BIOL 4640 Mol Micro
Lecture 17 10/2/26
Cell Structures Part 3

- Exam 1 on Monday, October 5
  - A study guide and an old exam is posted
  - Key to assignments posed

- Assignment 11 – due on 10/7/26
- Assignment 12 due on 10/9/26
- Assignment 13 due on 10/9/26 – in class activity for today

Unit 3. Features and Structures of Microbial Cells - C

A. Size and Shape of bacteria
B. Specialized External Structures of bacteria
C. Cell envelope of bacteria
D. Internal structures of bacteria
E. Cell Division in Bacteria
F. Viruses – Chapter 6
G. Atypical bacteria and viruses

Mostly Chapter 3 in book

C. Cell Envelopes (rev)

1. Major Styles/Configurations Observed
   a. Gram-positive (section 3.3)
   b. Mycobacterial (Gm+ actinomycete) - Acid-fast (section 3.3)
   c. Gram-negative (section 3.3)
   d. Mollicutes – *Mycoplasma* – no cell wall (pp. 734-735 6e)
   e. Archaeal (section 19.1)
2. Layers and Components
3. Peptidoglycan Synthesis and inhibition
4. Antibacterial Chemicals and resistance

C. Cell Envelope of Bacteria

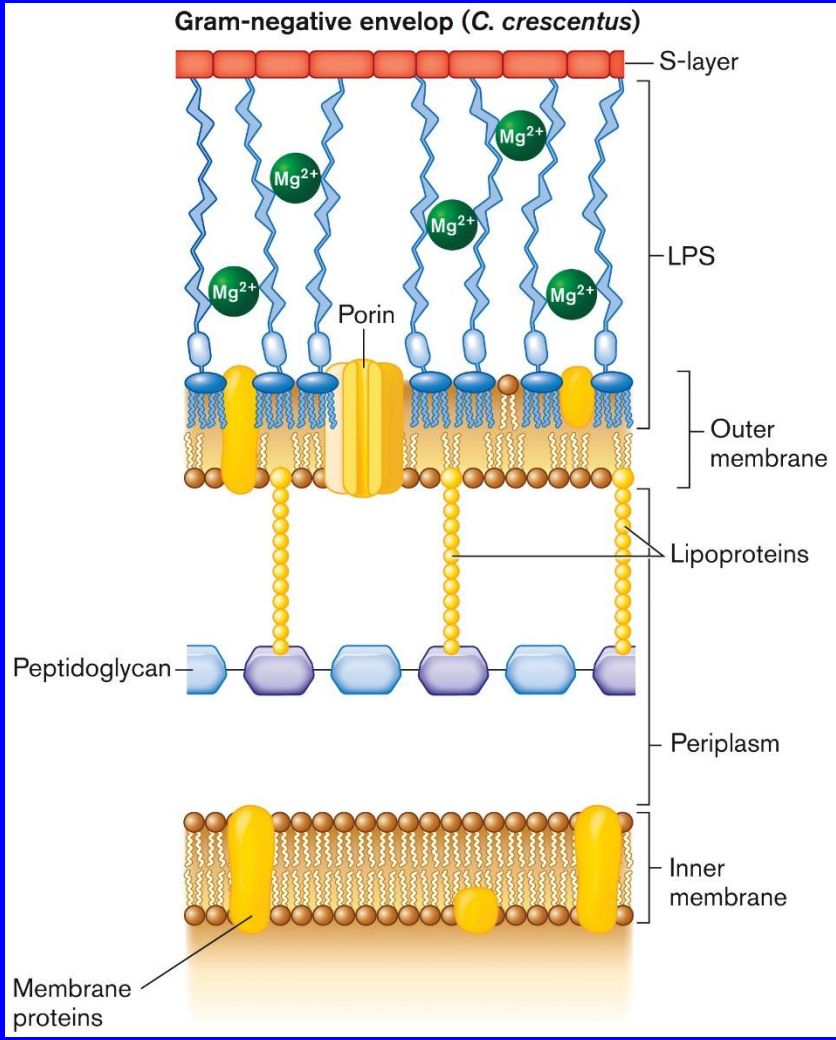
2. Layers and Components
   a. Glycocalyx – capsule
   b. S layer -
   c. Outer membrane
      - LPS and phospholipids
   d. Cell wall -
      - Peptidoglycan, Pseudopeptidoglycan, Teichoic acid, Mycolic acids, Arabinogalactan, Periplasm
   e. Periplasm
   f. Cell membrane
      - Phospholipids, Isoprenoids and hopanoids

2. Layers of Cell Envelope

c. Outer membrane

- A second membrane beyond the cell membrane observed in Gram-negative bacteria
- Inhibits diffusion of most hydrophobic molecules (bile salts, some antibiotics)

Figure 3.15b 6th edition



c. Outer membrane

Components of OM

1) Lipopolysaccharide (LPS) – in outer leaflet with sugar chain pointing out
2) Phospholipids – mainly in inner leaflet
3) Protein channels (porins)
4) Murein lipoprotein –

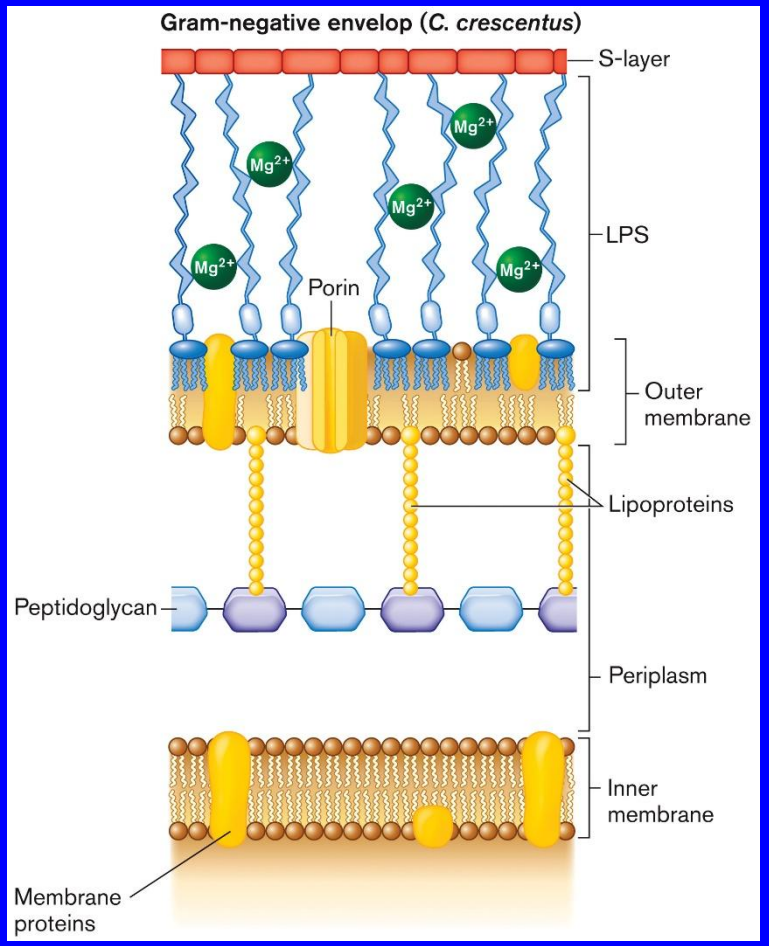
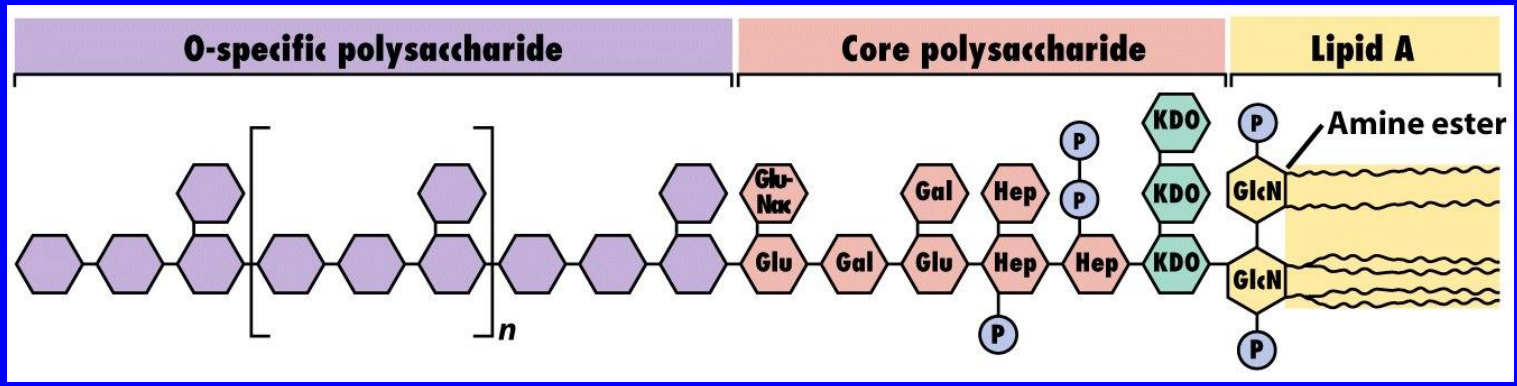


Figure 3.15B 6th edition

c. Outer membrane - 2

1) Lipopolysaccharide (LPS) in outer leaflet
   a) Structure
      - Lipid A – 4-6 fatty acids attached to disaccharide of N-acetylglucoamine phosphate, endotoxin – septic shock
      - Core polysaccharide – branched chain of sugars (same for a species)
      - O-specifc polysaccharide – usually a 4-5 sugar repeat, length and composition varies, also contributes to glycocalyx, sticks out from OM



c. Outer membrane - 3

1) Lipopoly-saccharide

b) Function/Role

- Protection – Polysaccharides blocks diffusion of hydrophobic molecules (bile salts, antibiotics, dyes)
- Induces inflammatory response (lipid A)

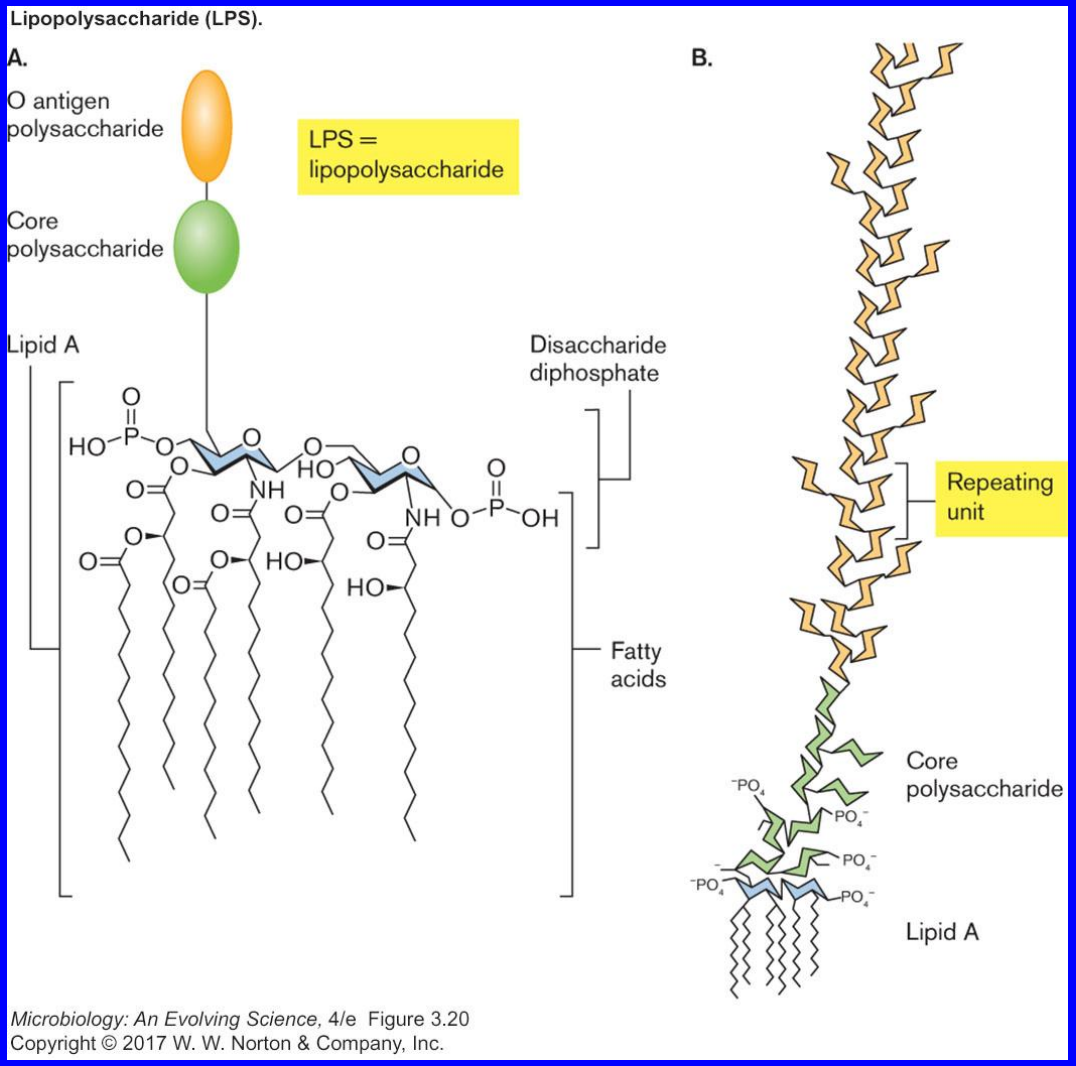
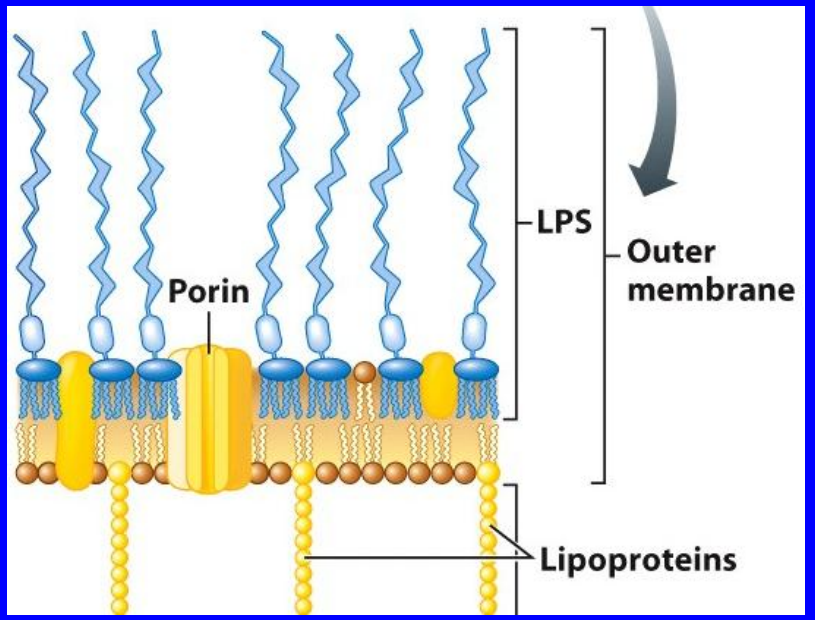


