→ Also has an S-layer (slime layer)
- a sticky layer on the surface of the pseudomurein
- gives stability to the cell wall
- consists of interlocking molecules of protein or glycoprotein
- functions to prevent osmotic lysis and selective entry of low molecular weight solutes
- some archaea only have an S-layer (only component of their cell wall outside of their cytoplasmic membrane)

Cell Surface Structures and Inclusions

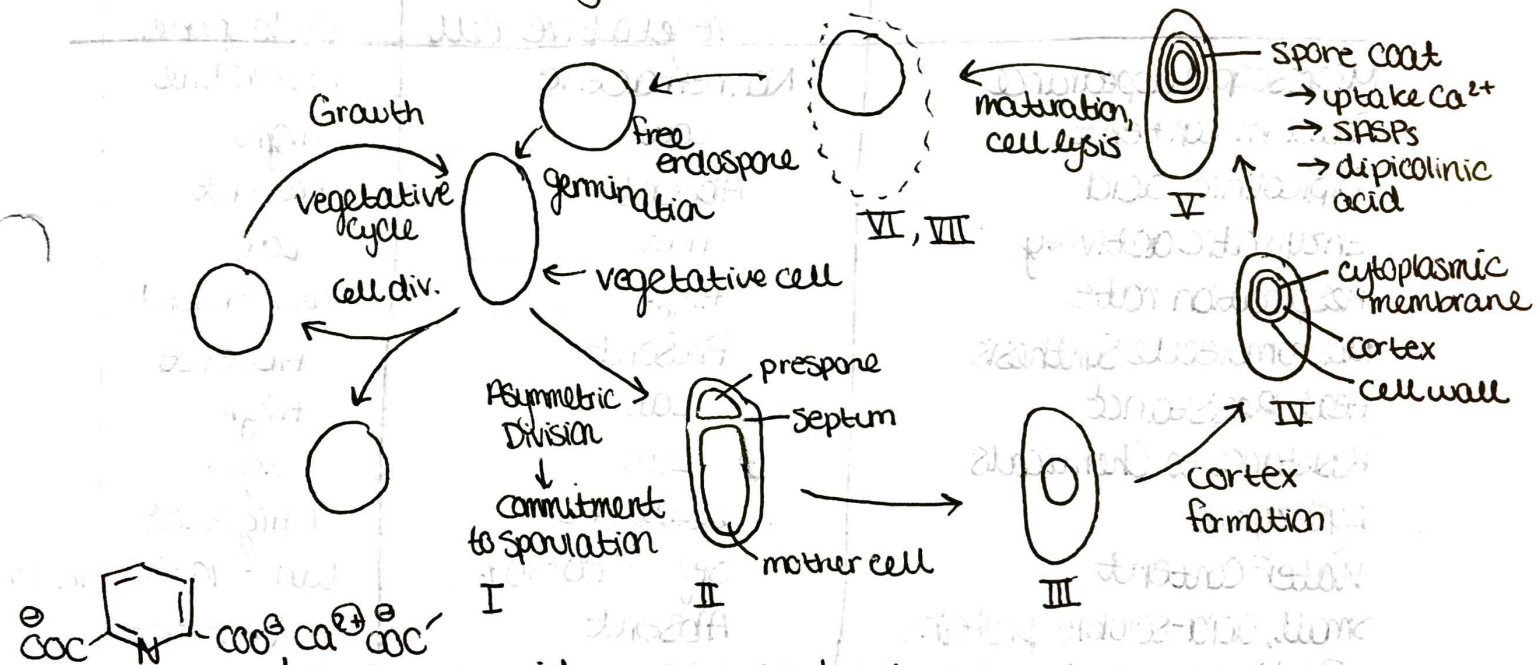
- **Cell wall** - contact with and protection from extracellular environment
  - → Cytoplasmic membrane
  - → Peptidoglycan
  - → Periplasm
  - → Outer membrane
  - } Gram-negative
- Some cells have other layers and structures in contact with the environment
  - → often one or more types of inclusions
- Capsule and Slime Layers
  - → Secreted sticky or slimy materials
    - Polysaccharides / protein
    - Differentiated by India ink, shape, visibility
  - → Capsules are firm, organized, and sometimes covalently-bound
  - → Slime - loose, unorganized, can be lost

