Growth and Metabolism of Bacteria

Prepared by

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GROWTH AND METABOLISM

- All cells must accomplish certain metabolic tasks to grow and divide.
- All cells, whether bacterial or human, accomplish these metabolic tasks by similar pathways.
- There are, some important differences that set bacteria apart metabolically from eukaryotic cells, and these differences can often be exploited in the development of antibacterial therapies.

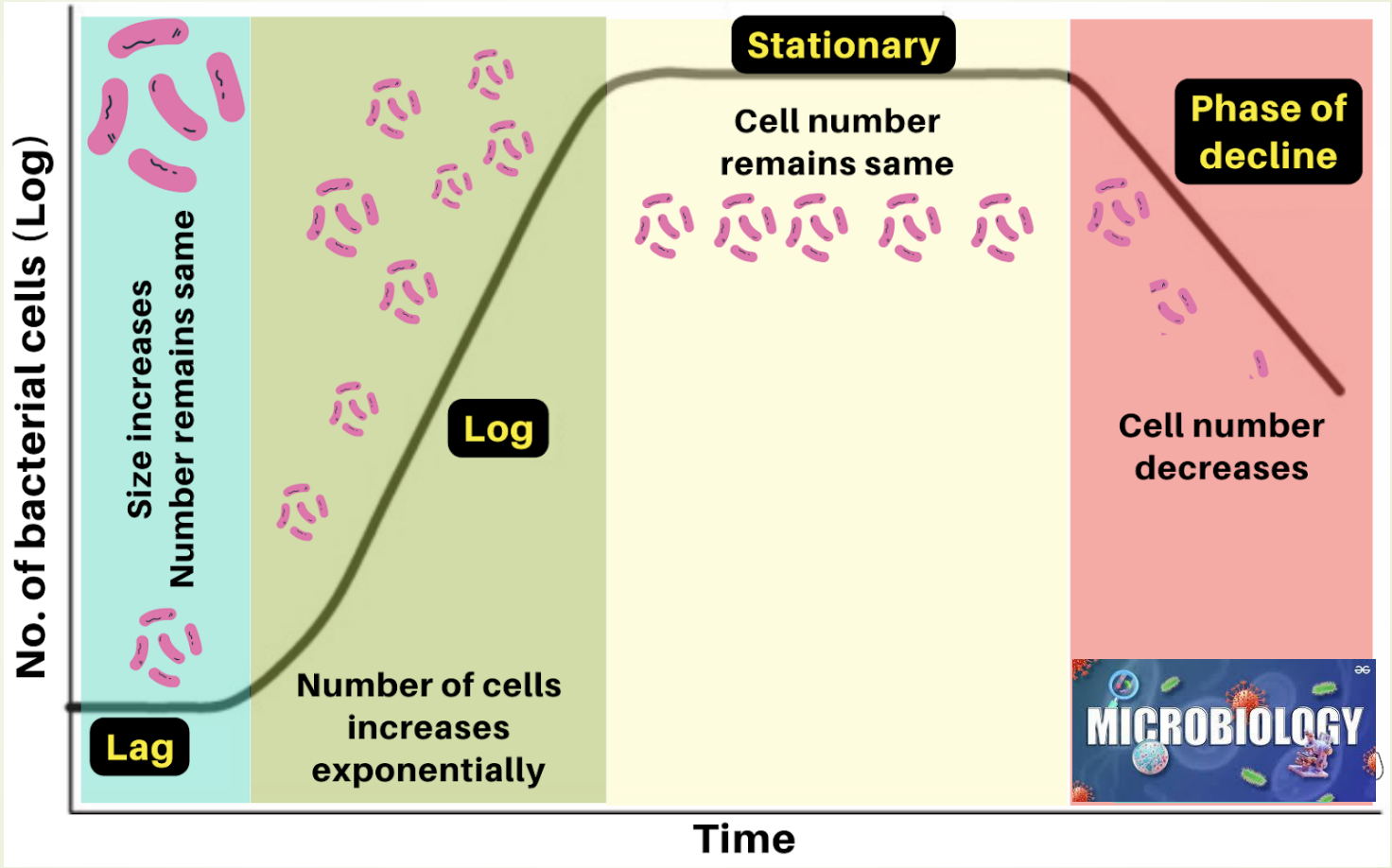
Characteristics of bacterial growth

- If bacterial cells are suspended in a liquid nutrient medium, the increase in cell number or mass can be measured in several ways.
- Techniques include microscopically counting the cells in a given volume using a ruled slide, counting the number of appropriately diluted cells that are able to form colonies following transfer to a solid nutrient (agar) surface, or quantitating the turbidity which is proportional to the cell mass of a culture in liquid medium.