Figure 3.19 6th edition

c. Outer membrane - 4

3) Protein channels (porins)
   - A few different types
   - Selective for type or size of molecule
   - Maximum size: 700 daltons (short chains of sugars and amino acids)



Portion of Figure 3.15B 6th edition

c. Outer Membrane - 5

3) Porins in *E. coli*

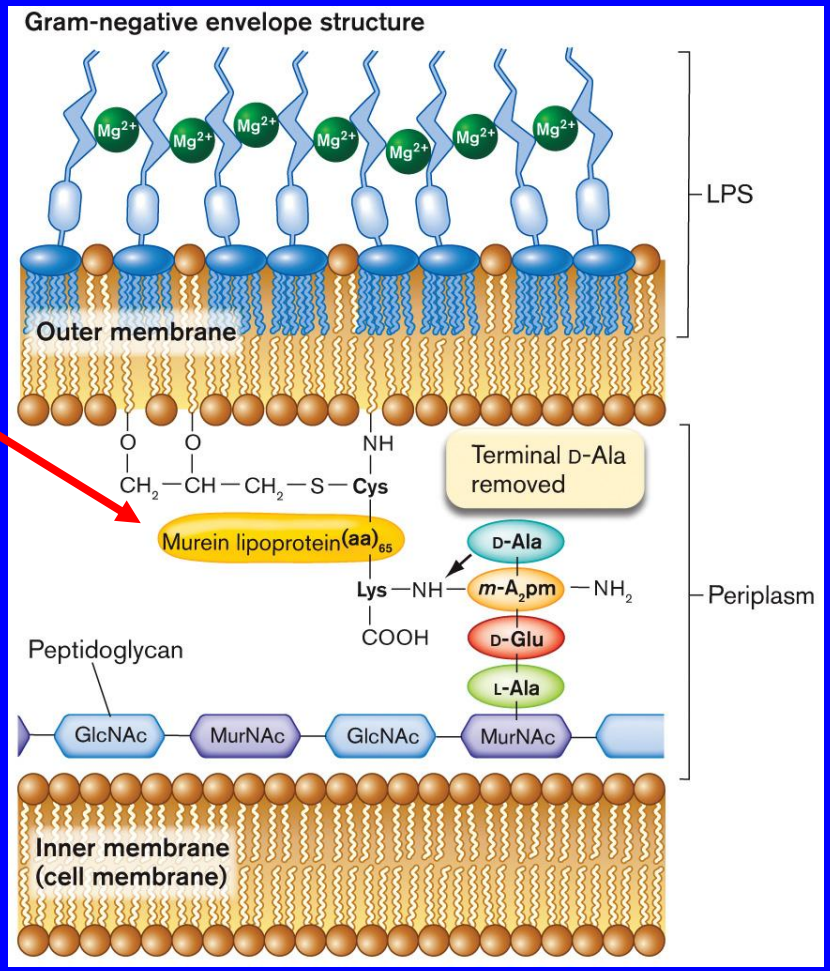
Protein	Function
OmpF	Nonspecific - small molecules Receptor for phage T2
OmpC	Nonspecific - for small molecules Receptor for phage T4
OmpA	Specifc for peptides Receptor for mating pili
LamB	Porin for maltose, maltodextrin Receptor for phage λ
PhoE	Anion-selective channel

c. Outer membrane - 6

Components of OM

4) Murein lipoprotein
   - 65 aa protein that is linked to fatty acids in inner leaflet of OM via N-terminus and peptidoglycan layer via C terminus
   - Links outer membrane to peptidoglycan

Figure 3.18A 6th edition



2. Layers of Cell Envelope - 2

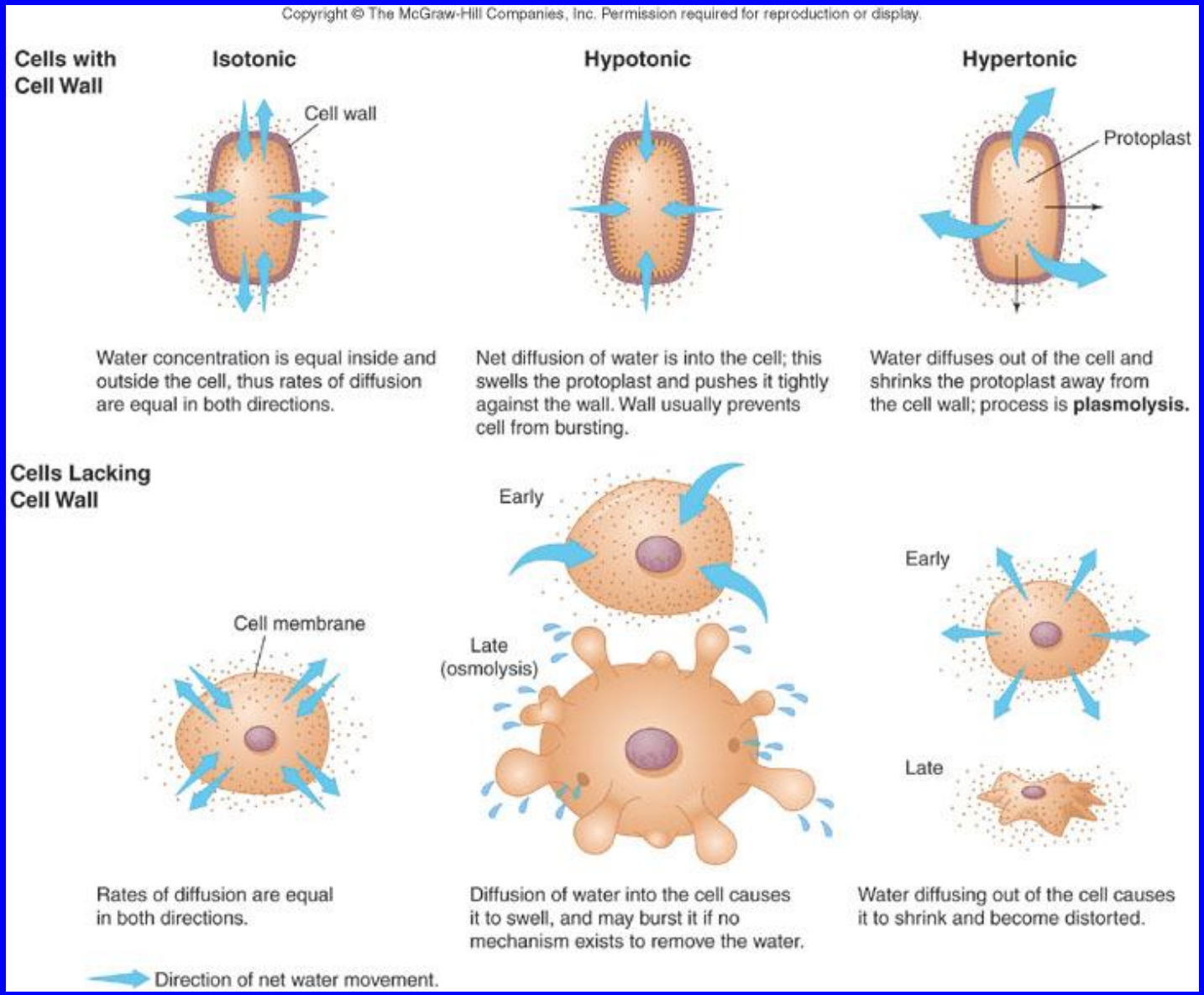
d. Cell wall

– Semi-rigid, porous layer beyond the cell membrane

1) Role: Provides structural support, rigidity
   - Prevent cells from lysing in hypotonic conditions
   - Helps determines cell shape
2) Composition vary but most eubacteria have one principal component
3) Synthesis blocked by some antibiotics

1) Role of Cell Wall

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d. Cell Wall

2) Components found in Cell wall in Bacteria
   a) Peptidoglycan (murein)
   b) Pseudopeptidoglycan
   c) Teichoic acid –
   d) Mycolic acid –
   e) Arabinogalactan –
   – Plants – cellulose – chains of glucose
   – Fungi – chitin - chains of a modified glucose

a) Peptidoglycan - 1

- Long glycan chains of two alternating sugars cross-linked by a peptide of amino acids
- Thickness varies
  - Gm pos. – 3-20 layers
  - Gm neg. – thinner, 1-2 layers
- Many antibiotics inhibit its synthesis

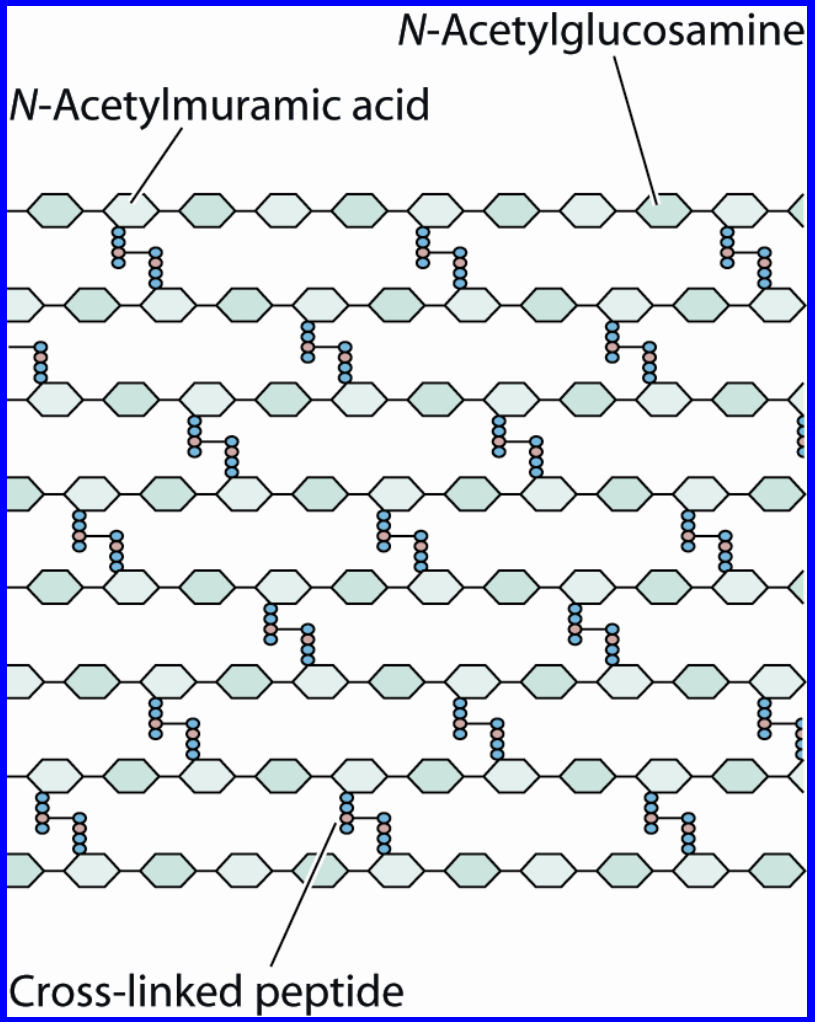


Fig 2.3 Microbe

a) Peptidoglycan

- Forms one large, interconnected molecule around outside of cell

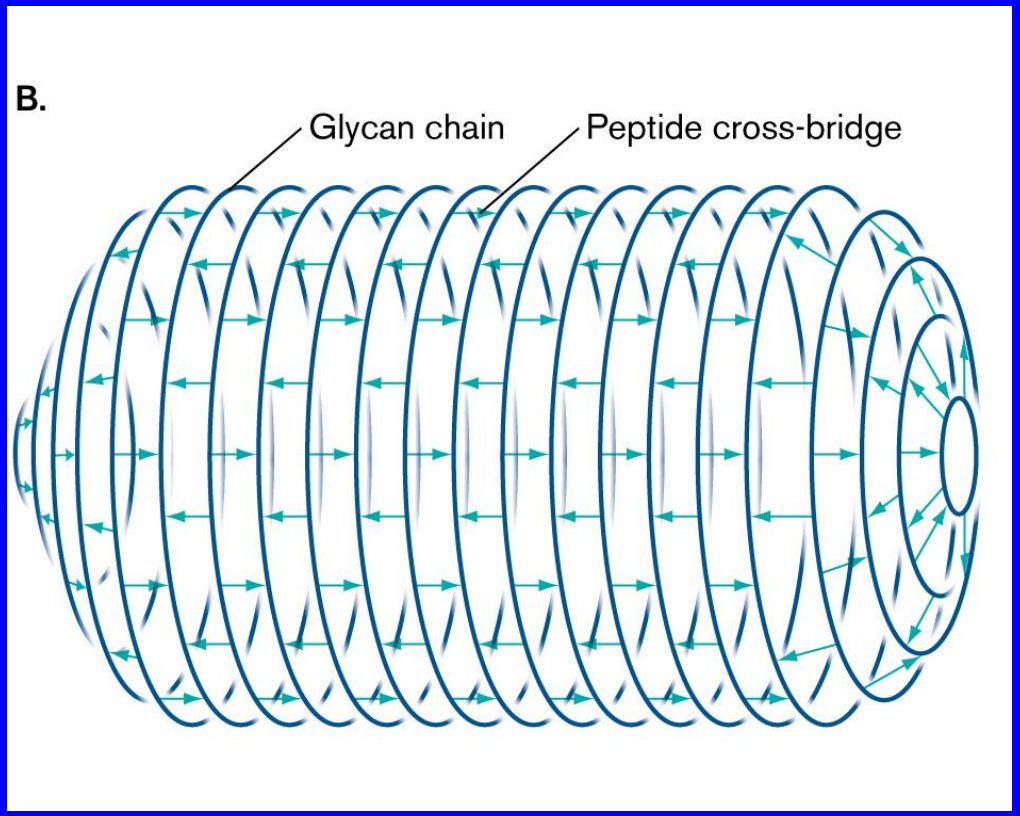


Figure 3.16 2nd edition

a) Peptidoglycan - 2

Composition

- Two alternating sugars
  - N-acetyl-glucosamine (GlcNAc, NAG or G)
  - N-acetylmuramic acid (MurNAc, NAM or M)
  - Sugars linked via β-1-4 linkage
- Crosslinked by peptide of amino acids
  - Peptide sequence varies
  - Most contain some *D*-amino acids. (*L*-forms are found in amino acids in proteins).

