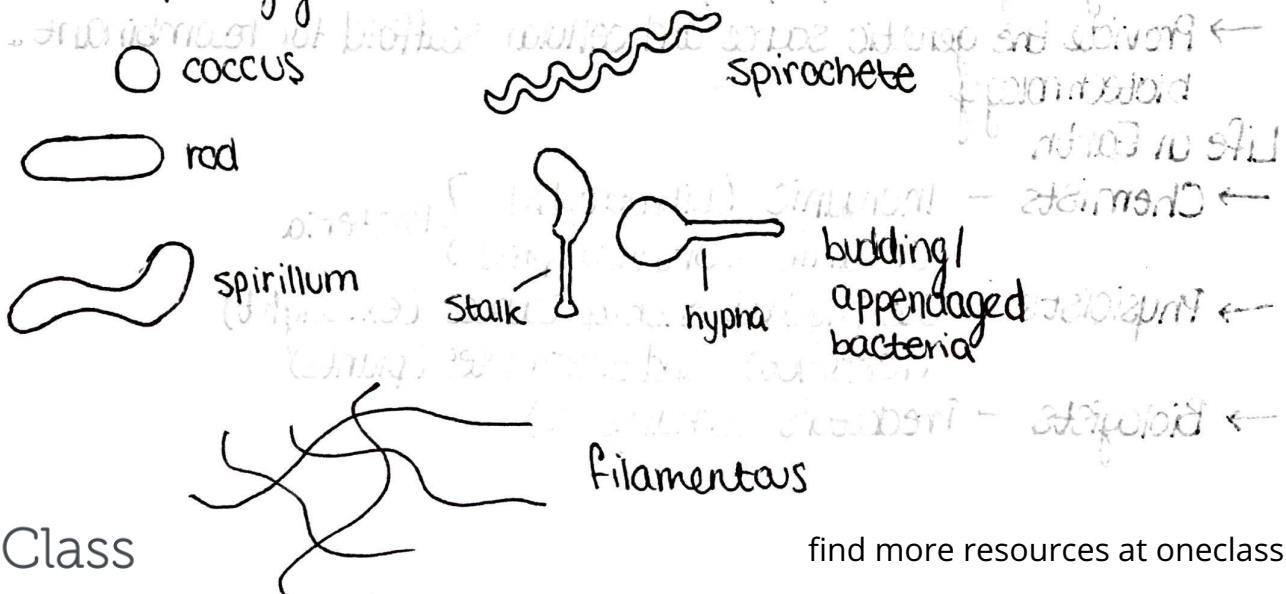
Structure and Function of Prokaryotes

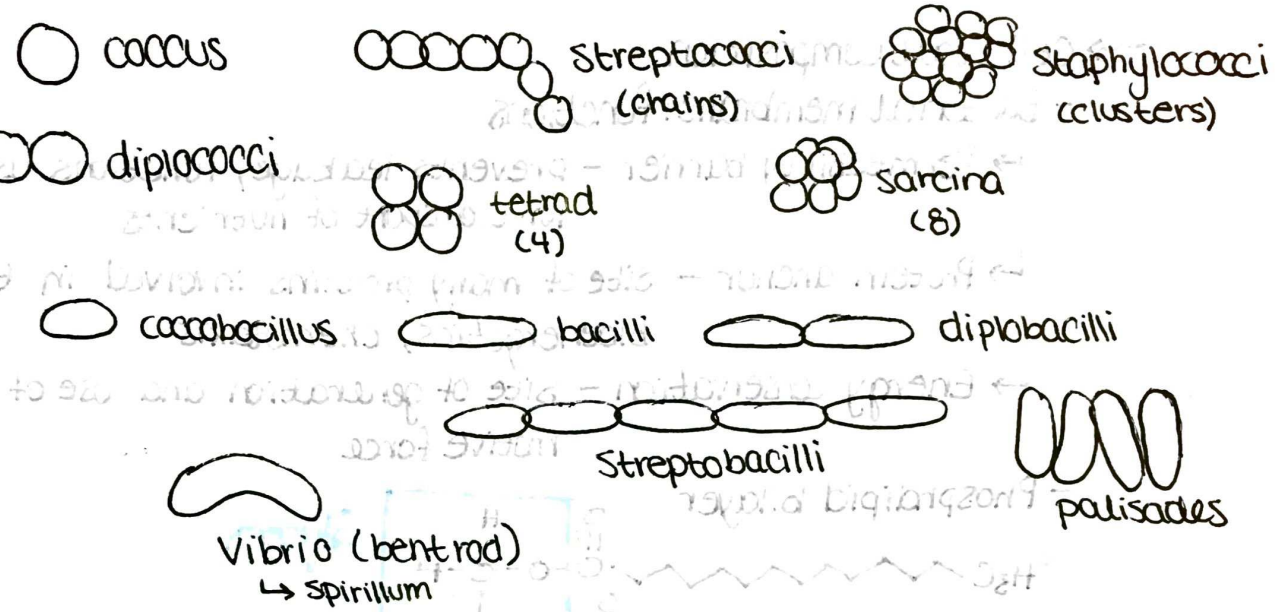
- Naming microorganisms
  - → Each organism has two names: genus and species
  - → May be descriptive or honor a scientist
  - → often describe characteristics
    - ex. Staphylococcus aureus
      - ↳ clustered arrangement (staphylo-)
      - ↳ golden colour of the colonies (aureus)
- Domains of life
  - → Bacteria (most studied)
  - → Archaea
  - → Eukarya
- Importance of bacteria to our lives
  - → Most prevalent disease-causing organisms (>80% of pathogenic diseases)
  - → Involved in:
    - Food production, additives, and spoilage
    - Drug production
    - wastewater treatment
    - Mutually beneficial relationships w/ hosts
  - → Greatest metabolic diversity
    - recycling of C, N, S, Fe, etc.
  - → Provide the genetic source and cellular scaffold for recombinant DNA biotechnology
- Life on Earth
  - → Chemists – Inorganic (Lithotrophs) } Bacteria
    Organic (Organotrophs) }
  - → Physicists – Use physical energy sources (ex. light)
    Prokaryotes and eukaryotes (plants)
  - → Biologists – Predators (eukaryotes)

