Activities of microbial cells
Movement, Growth and Reproduction

Overview

- **Types of activities of microbial cells**
- **Support for activities: metabolism**
  - Factors affecting metabolism
  - Measurement of activities of microbial cells
- **Motility by microorganisms**
  - mechanism of chemotaxis by bacteria

Overview 2

- **Growth and reproduction**
  - Synthesis of peptidoglycan
  - Structures of cell walls
    - Gram positive
    - Gram negative microorganisms
- **Measurement of microbial activities**

Types of activities of microbial cells

- **Movement**
  - flagella, cilia
  - chemotaxis, phototaxis, other taxes
- **Growth**
  - increase in size of cell
  - more cell materials and structures; limited
- **Reproduction**
  - increase in numbers of cells
  - duplication of materials and structures

Energy for activities

Cell metabolism

- **is the sum of all chemical reactions occurring in a cell**
- **an interaction of**
  - energy from different sources
  - carbon compounds and other nutrients
- **there are two processes**
  - Catabolism
    Breakdown of organic molecules to produce energy and metabolites
  - Anabolism
    Biosynthesis (requires energy and metabolites)

Factors affecting metabolism

Factors

- Temperature
- pH
- Water availability (A_w)
- Oxygen

Effects

- Denaturation of enzymes and structural proteins; (T^o; A_w; Oxidation [charge bonding])
- Solubility of solutes (T^o; pH; A_w)
- Dependency aerobic respiration on oxygen
- Dependency of anaerobic respiration on absence of oxygen and reduce environment

Measurement of microbial activity

- **Motility**
  Microscopic observation via hanging drop
  Macroscopic observation of swarming on agar plate
- **Increase in cell size**
  Microscopic measurement
- **Reproduction**
  Changes in biomass
  - weight (dry or fresh)
  - viable cell number
- **Production of metabolities**
  Assays

Motility by microorganisms

Motile can respond to nutrients, light, toxic chemicals and magnetic fields

Motility depends on

- Prokaryotic flagella (bacteria only)
  Thin (*ca.* 20 nm) protein filaments
  Singular or in multiples
- Eucaryotic flagella (protozoa; algae; zoospores of “lower” fungi)
  Similar structure to cilia but longer (100 – 200 μm) and fewer on cell.
- Eucaryotic cilia
  Thick (0.2 μm), short (5 – 20 μm) organelles of different proteins forming microtubules and the supporting structure
  Many over the surface of the cell

Chemo-, Photo, and other taxis

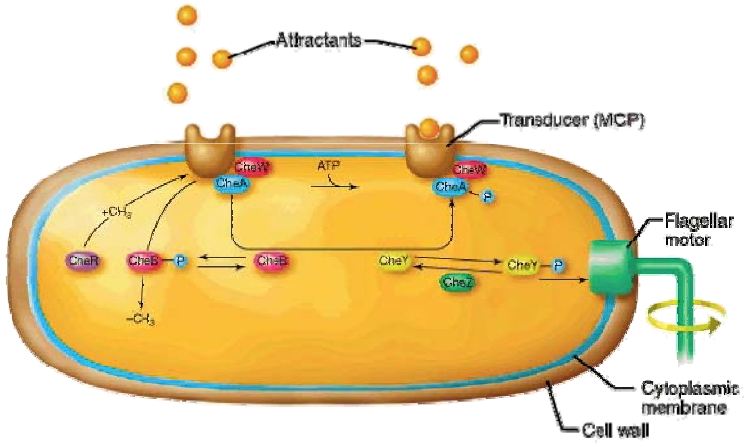
Response to gradient in stimulus/signal

- Physical sources
  - light, magnetic field
- Chemical sources
  - nutrients, gases(O_2), CO_2), toxic compounds (antibiotics; O_2)

Requires mechanisms for

- Detection
  receptor-transducer proteins (transducers)
- Communication
  signal to flagella/cilia of need to move
- Commencement and maintenance of movement
- Directing cell movement to, away from gradient

Mechanism of chemotaxis



Bacterial chemotaxis (Brock *et al.* 2000; Fig. 7.23)

Transducers

- Detect changes in chemical concentration over time
- Are methyl-accepting chemotaxis proteins (MCPs)
- Different transducers for different stimuli *e.g.*
  with *Tar*, aspartate and maltose are attractants; Co and Ni are repellants
- Bind either directly or indirectly with chemicals

