# Physiology and diversity of prokaryotes

## The Prokaryotic Cell

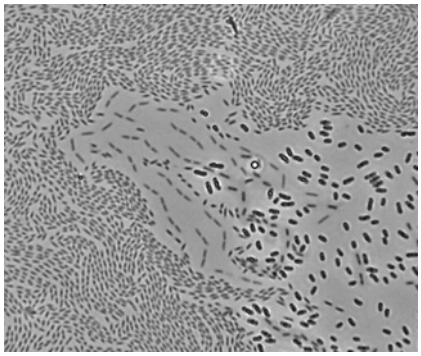


Foto: Heribert Cypionka

Bert Engelen

# Physiology and diversity of prokaryotes

**Physiology and Diversity of Prokaryotes**

**Bert Engelen, Martin Könneke**

Mo, Tu, We, Thu, 12.15 - 13.45, Room W15-1-146

This lecture introduces into the metabolism and physiological diversity of prokaryotes. Participance is obligatory for master-of-microbiology students and also open for biology- and environmental-science students. It is obligatory for participating in the practical course 'Physiology of Bacteria'. A successful participation will be certified after passing two short written tests.

| | | |
|---|---|---|
| Mo - 19.10. | General introduction | B. Engelen |
| Tu - 20.10. | Prokaryotic cell | B. Engelen |
| We - 21.10. | Principles of metabolism | B. Engelen |
| Th - 22.10. | Bioenergetics | M. Könneke |
| Mo - 26.10. | Transport and regulation | M. Könneke |
| Tu - 27.10. | Microbial growth | M. Könneke |
| We - 28.10. | Recapitulation of the first block | B. Engelen, M. Könneke |
| Th - 29.10. | Phylogeny | B. Engelen |
| Mo - 02.11. | 1st written examination | B. Engelen, M. Könneke |
| Tu - 03.11. | Fermenters | B. Engelen |
| We - 04.11. | Aerobic respiring microbes | B. Engelen |
| Th - 05.11. | Sulfate- and nitrate reducers | M. Könneke |
| Mo - 09.11. | Methanogens und homoacetogens | M. Könneke |
| Tu - 10.11. | Chemolithotrophs | M. Könneke |
| We - 11.11. | Photosynthesis | M. Könneke |
| Th - 12.11. | Recapitulation of the second block | B. Engelen, M. Könneke |

2nd written examination (date to be announced)

Bert Engelen

## Physiology and diversity of prokaryotes

**What is Physiology?**

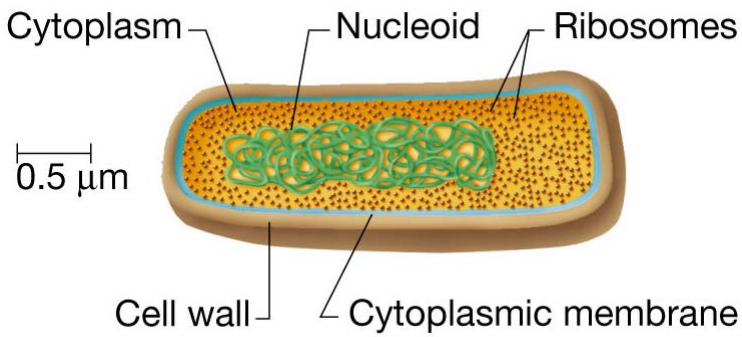
**Greek *physis*, nature, *logos*, word, *logia* science**

**compare with Morphology, Taxonomy...**

**What is Diversity?**

**A property of communities or groups**

## The prokaryotic cell




Brock/Madigan 10th ed.

## Building blocks of organisms

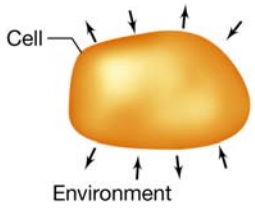
| | Example |
|---|---|
| • Subatomic | • (Quarks, ...) proton, electron |
| • Chemical element | • Hydrogen, carbon, oxygen |
| • Molecule | • Water: $H_2O$, sugar: $C_6H_{12}O_6$, peptide |
| • Molecule aggregate | • Multi-enzyme complex |
| • Organelle | • Nucleus, mitochondrium |
| • Cell | • Bacterium, mouth mucosa cell |
| • Tissue | • Fat tissue |
| • Organ | • Heart |
| • Organism | • Bacterium, amoeba, lion, tree |
| (• • • Population, community, biotope, biosphere) | |

**Living organisms consist of one or of many cells – most are unicellular**

## Definition and characteristics of life

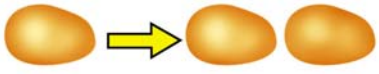
**1. Metabolism**
Uptake of chemicals from the environment, their transformation within the cell, and elimination of wastes into the environment. The cell is thus an *open* system.

Energy transformation




**2. Reproduction (growth)**
Chemicals from the environment are turned into new cells under the direction of preexisting cells.

Replication



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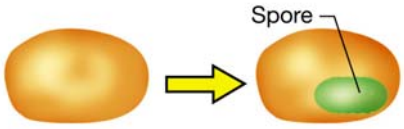
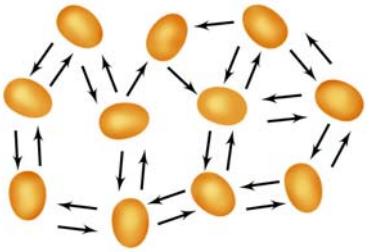
**3. Differentiation**
Formation of a new cell structure such as a spore, usually as part of a cellular *life cycle*.