- Properties of Microbial Cells
  - → All microbial cells
    - Metabolism (genetic and catalytic)
    - Growth
    - Evolution
  - → Some microbial cells
    - Differentiation (ex. sporylation)
    - Communication (chemical messengers)
    - Genetic exchange (horizontal gene transfer)
    - Motility (ex. flagella)
- Structural differences between prokaryotes and eukaryotes
  - → Prokaryotes have no defined organelles
  - → Prokaryotes are generally smaller in size
    - beneficial in terms of growth rate
      - ↳ smaller space to fill
      - ↳ rapid nutrient acquisition
      - ↳ Prokaryotes grow faster than eukaryotes due to large surface area : volume ratio

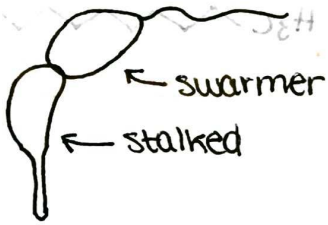
★Exceptions to the size rule:
- Epulopiscium fishelsoni (0.08mm)
- Thiomargarita namibiensis (0.75mm) (v. large bacteria)

  - → Prokaryotes tend to be structurally simpler
- Classification of Bacteria
  - → Morphology





- Appendaged / budding
  - ↳ Caulobacter ("swarmer" / "stalked")
  - ↳ Found in freshwater
  - ↳ A model system of complex prokaryotic life cycle
    - * regulation of cell cycle is important in generating a morphology like this



