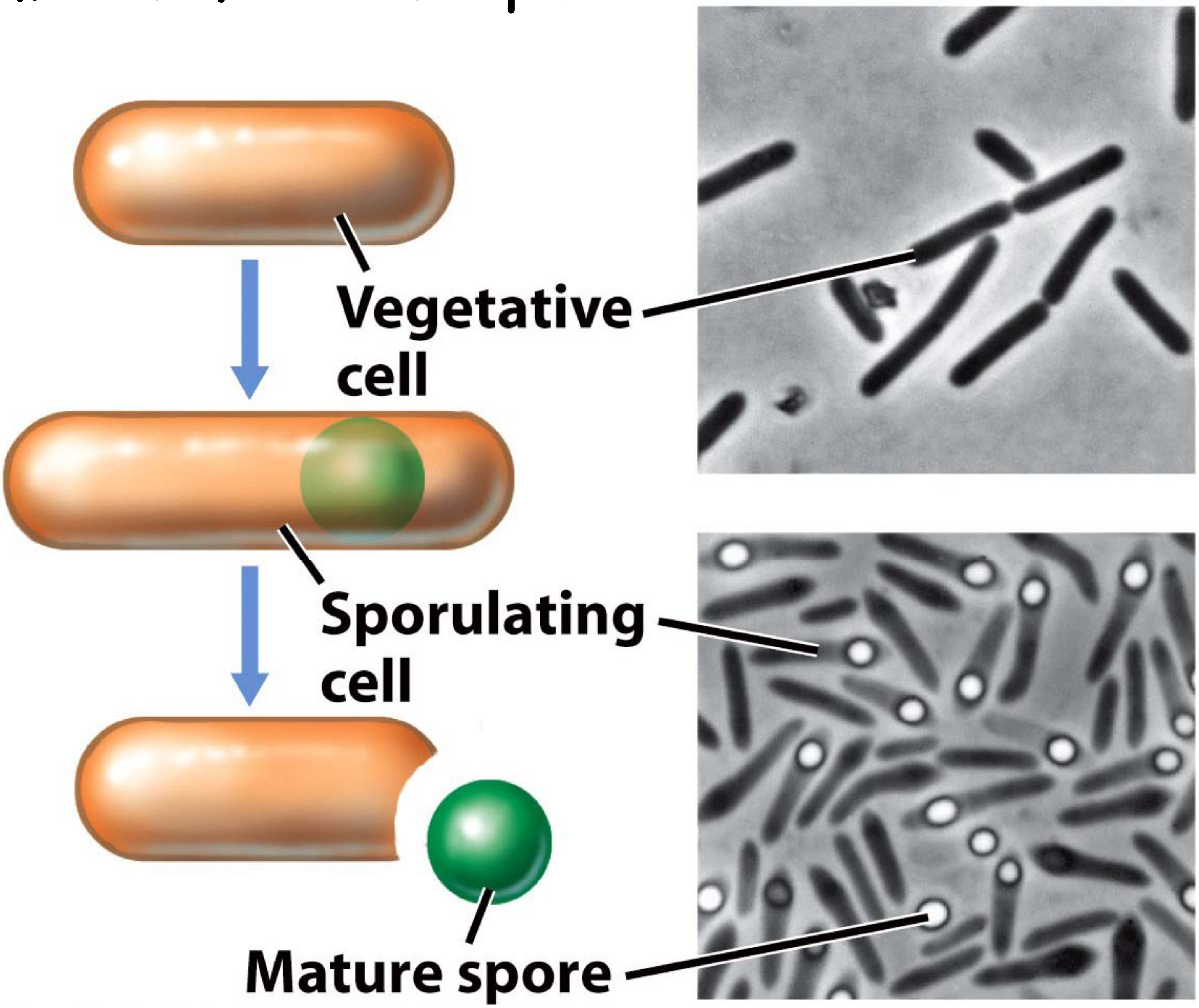
…other Archaea have polysaccharide cell walls



N-Acetyltalosaminuronic acid
aka NAT

Pseudopeptidoglycan of *Archaea*

Formation of the endospore

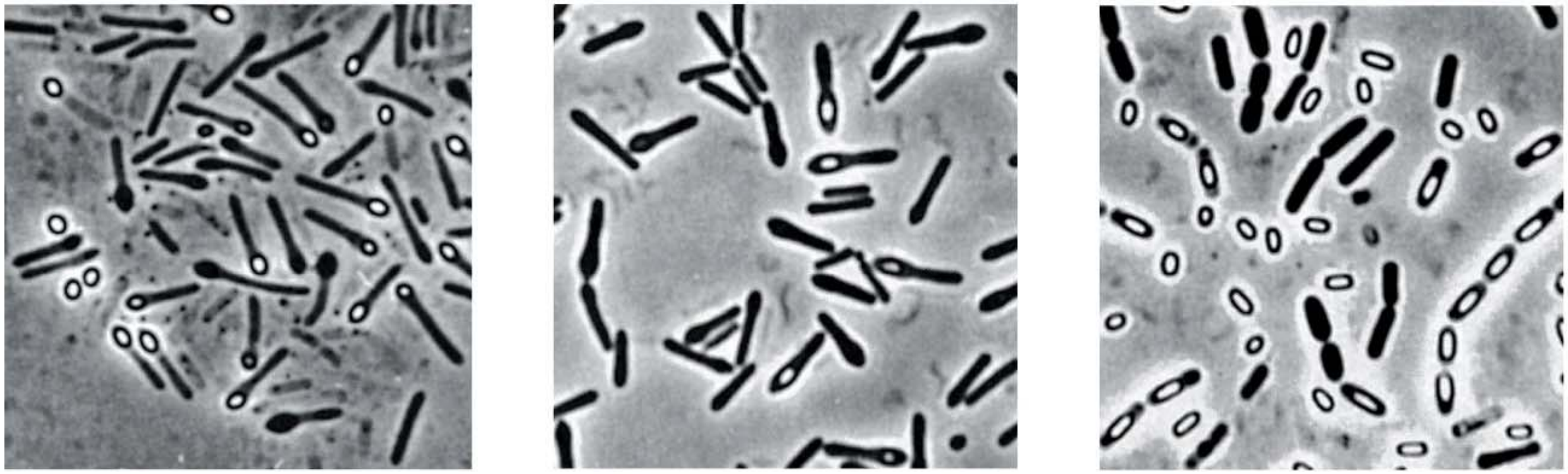


Spores remain viable in the environment after long periods of dormancy.

Extreme reports of endospore revival (successful germination from):

1. *Bacillus sphaericus* found in the guts of bees preserved in 40 million year old Dominican amber

2. *Virgibacillus* spp. found in salt crystals in the 250 million year old Salado Formation in New Mexico



(a) (b) (c)

Morpology of the bacterial endospore
(a) Terminal (b) Subterminal (c) Central

Endospores are a highly resistant differentiated bacterial cell produced by certain gram-positive *Bacteria*.

- -mostly soil bacteria of phylum Firmicutes
- -evolved just once
- -most common in *Clostridium*, *Bacillus*
- -agents of **survival**
- -metabolically inert, highly dehydrated (10-15% water)
- -most resistant biological structure known: heat up to 150^{o}C, dryness, UV, strong acids, disinfectants
- -can survive 100's (thousands? millions?) of years

Exospores are formed by pinching off of tips of filamentous bacteria (and of fungi)

- -*Streptomyces, Myxobacteria*
- -agents of **dispersal**

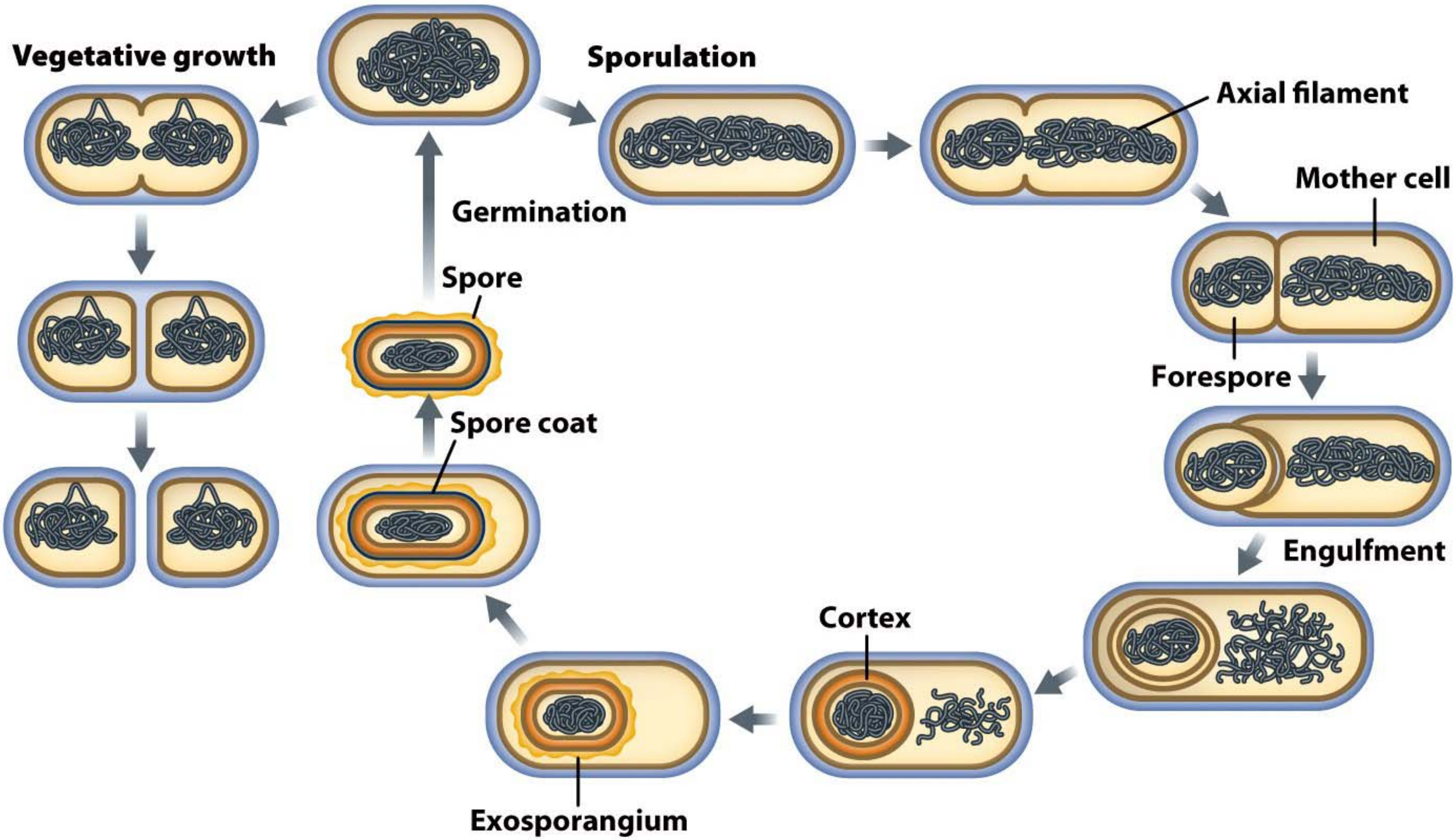
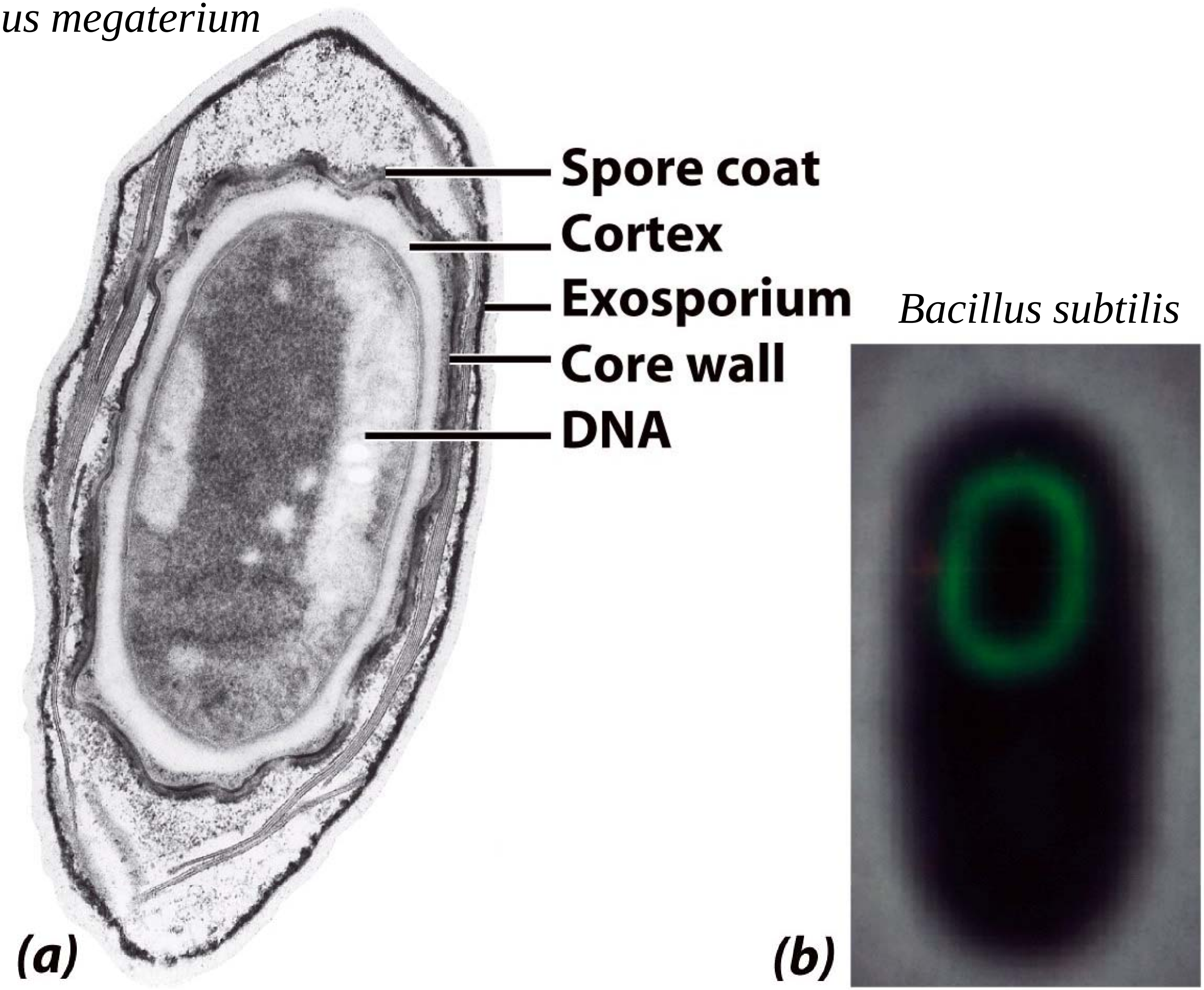