a) Peptidoglycan - 3

- Chains of alternating sugars NAG and NAM
- Crosslinked by two linked peptides

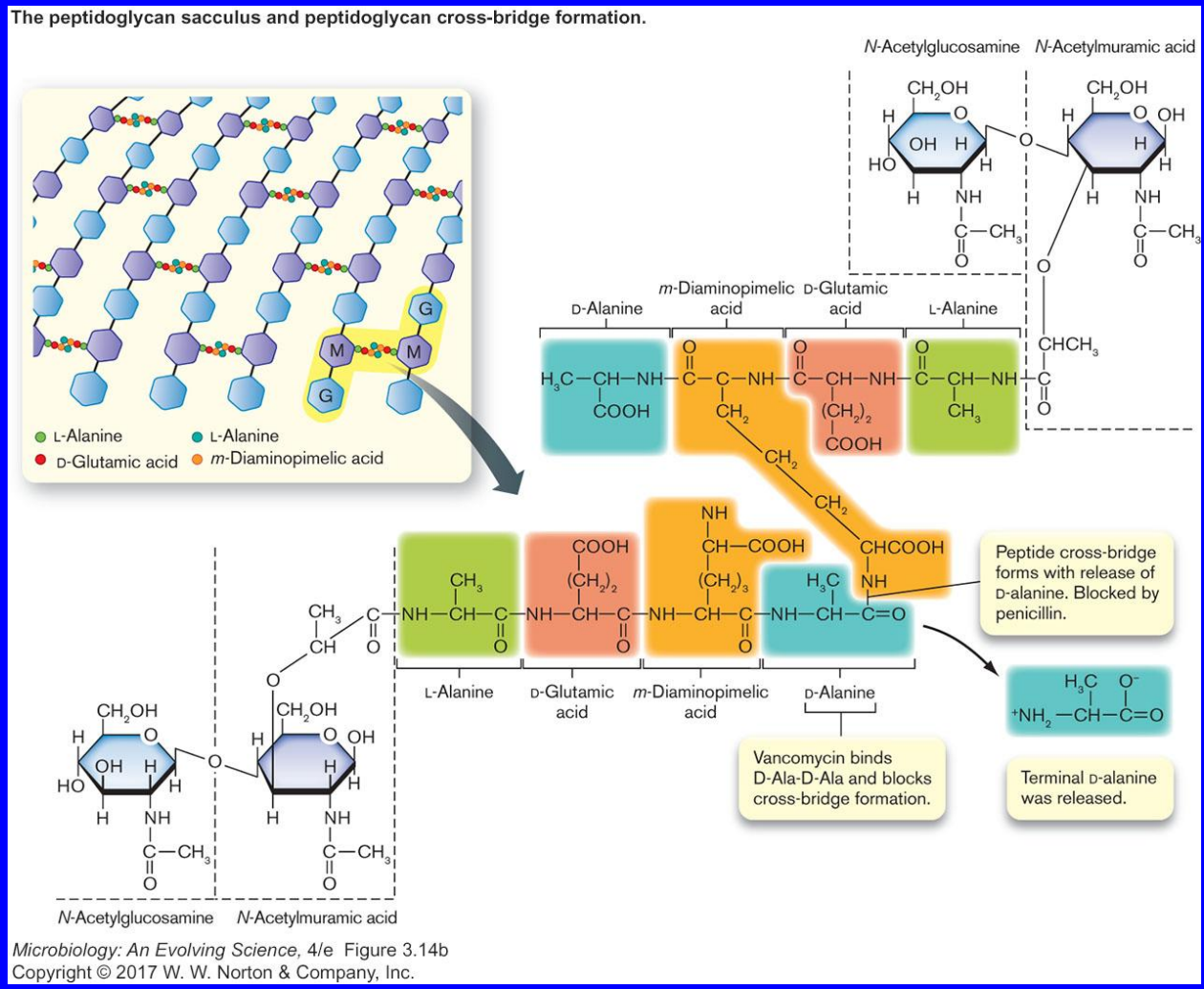
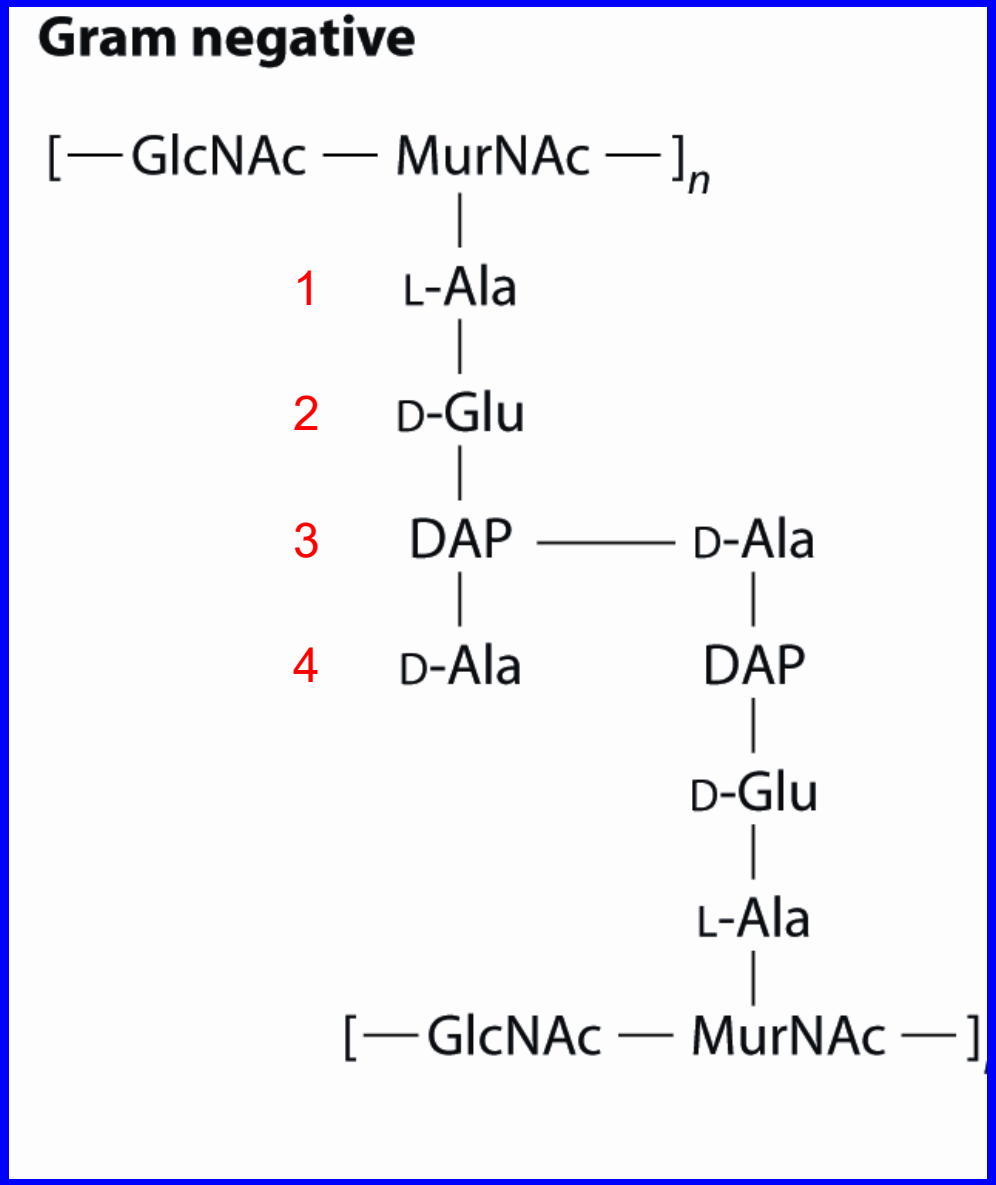


Figure 3.12B
6th edition

a) Peptidoglycan - 4

Peptide in Peptido-glycan of Gm neg.

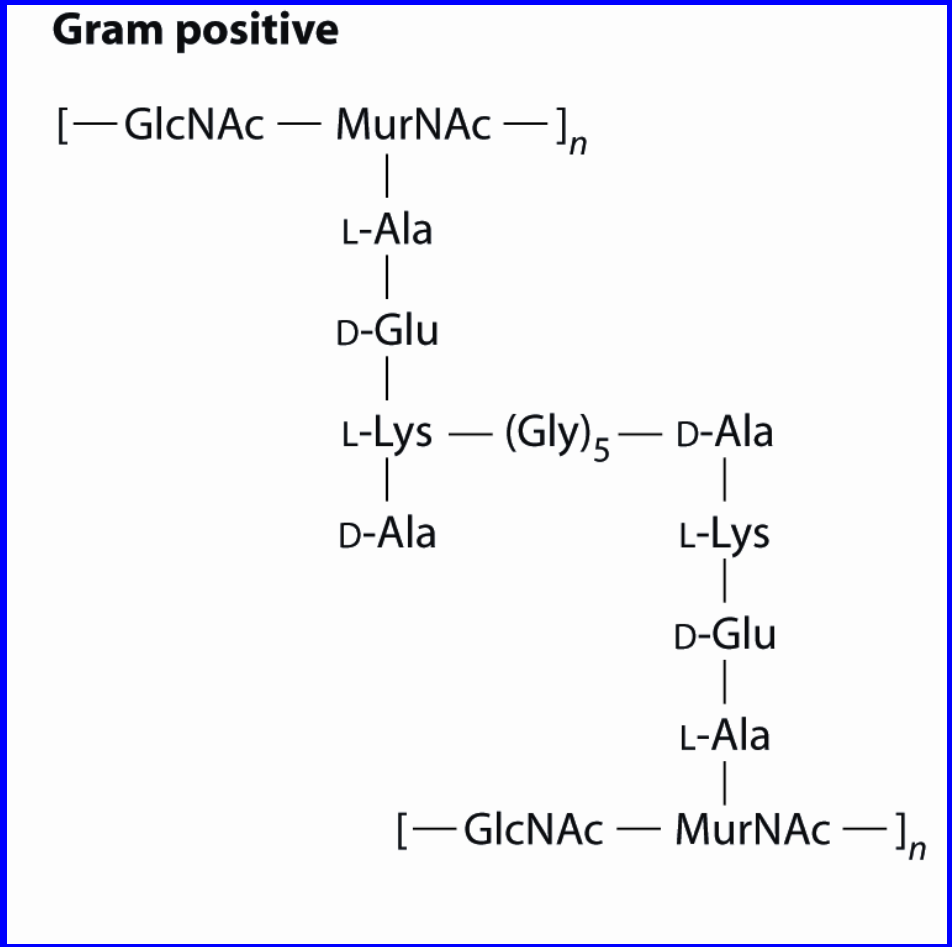
- *D* amino acids in 2nd and 4th position
- DAP or diaminopimelic acid (modified lysine) in 3rd position
- Crosslink between DAP and *D*-Ala in 4th position