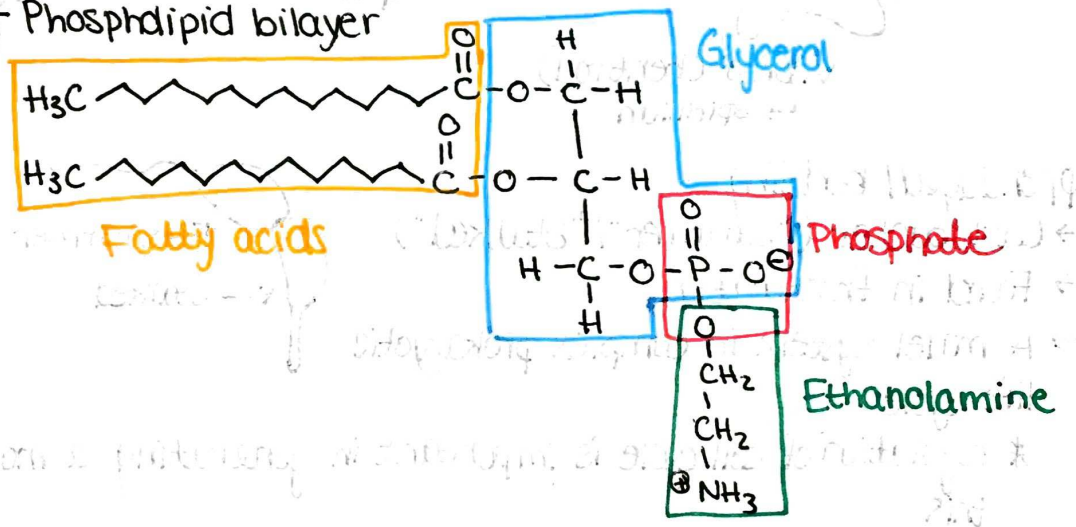
- Filamentous
  - ↳ Chloroflexus
  - ↳ Ancient, does not produce O_2 but is photosynthetic
  - ↳ stability in harsh conditions
- Morphogenesis (change in shape)
  - ↳ Monomorphic = has one shape (ex. E. coli is always a rod)
  - ↳ Pleomorphic = multiple shapes
    - * shape changes during growth
    - * Response to environmental cues (ex. sporulation due to nutrient limitation)
    - * Ex. Arthrobacter sp. undergoes morphogenesis from rod to coccus during growth
    - * Ex. B. cereus - sporulates (spores and rods in pure culture)

☆ know example!

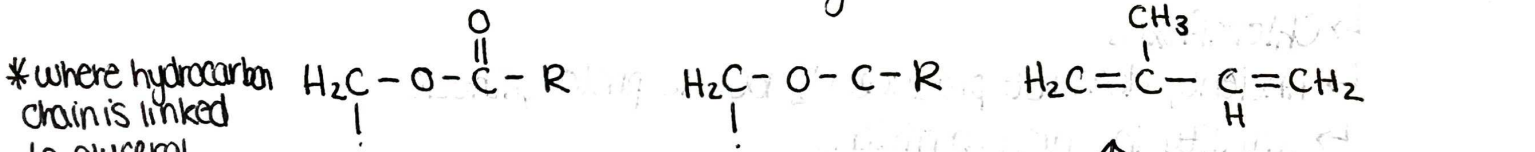
→ Cell Wall Composition

- Bacterial membrane: functions
  - ↳ Permeability barrier – prevents leakage, functions as a gateway for transport of nutrients
  - ↳ Protein anchor – site of many proteins involved in transport, bioenergetics, chemotaxis
  - ↳ Energy conservation – site of generation and use of proton motive force

- Phospholipid bilayer



- Differences in membrane chemistry



* where hydrocarbon chain is linked to glycerol phosphate

Ester-linked lipids
→ Bacteria and Eukaryotes

Ether-linked lipids
→ Archaea

↑ Isoprene chain instead of fatty acid chain in archaeal lipids

★ Archaea can have a monolayer or a bilayer, or a mix of both

Bilayer → Phytanyl

Monolayer → Biphytanyl or chrenarchaeol

★ More stable under harsh conditions

↳ Hopanoids and membrane rigidity
* Hopanoids impart rigidity to an otherwise flexible membrane due to planar configuration
* Ex. Eukaryotic cholesterol and bacterial diploptene.