Stages of the bacterial growth cycle

- Because bacteria reproduce by binary fission (one becomes two, two become four, four become eight, etc.), the number of cells increases exponentially with time (the exponential, or log, phase of growth).
- Depending on the species, **the minimum doubling time can be as short as 10 minutes or as long as several days.** For example, for a rapidly growing species such as *Escherichia coli* in a nutritionally complete medium, a single cell can give rise to some 10 million cells in just 8 hours.

- Eventually, growth slows and ceases entirely (stationary phase) as nutrients are depleted, and toxic waste products accumulate.
- Most cells in a stationary phase are not dead, however. If they are diluted into fresh growth medium, exponential growth will resume after a lag phase.

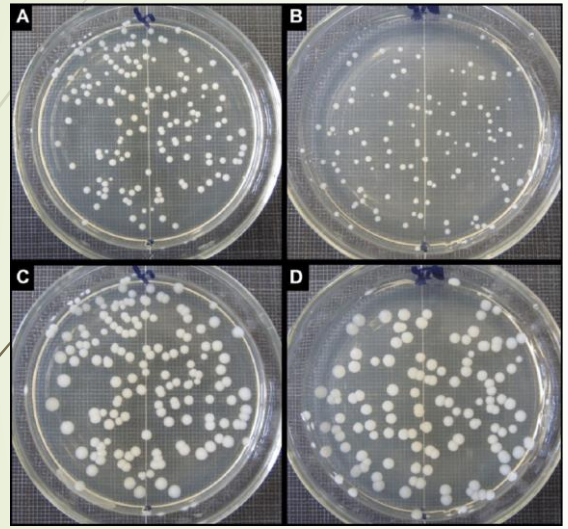


Growth curve of bacteria in liquid media

Surface growth

- If a single bacterial cell is placed on a solid nutrient agar surface, the progeny of this cell remain close to the site of deposition and eventually form a compact macroscopic mass of cells called a colony.
- For rapidly growing species, overnight incubation at 30°C to 37°C is sufficient to produce visible colonies, each containing millions of cells. The gross characteristics of colonies (for example, color, shape, adherence, smell, and surface texture) can be useful guides for identification of the species of bacterium.

- Some species do not form compact circular colonies because the cells are capable of movement and swarm over the agar surface, especially if the surface is moist.
- Other species, particularly the actinomycetes, grow as long filaments of cells (mycelial growth).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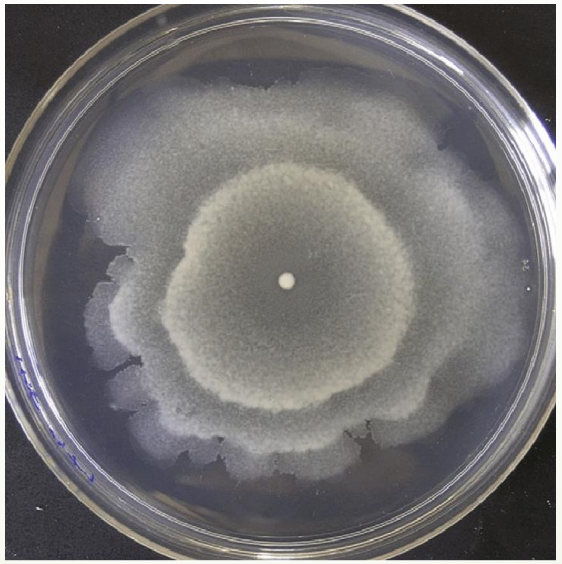


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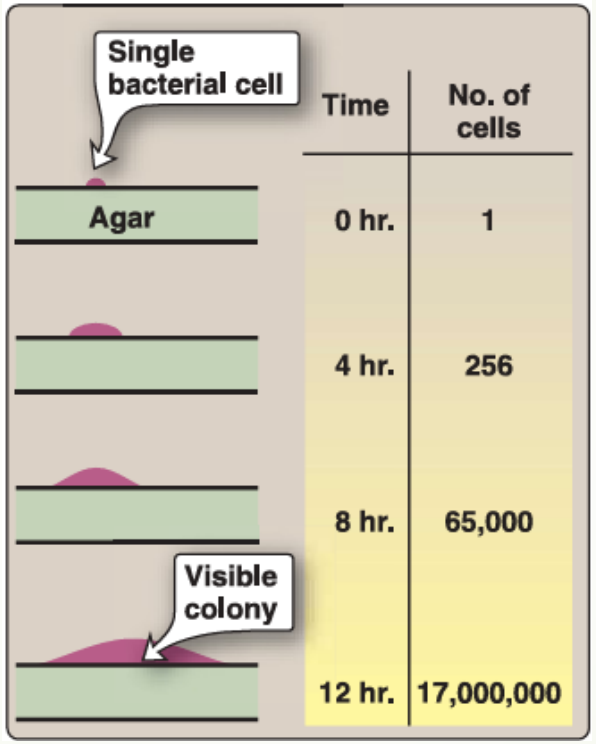