a) Peptidoglycan - 5

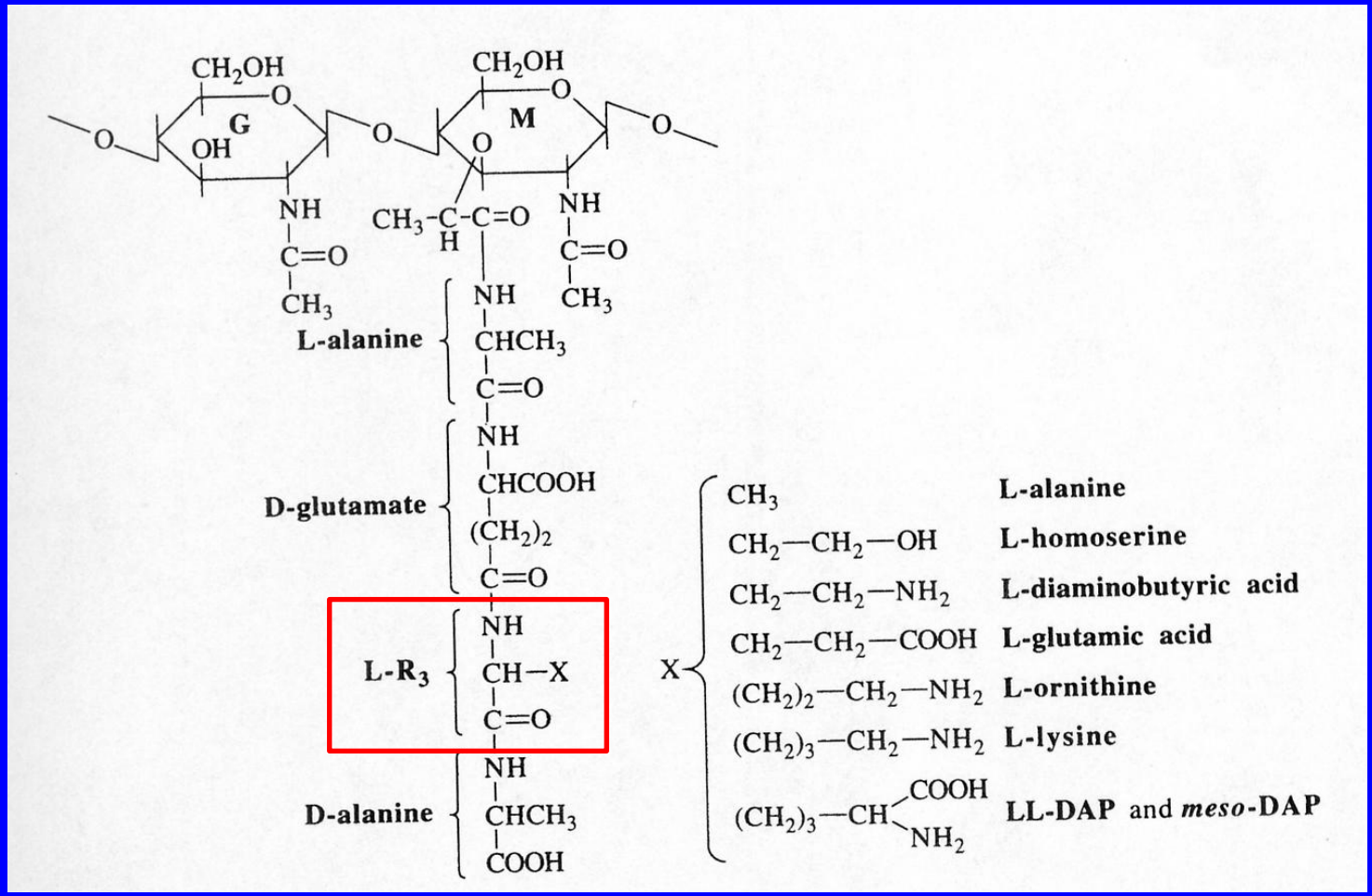
Peptidoglycan in Gram positive staphylococci

- How is this different from Gm negative?



a) Peptidoglycan - 6

- Summary of amino acids seen in peptidoglycan peptides



a) Peptidoglycan - 7

Peptide starts out with five amino acids and 5th aa is cleaved off when cross link is made. Cut between two *D*-alanine

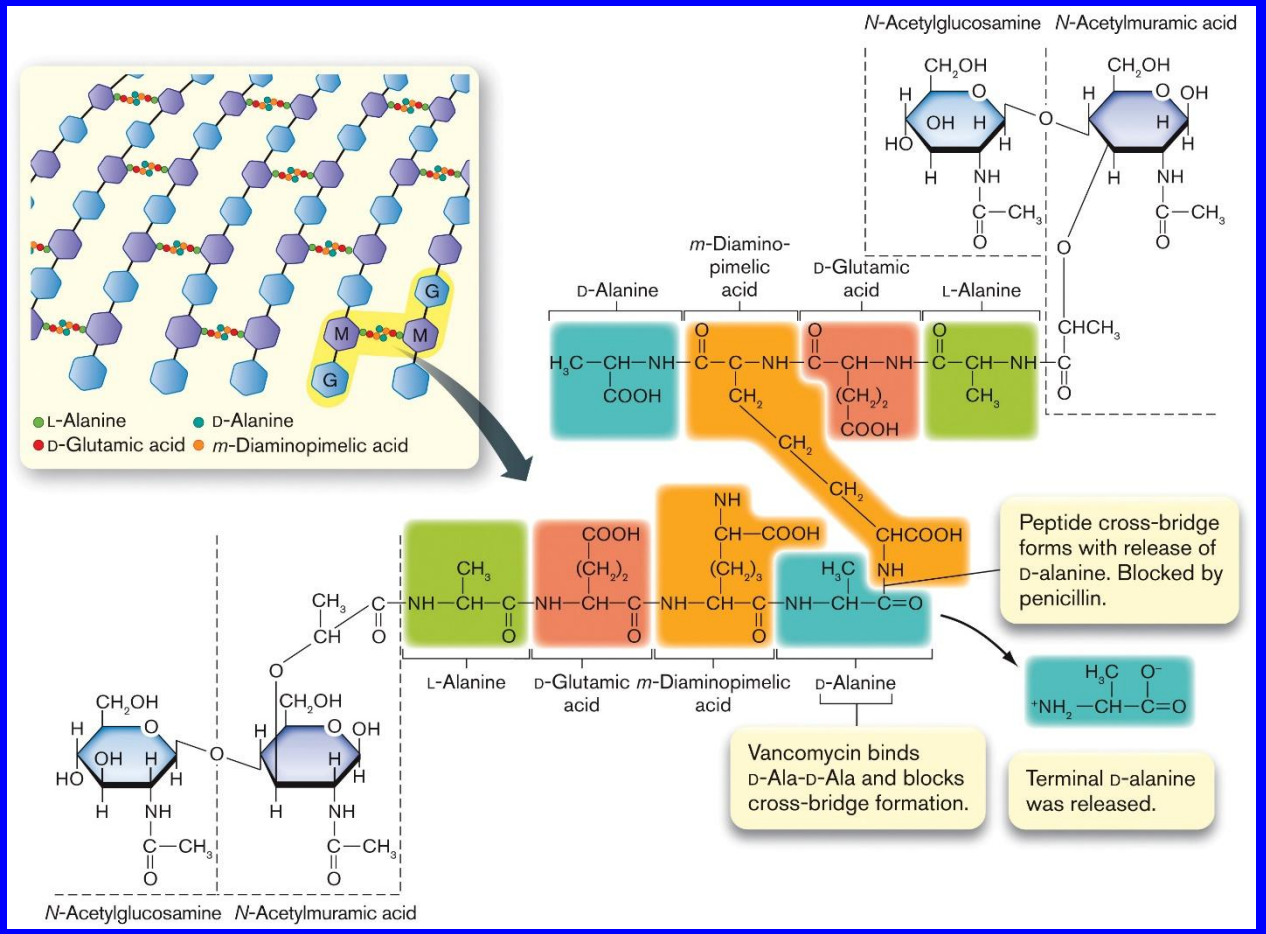
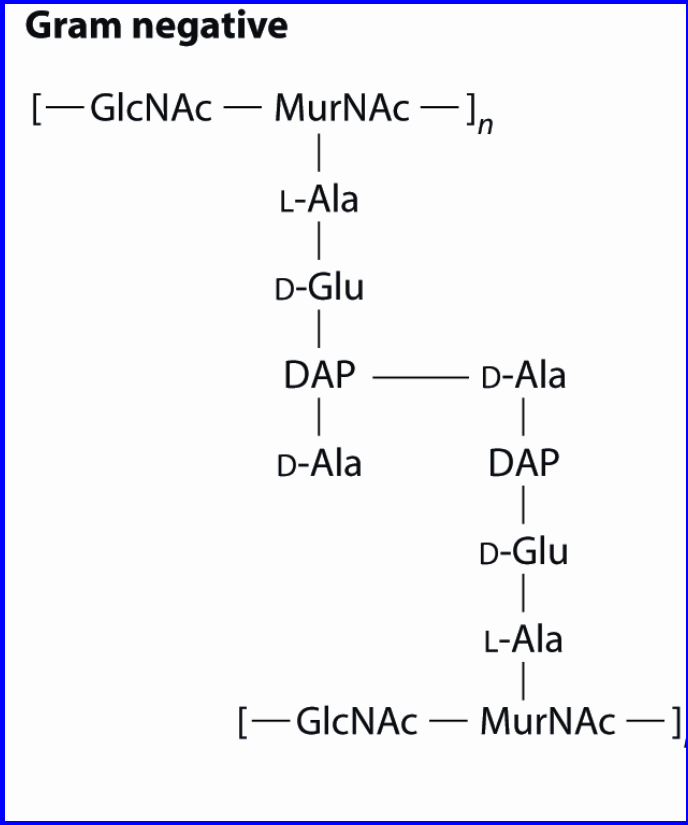
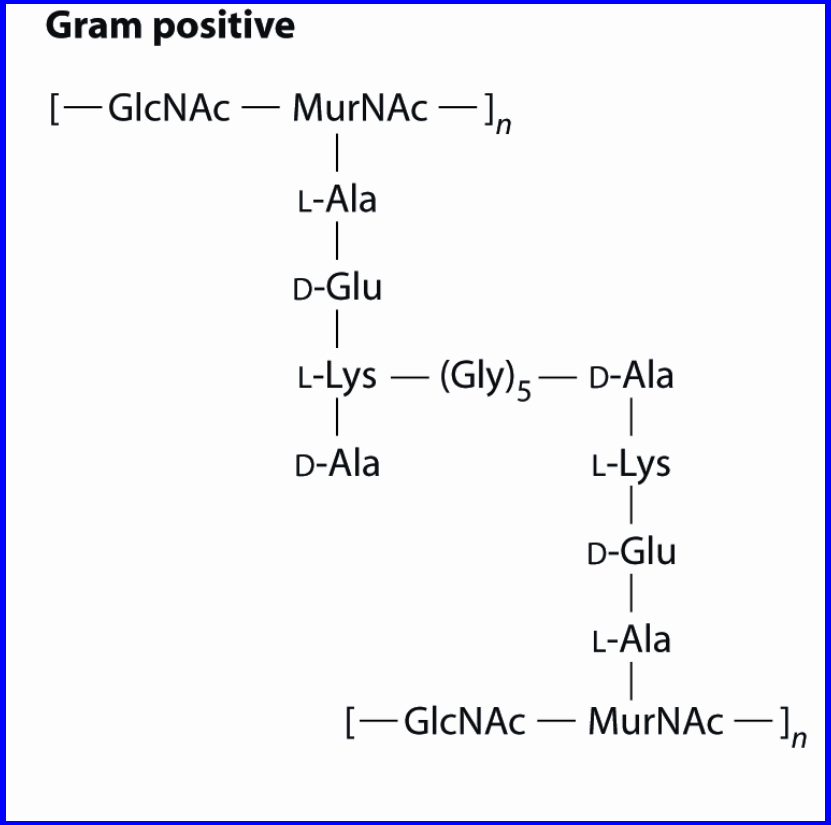


Figure 3.12B
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Assignment 13 Question 8

- How is peptidoglycan different between different species of bacteria?

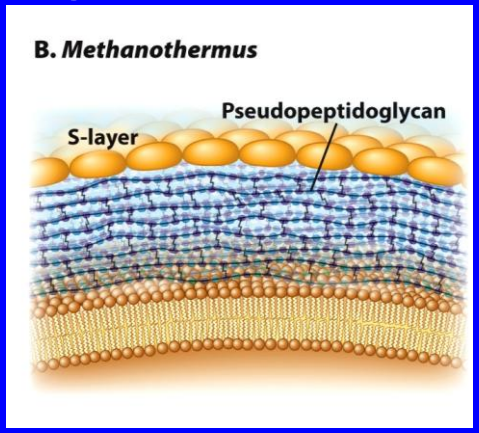


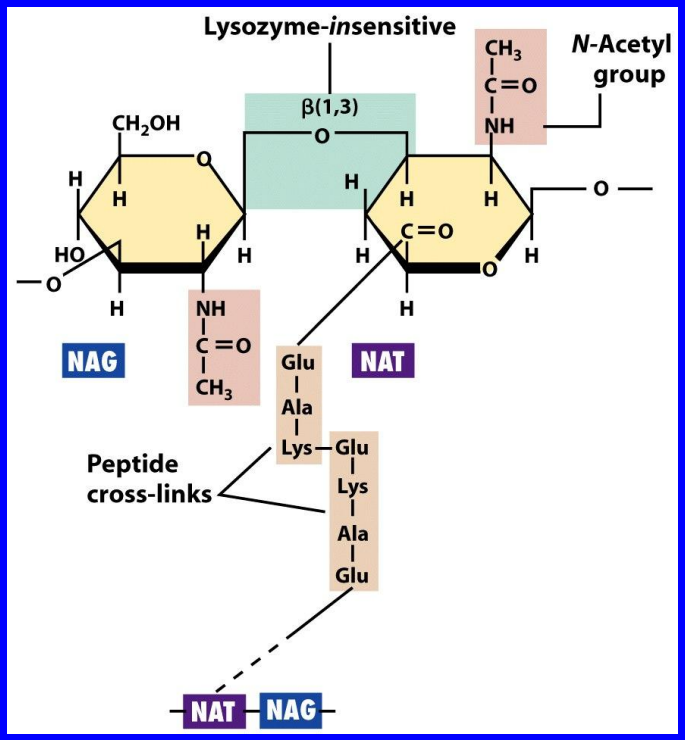


b) Pseudopeptidoglycan

- Found in some archaeal bacteria
- Two sugars: N-acetyl-glucosamine (NAG) and (N-acetyltalosaminuronic acid) – NAT
- Can have many layers
- Linked by β-1-3 linkage
- Crosslinked by peptide
  - All *L*-amino acids
- How is this different from Gm-neg. peptidoglycan?