Figure 4.25c Microbiology: An Evolving Science

Bacillus megaterium

Bacillus subtilis



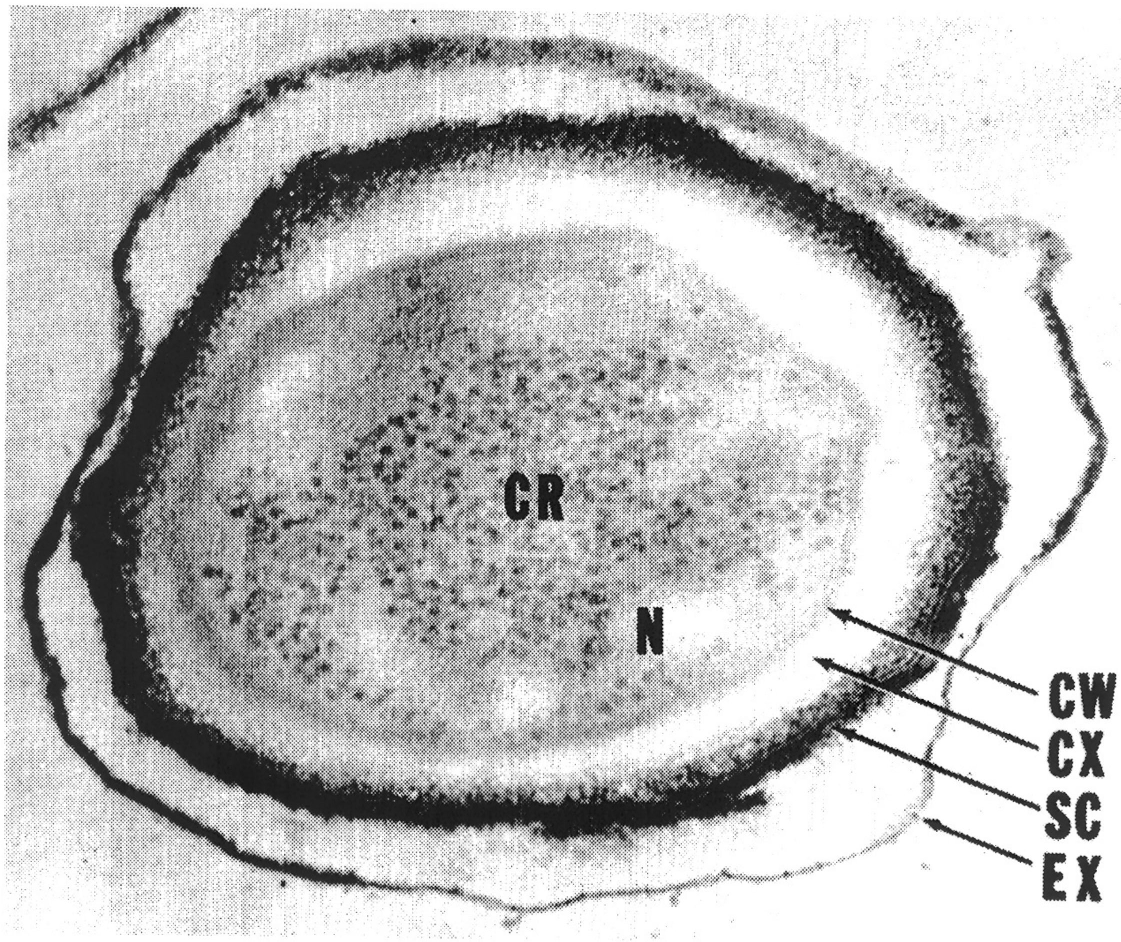
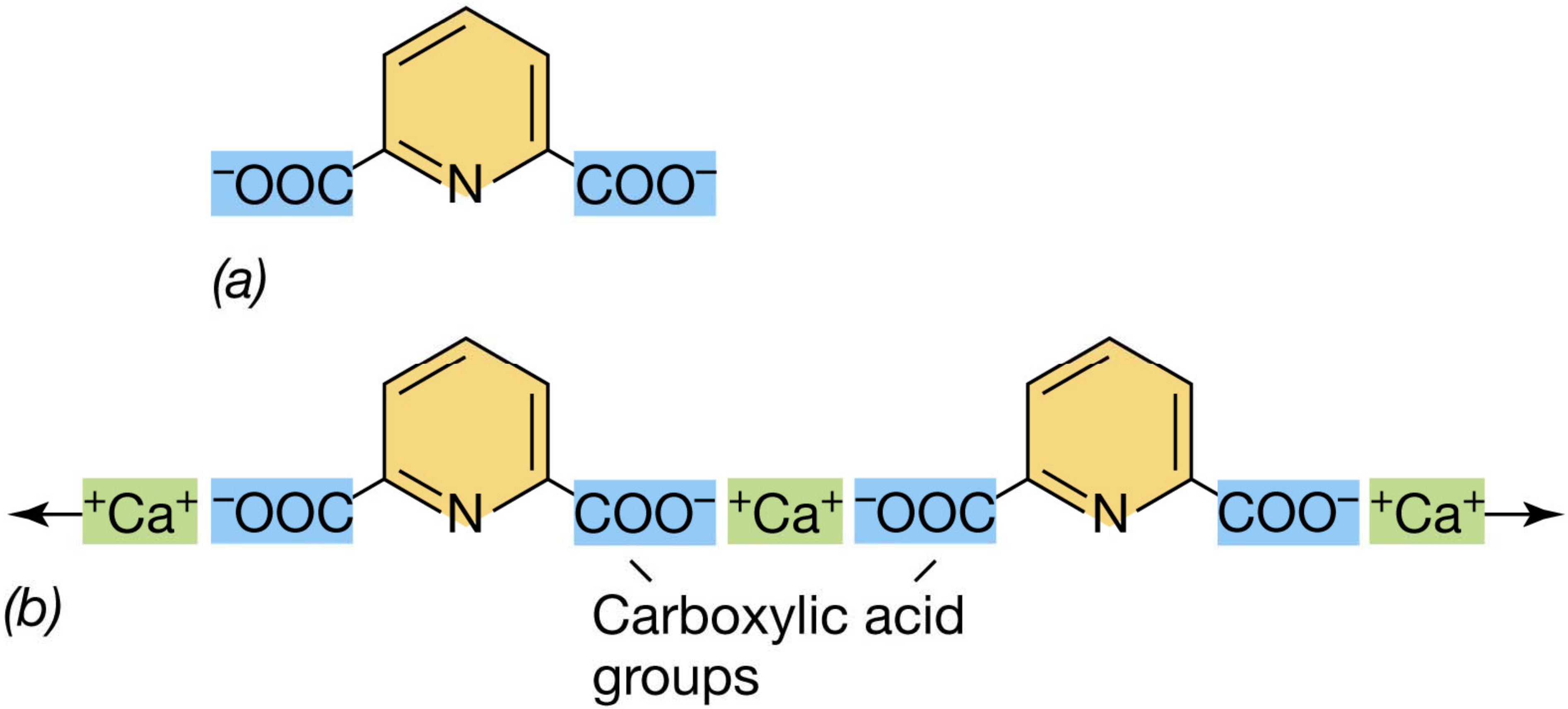


Figure 3.45 Endospore Structure. *Bacillus anthracis* endospore (×151,000). Note the following structures: exosporium, EX; spore coat, SC; cortex, CX; core wall, CW; and the protoplast or core with its nucleoid, N, and ribosomes, CR.



(a) Structure of Dipicolinic Acid & (b) crosslinked with Ca^{++}

Table 4.3 **Differences between endospores and vegetative cells**

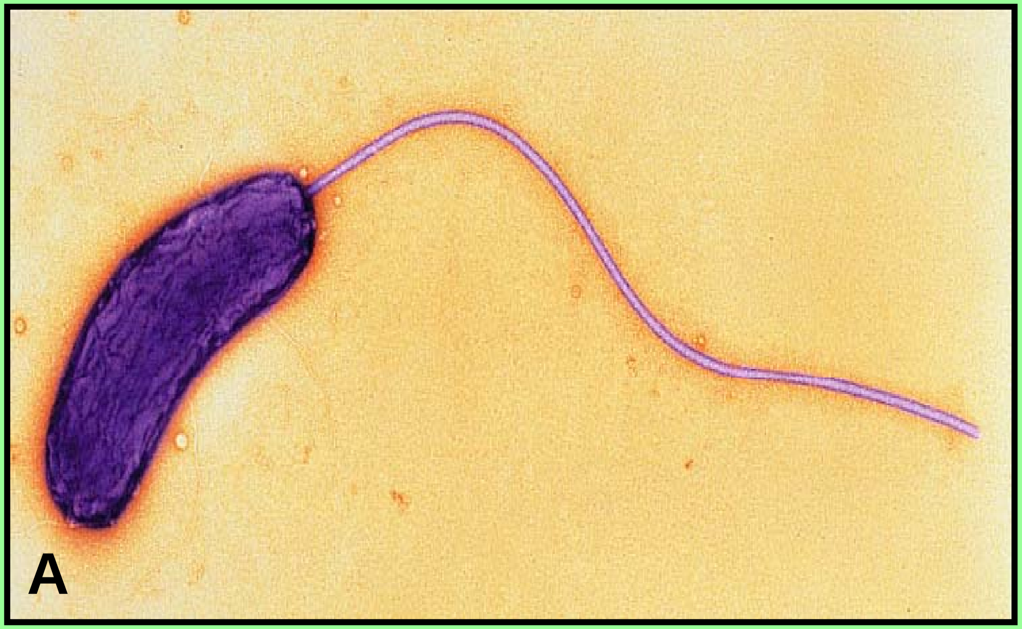
Characteristic	Vegetative cell	Endospore
Structure	Typical gram-positive cell; a few gram-negative cells	Thick spore cortex Spore coat Exosporium
Microscopic appearance	Nonrefractile	Refractile
Calcium content	Low	High
● Dipicolinic acid	Absent	Present
Enzymatic activity	High	Low
Metabolism (O_2 uptake)	High	Low or absent
Macromolecular synthesis	Present	Absent
mRNA	Present	Low or absent
Heat resistance	Low	High
Radiation resistance	Low	High
Resistance to chemicals (for example, H_2O_2) and acids	Low	High
Stainability by dyes	Stainable	Stainable only with special methods
Action of lysozyme	Sensitive	Resistant
Water content	High, 80–90%	Low, 10–25% in core
● Small acid-soluble proteins (product of *ssp* genes)	Absent	Present
Cytoplasmic pH	About pH 7	About pH 5.5–6.0 (in core)