Complexity




**4. Communication**
Cells *communicate* or *interact* primarily by means of chemicals that are released or taken up.

Regulation upon intra- and extracellular signals



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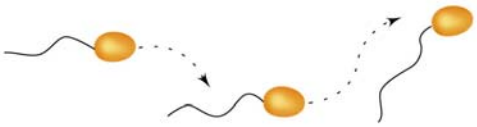
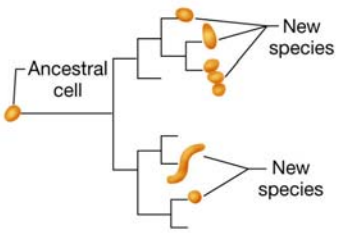
Response to environmental stress

**5. Movement**
Living organisms are often capable of self-propulsion.



**6. Evolution**
Cells *evolve* to display new biological properties. Phylogenetic trees show the evolutionary relationships between cells.

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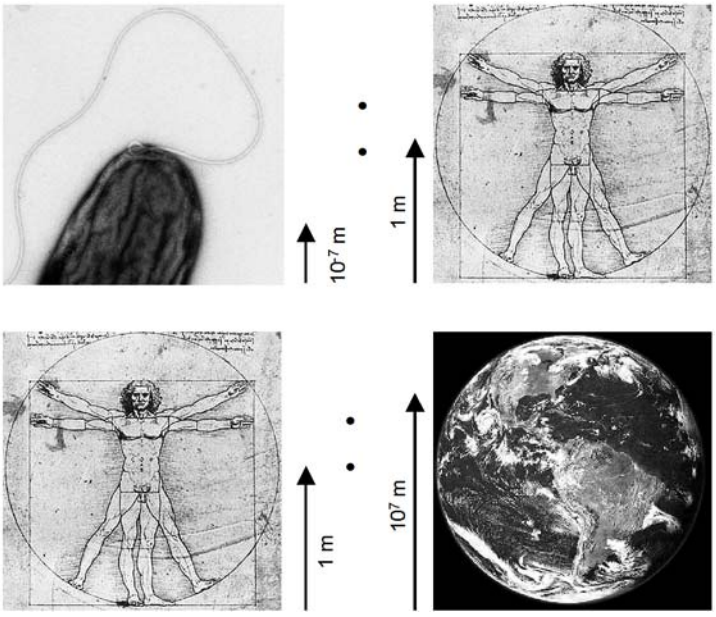
## Size - the relevance of being small




Bacterium : Man : Earth

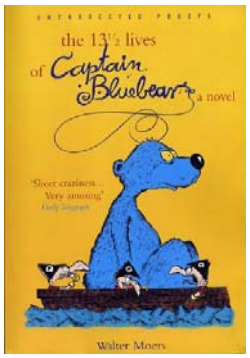
## Consequences of size relations

**bacteria : humans**

**1-D: $10^{-7}$**

**2-D: $10^{-14}$** **Biological activity is proportional to the membrane surface.**

**3-D: $10^{-21}$** **For bacteria diffusion is a fast process.**



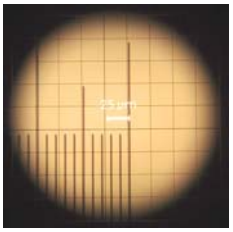
## An example of size and number

**Many natural water bodies contain about $10^6$ bacteria per ml. How many of these will you see if you bring 10 µl water under a cover slip of 20 x 20 mm and count them through the 100-fold objective in a microscopic field of view with 100 x 100 µm?**

10 µl = $10^{-2}$ ml containing $10^4$ bacteria under a cover slip with 400 $mm^2$.

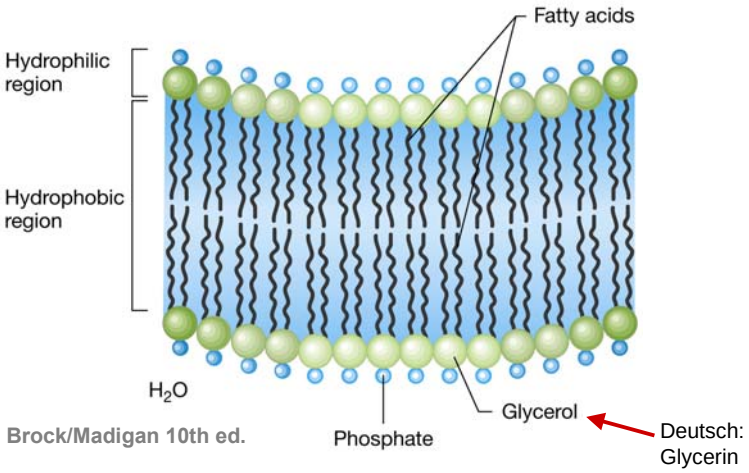
View field is only 0.01 $mm^2$:

(0.01 / 400) x $10^4$ = **0.25 per view field**



# Membranes

- **Properties, permeability, "function"**
- **Building blocks**
- **Differences between Bacteria, Archaea, Eukarya**

