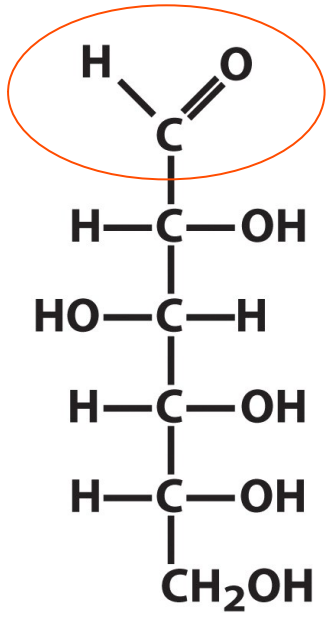
# BioChem 330 - Course Outline

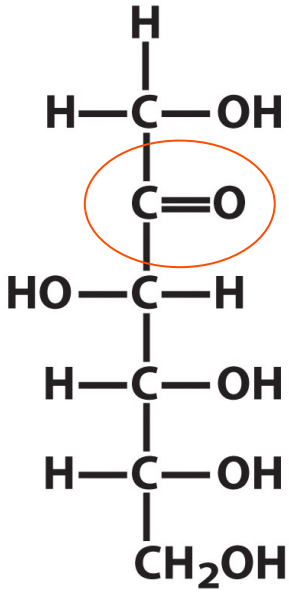
**October 4-6, 2011**

- **Bio-molecular Structure/Function (I cont'd)**
  - NUCLEIC ACID
    - DNA sequence and structure
    - Protein/nucleic acid interactions
  - CARBOHYDRATES
    - Sugars - mono and disaccharides
    - Polysaccharides
    - Glycerides and glycerol
  - FATS AND LIPIDS
    - Chemistry and nomenclature for fatty acids
    - Saturated and unsaturated fatty acids
    - Fluid mosaic model of membrane structure