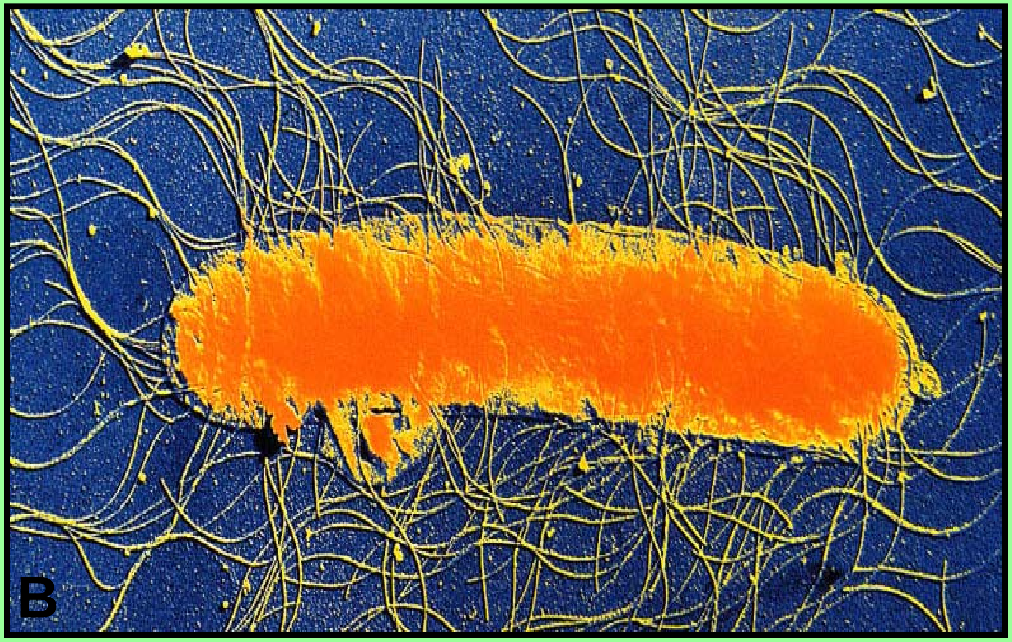
Characteristics of Endospore: Take Home Message

- The endospore is a highly resistant differentiated bacterial cell produced by certain gram-positive *Bacteria*.

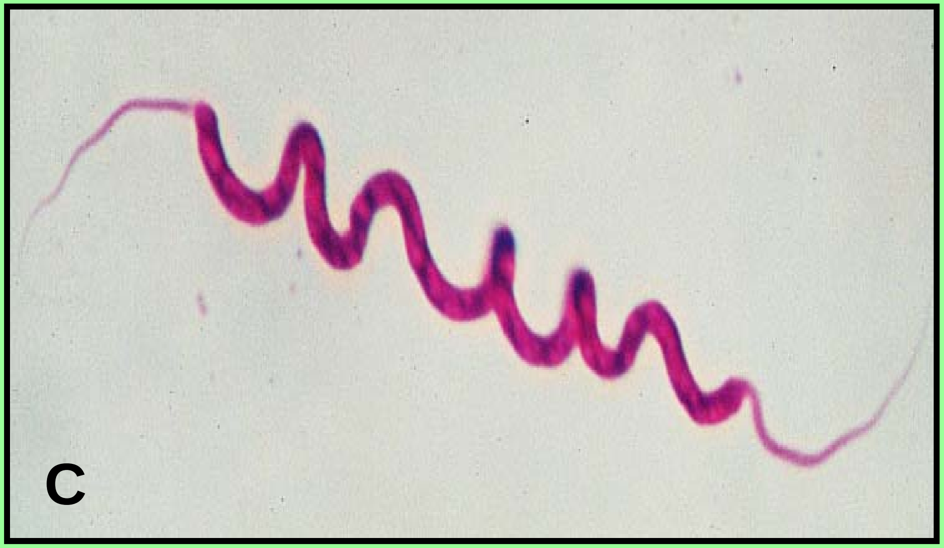
- Endospore formation leads to a highly dehydrated structure that contains essential macromolecules and a variety of substances such as calcium dipicolinate and small acid-soluble proteins, absent from vegetative cells.

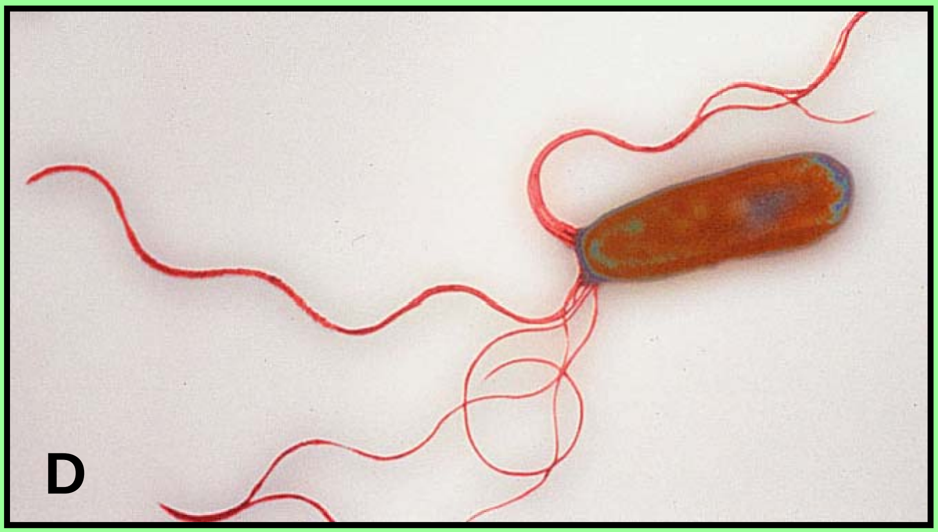
- Endospores can remain dormant indefinitely but germinate quickly when the appropriate trigger is applied.





Bacterial flagella
(**A**) Polar
(aka monotrichous)
&
(**B**) Peritrichous

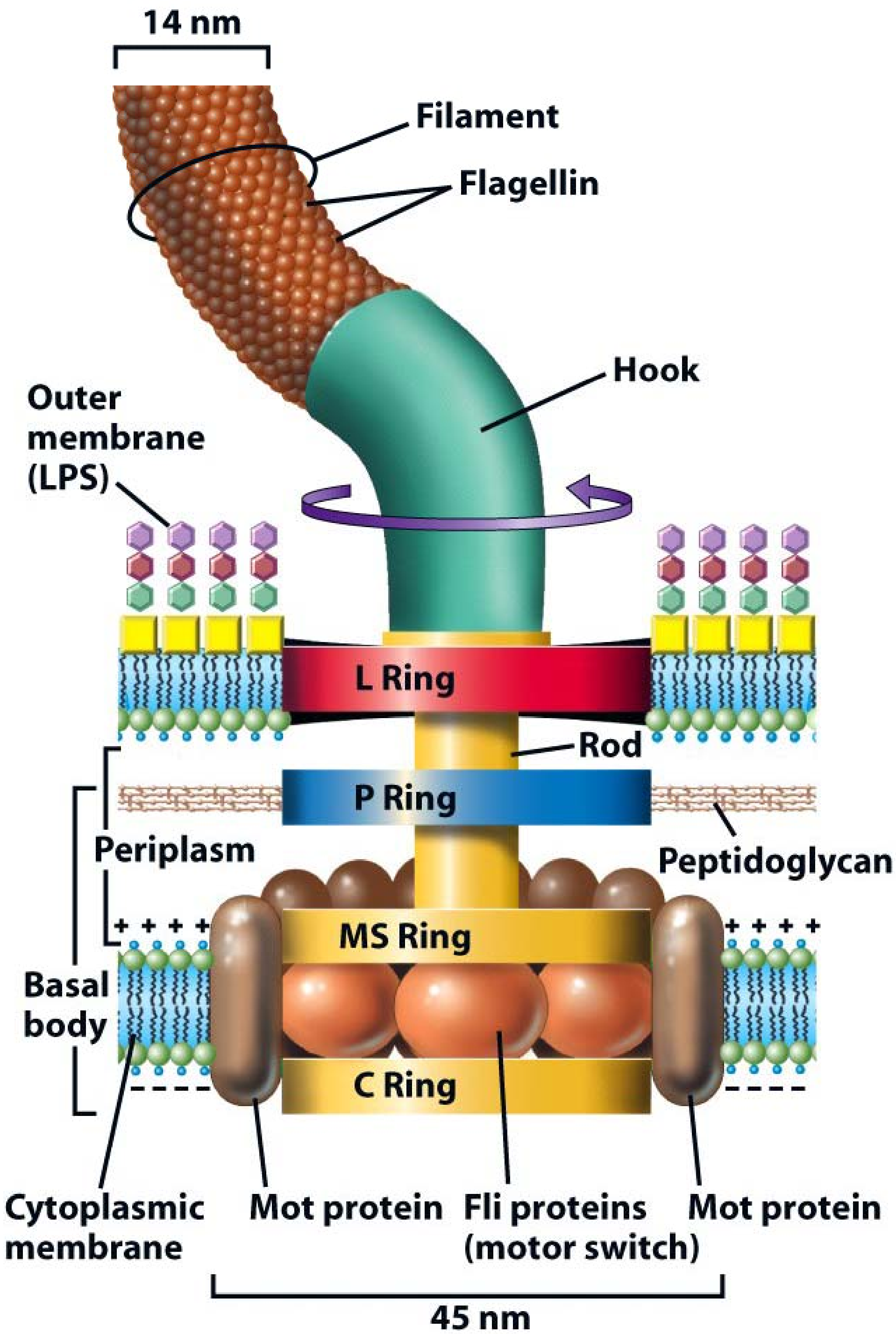




Bacterial flagella cont.