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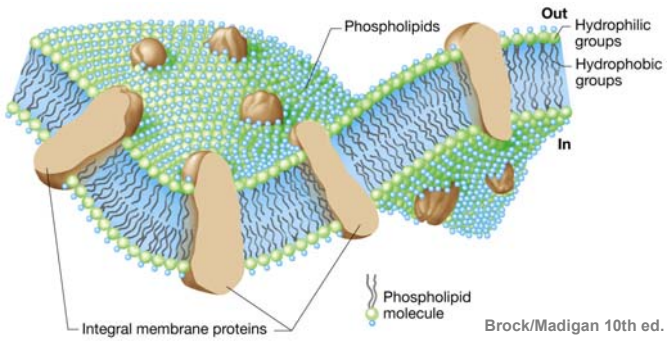
# Membranes

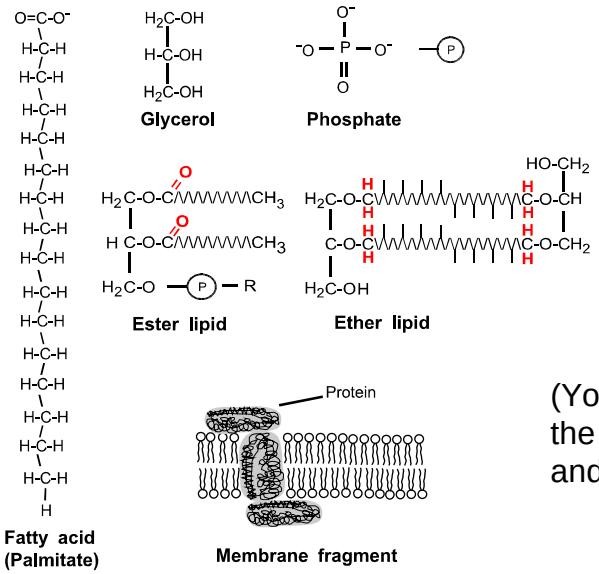
- **Thickness 2.5 + 3 + 2.5 = 8 nm**
- **Sidedness: defined by the proteins**
- **Semi-permeable (?)**




Brock/Madigan 10th ed.

- **Stands a membrane potential of 160 mV**
- **Permeable for uncharged small molecules**
- **Impermeable for the rest, if not mediated by transport proteins**

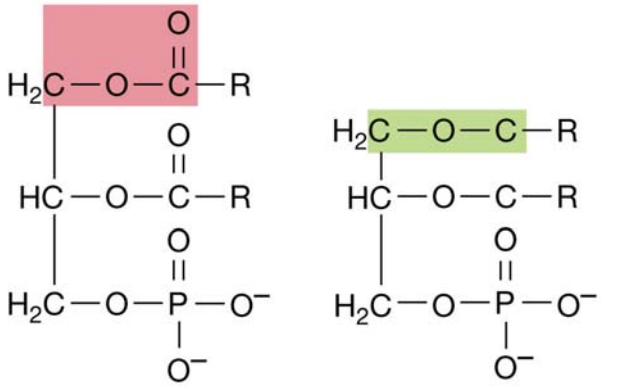
# Membrane – building blocks




(You should know the building blocks and bonding types)

Cypionka, Grundl. der Mikrobiologie

## Ester vs ether bonding

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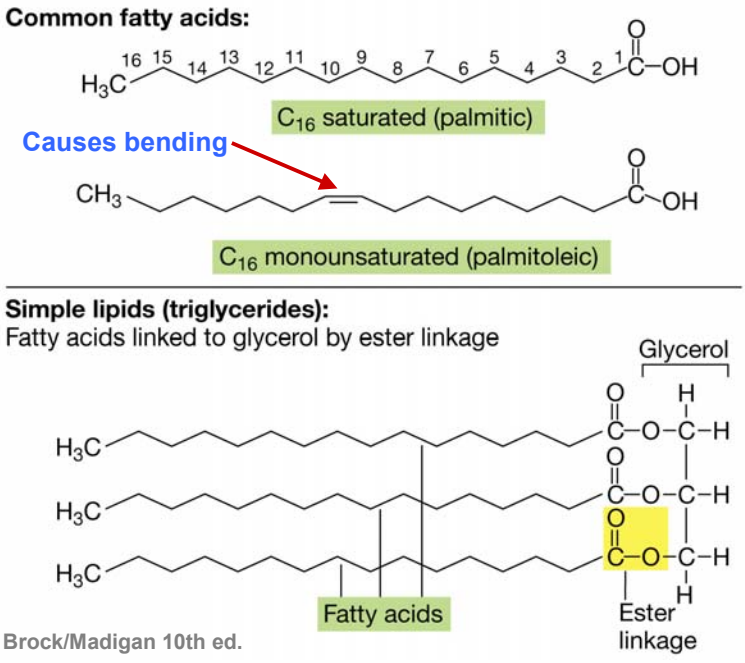
## Simple lipids

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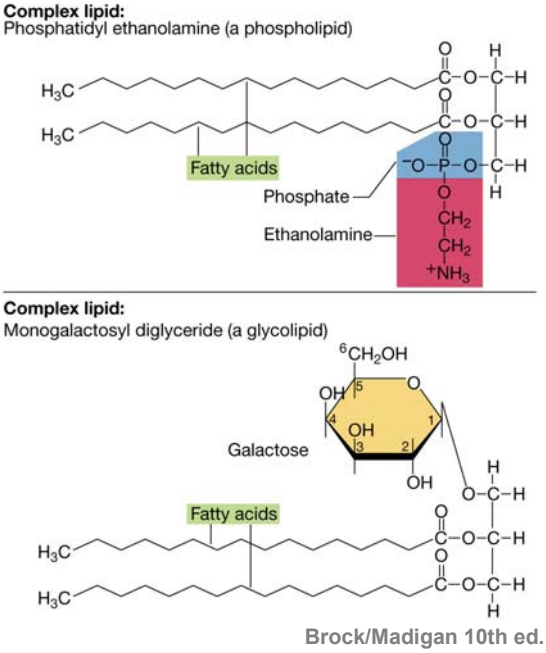
# Complex lipids