# sugar chemistry




D-Glucose,
an aldohexose

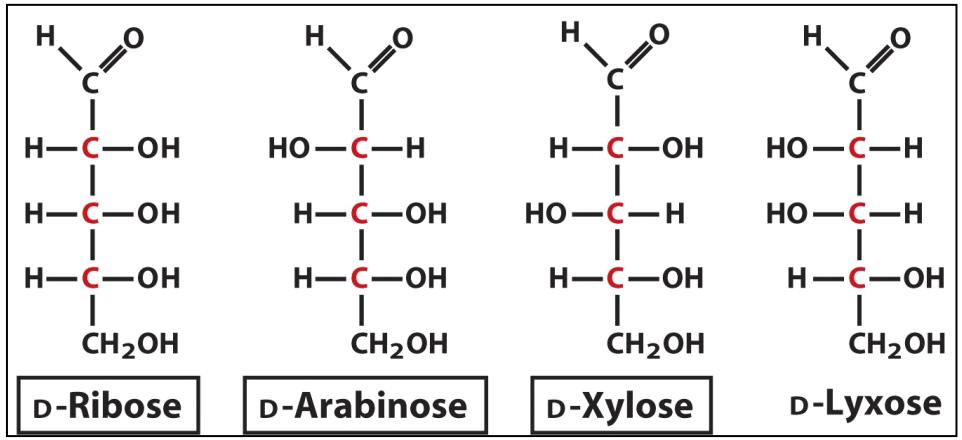


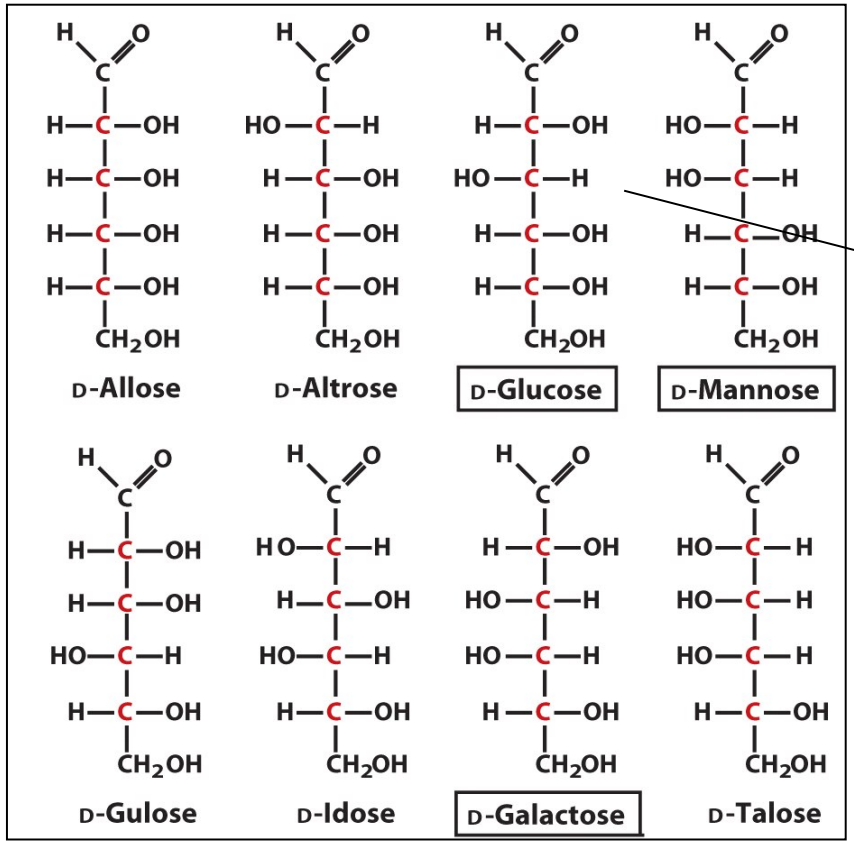

D-Fructose,
a ketohexose

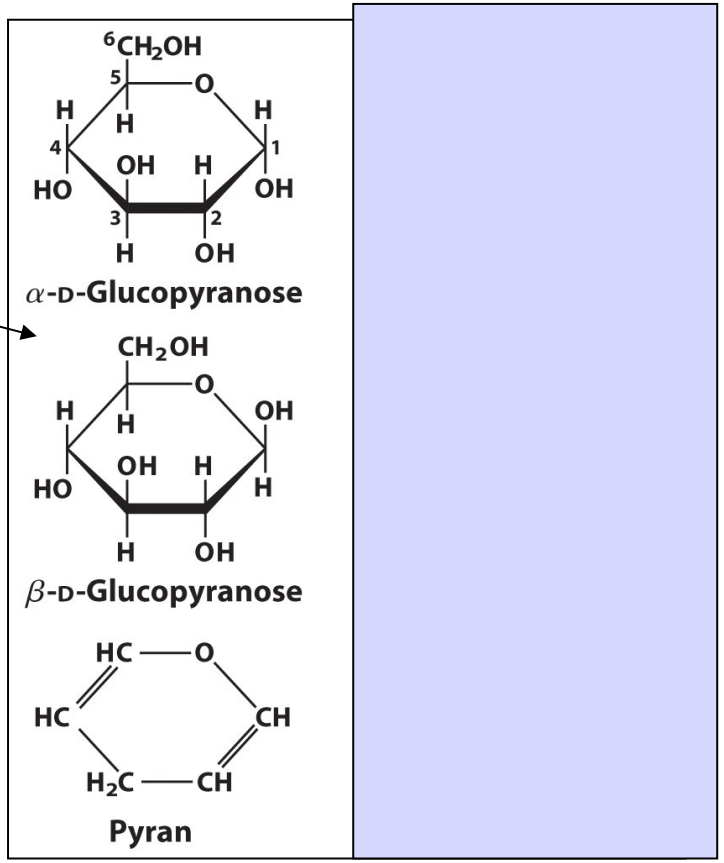

Fischer projection formulas


Perspective formulas

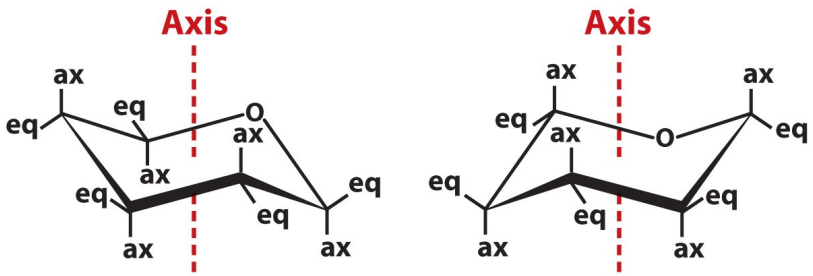
# Five and Six Carbon Aldose Sugars important in Biology