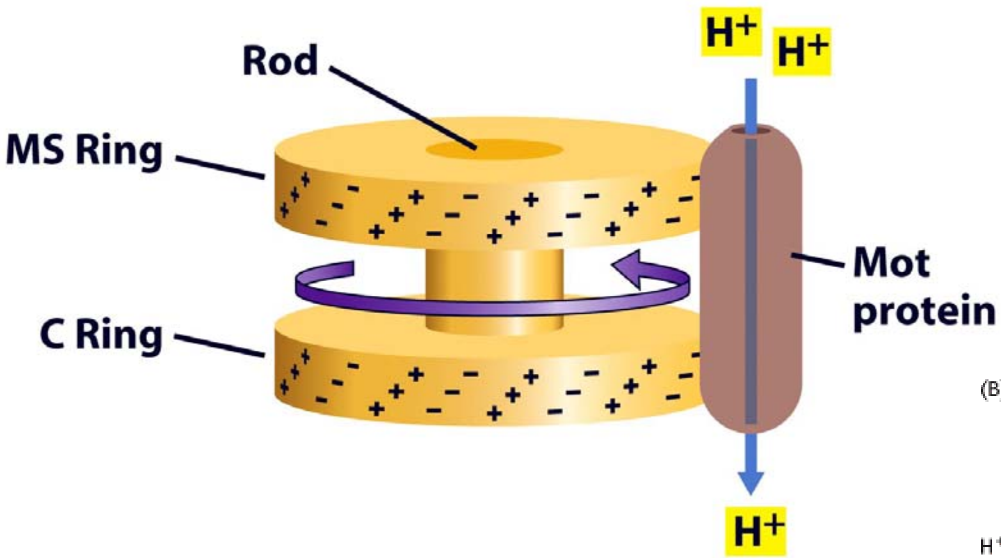
Also:
(**C**) Amphitrichous (bipolar)
&
(**D**) Lophotrichous (tuft)

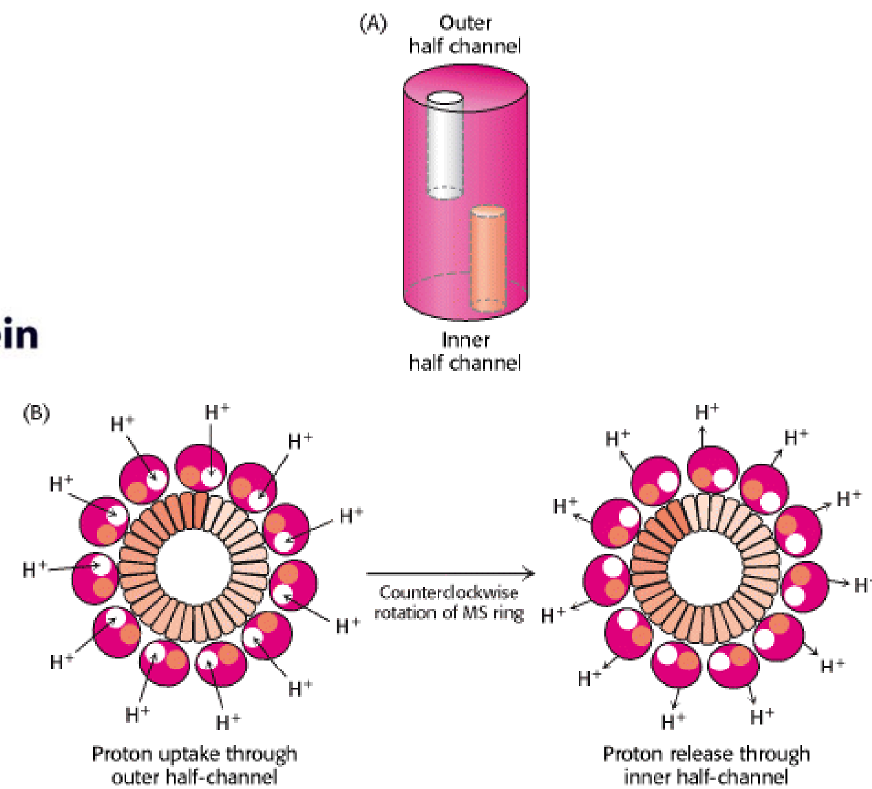
Structure of the bacterial flagellum



Bacteria: 60 cell lengths/second
Cheetah: 25 body lengths/second

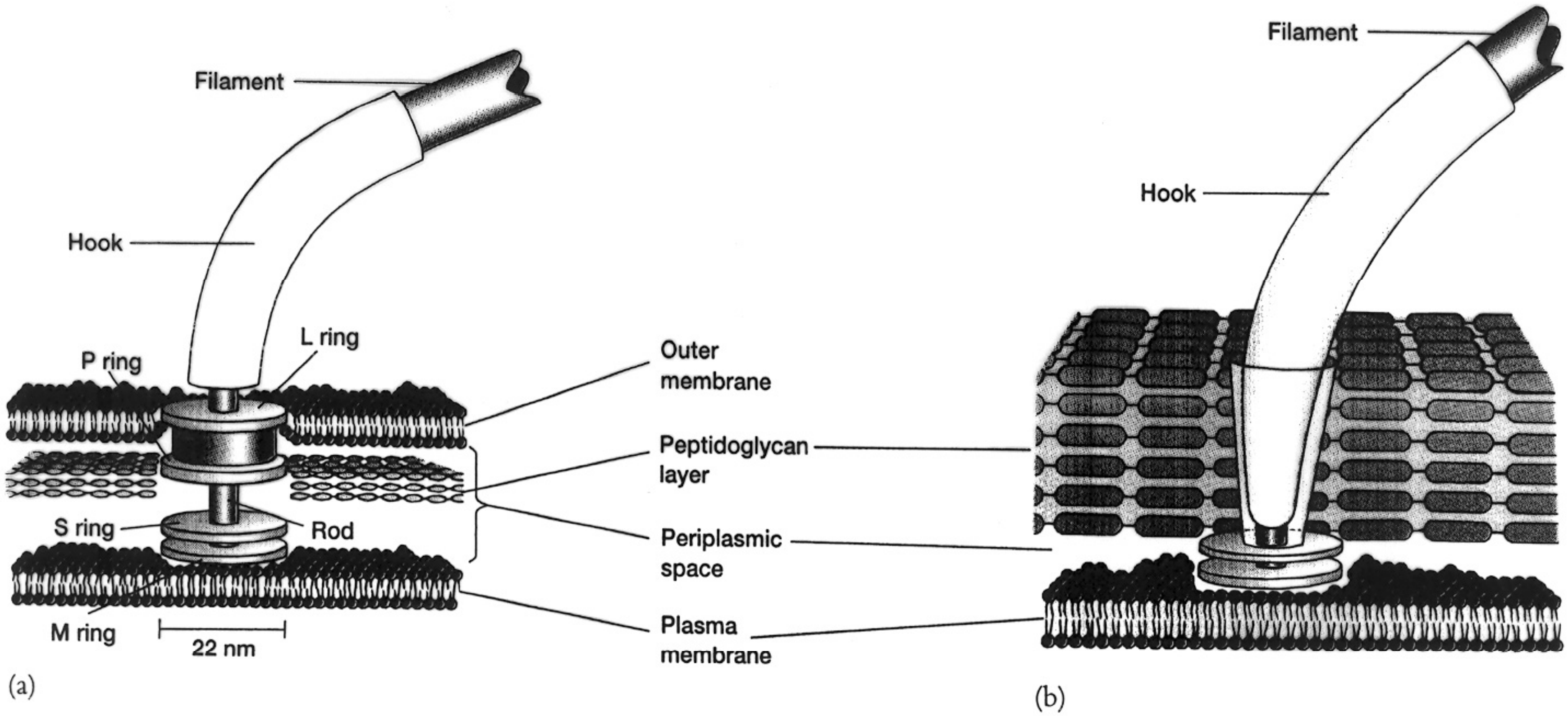
Proton Transport-Coupled Rotation of the Flagellum



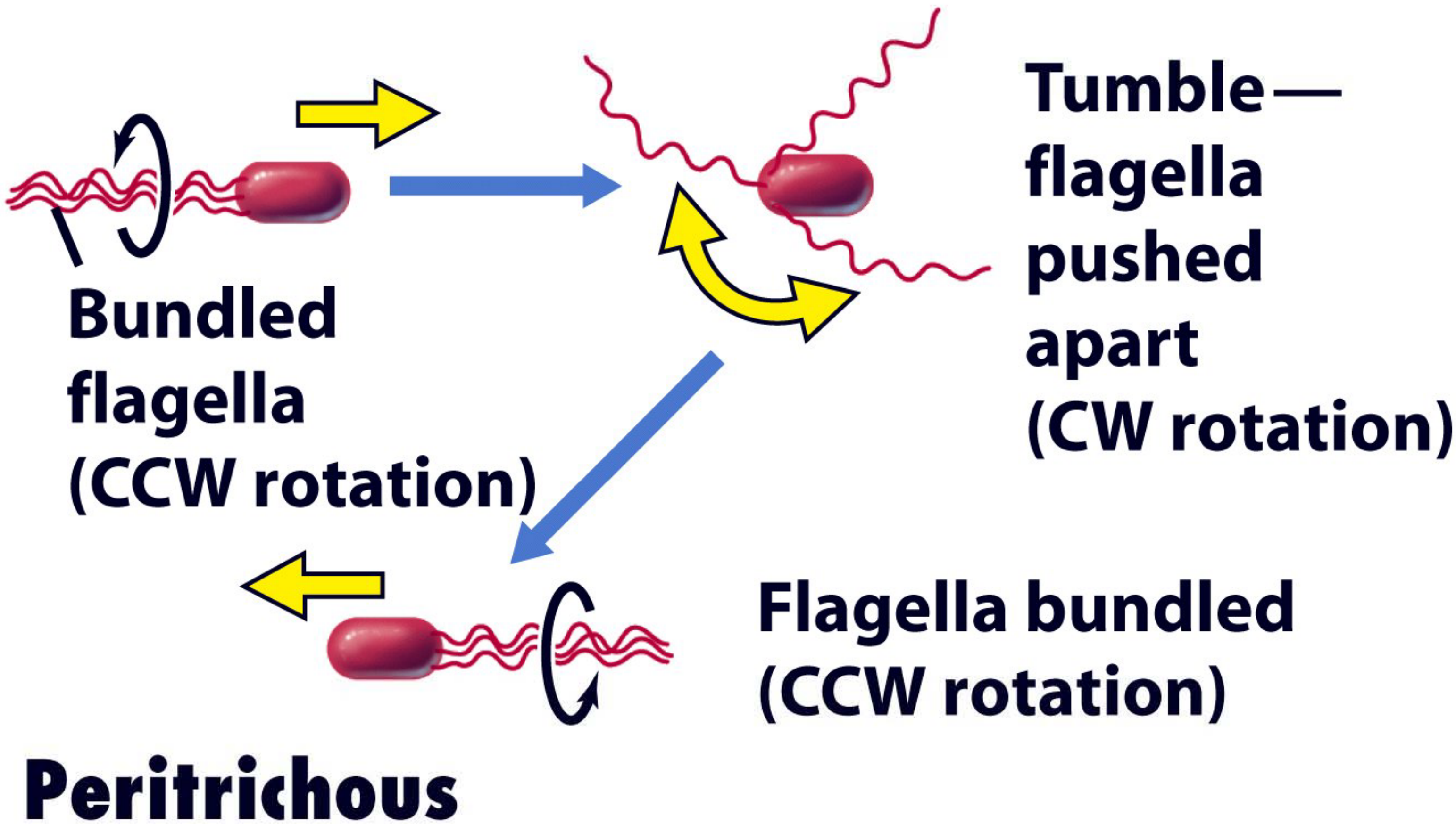


Model for Flagellar Rotation: Mot proteins (MotA/MotB complex) form two half-channels.