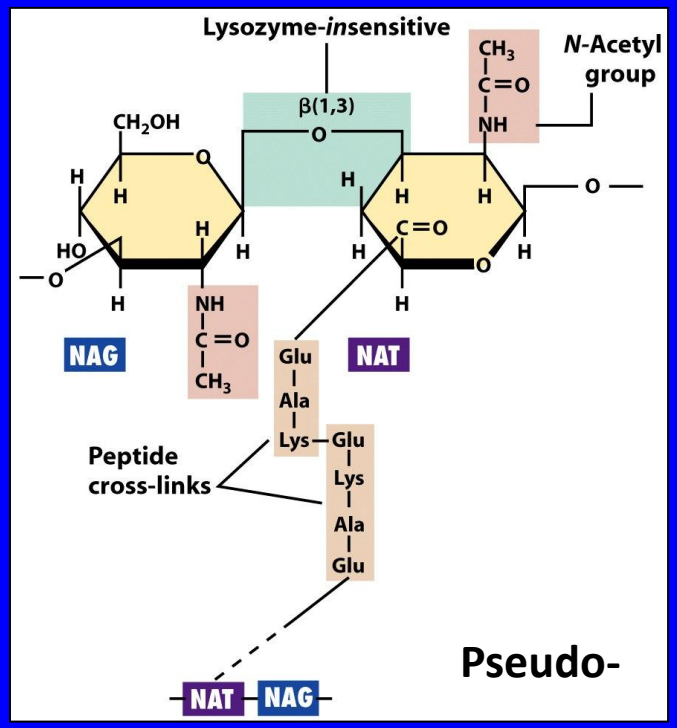
Fig 19.25 6th edition

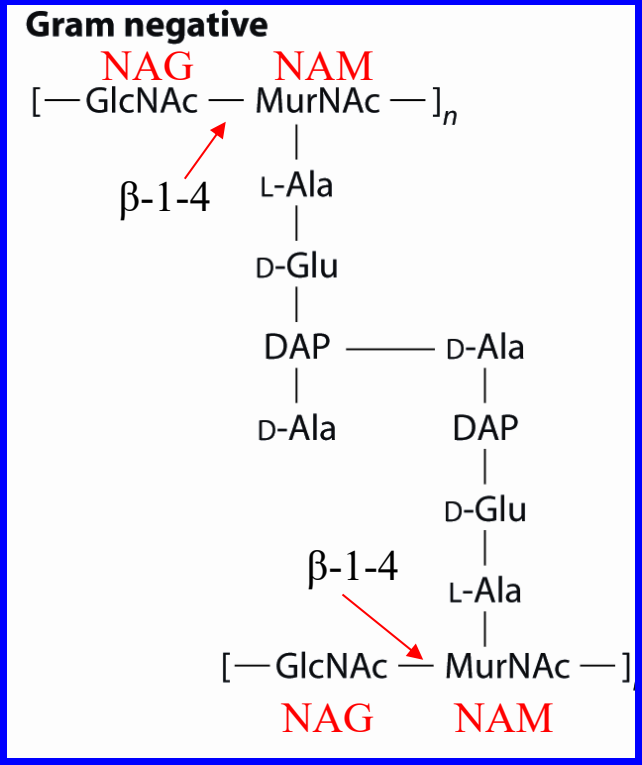




Assignment 13 Question 9

- How is Pseudopeptidoglycan different from Gram negative peptidoglycan?
  - ___
  - ___
  - ___





2) Components of Cell Wall - c

c) Teichoic Acids (tī-ˌkō-ik)

- Polyanionic polymers of glycerol phosphate or ribitol phosphate
  - Modified with amino acids (R)
- Observed in most Gram pos bacteria
- Composition varies - Can be used for identification

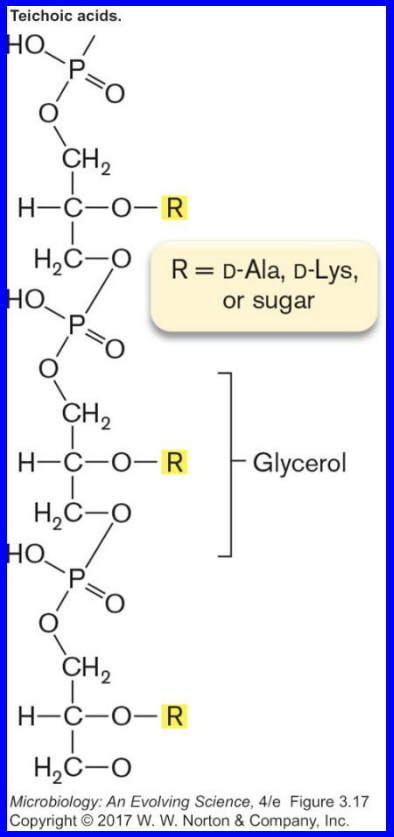
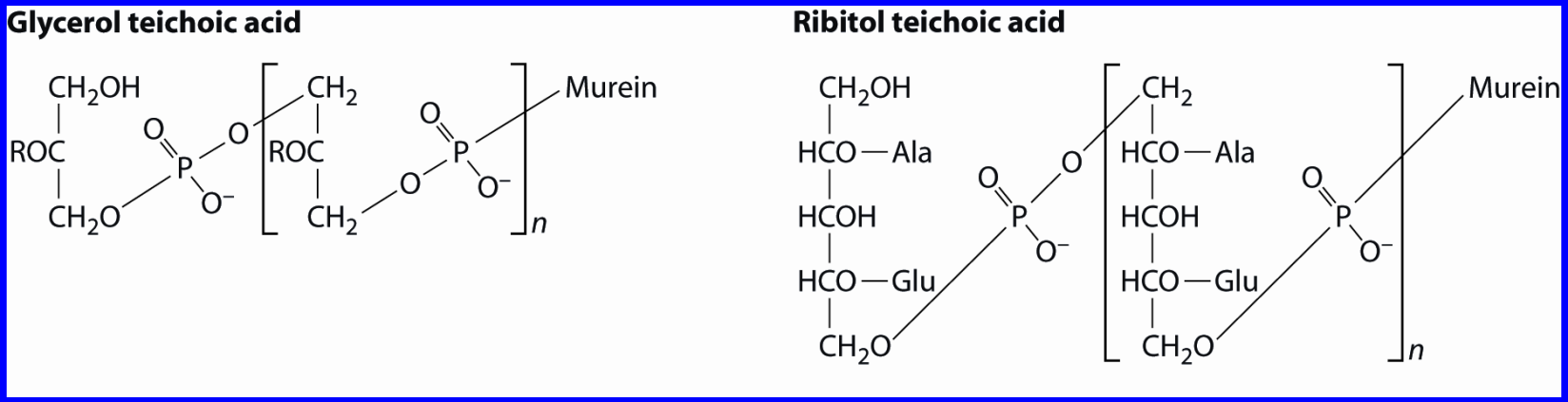


Figure 3.16 6th edition



2) Components of Cell Wall

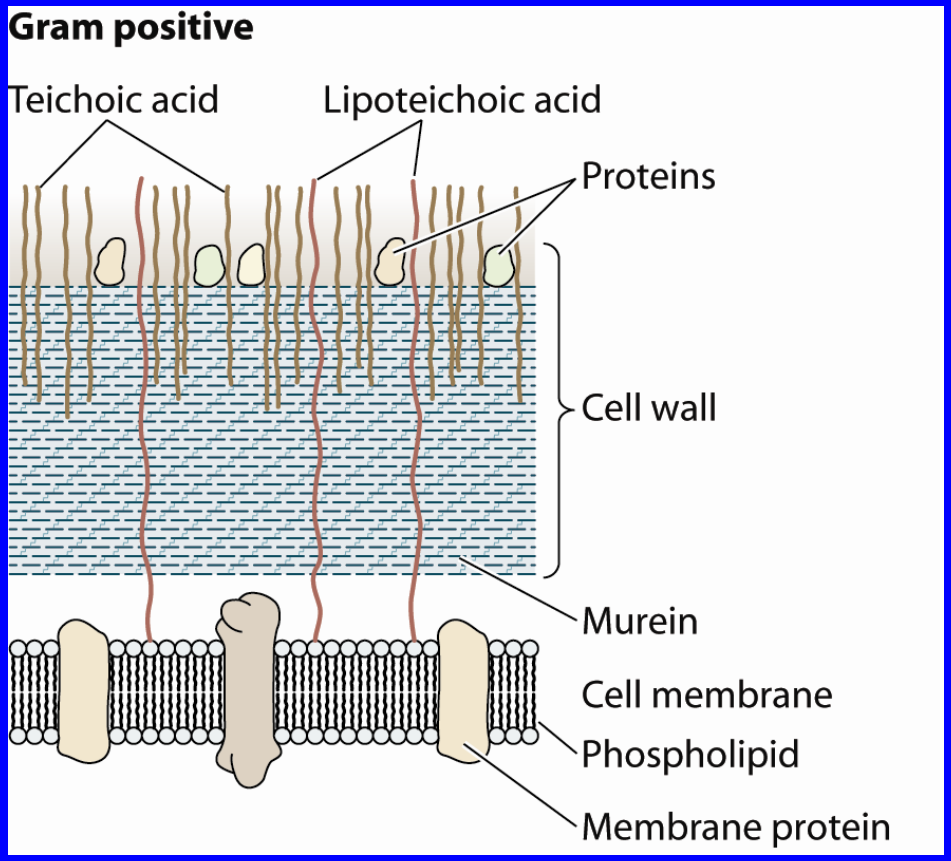


Figure 2.2 from Microbe

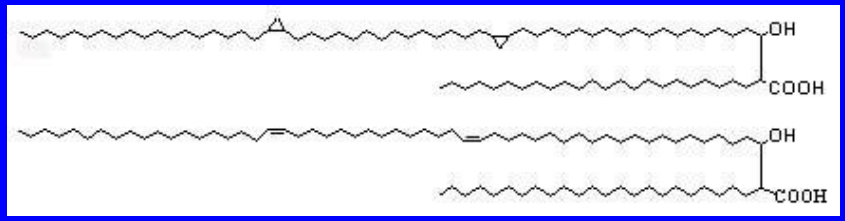
c) Teichoic acids

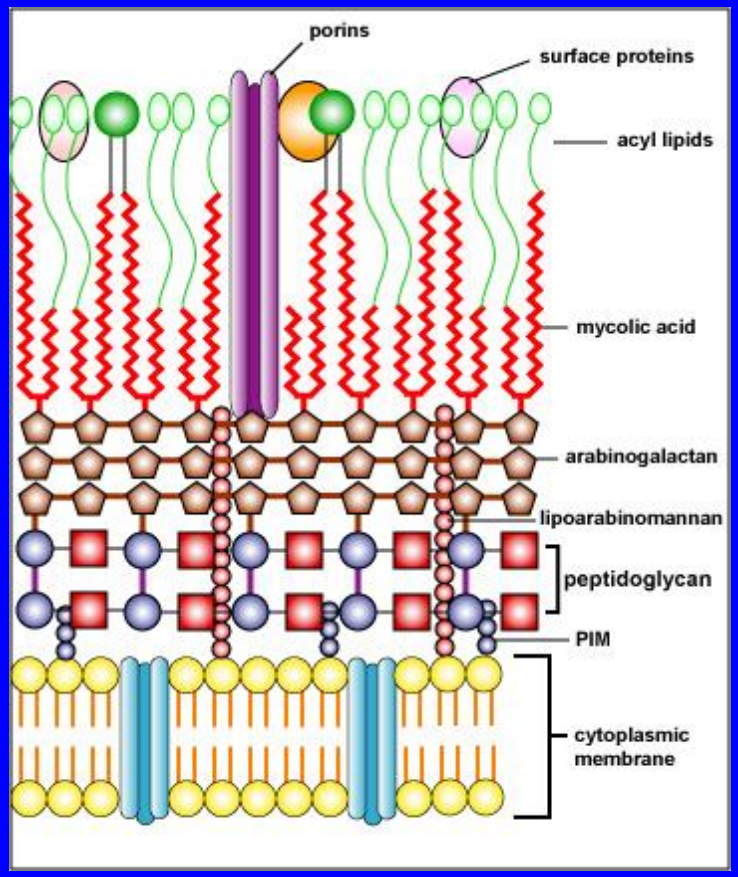
- Runs through peptidoglycan
- Can be linked to lipids in memb. (lipoteichoic) or peptidoglycan
- Role: regulation of cell shape, cell division, affects antibiotic resistance, integrity of cell wall

2) Components of Cell Wall - 2

d) Mycolic acid

- Complex hydroxylated branched-chain fatty acids with elevated carbon numbers (60-90 Cs) - Very hydrophobic
- Found in Mycobacteria
- Linked to arabinogalactan sugars
- Blocks diffusion of most molecules including nutrients
- Makes cells resistant to acids, bases, antibiotics and dehydration





2) Components of Cell Wall - 3

e) Arabinogalactan
(ə-ˌra-bə-ˌnō-gə-ˈlak-tən)

- Polysaccharide found in Mycobacteria cell wall
- Chains of arabinose sugar (5 carbons) and chains of galactose
- Linked to peptidoglycan and mycolic acid
- Synthesis inhibited by some antibiotics used against mycobacteria