Growth of bacterial colonies on a solid nutrient surface (doubling time of bacteria is assumed to be 0.5 hr)

Energy production

- A distinctive feature of bacterial metabolism is the variety of mechanisms used to generate energy from carbon sources.
- Depending on the biochemical mechanism used, bacterial metabolism can be categorized into three types:

1. **Aerobic respiration,**
2. **Anaerobic respiration, and**
3. **Fermentation**

- **Aerobic respiration** is the metabolic process in which molecular oxygen serves as the terminal electron acceptor of the electron transport chain.
- In this process, oxygen is reduced to water.
- Respiration is the energy-generating mode used by all aerobic bacteria.

- **Anaerobic respiration** is the metabolic process in which inorganic compounds other than molecular oxygen serve as the terminal electron acceptors.
- Depending on the species, acceptors can be molecules such as nitrate or sulfate.
- Anaerobic respiration can be used as an alternative to aerobic respiration in some species (facultative organisms), but is obligatory in other species (some obligate anaerobes).
- [Note: Other obligate anaerobes use fermentation as the main mode of energy metabolism. This is particularly true among the anaerobic bacteria of medical importance.]

- **Fermentation** is an anaerobic process utilized by some bacterial species.
- It is the metabolic process by which an organic metabolic intermediate derived from a ‘’fermentable" substrate serves as the final electron acceptor.
- The substrates that can be fermented and the final end products depend on the species.
- Regardless of the bacterium and the fermentation pathway, several unifying concepts are common to fermentation.
- **By comparison to aerobic and anaerobic respiration, fermentation yields very little energy.**

- The purpose of fermentation is to recycle nicotinamide adenine dinucleotide hydrogen (NADH) back to NAD.
- The reducing power that can be converted to energy via respiration is unrealized.
- The terminal electron acceptor in fermentation is pyruvate or a pyruvate derivative.

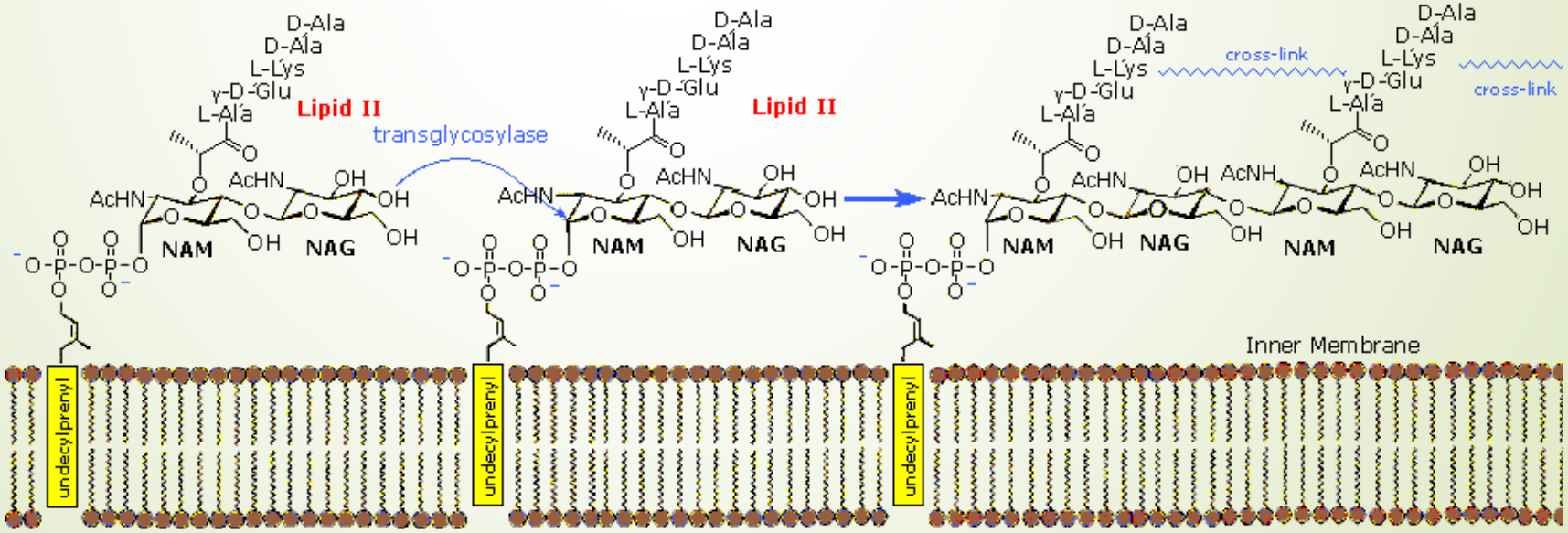
- Beyond these commonalities, the pathways and end products of fermentation are incredibly varied.
- These end products can be measured and are sometimes diagnostic for a given species.
- In addition, **some fermentation end products can result in host toxicity and tissue damage.**