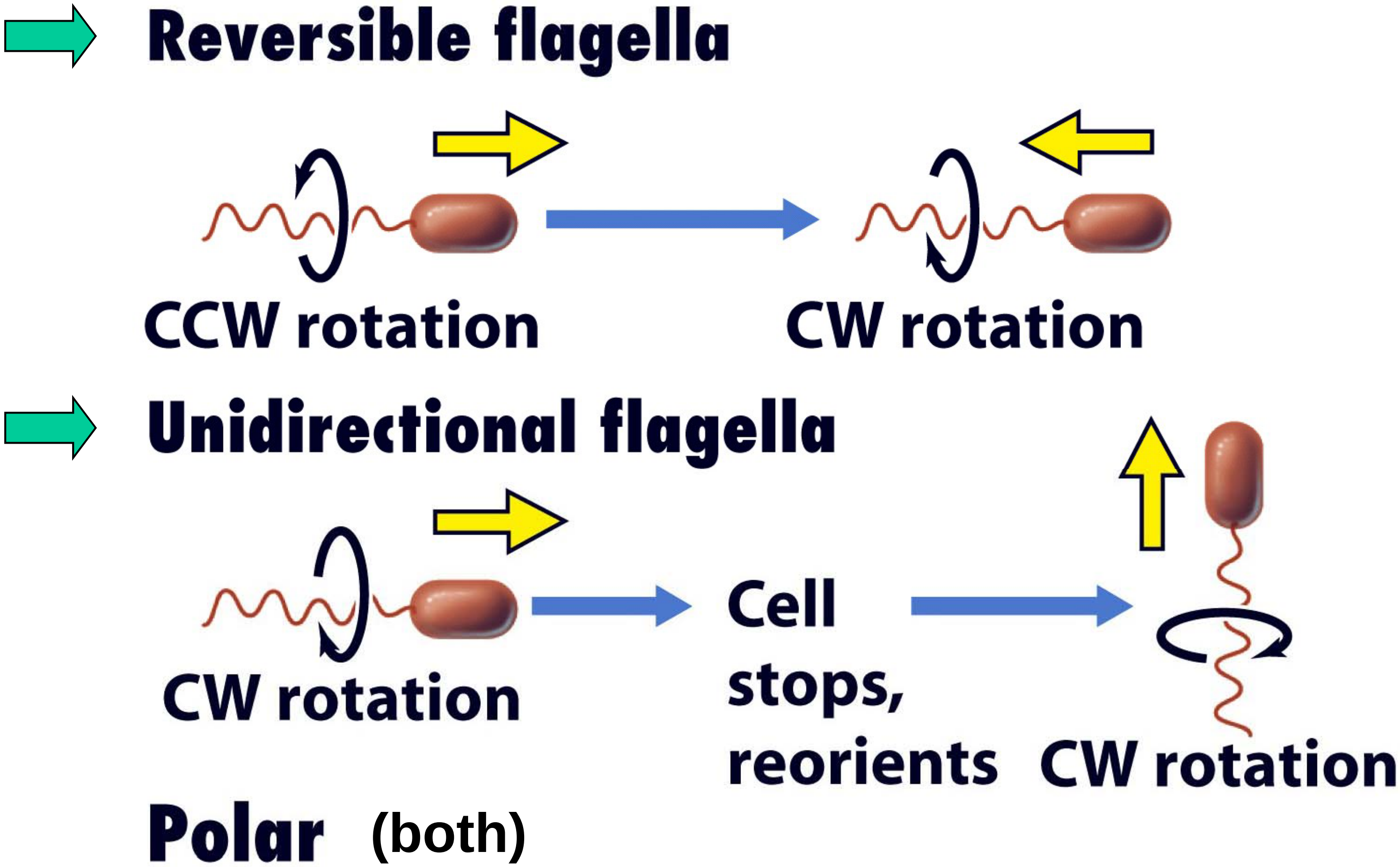
Estimate: *~1000 protons/1 turn*



The Ultrastructure of Bacterial Flagella. Flagellar basal bodies and hooks in (*a*) gram-negative and (*b*) gram-positive bacteria.

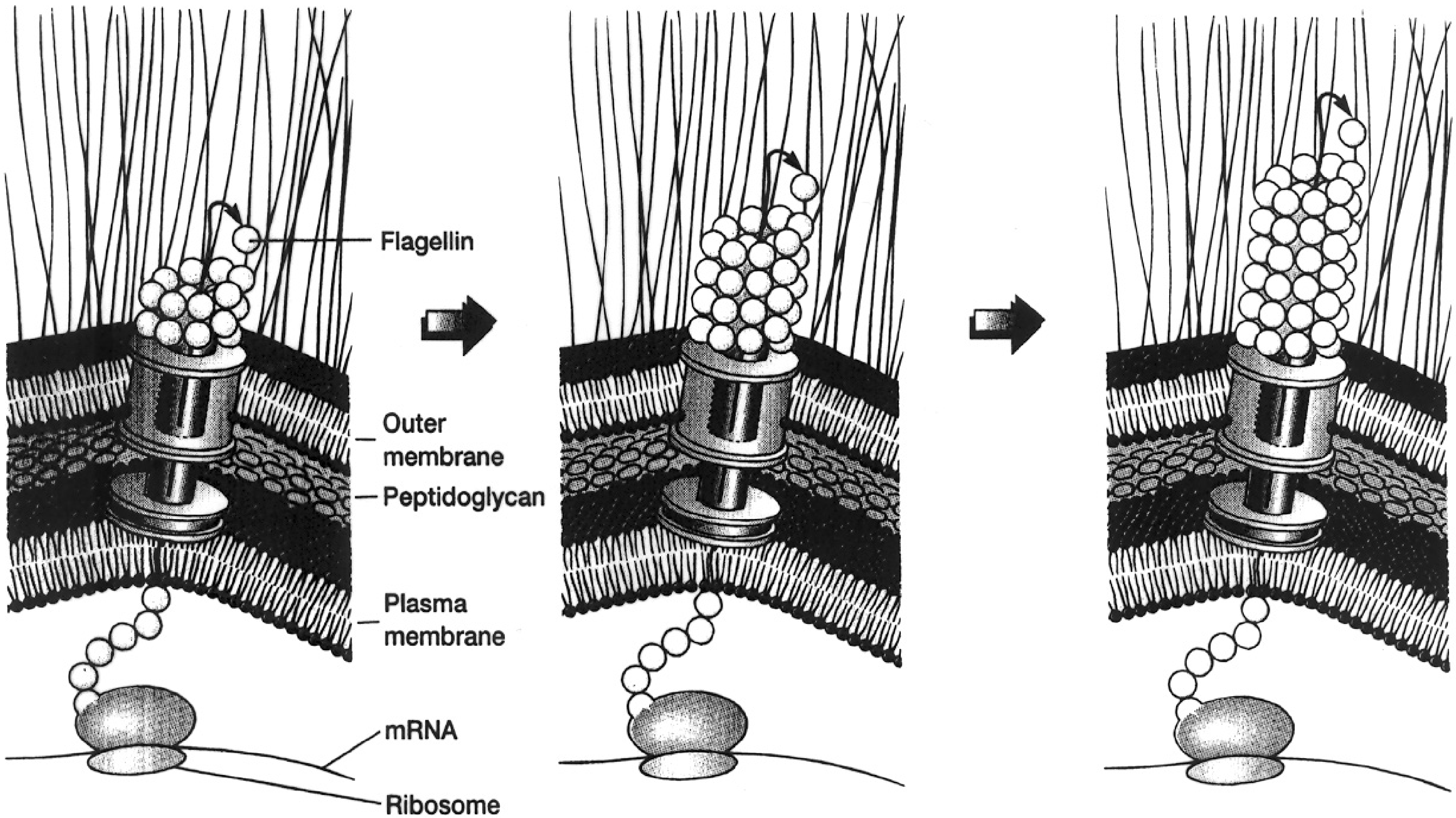


Flagellar Motility: Relationship of flagellar rotation to bacterial movement.



Flagellar Motility: Relationship of flagellar rotation to bacterial movement.

Flagellar Assembly



Growth of Flagellar Filaments. Flagellin subunits travel through the flagellar core and attach to the growing tip.