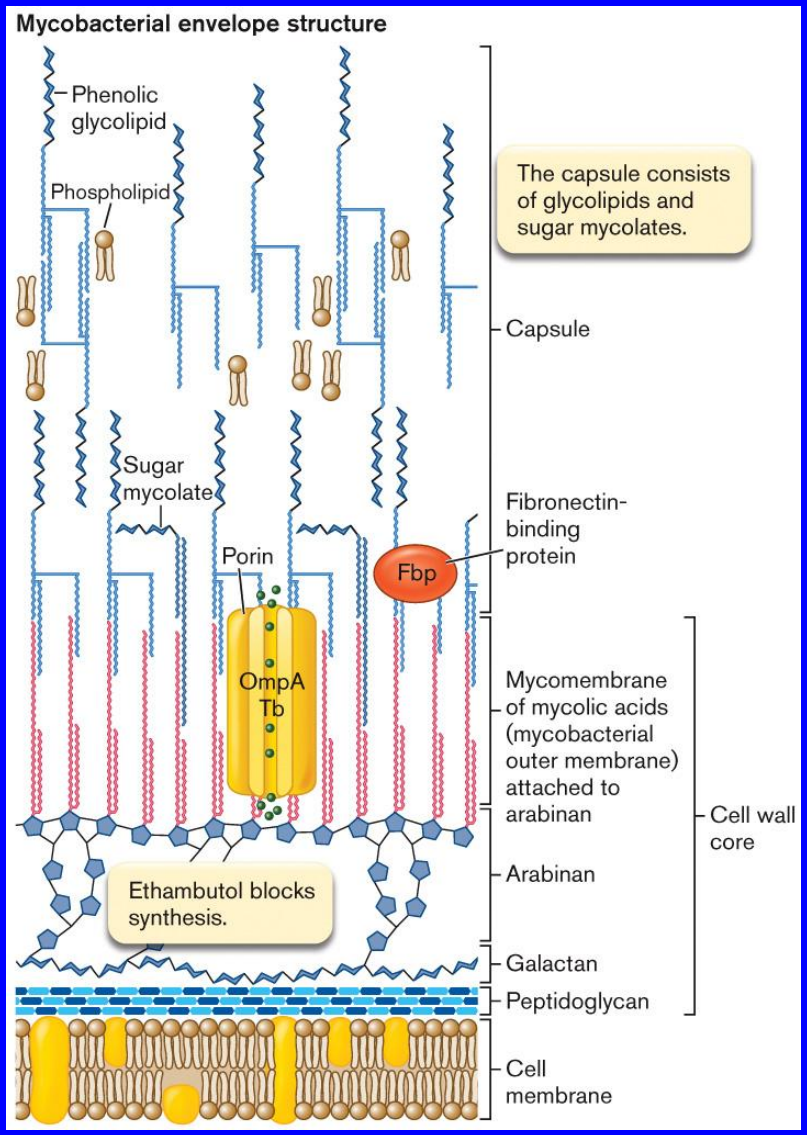


Figure 3.21 6th edition

C. Cell Envelope of Bacteria - e

2. Layers and Components
   a. Glycocalyx – capsule
   b. S layer
   c. Outer membrane
      - LPS and phospholipids
   d. Cell wall -
      - Peptidoglycan, Pseudopeptidoglycan, Teichoic acid, Mycolic acids, Arabinogalactan, Periplasm
   e. Periplasm
   f. Cell membrane
      - Phospholipids, Isoprenoids and hopanoids

e. Periplasm

- Aqueous compartment between outer membrane and inner membrane in Gram negative
- Contains its own unique set of proteins

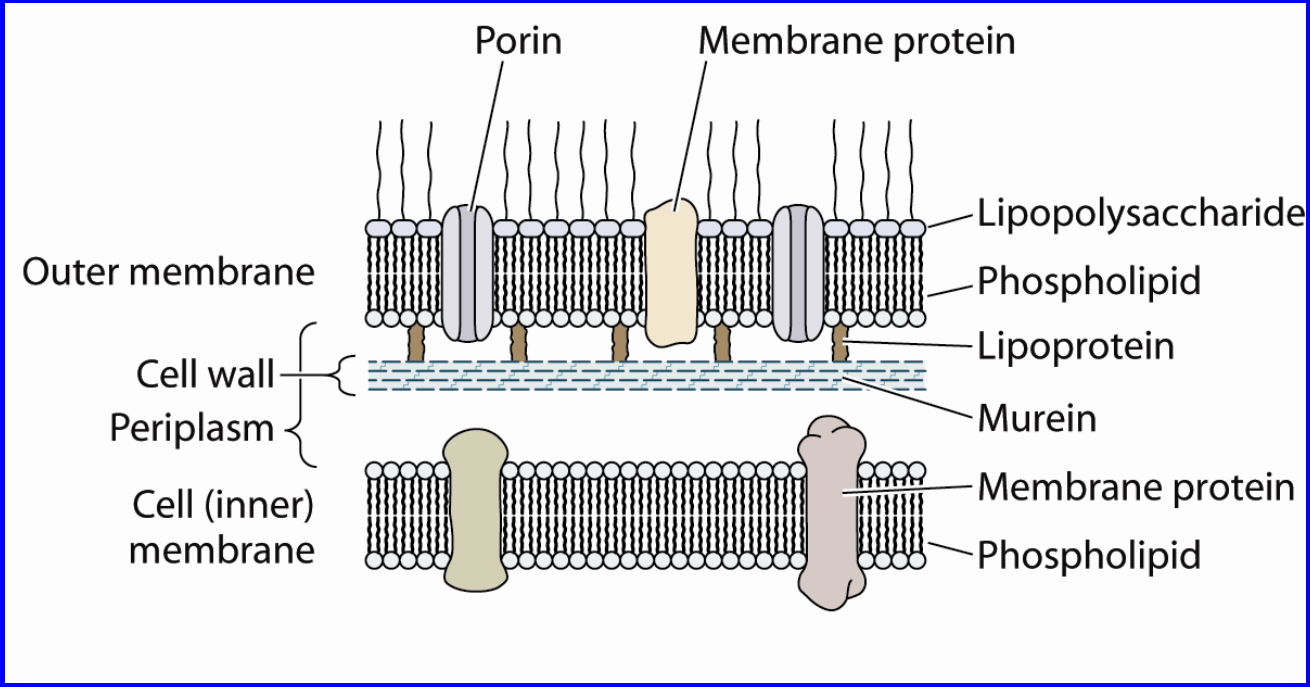


Figure 2.2 Microbe

e. Periplasm - 2

Main Functions

1. _Osmotic protection – contains oligosaccharides
2. Transport of nutrients - Has proteins that bind solutes (food) and transport them to inner membrane transporter proteins
3. Oxidation-reduction reactions involved in electron transport chain, stores H^+ ions
4. Hydrolysis of nutrients into smaller subunits that can be transported into the cytoplasm

f. Cell membrane

- Composed of lipids and proteins
  - Proteins a major component by weight
- Boundary and barrier

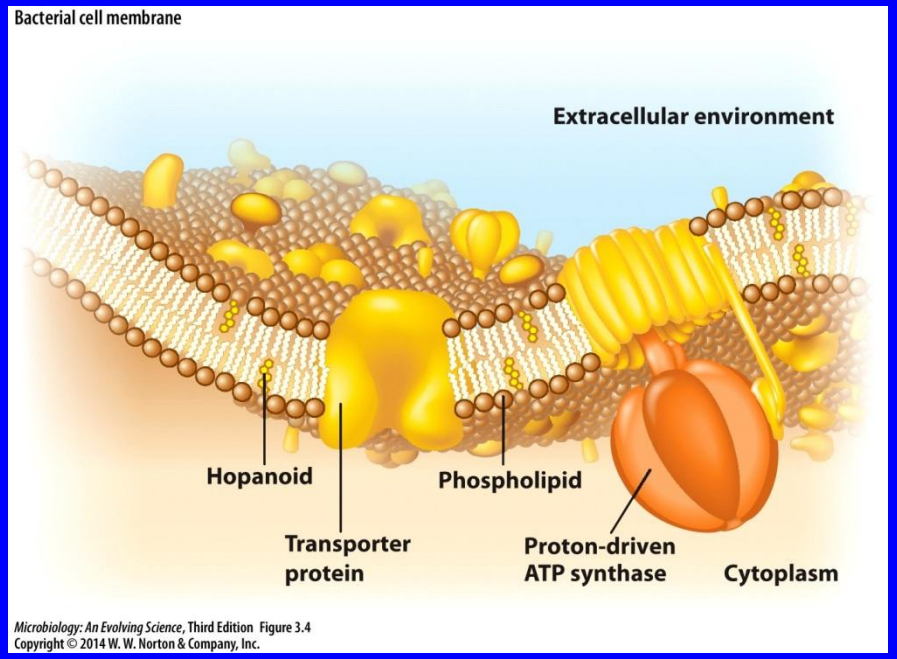


Fig 3.2 6/e

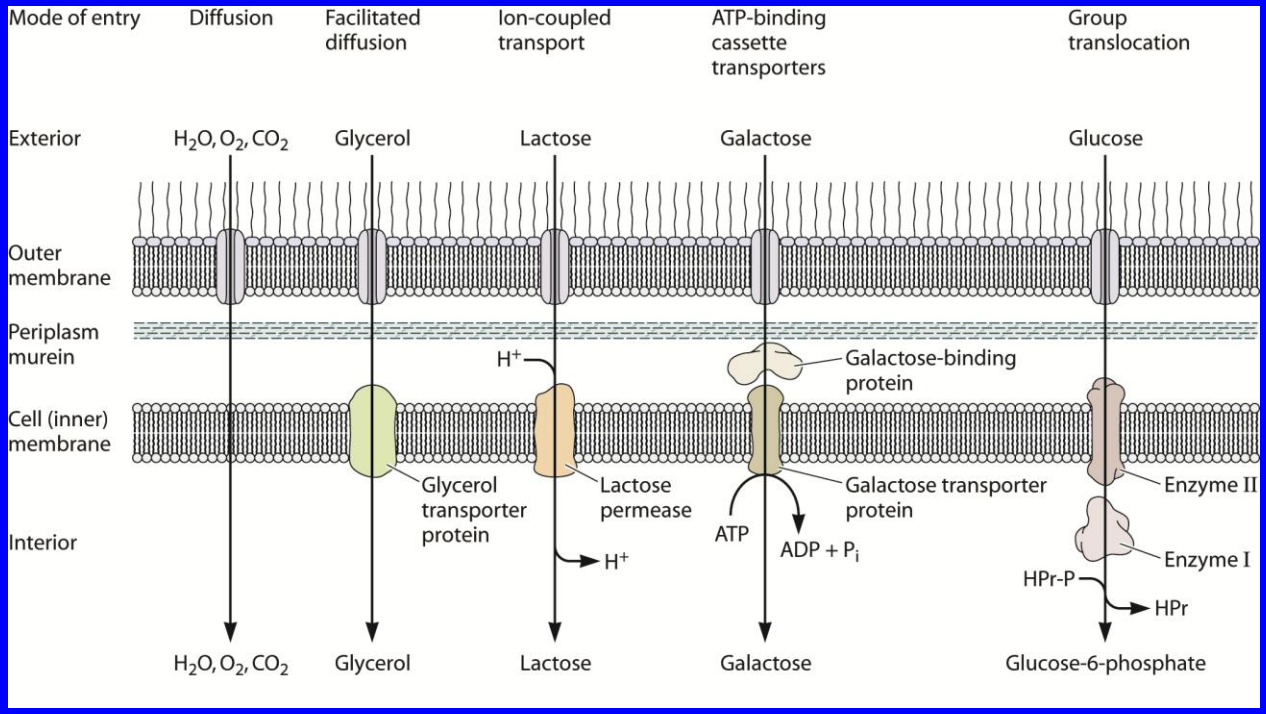
TABLE 11–1 Major Components of Plasma Membranes in Various Organisms

	Components (% by weight)				
	Protein	*Phospholipid*	*Sterol*	*Sterol type*	*Other lipids*
Human myelin sheath	30	30	19	Cholesterol	Galactolipids, plasmalogens
Mouse liver	45	27	25	Cholesterol	–
Maize leaf	47	26	7	Sitosterol	Galactolipids
Yeast	52	7	4	Ergosterol	Triacylglycerols, steryl esters
Paramecium (ciliated protist)	56	40	4	Stigmasterol	–
E. coli	75	25	0	–	–

Note: Values do not add up to 100% in every case, because there are components other than protein, phospholipids, and sterol; plants, for example, have high levels of glycolipids.

f. Cell membrane - 2

1) Components
2) Function
3) Transport across cell membrane
   - see sections 3.2 and 4.2



f. Cell membrane - 3

1) Components in Cell membrane
   a) Phospholipids – most bacterial cells
   b) Isoprenoids
   c) Hopanoids –
   d) Cardiolipin
   e) Proteins