- Membrane permeability

Permeable ⟷ Somewhat permeable ⟷ Non-permeable

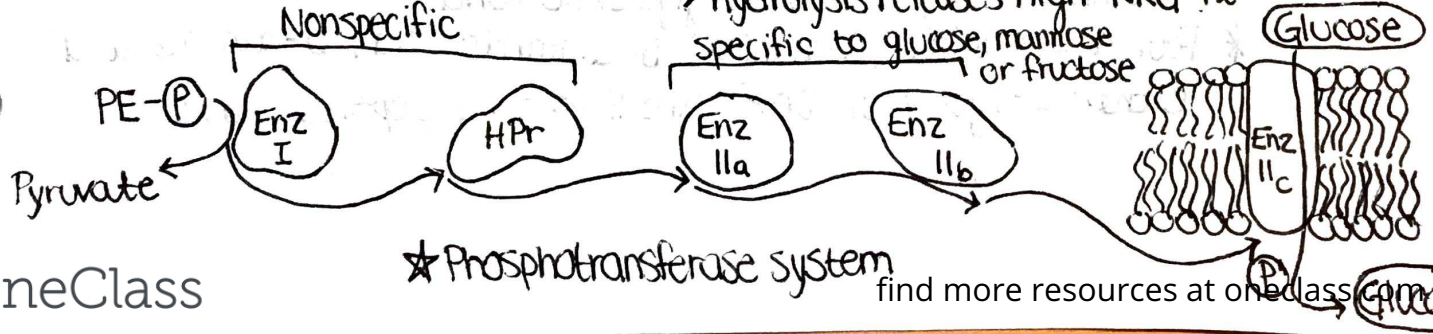
water, glycerol, tryptophan, glucose | Chloride ion, Potassium ion, Sodium ion

★ porins affect permeability of water and small molecules

need transport proteins and ion channels

- Membrane Transport
↳ Diffusion does not occur at a rate suitable to fuel metabolism and growth
↳ Require transport mechanisms
↳ Main transport mechanisms:
* Simple transport - driven by energy in proton motive force
- transported goods are metabolized for ATP synthesis
- PMF is diminished, but will be reestablished by downstream reactions

* Group Translocation - chemical modification of the transported substance driven by phosphoenolpyruvate (PEP)
↳ PEP is a high-energy intermediate of glycolysis
↳ hydrolysis releases high-NRG Pi



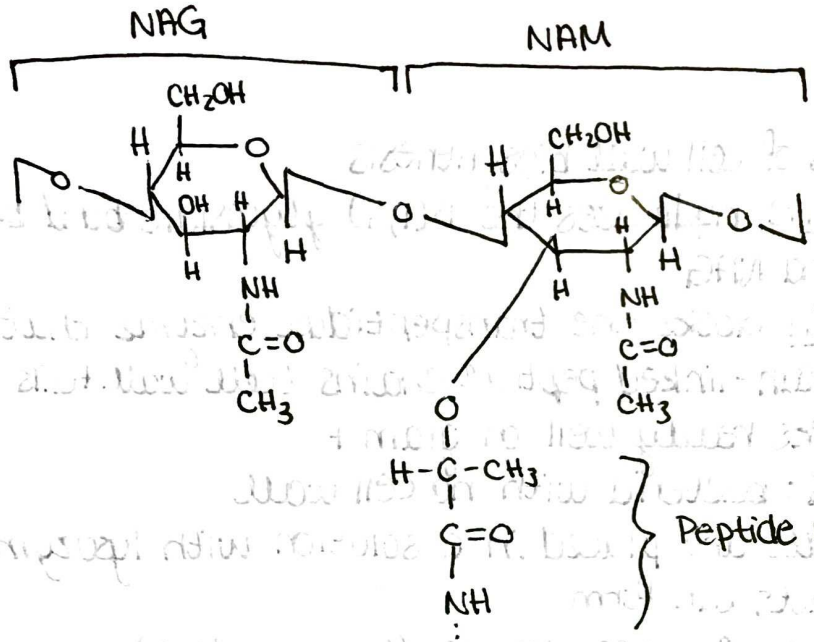
★ Phosphotransferase system

* ABC Transporter (ATP-Binding Cassette) (ONLY Gram -)
  - Periplasmic binding proteins are involved and NRG comes from ATP
  - Periplasmic binding proteins have a high substrate affinity
  - Once the substrate is bound, binding protein interacts w/ its membrane transporter
  - Substance is transported into the cell driven by the energy in ATP
  - Gram + have membrane-bound carrier proteins (substrate-binding proteins) that perform the same function