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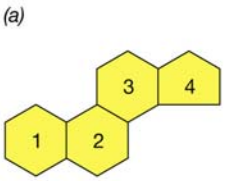
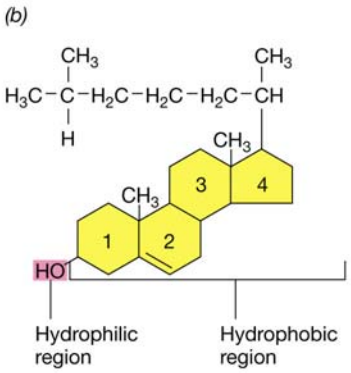
# Complex lipids

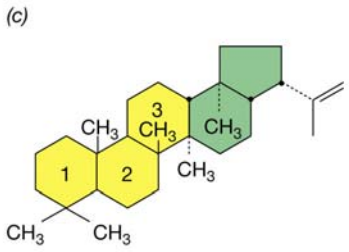
**Sterol ring structure**




**Cholesterol [Eukaryotes]**




**Hopanoid (Diploptene) [Bacteria]**

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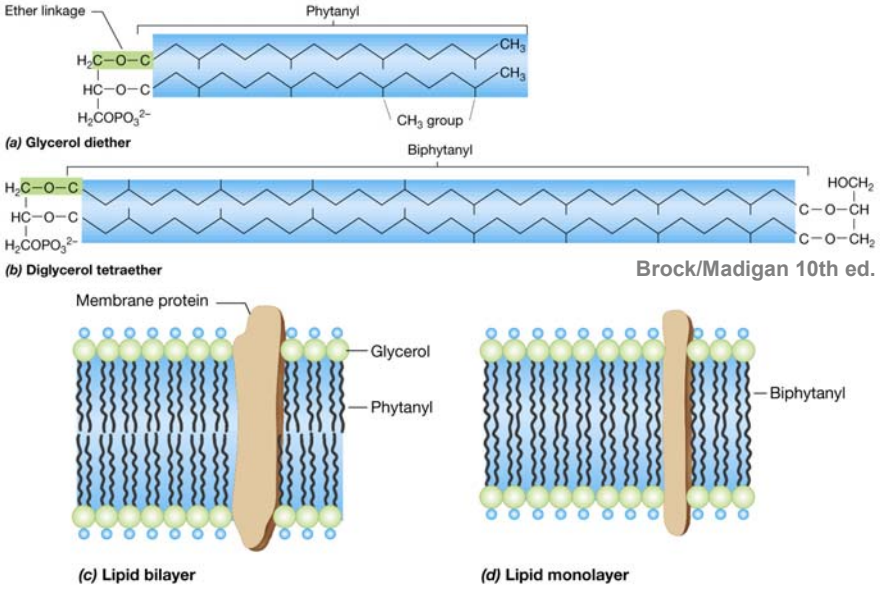
## Archaeal lipids

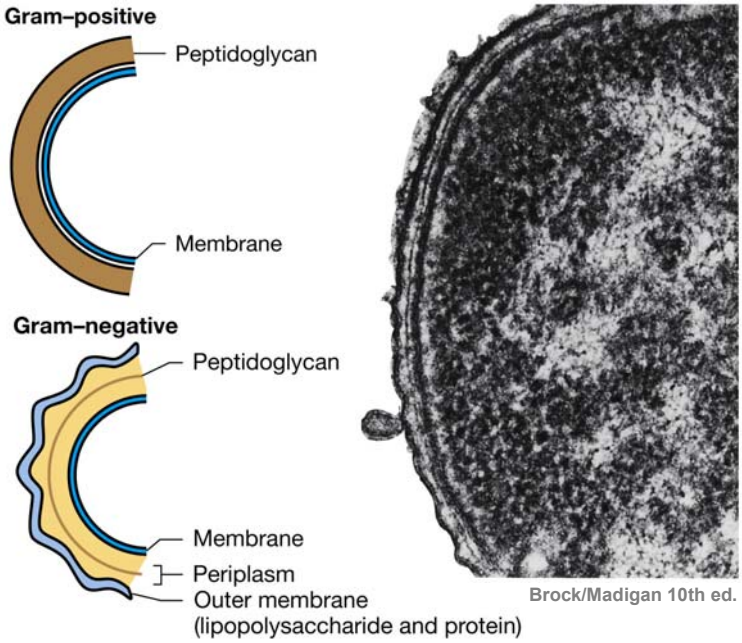



# Cell wall

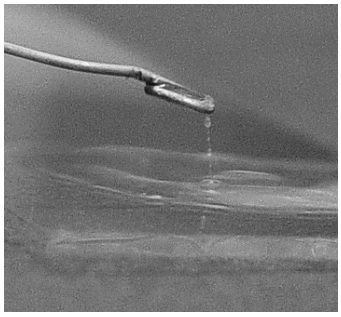
- **Properties, permeability, "function"**
- **Building blocks**
- **Differences between Bacterial groups and Archaea**