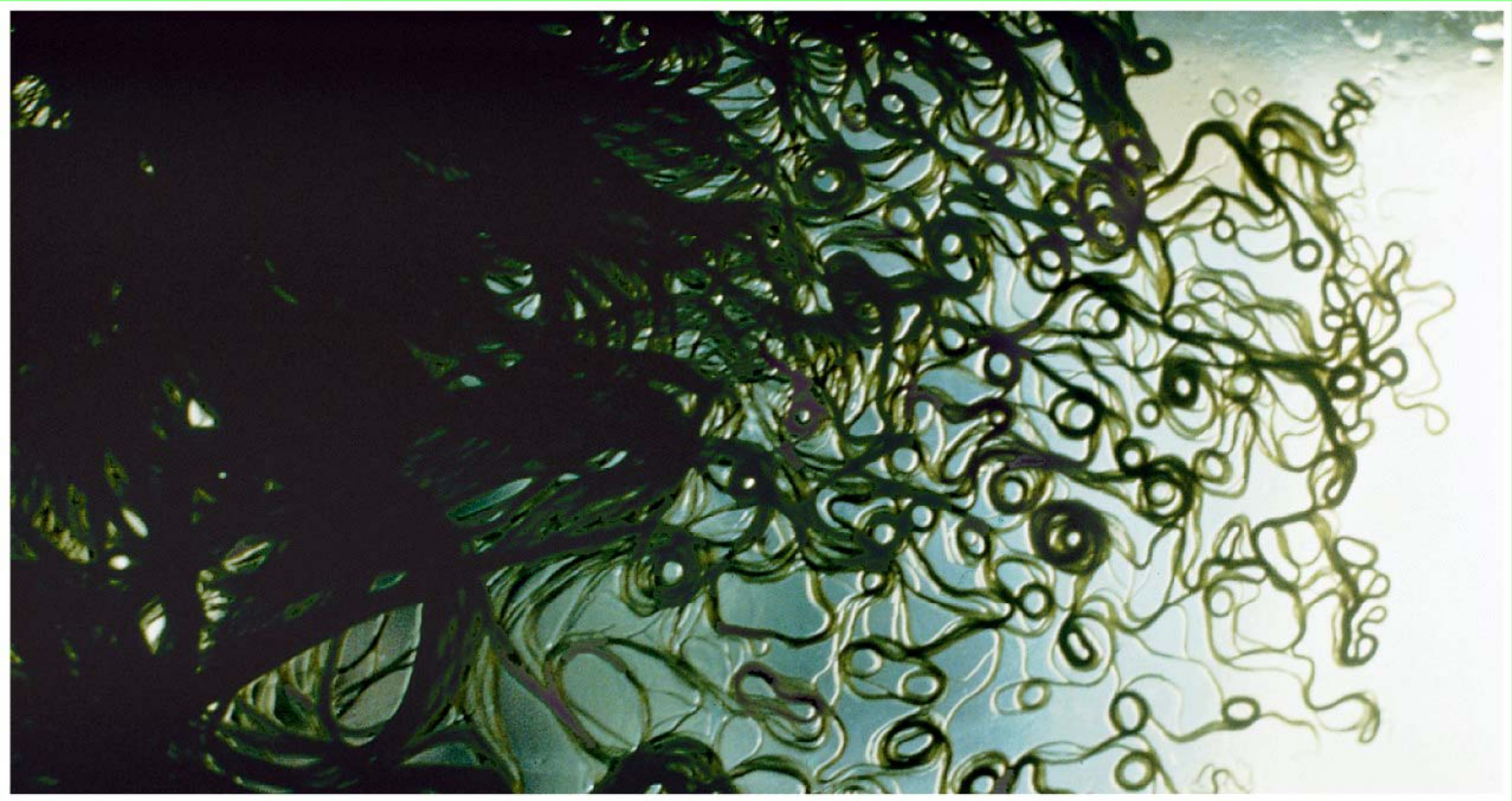
Flagellar Motility: Take Home Message

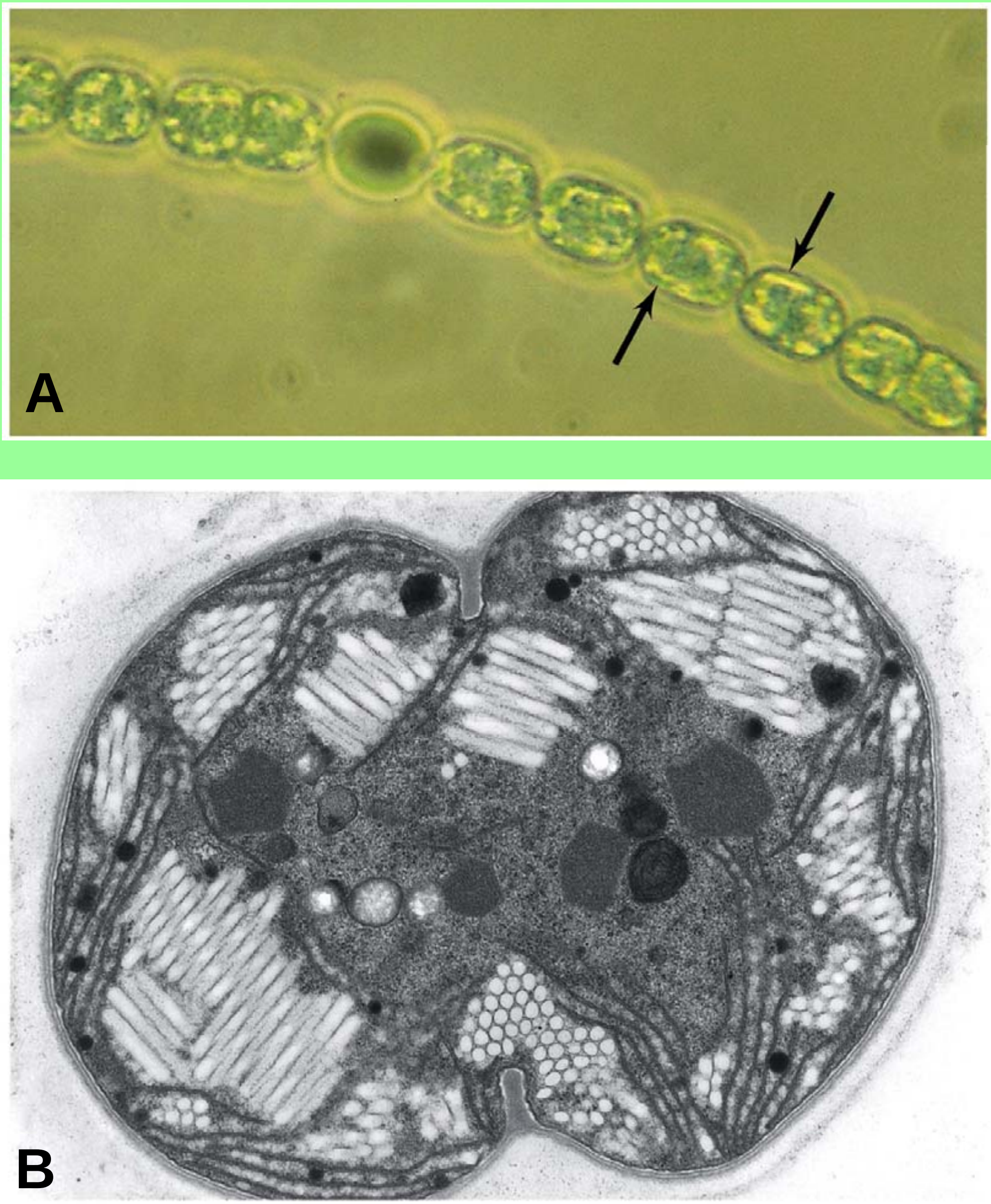
- Motility in most microorganisms is due to flagella.

- In bacteria the flagellum is a complex structure made of several proteins, most of which are anchored in the cell wall and cytoplasmic membrane.

- The flagellum filament, which is made of a single kind of protein, rotates at the expense of the proton motive force, which drives the flagellar motor.

Gliding Motility: Mechanism??



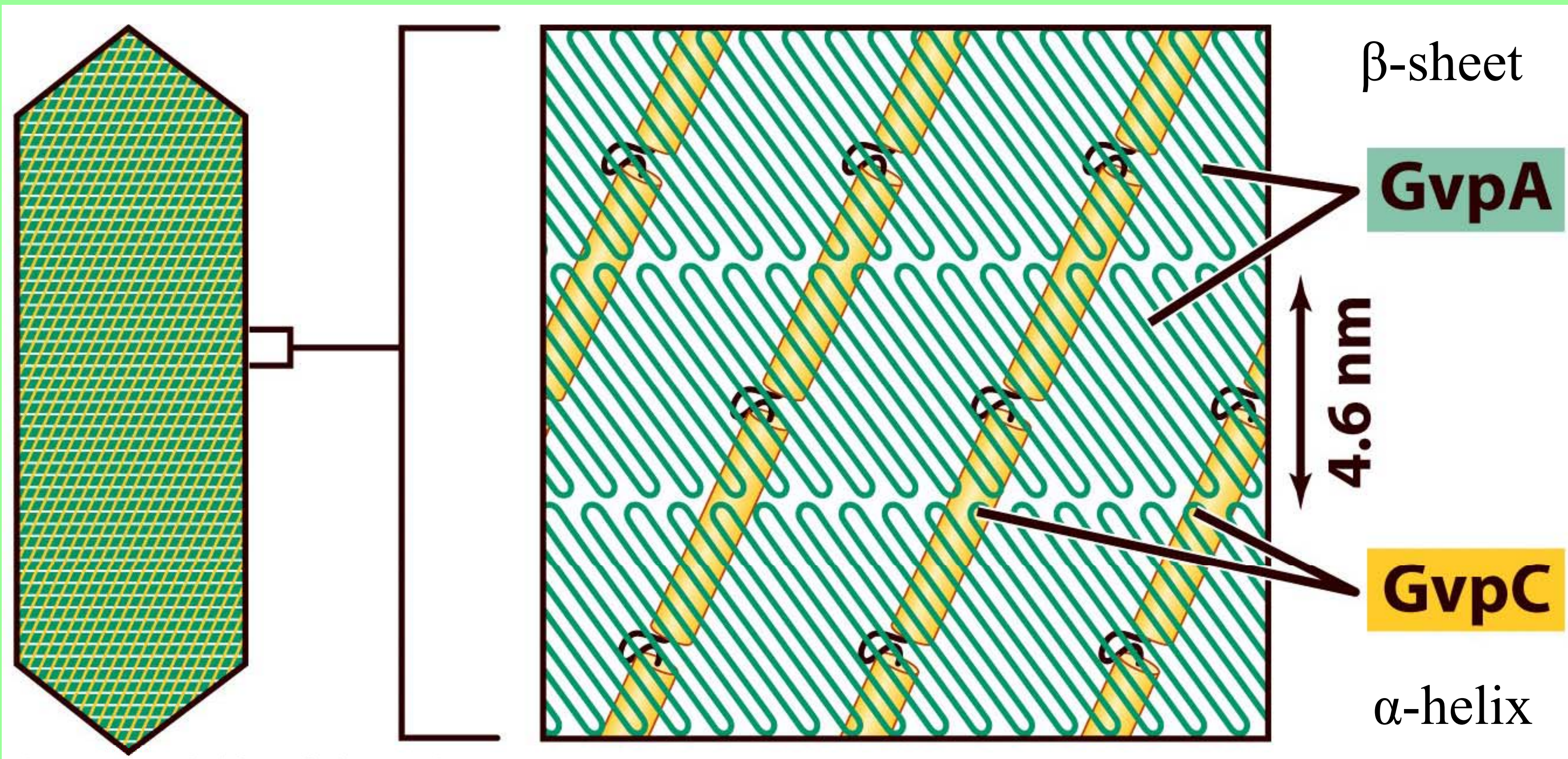


Gas Vesicles
(**A**) *Anabaena flos-aquae*
(**B**) *Microcystis* sp.

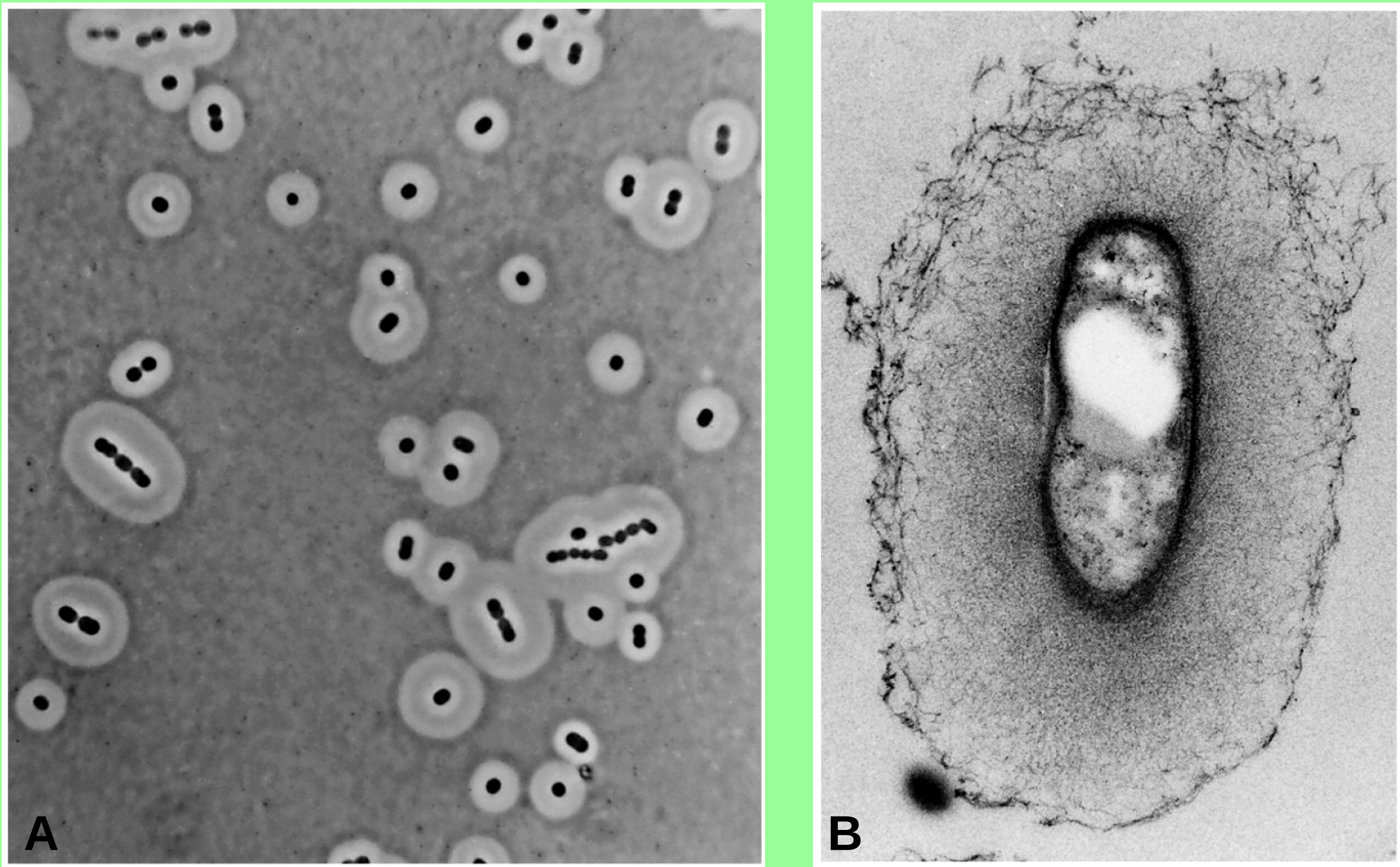
The Hammer, Cork, and Bottle Experiment

(Before) (After)

Model of how the two proteins that make up the gas vesicle, GvpA and GvpC, interact to form a watertight but gas-permeable structure.