- Bacterial Cell Walls
  - ↳ Provides stability, shape, and protection
  - ↳ Understanding structure allows us to create antibiotics, etc.
  - ↳ 2 Types:

Gram-Positive	Gram-Negative
* Thick layer of peptidoglycan	* Thin layer of peptidoglycan
* Tiny periplasmic space	* Large periplasmic space
* No outer membrane	* Outer membrane
* Stains purple	* Stains pink

↳ Peptidoglycan ("glycan" "peptido")
* made of two sugars and four amino acids
* Glycan = NAM + NAG
  - ↳ N-acetylmuramic acid and N-acetylglucosamine
  - ↳ connected by a β-(1,4) glycosidic bond
* Four amino acids (L-alanine, D-Glutamic acid, D-alanine and either L-lysine or DAP) are linked by peptide bonds

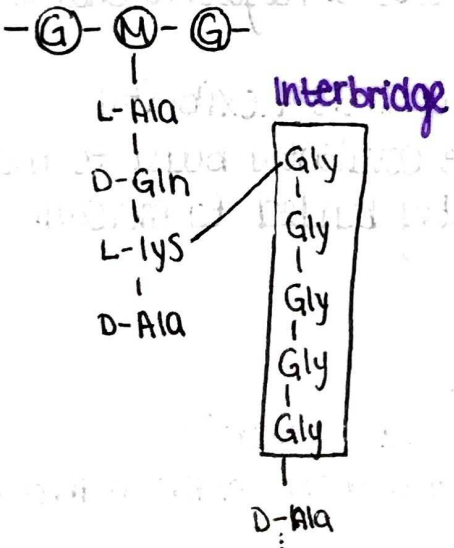


↳ Peptidoglycan of gram + vs. gram −
* 2 amino acid substitutions

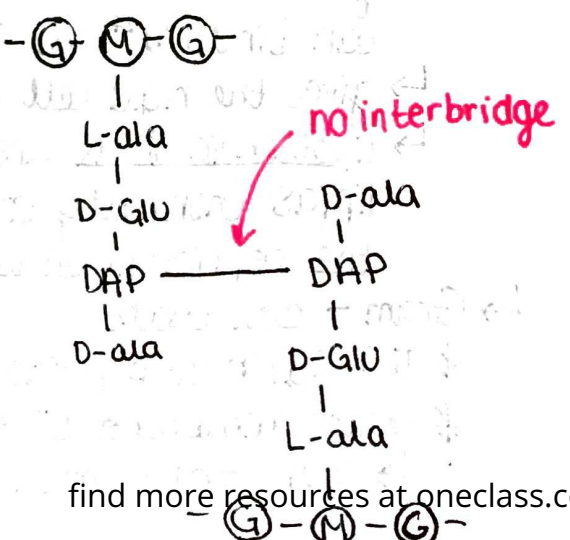
Gram +	Gram −
L-alanine	L-alanine
D-glutamine	D-glutamate
L-lysine	meso-Diaminopimelic acid (DAP)
D-alanine	D-alanine

* Interbridge (kinds and numbers of amino acids vary)
↳ cross-linking

Gram +



Gram −



↳ Inhibitors of cell wall biosynthesis
* Lysozyme hydrolyzes the B(1,4) glycosidic bond between NAM and NAG
* Penicillin blocks the transpeptidase enzyme that cross-links the glycan-linked peptide chains (cell wall fails to assemble)
↳ works really well on gram +