  - **Jute bag around a balloon**
  - **Pressure resistant (0.3 bar osmotic pressure)**
  - **Shaping the cell**
  - **Not a barrier for diffusing molecules**
  - **Diaminopimelic acid as cross-linker**
  - **Occurence of D-amino acids**

## Bacterial cell walls

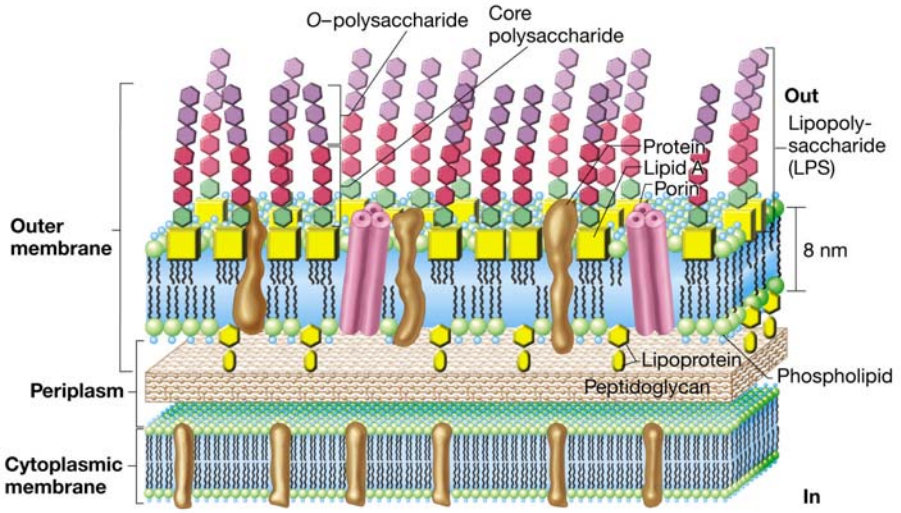



## Gram-Test with KOH



**3 % KOH causes lysis of Gram-negative cells and releases DNA**

## Cell wall of a Gram-negative bacterium

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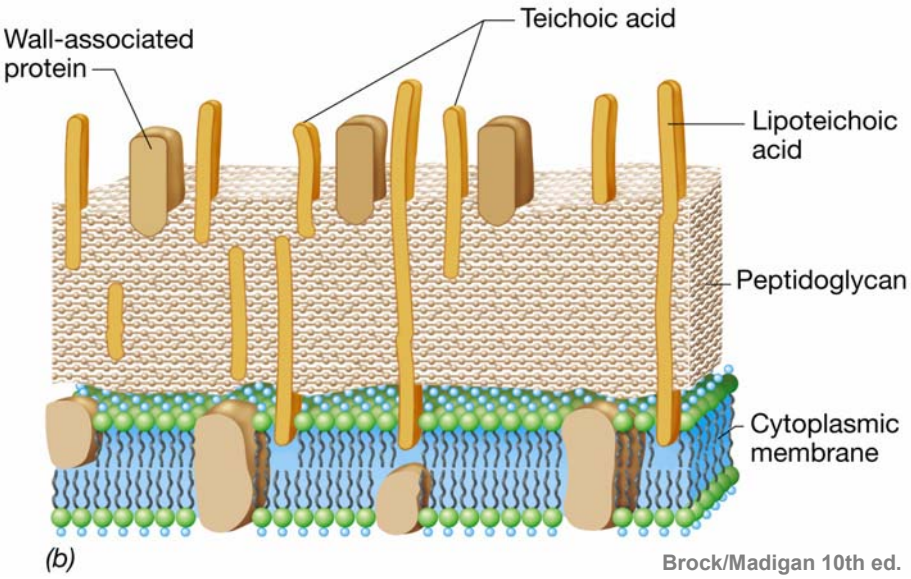
## Cell wall of a Gram-positive bacterium