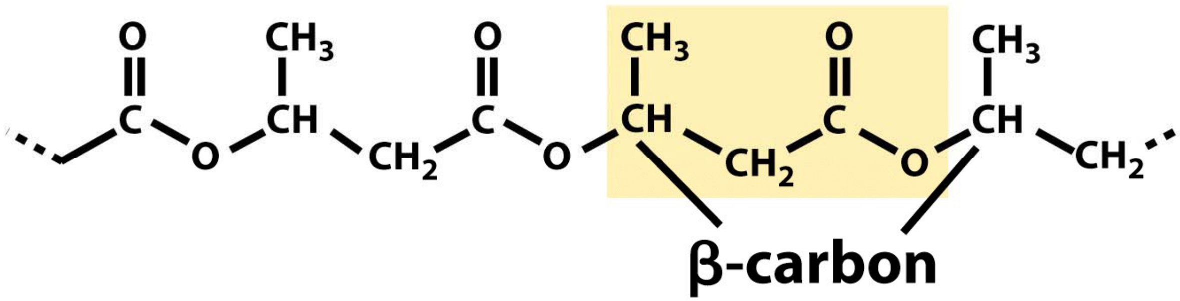


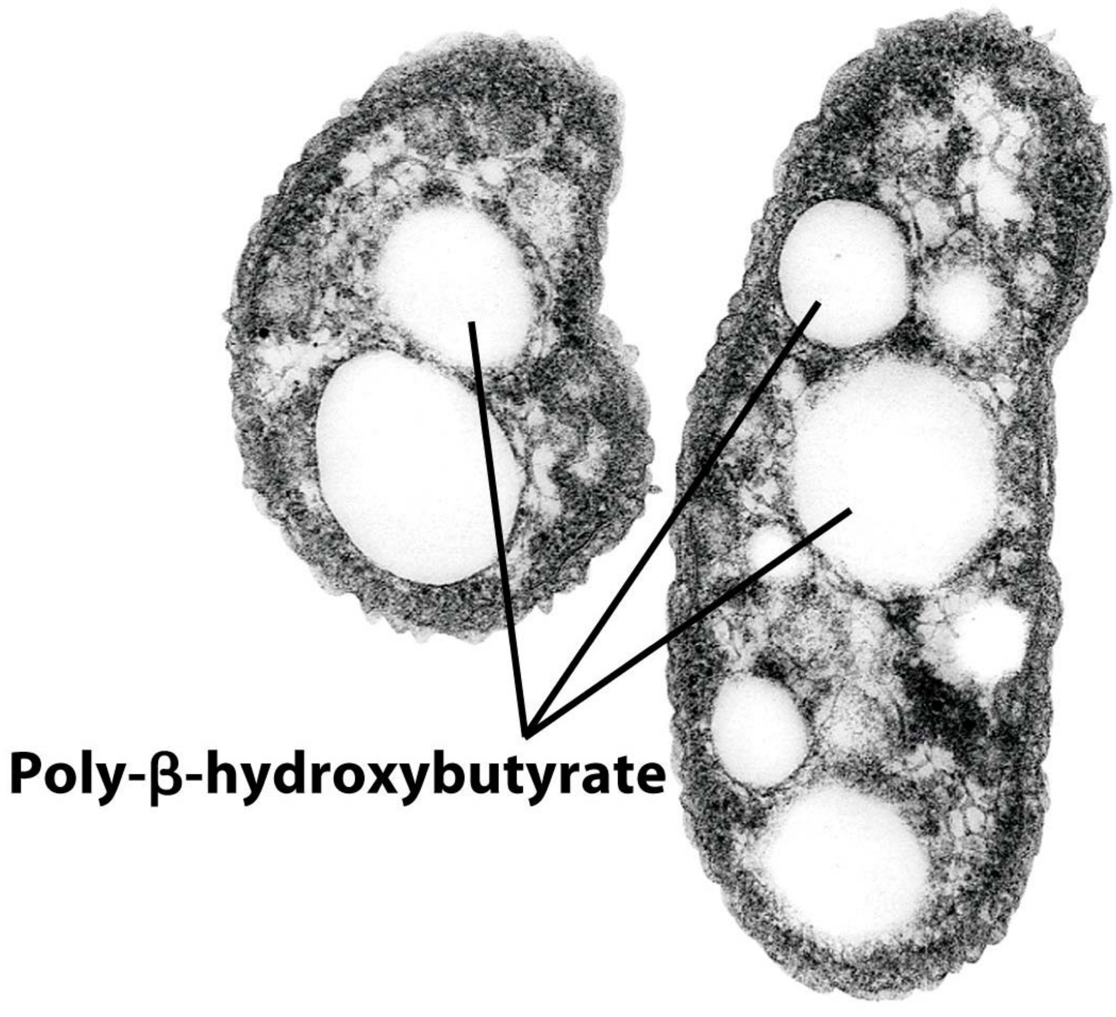
Bacterial Capsules: (**A**) *Acinetobacter* sp. (**B**) *Rhizobium trifolii*