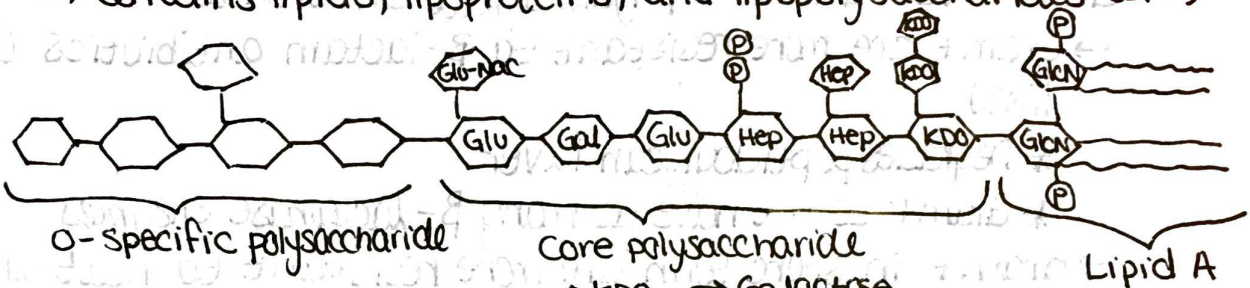
↳ Protoplasts: bacteria with no cell wall
* when cells are placed in a solution with lysozyme and sucrose, protoplasts can form
* In nature: Archaea plasmas (hyper-saline)
↳ mycoplasmas ★ Have a v. tough cytoplasmic membrane with more sterols*
↳ Thermoplasma

↳ Gram+ cell wall
* Up to 90% peptidoglycan
* Thought that peptidoglycan is synthesized by the cell in 50 nm "cables", with each cable containing several cross-linked glycan strands
* Cables are also cross-linked to form a v. strong cell wall structure
* Gram + cells also have acidic molecules called teichoic acids in their cell wall
↳ extend the surface of the cell wall
↳ gives the outside of the cell a negative charge so that it can bind Mg^{2+} and Ca^{2+}
↳ gives the rigid cell wall a little flexibility
↳ lipoteichoic acids are those covalently bound to membrane lipids (normally covalently bonded to muramic acid in the peptidoglycan layer)

↳ Gram − cell wall
* Thin layer of peptidoglycan
* outer membrane ("second lipid bilayer")
↳ chemistry is much different than inner membrane

↳ contains lipids, lipoproteins, and lipopolysaccharides (LPS)

LPS:



O-specific polysaccharide

Core polysaccharide
→ KDO → Galactose
→ Glucose → NAG
→ 7-C sugars

Lipid A
→ endotoxin
→ common in food-borne pathogens

★ Important barrier against host defenses

★ Provides strength
- ties the outer membrane to peptidoglycan

↳ Periplasm / Periplasmic space
* virtually non-existent in Gram +
* Has a gel-like consistency due to periplasmic proteins
* ~15 nm wide
* Contains enzymes / proteins contributing to nutrient acquisition, environmental signaling, stress response, etc.
* Bind, degrade, transport, sense