* Capsule is impenetrable by stains → must do a negative stain

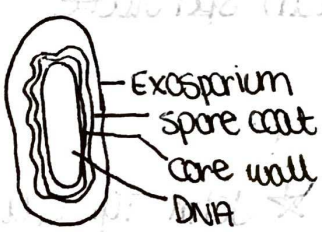
* Not considered cell wall - does not provide structural support
- → Function in lifestyle and survival
  - offer protection against immune attack, environmental stress, and hydrolytic enzymes
  - important for surface attachment / biofilms / pathogenicity
    - ↓
    - virulence factor

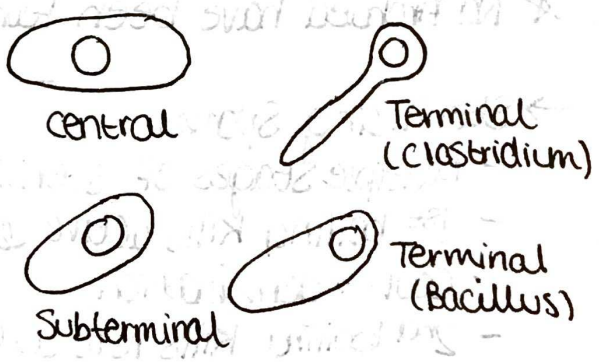
- Surface Appendages
  - → Pili
    - A pilus is a filament of protein pilins; long and few
    - Used in horizontal gene transfer to exchange genetic information
    - Twitching motility
    - Surface attachment
    - ✱ visualized by radioactive bacteriophage
  - → Fimbriae
    - Short + numerous surface attachments
    - allow cells to stick to surfaces
    - form pellicles - thin sheets of cells on a liquid surface
    - biofilms
- Cellular Inclusions
  - → Inclusion bodies often function as energy reserves and/or carbon reservoirs
    - storing molecules in an insoluble form reduces osmotic stress in the cytoplasm
  - → Carbon storage (organic storage)
    - Poly-β-hydroxybutyrate (PBH) or glycogen
  - → Phosphate, Sulfur, Carbonate storage
    - Polyphosphate
    - Sulfur granules in photosynthetic purple sulfur bacteria
    - Carbonate → biomineralization
  - → Magnetosomes (magnetite particles)
    - allows bacteria to orient and migrate along geomagnetic fields
      - ↳ magnetotaxis
    - Fe_3O_4
  - → Gas vesicles
    - allows aquatic organisms to float in large mats on the surface of the water
    - Closest thing to a true organelle
    - ex. cyanobacteria

- Endospores
  - → occur as a stress response to nutrient deprivation, etc.
  - → extremely resistant to environmental stress
  - → controlled by complex sigma (σ) factor regulatory systems
    - interact with RNA polymerase to control transcription
  - → With a few exceptions, all spore-forming bacteria are gram positive
    - but not all gram-positive bacteria are spore-forming
    - the ability to sporulate arose later in evolution



★ Dipicolinic acid = unique to bacterial spores
- makes up 10% dry weight of endospores
- high in Ca^{2+} concentration → crosslinks DPA molecules





→ Return to vegetative state
1. Activation - heat endospore to subletral temperature
2. Place in a nutrient broth
3. Germination - very rapid; synthesizes RNA, DNA, protein; breaks and discards spore coat
4. Outgrowth - swelling due to entry of water

→ Endospores vs. Vegetative cells

	Vegetative Cell	Endospore
Microscopic appearance	Nonrefractive	refractive
Calcium content	Low	High
Dipicolinic acid	Absent	Present
Enzymatic activity	High	Low
Respiration rate	High	Low/absent
Macromolecule Synthesis	Present	Absent
Heat Resistance	Low	High
Resistance to Chemicals	Low	High
Lysozyme	Sensitive	Resistant
Water Content	High - 80-90%	Low - 10-25% in core
Small, acid-soluble proteins	Absent	Present
Radiation Resistance	Low	High

☆ What triggers sporulation can differ between species
☆ No Archaea have been found that can sporulate

→ Sterilizing Spores
- Multiple stages of sterilization
- 1st boiling kills active cells
- Cool → germination
- 2nd boiling kills new cells

☆ John Tyndall (1877)
→ Full disproval of Spont. generation
→ spores would sometimes contaminate Pasteur's broth