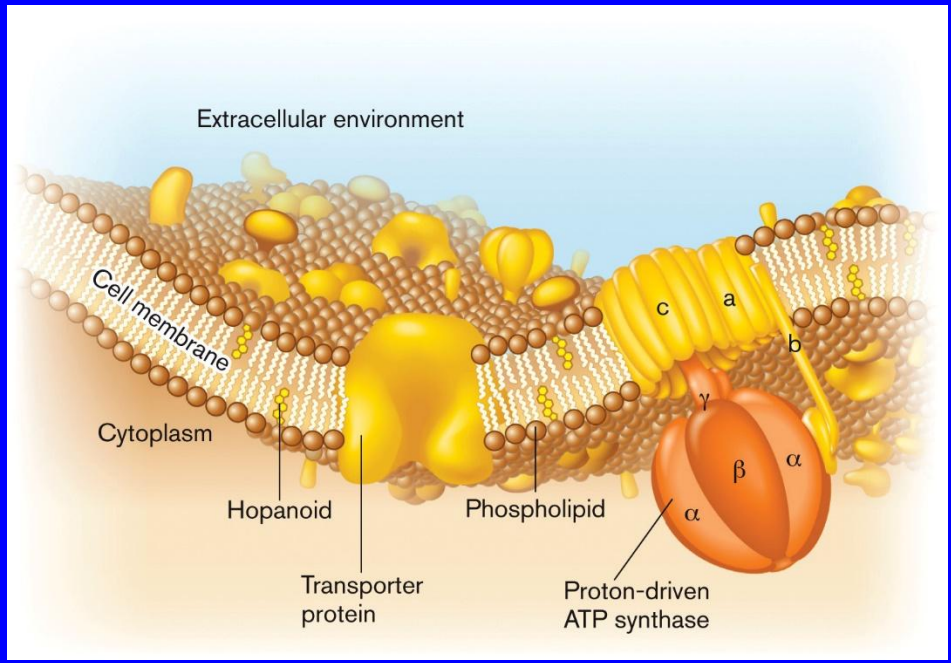
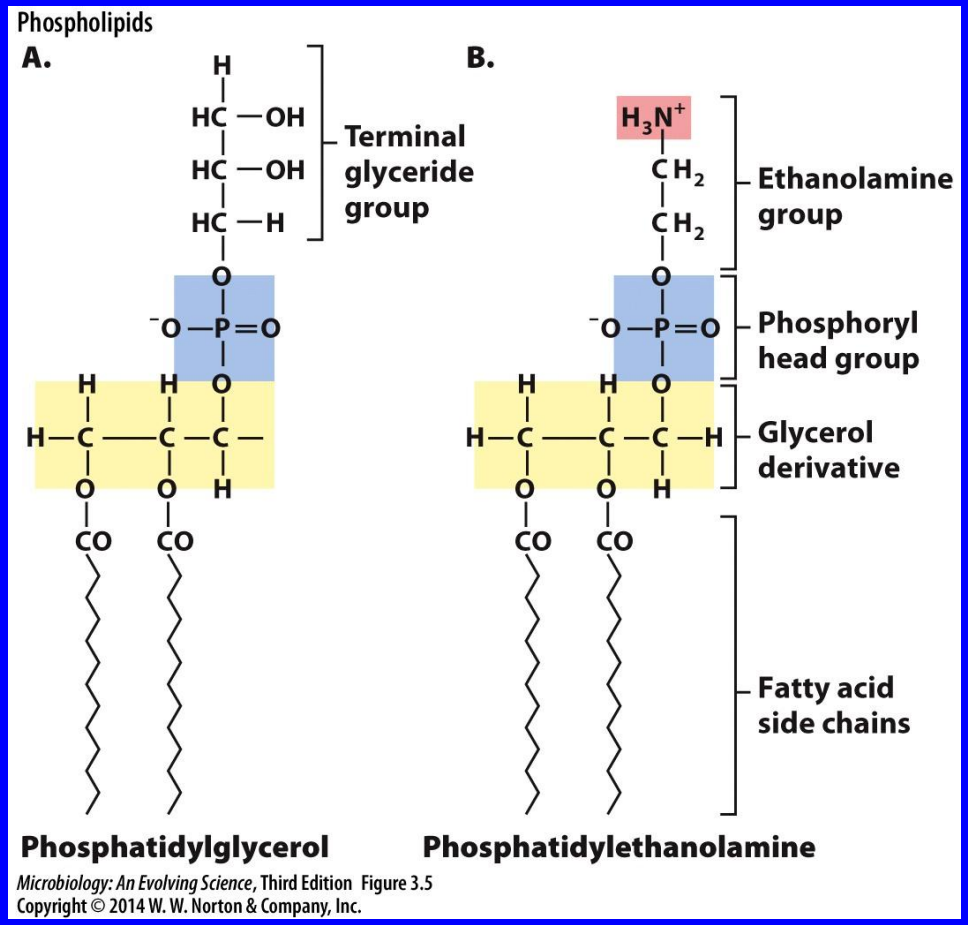


Figure 3.2
6th edition

1) Components

a) Phospholipids
   - Glycerol with ester linkages to two fatty acids and a phosphoryl head group.
   - Head group varies
   - Fatty acid chains vary in length and # of double bonds



a). Phospholipids

- Alter chain length and saturation (# of double bonds) in response to temperature (Table 11-2)
- What types are more abundant in low temperatures?
-

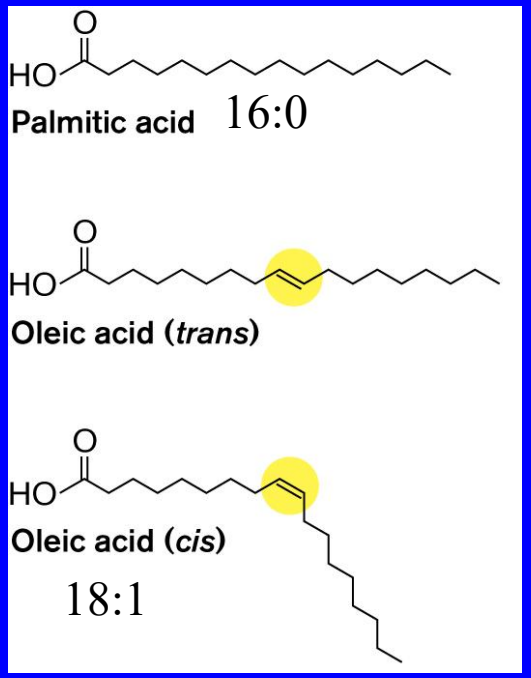


TABLE 11–2 Fatty Acid Composition of *E. coli* Cells Cultured at Different Temperatures

	Percentage of total fatty acids*			
	10 °C	*20 °C*	*30 °C*	*40 °C*
Myristic acid (14:0)	4	4	4	8
Palmitic acid (16:0)	18	25	29	48
Palmitoleic acid (16:1)	26	24	23	9
Oleic acid (18:1)	38	34	30	12
Hydroxymyristic acid	13	10	10	8
Ratio of unsaturated to saturated†	2.9	2.0	1.6	0.38

Assignment 13 Question 10

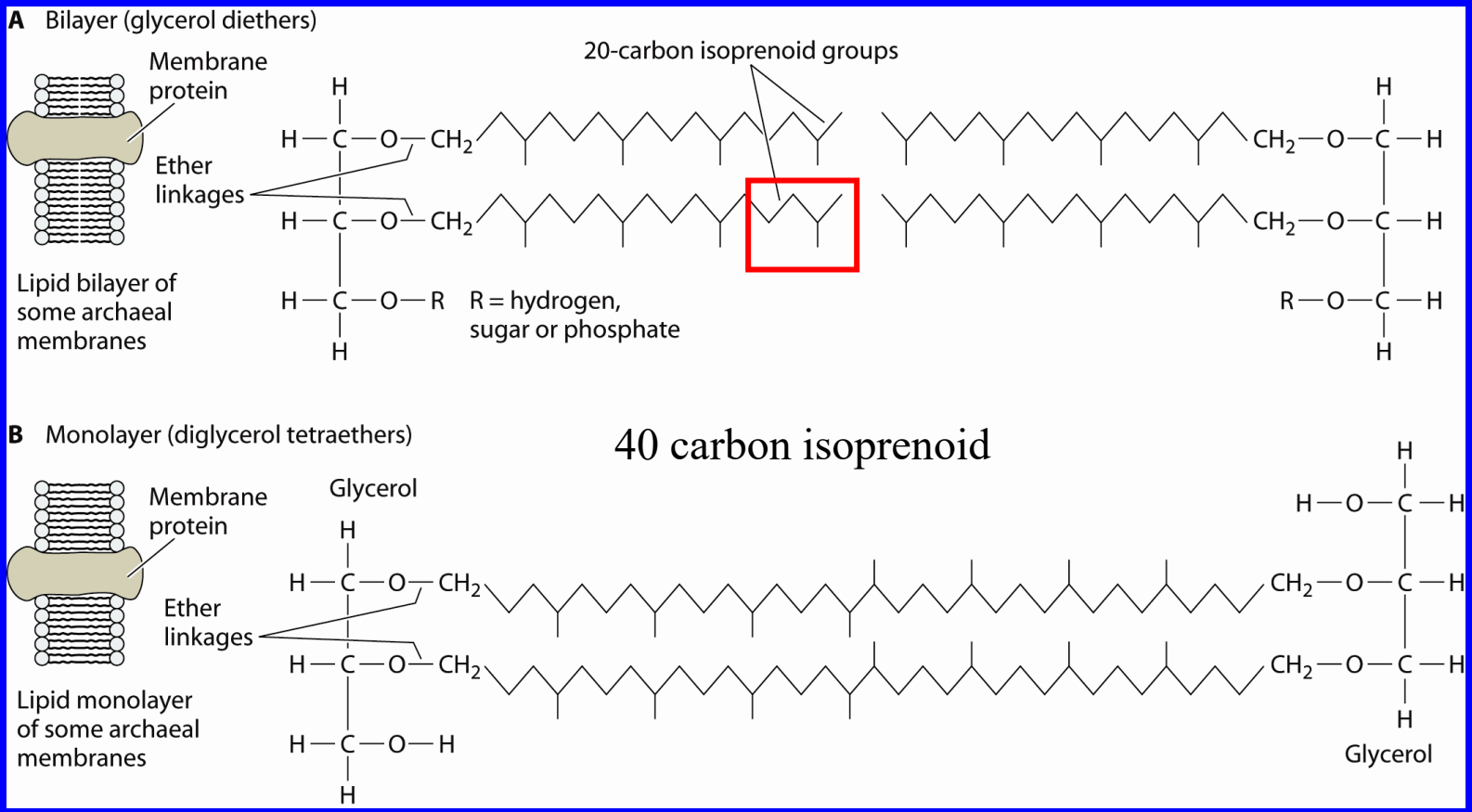
10. What types of fatty are more abundant in low temperatures?

TABLE 11–2 Fatty Acid Composition of *E. coli* Cells Cultured at Different Temperatures

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Palmitic acid (16:0)	18	25	29	48
Palmitoleic acid (16:1)	26	24	23	9
Oleic acid (18:1)	38	34	30	12
Hydroxymyristic acid	13	10	10	8
Ratio of unsaturated to saturated†	2.9	2.0	1.6	0.38

b). Isoprenoids

- 20 or 40 carbon trepenoids with branched 5 carbon isoprenoid repeats
- Linked to glycerol via ether linkage
- Found in Archaea



c) Hopanoids

- 5 ring hydrocarbon similar to sterols (cholesterol)
- Found in membrane of some Gram-negative and a few Gram-positive bacteria,

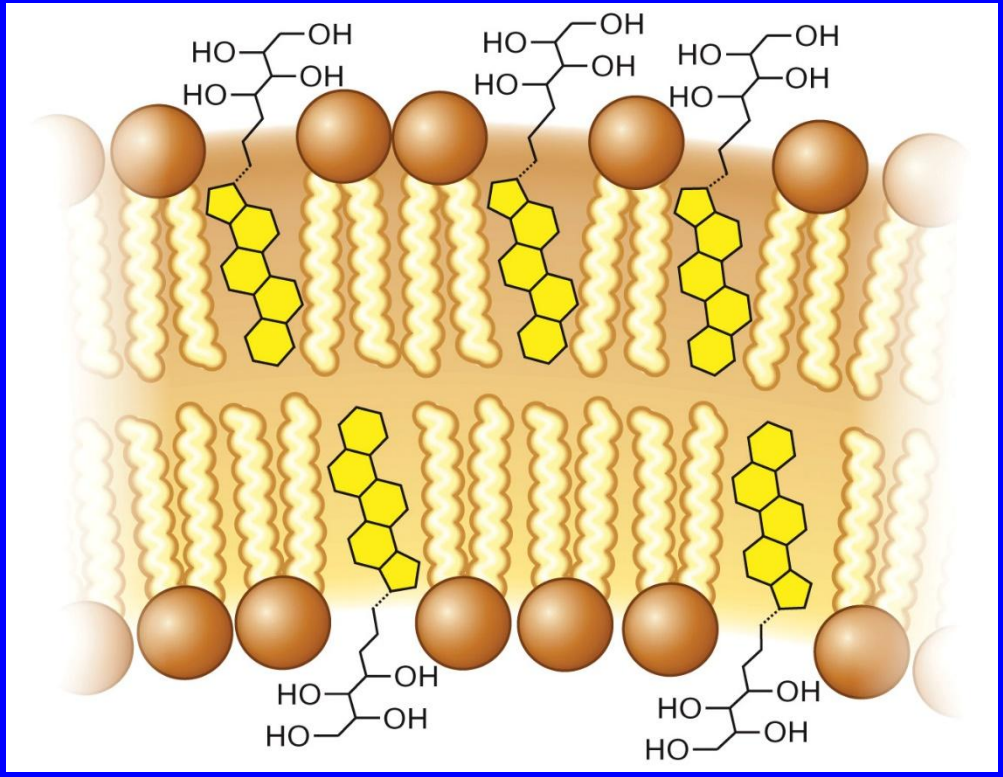
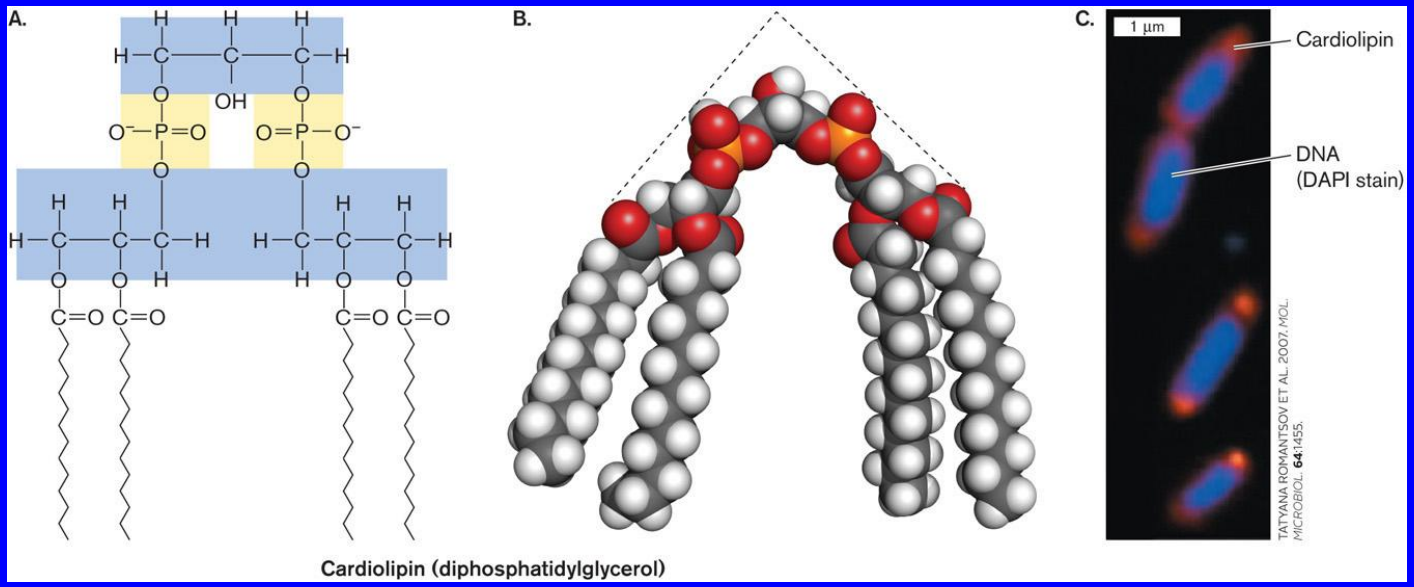