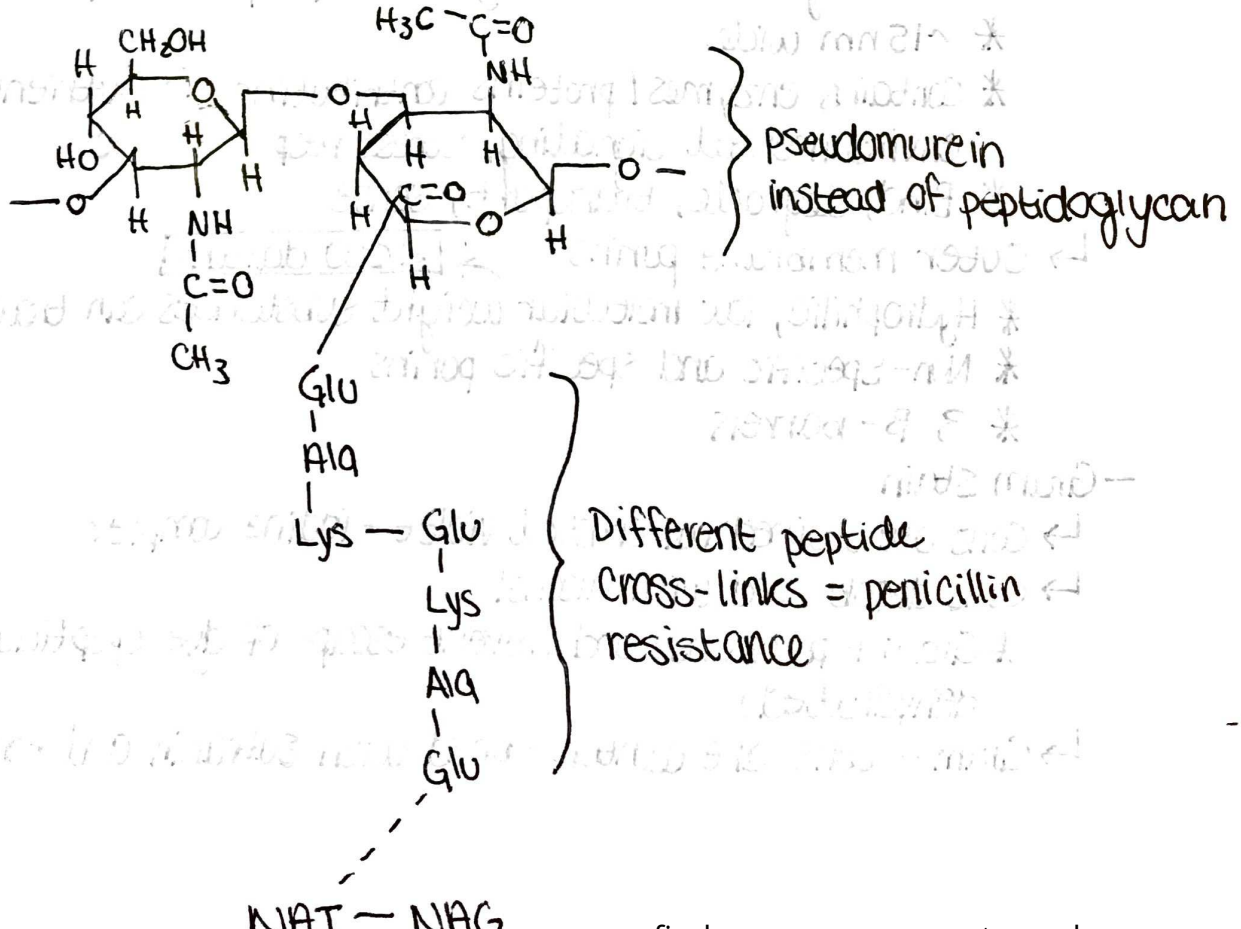
↳ Outer membrane porins → <600 daltons
* Hydrophilic, low molecular weight substances can travel through
* Non-specific and specific porins
* 3 β-barrels

- Gram stain
↳ Cells are stained w/ crystal violet - iodine complex
↳ cells decolorized with alcohol
* Gram + pores close and prevent escape of dye (peptidoglycan = dehydrated)
↳ Gram - cells are counterstained with safranin and turn pink

- Gram + vs. Gram - : physiological differences
  - ↳ gram + are more susceptible to β-lactam antibiotics (penicillin-like)
    - * Degrades peptidoglycan layer
    - * Gram + do not have as many β-lactamase enzymes
  - ↳ gram + in spore form are more resistant to heat and stress
  - ↳ gram + require more vitamins and amino acids for growth

Back to classification of bacteria:
- → Nutritional needs
- → Biochemical activity / energy source

- Pseudopeptidoglycan of some methanogenic bacteria
  - → β(1,3) linkage between NAG and NAT prevents lysozyme attack
    - NAT = N-acetyl-talosaminuronic acid
  - → All L-stereoisomer amino acids



→ 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 glycaprotein
- 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)