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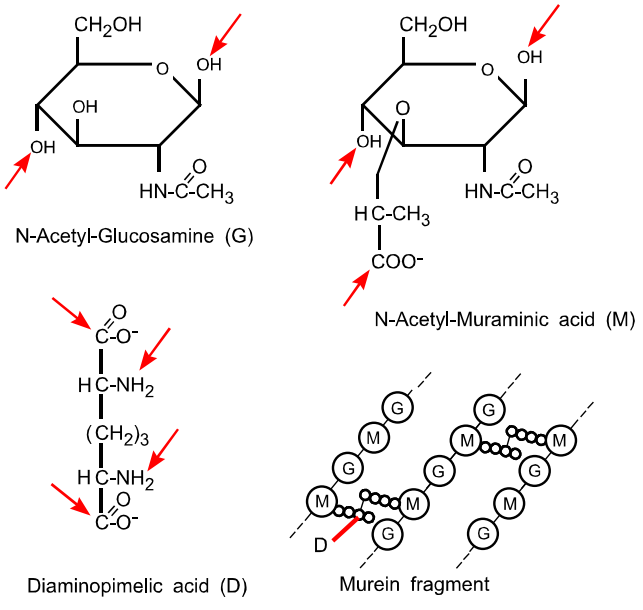
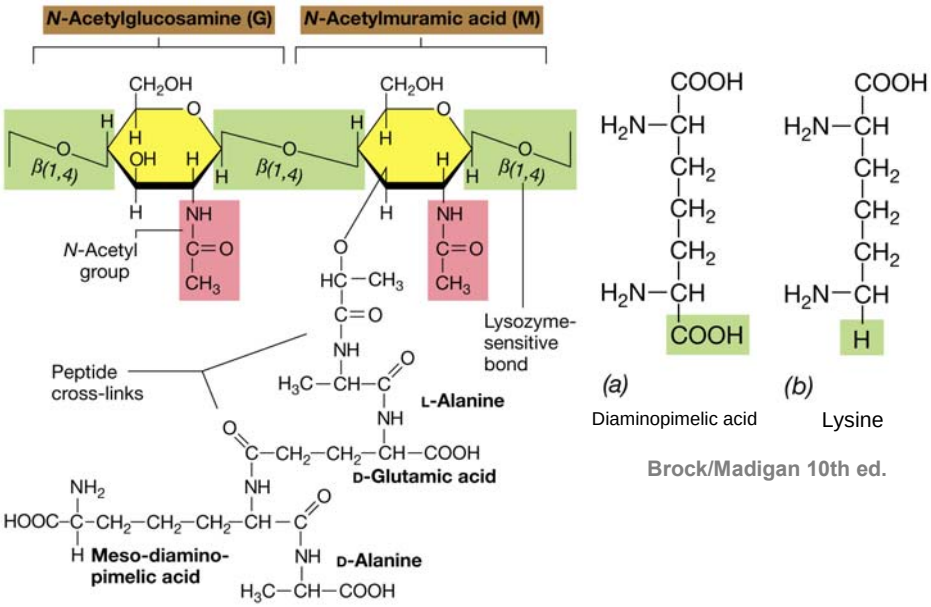
## Murein building blocks




Cypionka, Grundl. der Mikrobiologie

## Murein building block

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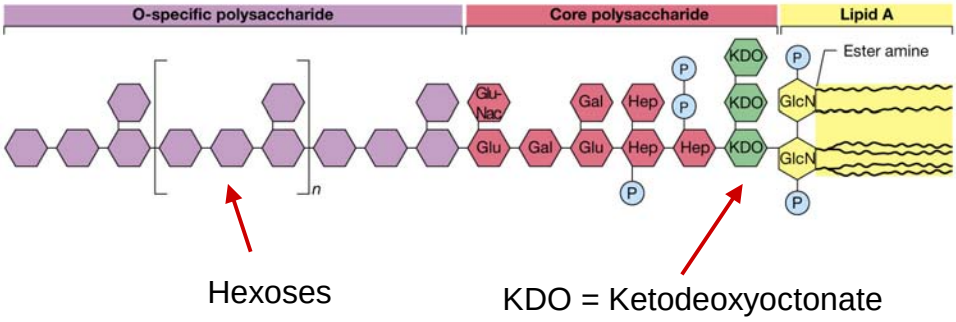
## Lipopolysaccharides typical for the cell wall of Gram-negative bacteria




LPS (Lipid A) active as Endotoxin

("although the major function is structural")

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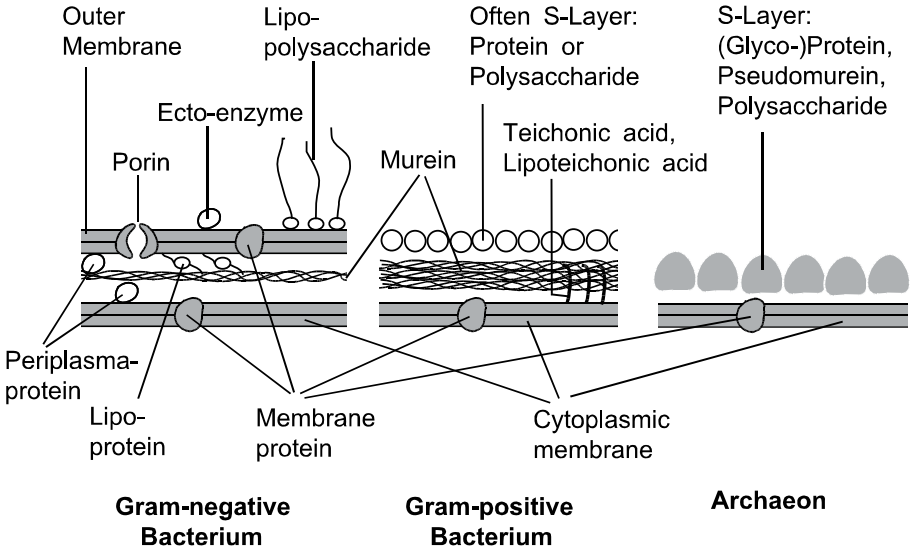
## Cell walls of Gram-negative and Gram-positive Bacteria and Archaea

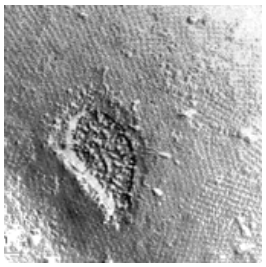



Cypionka, Grundl. der Mikrobiologie

## S-Layer

S-layers are the outermost component of the cell wall of many bacteria and most of archaea.