How it works

- MCP forms complex with *CheW* (sensor kinase) and *CheA* (coupling protein)
- *CheA* autophosphorylates to *CheA-P* (repellants increase rate of this).
- *CheA-P* can then phosphorylate the response regulators *CheY* and *CheB*.
- *CheY-P* interacts directly with the flagellar motor switch
  (induces clockwise rotation >>> tumble).
- *CheR* continually adds methyl groups to the transducer. *CheB-P* removes them.
- The degree of methylation of the transducers controls their ability to respond to stimuli.
- Attractants lead to lower levels of CheY-P >>> smooth runs
  Repellants lead to higher levels of CheY-P >>> tumbling and random direction

Growth and reproduction

Cell growth

changes in cell size

Reproduction

multiplication of cells

Involves production of new cell materials

- Structural metabolites
  amino acids; proteins; liposaccharides
- Intermediate metabolites
  pyruvate; primary metabolites
- Excreted metabolites: wastes:
  secondary metabolites; exoenzymes; excess primary metabolites

Processes of cell growth and reproduction

Cell growth

- increasing amounts of cytoplasm, enlarging cell wall and cytoplasmic membrane
- more organelles in eucaryotes
- Genetic and enzymatic mechanisms control maximum cell size

Cell reproduction

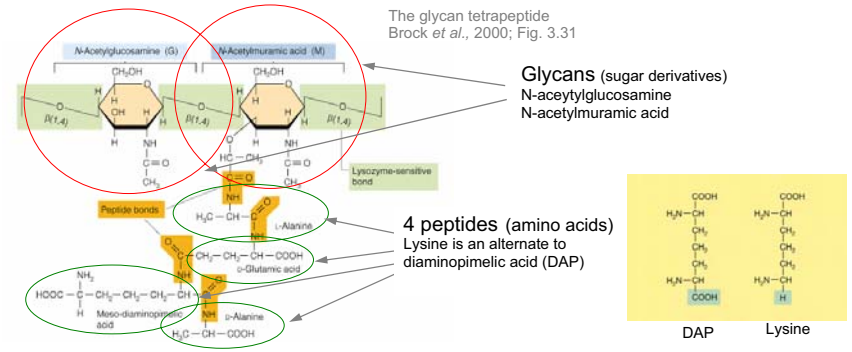
- separation of cytoplasm
- replication of nuclear material
- cell wall and membrane synthesis

Cell wall structure and synthesis

Structure of bacterial cell walls

- Gram positive: Thick peptidoglycan (murein) layer
- Gram negative: Thin peptidoglycan layer plus liposaccharide and protein layer

Peptidoglycan: polymer of glycan tetrapeptide



The glycan tetrapeptide
Brock *et al.*, 2000; Fig. 3.31

Glycans (sugar derivatives)
N-aceytylglucosamine
N-acetylmuramic acid

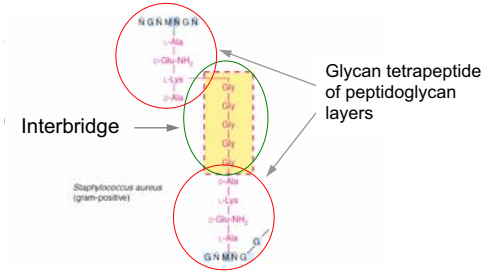
4 peptides (amino acids)
Lysine is an alternate to diaminopimelic acid (DAP)

DAP Lysine

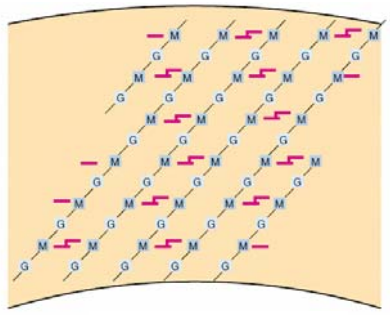
Gram positive bacterial cell walls

Peptidoglycan forms as much as 90% of the cell wall

- Most G(+) bacteria have lysine instead of DAP in their peptidoglycan
- Several to 25 layers of peptidoglycan
- Cross-linkage by peptide interbridge
- The interbridge varies with species (affects types of and number of amino acids)



