Bacterial structure

Prepared by

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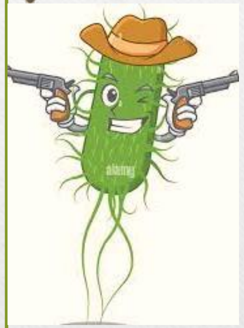
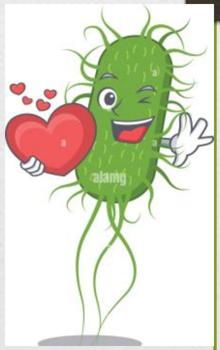


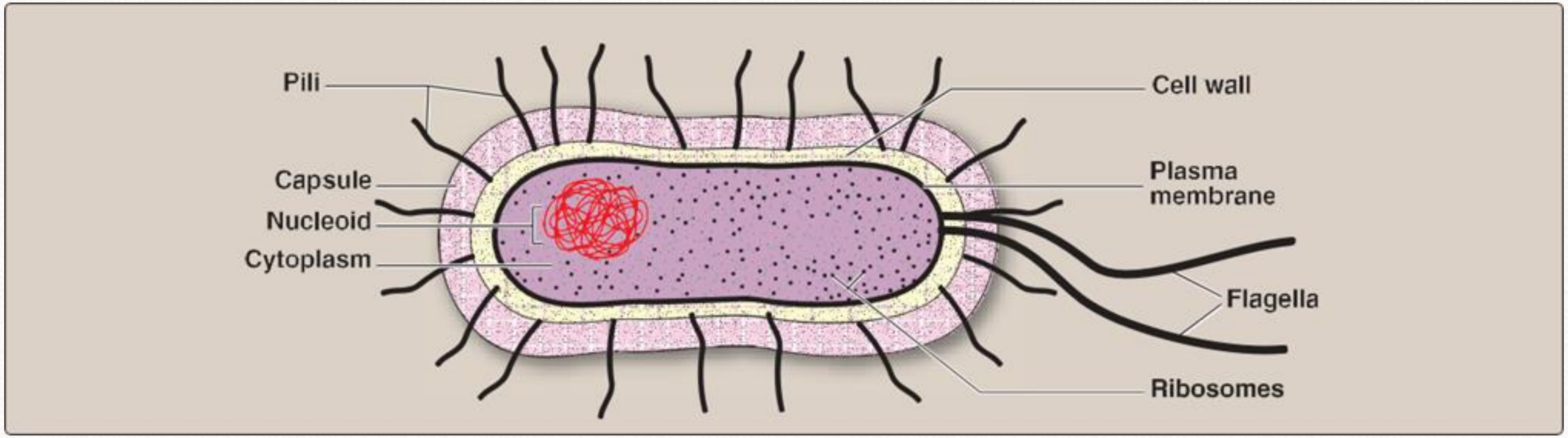


Overview

- **The cellular world is divided into two major groups, based on whether or not the cells have a nucleus (that is, an internal membrane-enclosed region that contains the genetic material).**
- Cells that have a well-defined nucleus are called **eukaryotic**, whereas cells that lack a nucleus are called **prokaryotic.**
- **All bacteria are prokaryotes**.
- In addition, bacterial DNA is not organized into the elaborate multichromosomal structures of

the eukaryotes, but typically is a single double-stranded molecule of DNA.

- Prokaryotes and eukaryotes employ very similar metabolic pathways to achieve cell growth and maintain viability.
- However, prokaryotes synthesize substances and structures that are unique to bacteria, for example, **peptidoglycan.**



Generalized structure of bacterial cell

Cell envelope

- The bacterial "cell envelope" is a term applied to all material external to
- and enclosing the cytoplasm.
- It consists of several chemically and functionally distinct layers, the most prominent of which are the cell wall and the cytoplasmic membrane.
- The cell envelope also includes the capsuleor glycocalyx, if present.