Peptidoglycan synthesis

- The bacterial peptidoglycan polymer is constructed on the surface of the cell membrane and is composed of a repeating carbohydrate backbone subunit, which is NAG NAM.
- These backbone chains are cross-linked by short peptides (PEP) to form a rigid meshwork.

Synthesis of Peptidoglycan

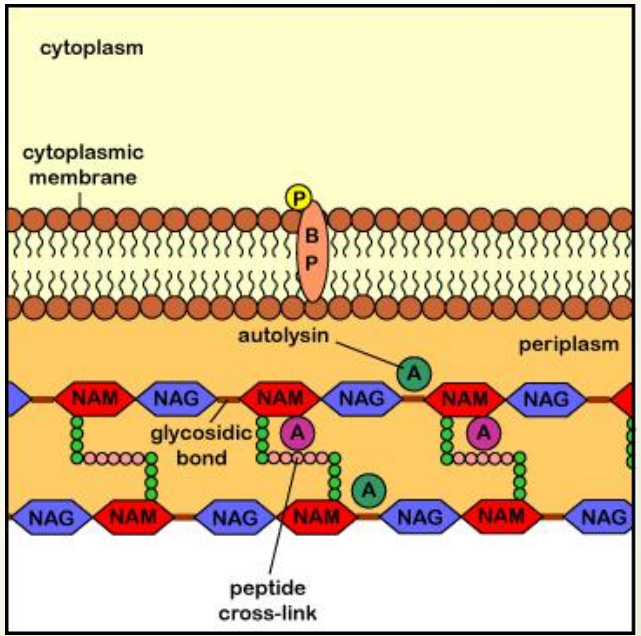
- In order for bacteria to increase their size following binary fission, links in the peptidoglycan must be broken, new peptidoglycan monomers must be inserted, and the peptide cross links must be resealed. The following sequence of events occur:



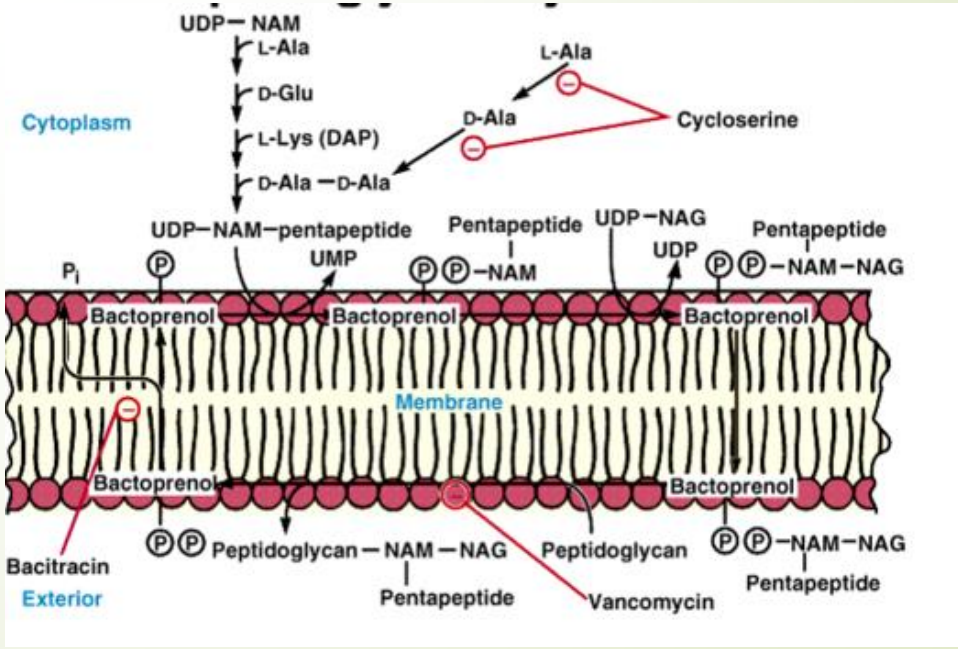
- Step 1. Bacterial enzymes called autolysins:

- a) Break the glycosidic bonds between the peptidoglycan monomers at the point of growth along the existing peptidoglycan.
- b) Break the peptide cross-bridges that link the rows of sugars together.
- In this way, new peptidoglycan monomers can be inserted and enable bacterial growth.

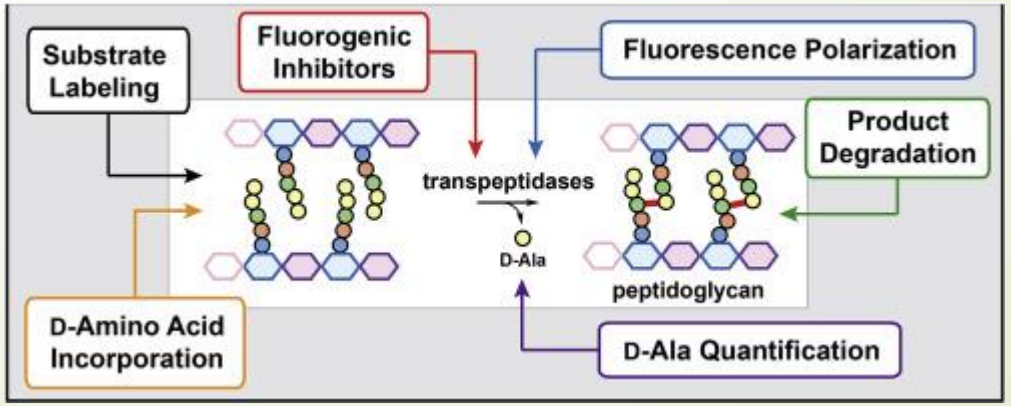
Function of Autolysins in Peptidoglycan Synthesis, Step 1



- Step 2. The peptidoglycan monomers are synthesized in the cytosol and bind to bactoprenol.
- The bactoprenols transport the peptidoglycan monomers across the cytoplasmic membrane and interacts with transglycosidases to insert the monomers into existing peptidoglycan.



- Step 3. Transglycosylase (transglycosidase) enzymes insert and link new peptidoglycan monomers into the breaks in the peptidoglycan
- Step 4. Finally, transpeptidase enzymes reform the peptide cross-links between the rows and layers of peptidoglycan to make the wall strong



Peptidoglycan biosynthesis as a target of some antibacterial agents:

- Because many of the reactions involved in the synthesis of peptidoglycan are unique to bacteria, cell wall synthesis is an ideal target for some highly specific antibacterial agents, particularly the B-lactam antibiotics.

a. β-Lactam antibiotics:

- Penicillins and cephalosporins inhibit the enzymes that catalyze transpeptidation and carboxypeptidation reactions of cell wall assembly.
- These enzymes are called penicillin-binding proteins (PBPs) because they all have active sites that bind B-lactam antibiotics.
- No single PBP species is the target of β-lactam antibiotics. Rather, their lethal effect on bacteria is the result of inactivation of multiple species of PBPs.

- Most PBPs are involved in bacterial cell wall synthesis.
- Acquired resistance to β-lactam antibiotics may result from genetic modifications that result in production of new PBPs that have a lower affinity for β-lactam antibiotics.

b. Bacitracin, cycloserine, and vancomycin:

- Other antibiotics that interfere with peptidoglycan synthesis include

1. **Bacitracin, which inhibits the recycling of bactoprenol phosphate.**
2. **Cycloserine, which inhibits synthesis of the Dala Dala dipeptide that provides the two terminal residues of the pentapeptide**
3. **Vancomycin, which blocks incorporation of the NAG-NAM-PEP repeat unit into the growing peptidoglycan chain.**

- Because vancomycin binds to the terminate D-ala-D-ala dipeptide, this antibacterial agent also prevents transpeptidation


Thank You