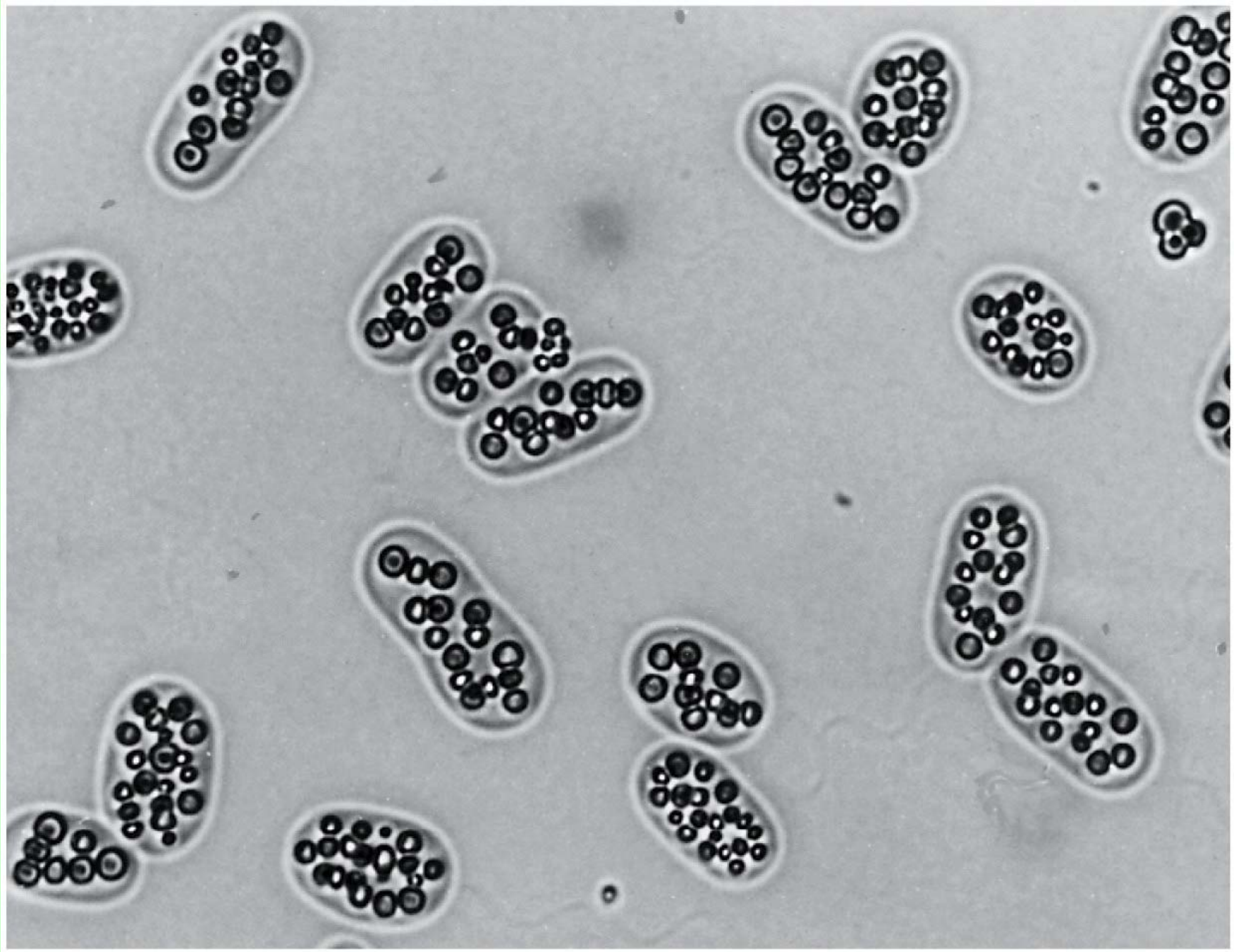


negative stain

Storage of PHB

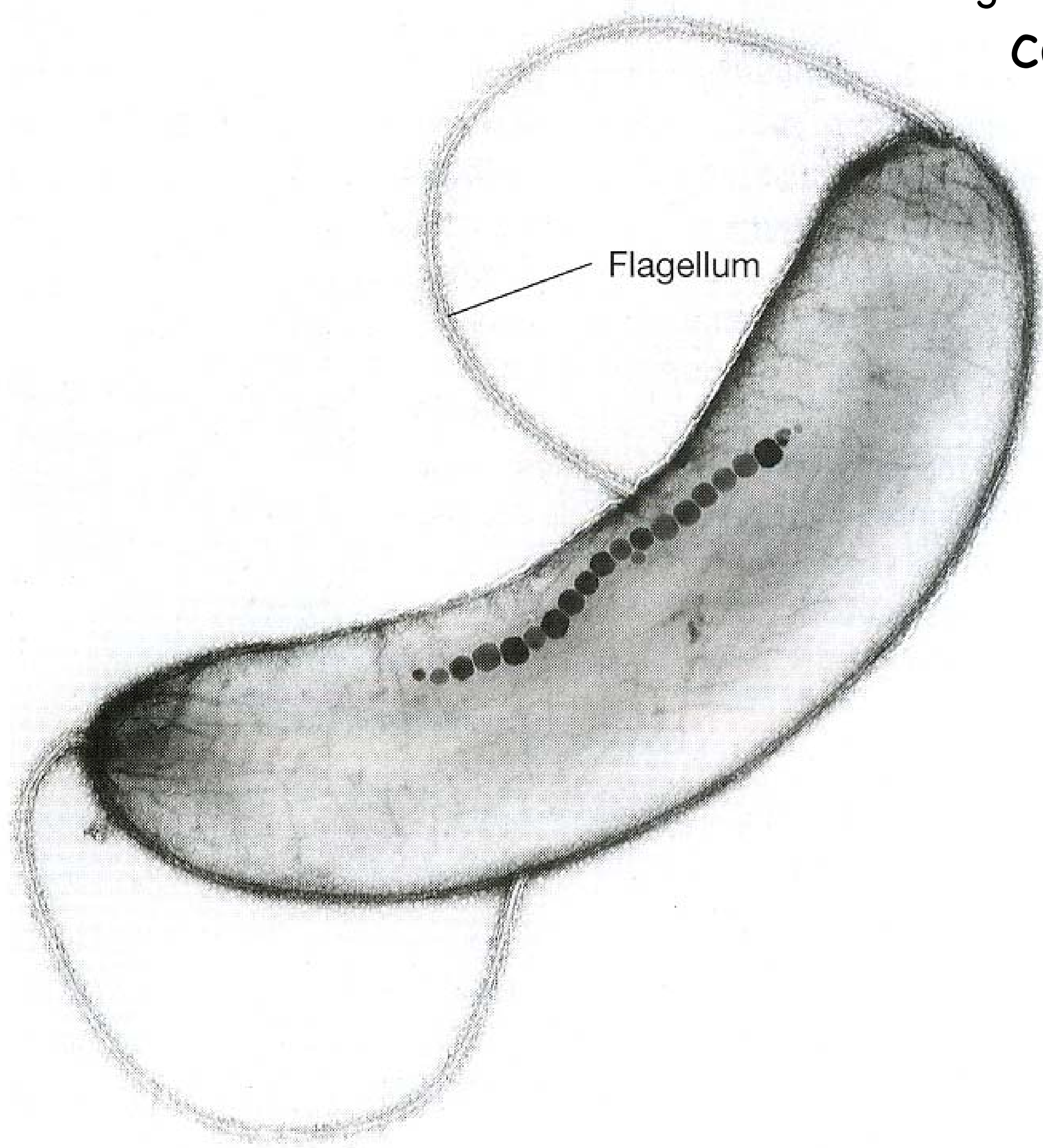


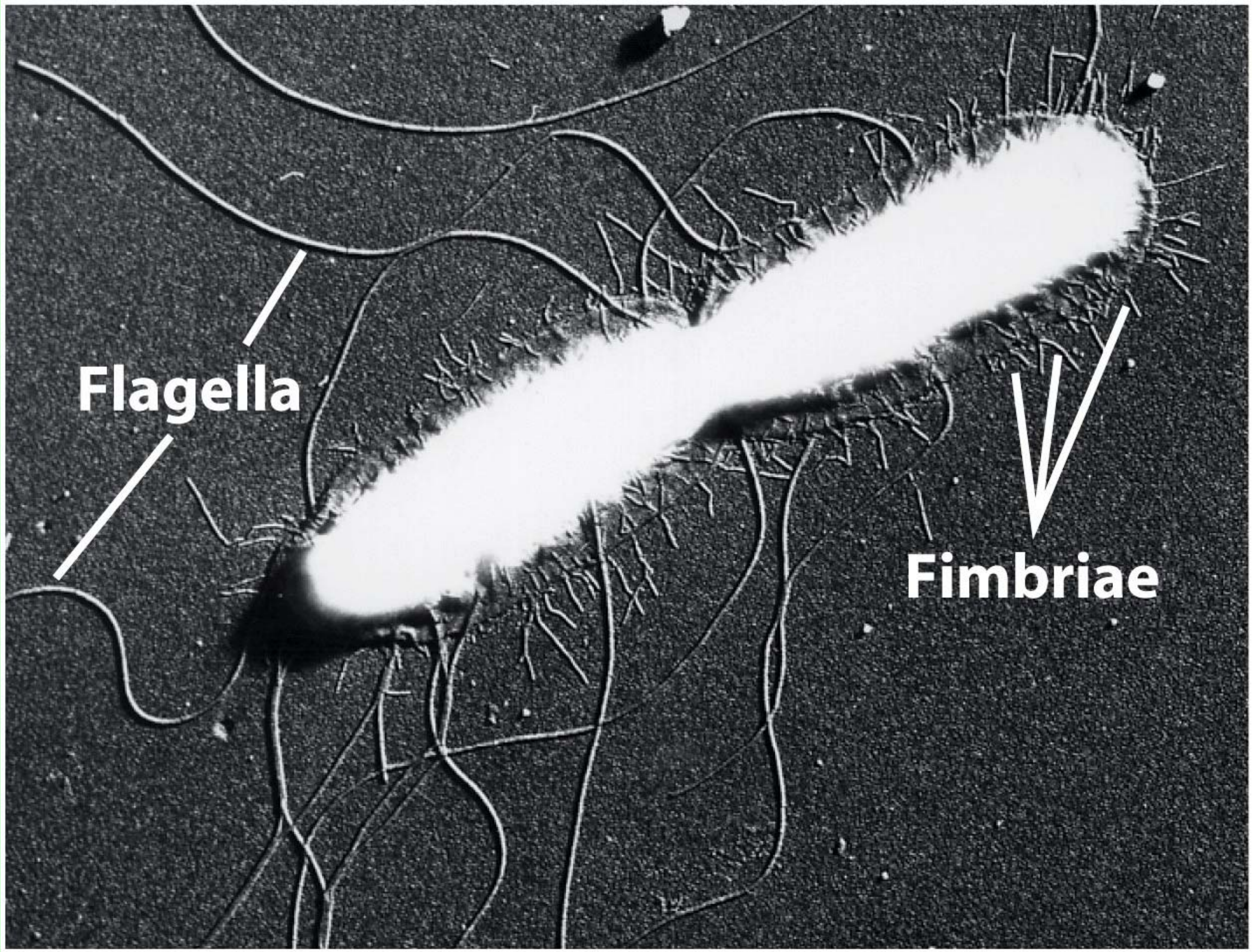




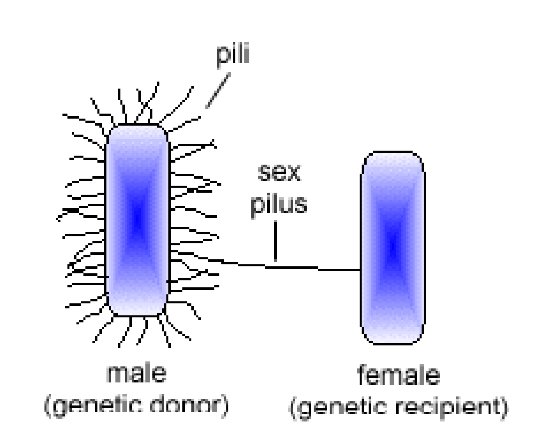
Sulfur globules inside the purple sulfur bacterium *Isochromatium buderi*

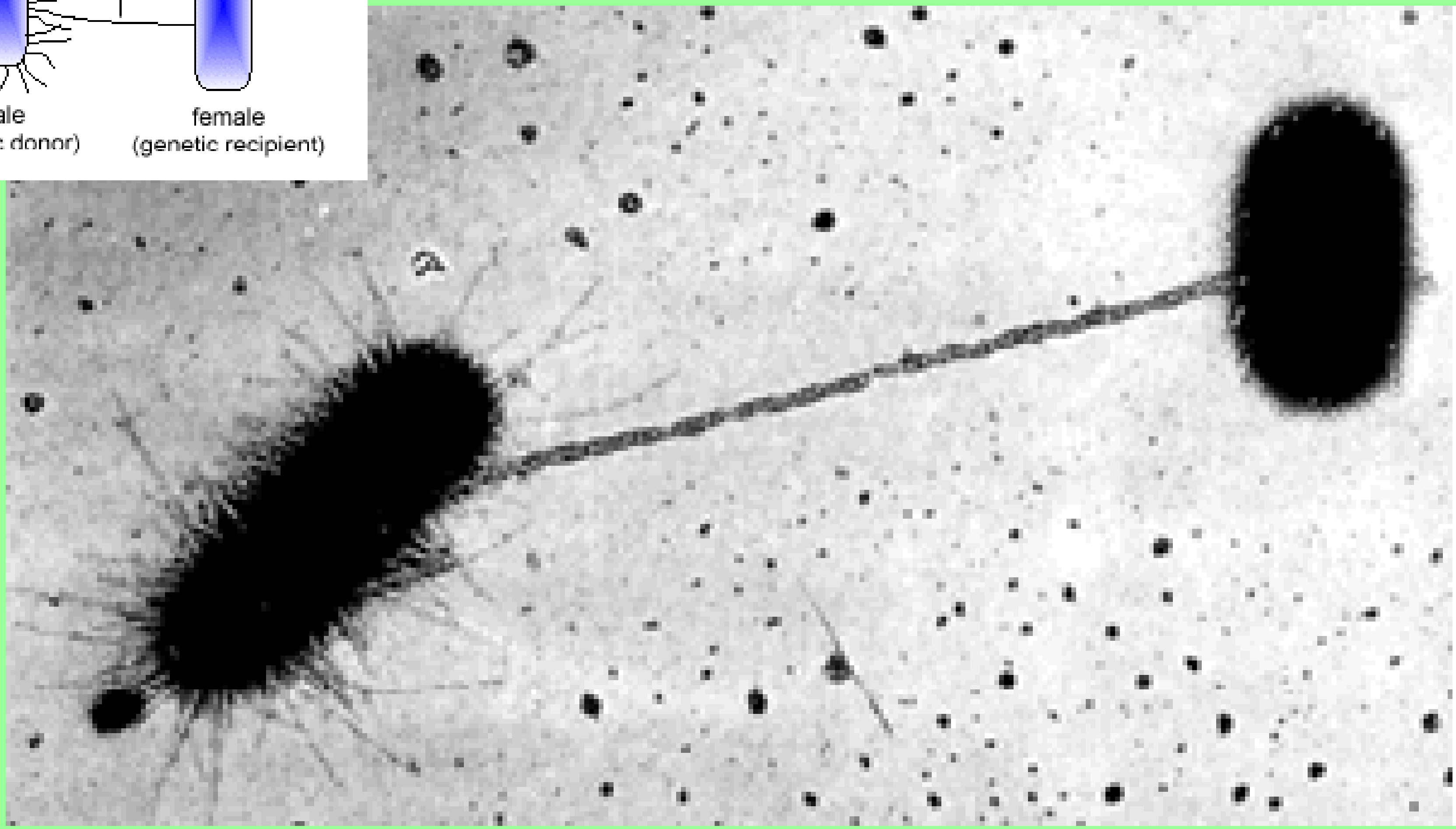
Magnetotactic bacteria with Fe_3O_4 (magnetite) particles called magnetosomes





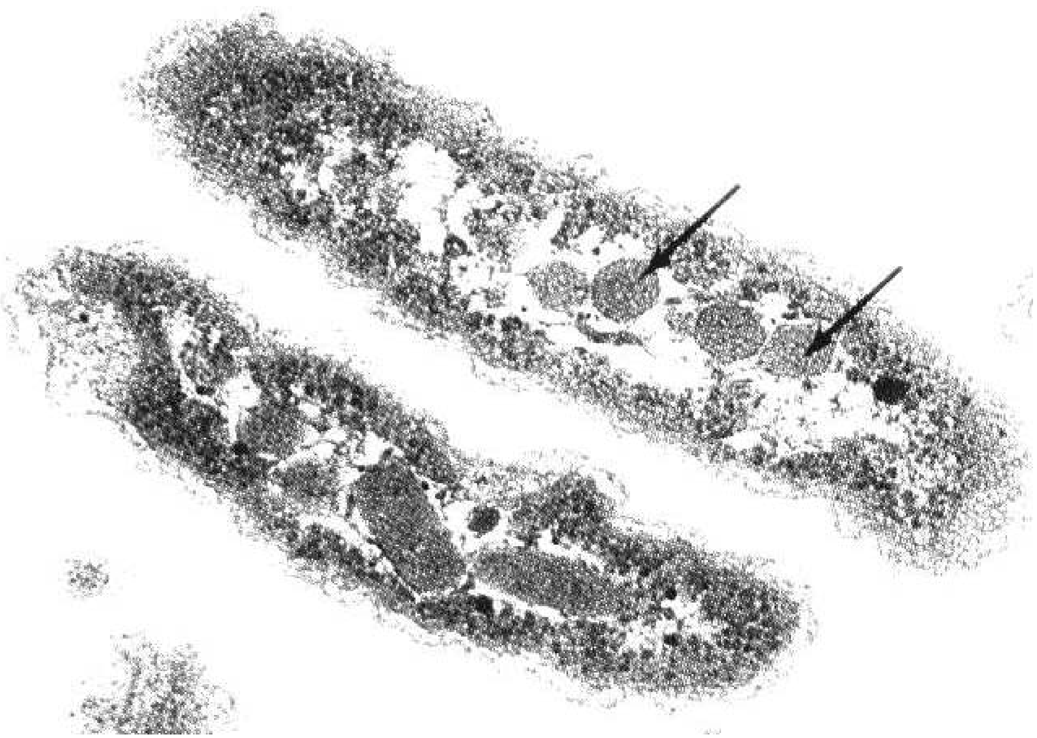
EM of *Salmonella typhi*





"Sex" Pili used in bacterial conjugation of *E. coli* cells

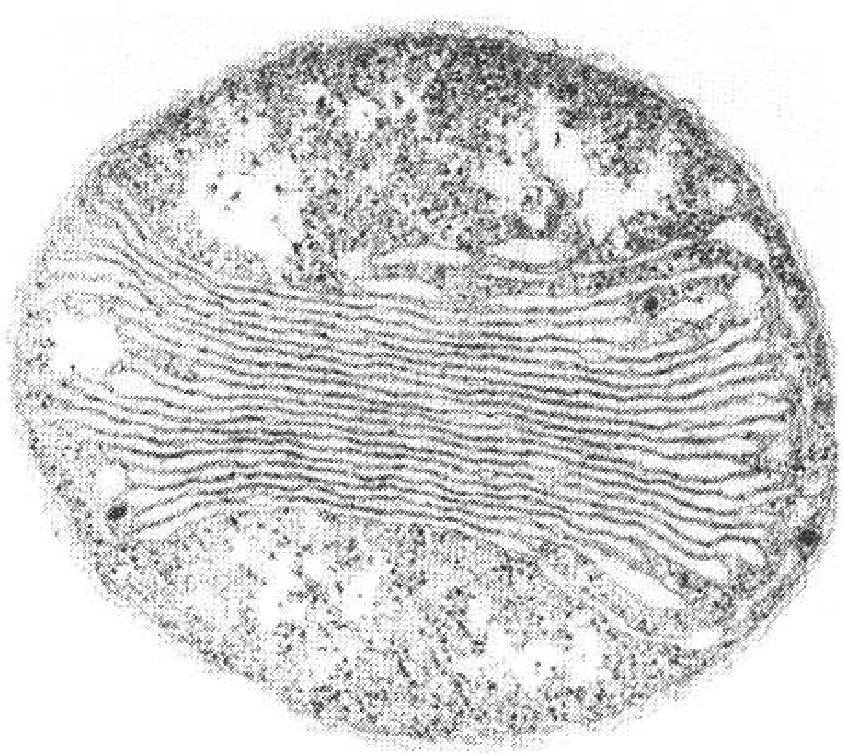
Carboxysomes of *Thiobacillus neapolitanus*



• Carboxysomes found in autotrophs

• Cytoplasmic inclusion involved in fixation of CO_2 into cellular biomass

Extensive cell membranes of *Nitrosococcus*:



Complex membrane structures of many chemolithotrophs and photoautotrophs – analogous to thylakoid membranes of chloroplasts.

Close linkage between e- transport (fueled by photon capture or oxidation of inorganic compound) and fixation of CO_2