Cytoplasmic membrane

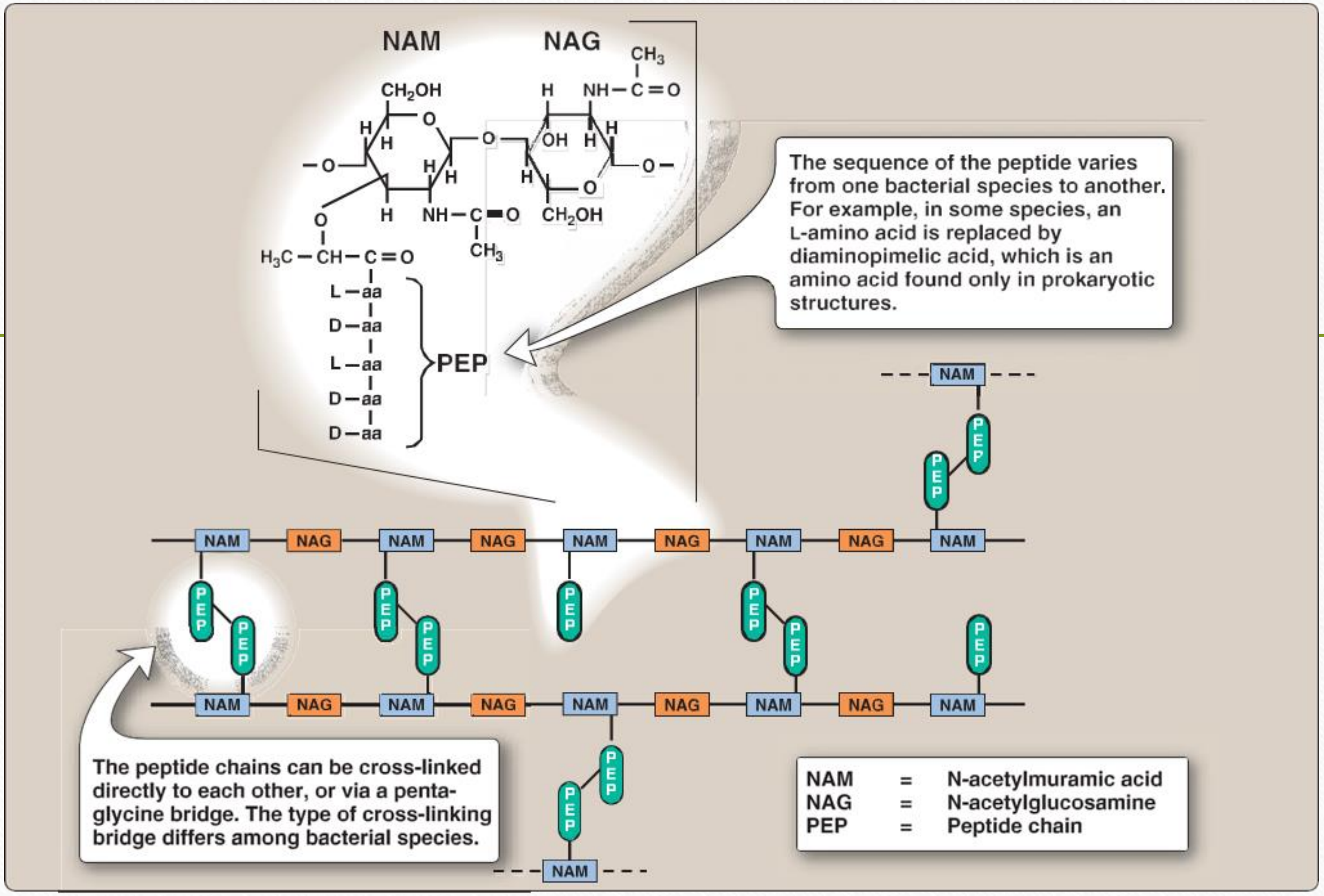
- The cell membrane is composed of phospholipid, the molecules of which form two parallel surfaces (**called a lipid bilayer**)
- Such that the **polar phosphate groups** are on the outside of the bilayer and the

nonpolar lipid chains are on the inside.

- The membrane acts as a **permeability barrier**, restricting the kind and amount of molecule that enter and leave the cell.

Peptedoglycan

- The peptidoglycan layer **determines the shape of the cell**.
- It is composed of a cross-linked polymeric mesh .
- The glycan portion is a linear polymer of alternating monosaccharide subunits: N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM).
- This polymer is the carbohydrate "backbone" of the mesh.