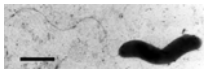
S-layer proteins form natural two-dimensional protein crystals covering the cell completely and confering stability in addition to other structures of the cell envelope.



www.biochem.mpg.de/baumeister/membran/S-layers

## Cell surface structures

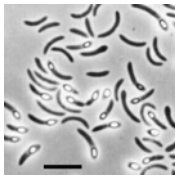
- **Flagella, Fimbriae**



- **Capsules**

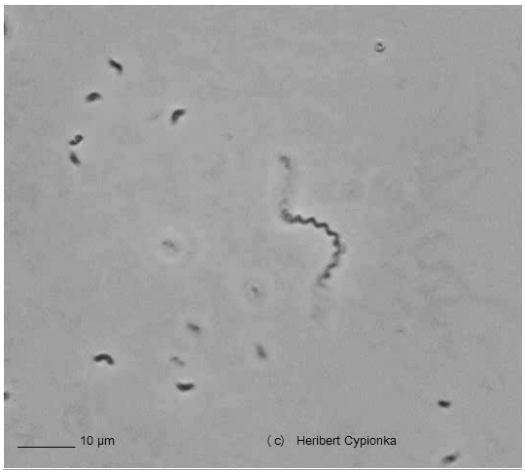
(Indian Ink contrasting)

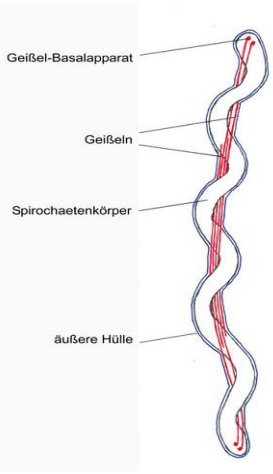
- **Spores**



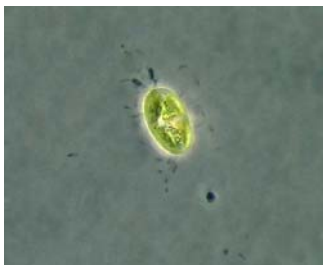
(not a surface structure)

## Spiroch(a)ete and Spirilli

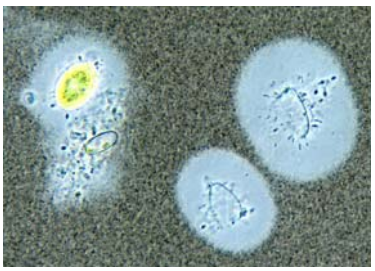



## Slime capsules

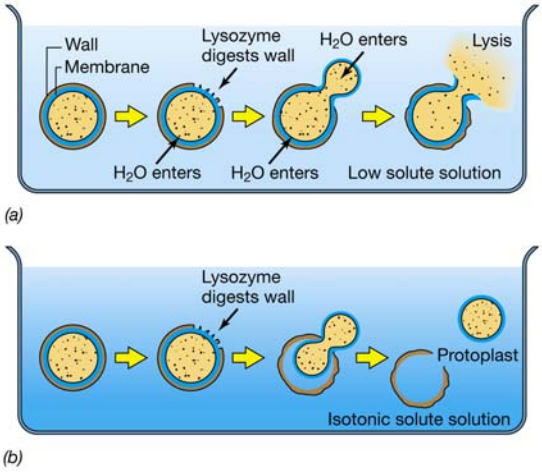


**Alga in a horse trough**



**Capsule visualisation by means of indian ink (negative contrasti)**

## Cells without cell wall?




*Mycoplasma*

*Thermoplasma*

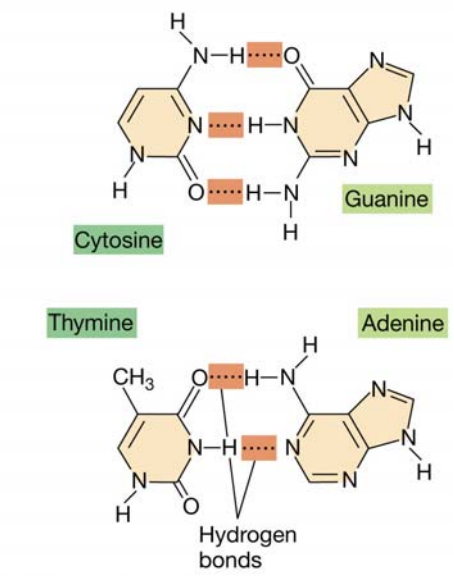
Brock/Madigan 10th ed.

## Nucleoid

- **Mostly 1 chromosome**
- **Many with plasmids**

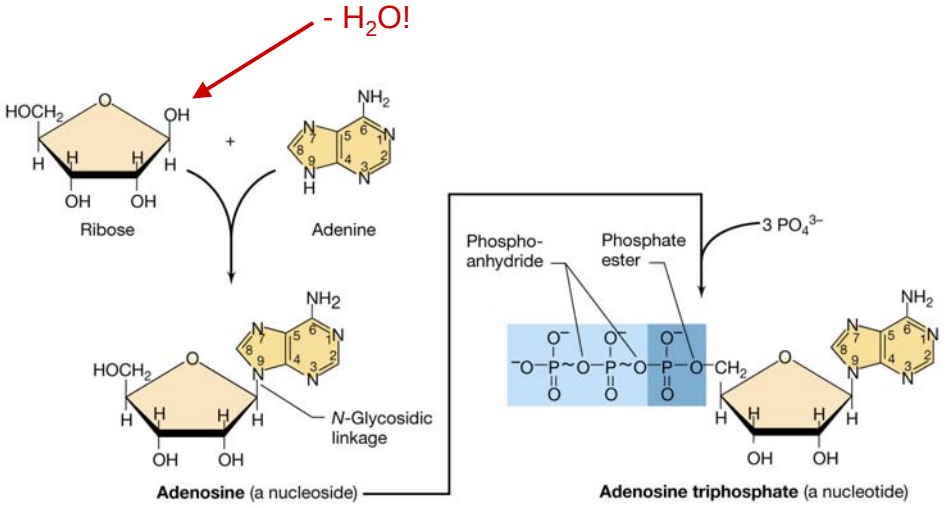
Brock/Madigan 10th ed.