Figure 3.8 6th edition

d) Cardolipins

- 2 phospholipids linked by a glycerol
- Made in bacterial cells entering stationary phase when cell size decreases and congregate at poles where membrane is highly bent
- Also observed in membranes of some other organisms (heart cells)

See Figure 3.6 in 6th edition



e) Membrane proteins

- Largest component by weight
- Many involved in transport of material in and out of cell

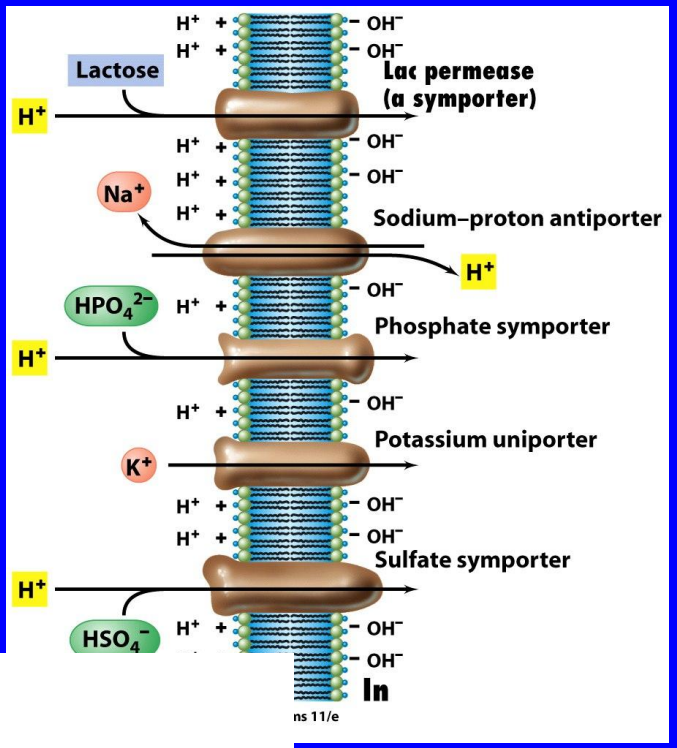


TABLE 11–1 Major Components of Plasma Membranes in Various Organisms

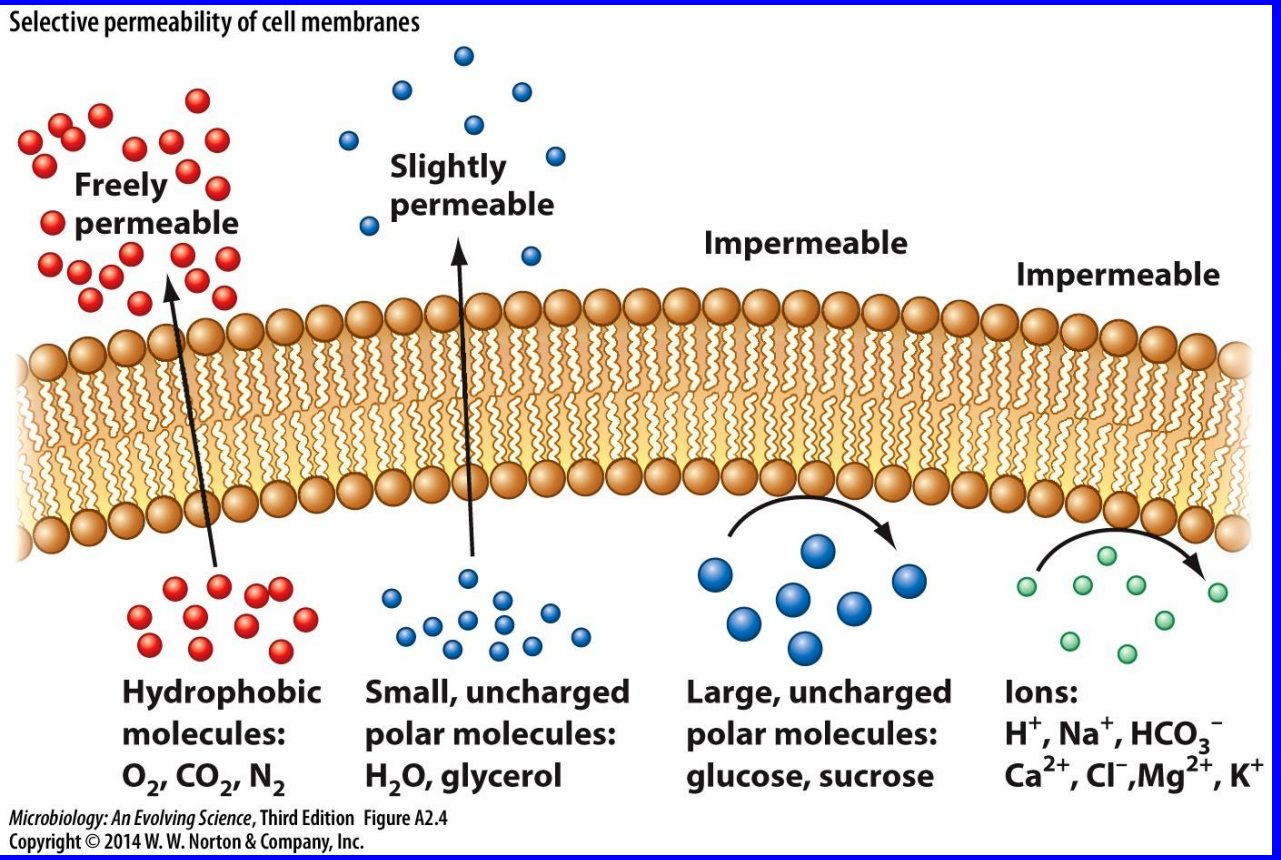
	Components (% by weight)				
	Protein	*Phospholipid*	*Sterol*	*Sterol type*	*Other lipids*
Human myelin sheath	30	30	19	Cholesterol	Galactolipids, plasmalogens
Mouse liver	45	27	25	Cholesterol	–
Maize leaf	47	26	7	Sitosterol	Galactolipids
Yeast	52	7	4	Ergosterol	Triacylglycerols, steryl esters
Paramecium (ciliated protist)	56	40	4	Stigmasterol	–
E. coli	75	25	0	–	–

Note: Values do not add up to 100% in every case, because there are components other than protein, phospholipids, and sterol; plants, for example, have high levels of glycolipids.

2) Functions of Cell Membrane

a) Permeability barrier

- Hydrophobic and small, polar molecules can diffuse through membranes



- Charged and large polar molecules cannot diffuse

Fig A2.4

2) Functions of Cell Membrane - 2

b. Regulate what is inside the cell
   - Transport nutrients in
   - Maintains osmotic balance
   - Maintains ion/charge gradients

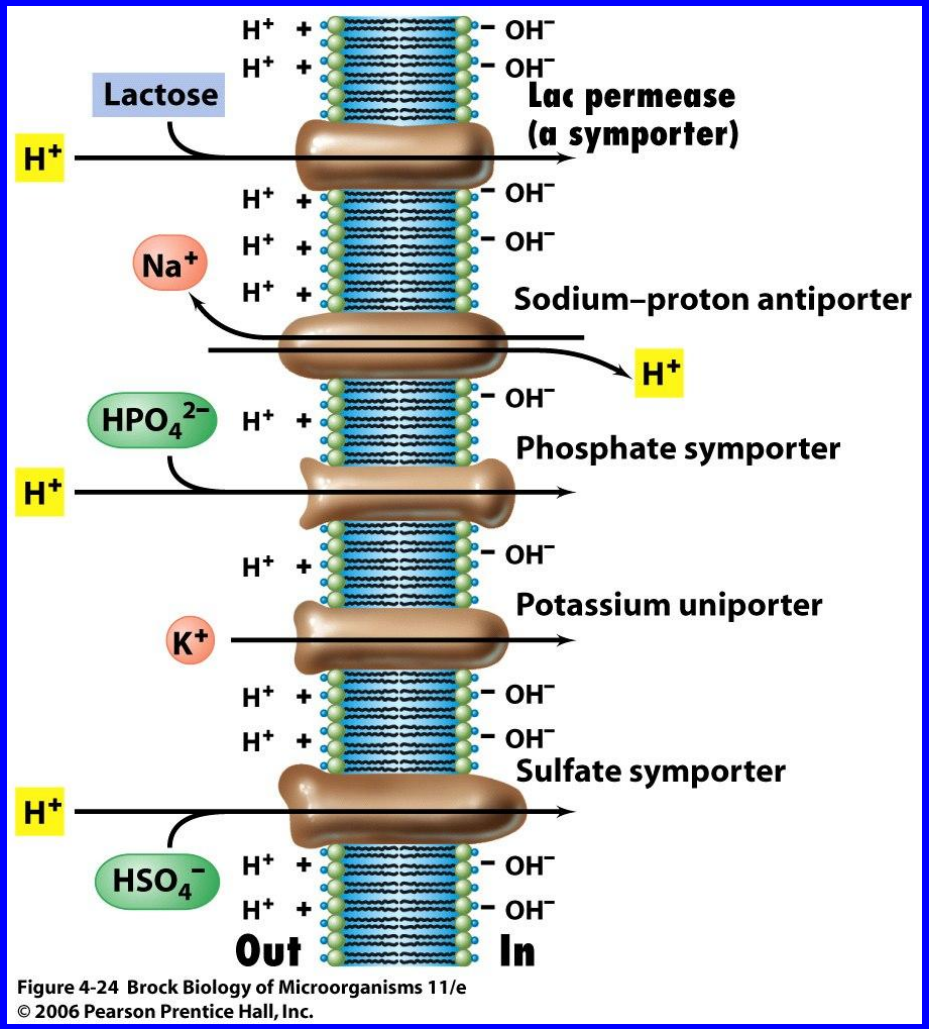


Figure 4-24 Brock Biology of Microorganisms 11/e
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2) Functions of Cell Membrane - 3

c) Energy reactions and storage
   - Electrochemical gradient is created across it
   - Electron transport chain
   - Proton gradient – chemo-osmotic force
   - Synthesis of ATP
   - Across inner membrane in Gm neg bacteria and mitochondria

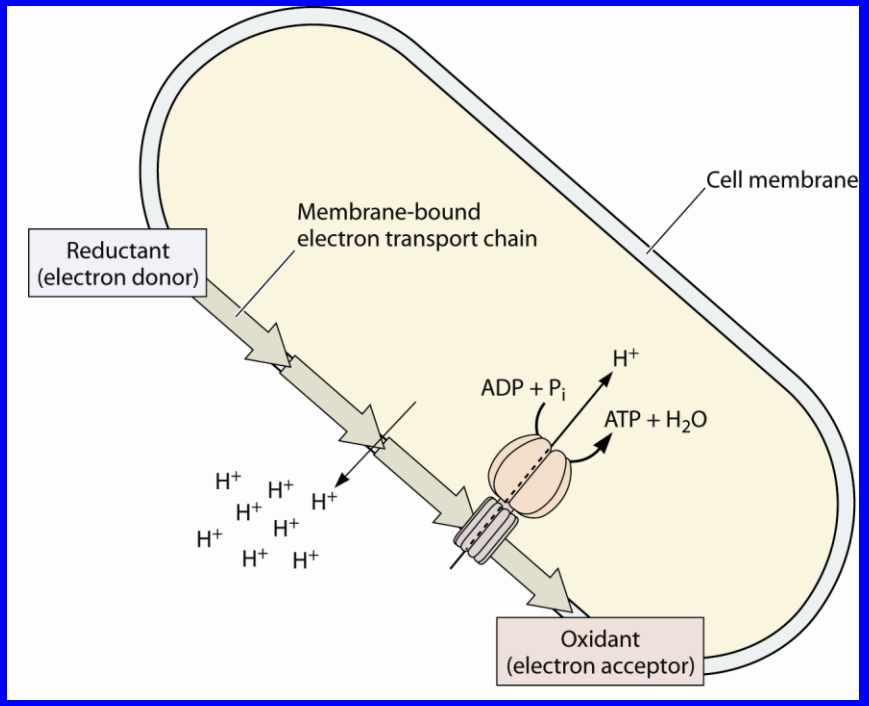


Fig 6.6 Microbe

2) Functions of Cell Membrane - 4

d) Sensing environment
   – Have receptor proteins in membrane
e) Synthesis of lipids