Structure of peptedoglycan

- The "peptido"portion of the polymer is a short string of amino acids that serves to cross-link adjacent polysaccharide strands at the NAM subunits of the backbone, forming a network with high tensile strength.

The presence of D-amino acids helps render the bacterial wall resistant to host peptidases such as those in the intestine.

Gram-positive bacteria

- Gram-positive organisms: Gram-positive bacteria have thick, multilayered, peptidoglycan cell walls that are exterior to the cytoplasmic membrane.
- The peptidoglycan in most gram-positive species is covalently linked to teichoic acid, which is essentially a polymer of substituted glycerol units linked by phosphodiester bonds.

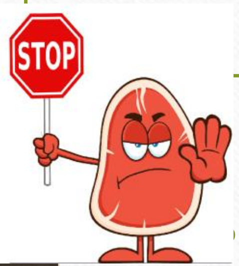
- The teichoic acids are <u>major cell surface antigens.</u>
- Teichoic acids are integrated into the peptidoglycan layers <u>but not tethered to the cytoplasmic membrane.</u>
- Lipoteichoic acids <u>are lipid modified and integrated by this moiety into the outer leaflet of the cytoplasmic membrane.</u>

Gram-negative bacteria

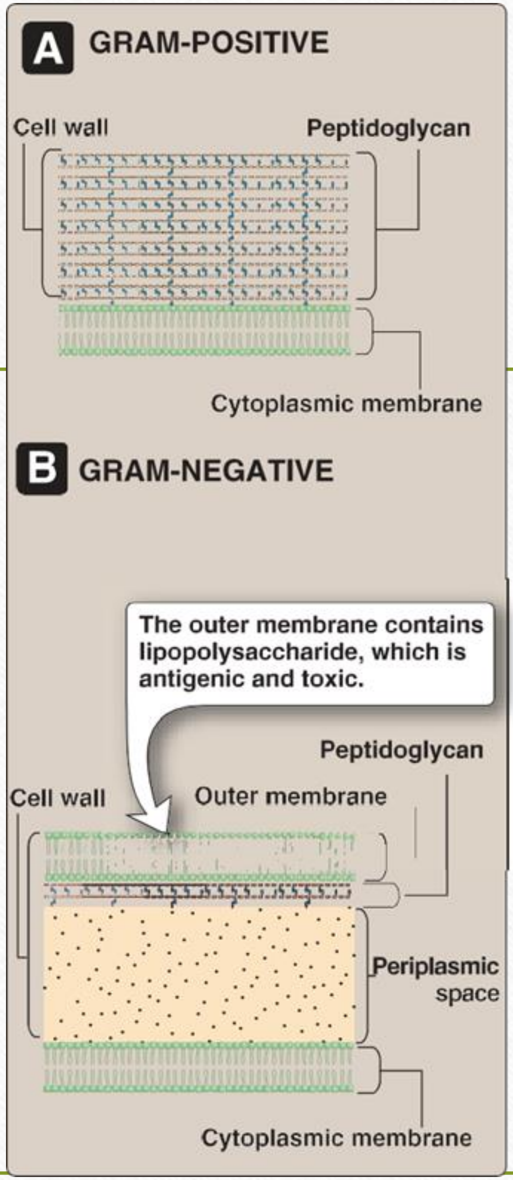
- Gram-negative organisms: Gram-negative bacteria have a more complex cell wall structure composed of two membranes (an outer membrane and an inner, that is, cytoplasmic, membrane).
- The two membranes **are separated by the periplasmic space**, which contains the peptidoglycan layer.
- The periplasmic space also contains degradative enzymes and transport proteins.
- In contrast to gram-positive cells, the peptidoglycan layer of gram-negative cells is thin, and the cells are consequently more susceptible to physical damage.

- The outer membrane is distinguished by the presence of embedded lipopolysaccharide (LPS) that is the major constituent of the outer leaflet of the outer membrane.
- The polysaccharide portion of LPS (O-polysaccharide) is antigenic and can, therefore, be used to identify different strains and species.
- The lipid portion (called lipid A) is imbedded in the membrane and is toxic to humans and animals.

- Because lipid A is integral part of the membrane, it is called **endotoxin**, as opposed to exotoxins, which are secreted substances.
- Do not confuse endotoxin or exotoxins with enterotoxins, which are exotoxins that toxic for the mucosal membrane of the intestine. "Enterotoxin“ denotes the site of action, rather than its origin.