## Building blocks of nucleic acids



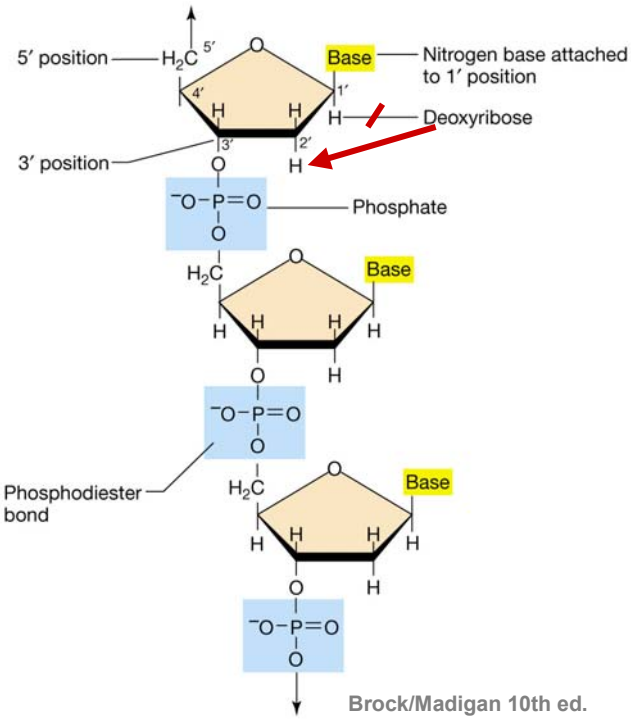

Brock/Madigan 10th ed.

## N-Glycosidic linkage, anhydride, ester

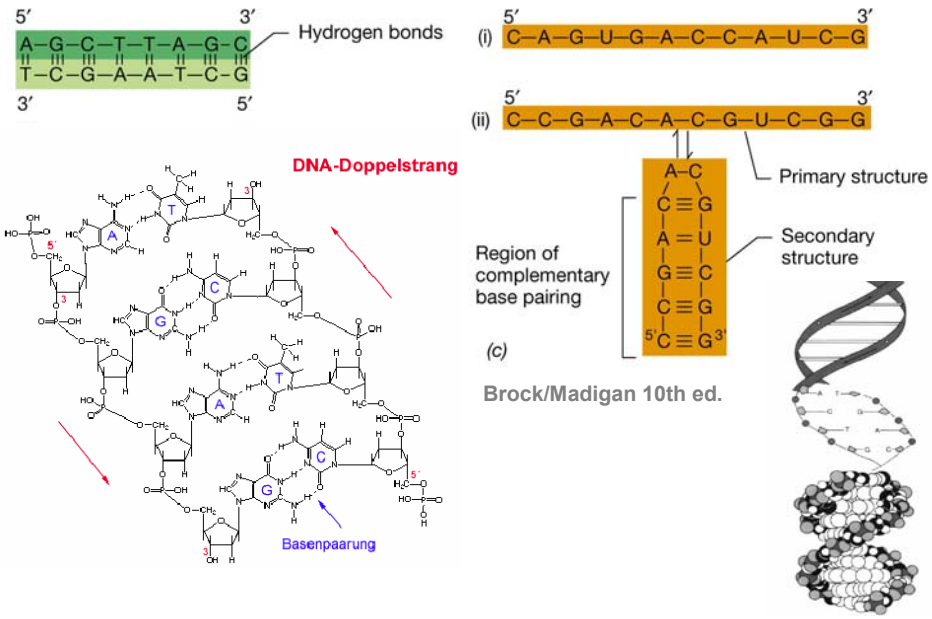



Brock/Madigan 10th ed.

## DNA




## Hydrogen bonds, primary and secondary structure



## How much information is encoded in DNA?

***E. coli*: 1.3 mm DNA = 4 million base pairs**

**about 4 000 proteins encoded**

**2 bits per base**

**8 million bits = 1 MB**

**For comparison: Human genome**

**1 m DNA, about 25 000 genes**

## Cytoplasm: Composition of a bacterial cell

| Compound | Percent of dry mass | Per cell (≈$10^{-15}$ l) | |
|---|---|---|---|
| | | Number of molecules | Different molecules |
| $H_2O$ | 500 | $10^{11}$ | 1 |
| Proteins | 50 | $10^6$ | 1000 |
| Cell wall | 20 | 1 | 1 |
| RNA | 15 | $10^4$ (Ribosomes) | 1000 (mRNAs) |
| DNA | 3 | 1 | 1 |
| Lipids | 5 | $10^6$ | 50 |
| Small org. compds. (Amino acids, ATP...) | 5 | $10^6$ | 200 |
| Inorg. Ions ($K^+$) | 1 | $10^8$ | 20 |
| $H^+$ (pH≈8) | 0 | 6 | 1 |