Glycine interbridge in *S. aureus*
Brock *et al.*, 2000; Fig. 3.32

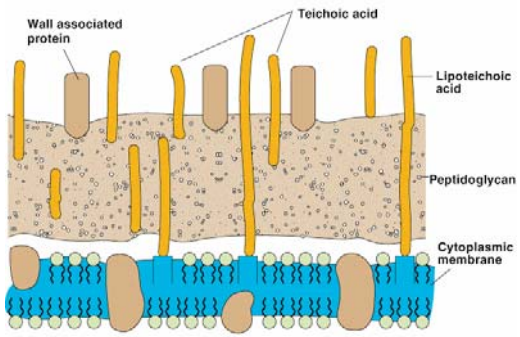


Overall srtructure of peptidoglycan
Brock *et al.*, 2000; Fig. 3.32

Gram positive bacterial cell walls 2

Teichoic acid also present in small amounts

- are ribitol phosphate or glycerophosphate residues (acidic polysaccharides)
- attached to cell wall
- negatively charged; contribute to overall negative charge of the cell surface thus affecting passage of ions through the cell wall
- Lipoteichoic acids are those bound to membrane lipids of G(+) bacteria



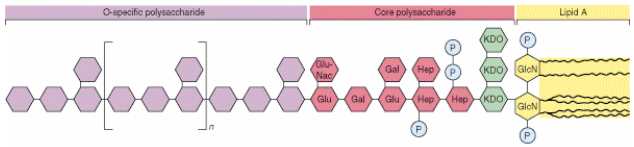
Overall structure of the G(+) cell wall
Brock *et al.*, 2000; Fig. 3.33

Gram negative bacterial cell walls

Peptidoglycan only forms about 10% of the cell wall

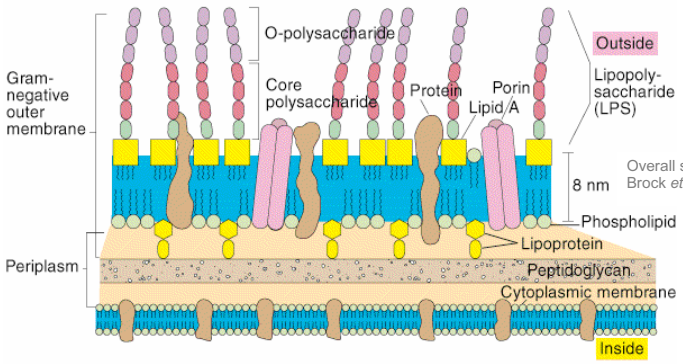
Have additional layer made of lipopolysaccharide (LPS layer)

- **similar to the cytoplasmic membrane (a lipid bilayer)**
  Different because it also contains polysaccharide and protein
- **The polysaccharide component comprises:**
  Core polysaccharide
  O-polysaccharide
  The lipid component comprises:
  Lipid A



A **lipoprotein complex** is also found in some G(-) bacteria

Gram negative bacterial cell walls 2



Overall structure of the G(-) bacterial cell wall
Brock *et al.*, 2000; Fig.3.37

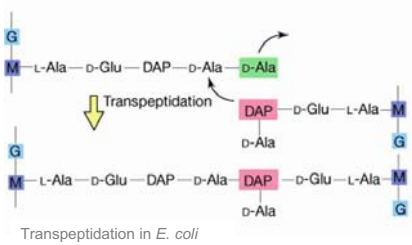
The outer membrane layer

- of many G(-) bacteria is often toxic to animals
  (*e.g. Salmonella, Shigella, Escherichia*)
  Associated with the LPS layer particularly Lipid A (termed endotoxin)
- relatively permeable (unlike the cytoplasmic membrane)
  Due to presence of porins (proteins) which function as channels for hydrophillic low-molecular-weight substances

Biosynthesis of peptidoglycan

Needed for cell growth and cell division

- autolysins break bonds in peptidoglycan structure to allow new cell wall patch to develop
- new molecules of sugars and amino acids are inserted into the glycan network
  - building blocks carried through plasma membrane by carriers (bactoprenol; uridine diphosphate
- peptide cross-linkage occurs (transpeptidation)
  - avoids the need for energy
    (occurs outside the cytoplasmic membrane where energy is not available)
  - inhibited by penicillin



Transpeptidation in *E. coli*
Brock *et al.*, 2000, Fig. 3.41

All the illustrations included in these notes are from the textbook prescribed for the subject Microbial Physiology & Genetics:

Brock, M.T.; Martinko, J.M. and Parker, J. (2000)
"Biology of Microorganisms"; Prentice-Hall Inc., Upper Saddle River, New Jersey.