Additional surface layers, capsule or glycocalyx, can be found outside of the cell wall in some species of gram-positive and gram-negative bacteria.



Comparison of gram-positive and gram-negative bacterial cell wall

The external capsule and glycocalyx

- Many bacteria secrete a sticky, viscous material that forms an extracellular coating around the cell.
- The material is usually a polysaccharide.
- However, in the case of pathogenic *Bacillus anthracis,* the capsule is composed of poly-D-glutamic acid.
- If the material is tightly bound to the cell and has an organized structure, it is called **a capsule**.

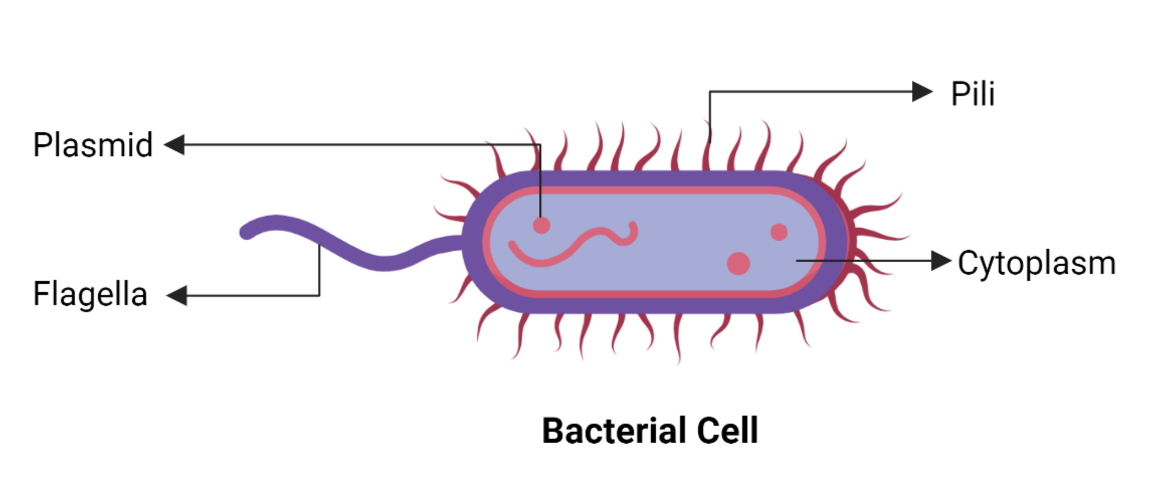
- If the material is loosely bound and amorphous, it is called **a slime layer**, or glycocalyx.

- The capsule or glycocalyx allow cells to adhere to surfaces, protect bacteria from antibodies and phagocytosis, and act as diffusion barriers against some antibiotics, thus contributing to the organisms' pathogenicity.
- Capsules can also protect bacteria against dessication, or drying, which facilitates transmission.

- Many bacteria have hair like appendages that project from the cell wall.

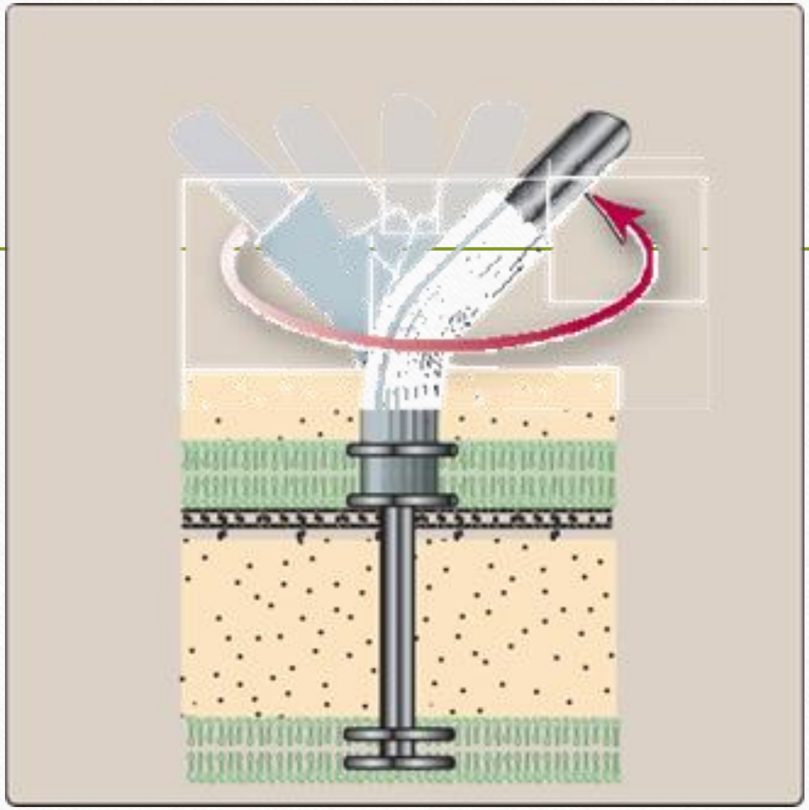
- There are of **two kinds of appendages**:

1. Flagella (singular, flagellum) and
2. Pili (singular, pilus)



➢ Flagella:

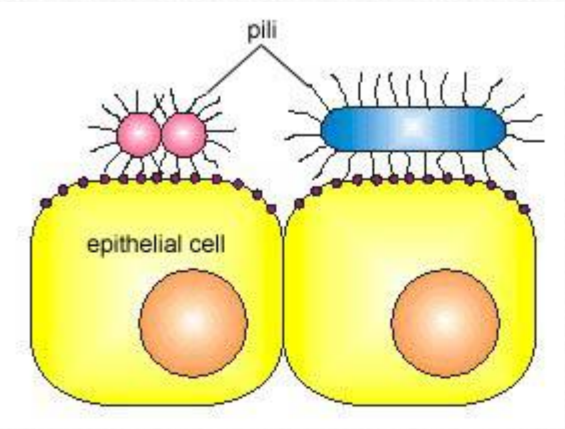
- Prokaryotic flagella are long, semi rigid, helical, hollow tubular structures composed of several thousand molecules of the protein flagellin.
- ~~They enable bacteria to move in a directed fashion,~~ **~~for example, in response to a~~ chemotactic stimulus.**
- Flagella are anchored in the cell membranes by a basal body, which is a complex molecular machine that rotates the flagellum like the screw propeller of a ship.
- Cells may have one or many flagella.
- Flagella are highly antigenic.
- Bacteria that have flagella often do not form compact colonies on an agar surface, but **instead swarm over the surface of the agar if it is sufficiently wet, producing a scum like mat.**



The flagellum rotator machine

➢ **Pili:**

- Pili (sometimes called fimbriae) are shorter and thinner than flagella and function as attachment structures that promote specific cell-to-cell contact.
- The attachment can between the bacterial cell and the host eukaryotic cell or between one bacterial cell and another.



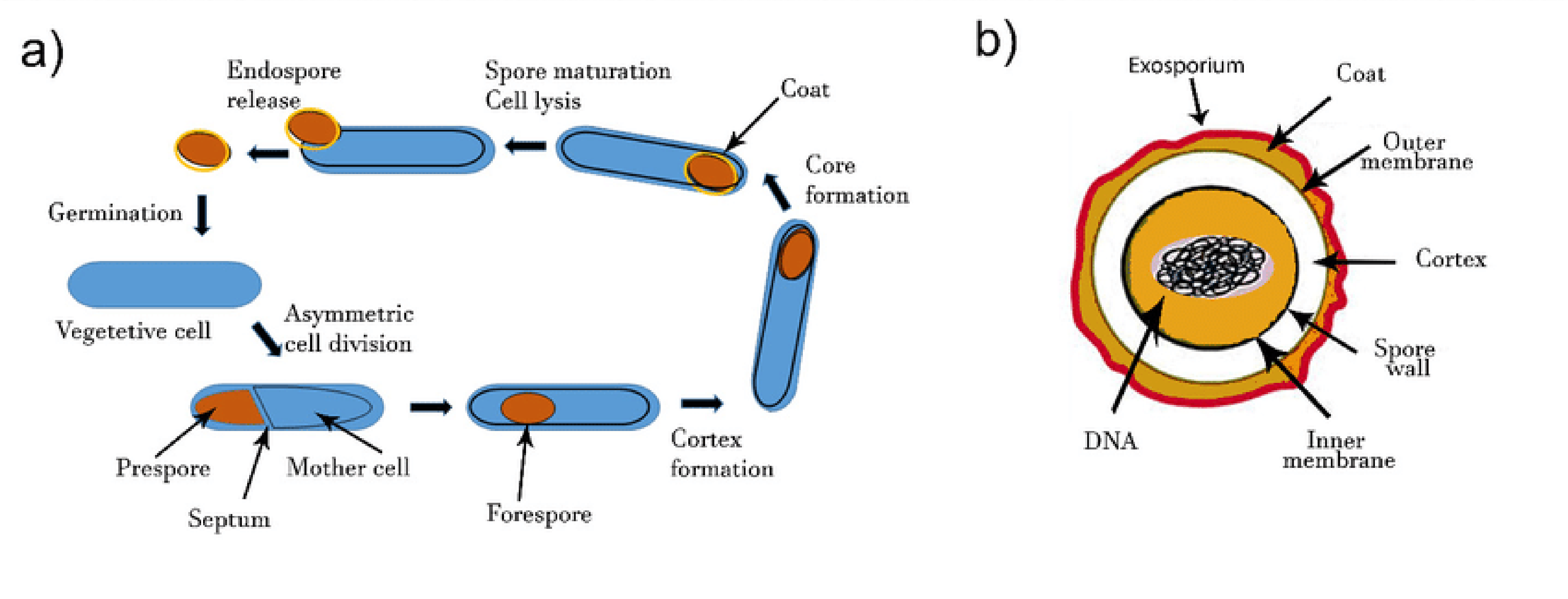
Bacterial Adherence with Pili

Antigenic variation

- Antigenic variation is the expression of various alternative forms of
- antigen on the cell surface.
- Most surface structures are subject to antigenic variation, including LPS, capsules, lipoteichoic acids, pili, and flagella.
- This variation is important for immune evasion by the pathogen. For example, in *Neisseria* species, antigenic variation by gene conversion allows the organism to produce antigenically different pilin molecules at high frequency.
- Variation in the surface structures between strains of the same species is detected by serology

Spores and sporulation

- To enhance survival during periods of environmental hostility (such as nutritional deprivation), some gram-positive rods undergo profound structural and metabolic changes.
- These result in the formation of a dormant cell **called an endospore** inside the original cell.
- Endospores can be released from the original cell as free spores.



Formation of endospores

- Spores are the most resistant life forms known.
- They are remarkably resistant to heat (they survive boiling), desiccation, ultraviolet light, and bactericidal chemical agents.
- In fact, sterilization procedures are assessed by their ability to inactivate spores.

Sporulation

- Sporulation can be thought of as repacking a copy of bacterial DNA into a new form that contains very little water, has no metabolic activity, does not divide, and has a restructured, highly impermeable, multilayered envelope.
- Spore formation begins with the invagination of the parent cell membrane, producing a double membrane that encapsulates and isolates a copy of the bacterial DNA in what will become the core of the spore.

- The mature spore retains the complete machinery for protein synthesis, and new spore-specific enzymes are synthesized in the core of the spore.

- The core also has high levels of a unique compound called calcium dipicolinate, which is thought to be important for protections of the spore DNA from environmental damage.

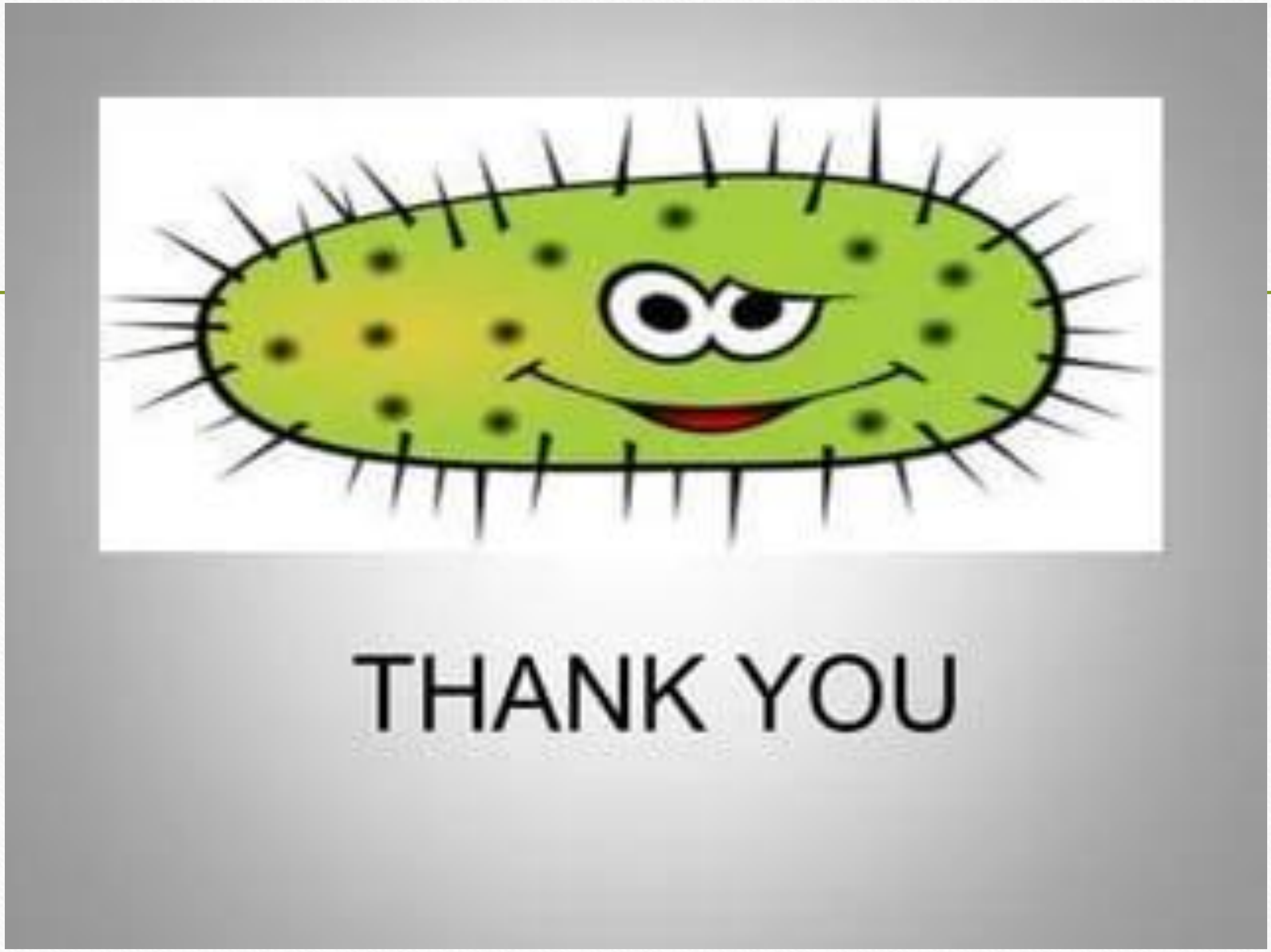
- Many enzymes of the original vegetative (nondividing) cell are degraded. When the endospore is completed, the parent cell lyses, releasing the spore.

Spore germination

- To return to the vegetative state, spores must first be subjected to a treatment that weakens the spore coat (such as heat or extremes of pH), thus allowing germination to occur.
- If the activated spore is in a nutritious environment, which it senses by monitoring various key metabolites, **it begins to germinate.**
- This process involves destruction of the cortex by lytic enzymes, followed by uptake of water, and release of calcium dipicolinate from the cell.

Medical significance of sporulation

- Some of the most notorious pathogens are spore-formers, including *Bacillus anthracis* (anthrax) *Bacillus cereus* (gastroenteritis), *Clostridium tetani* (tetanus), *Clostridium botulinum* (botulism), *Clostridium pertringens* (gas gangrene), and *Clostridium difficile* .
- Spores of these organisms can remain viable for many years and are generally not killed by boiling, but they can be killed by autoclaving (that is, subjecting the spores to temperatures above 120°C at elevated pressure).
- In the absence of an autoclave, spores can be largely eliminated by a primary boiling to activate germination and, after a short period of vegetative growth, a second boiling.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