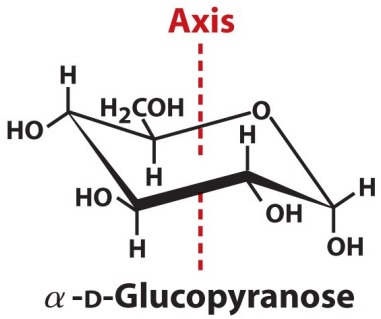


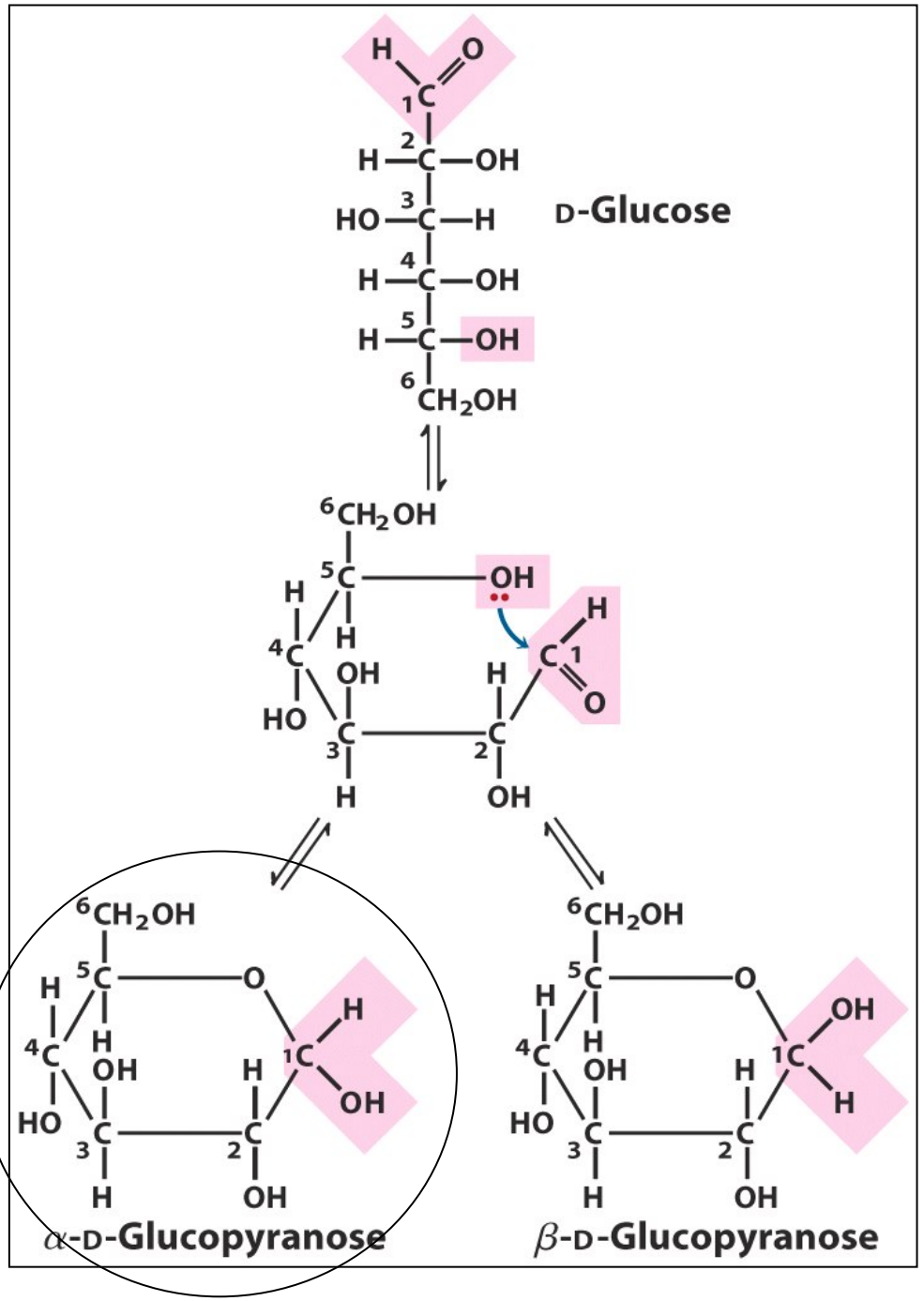



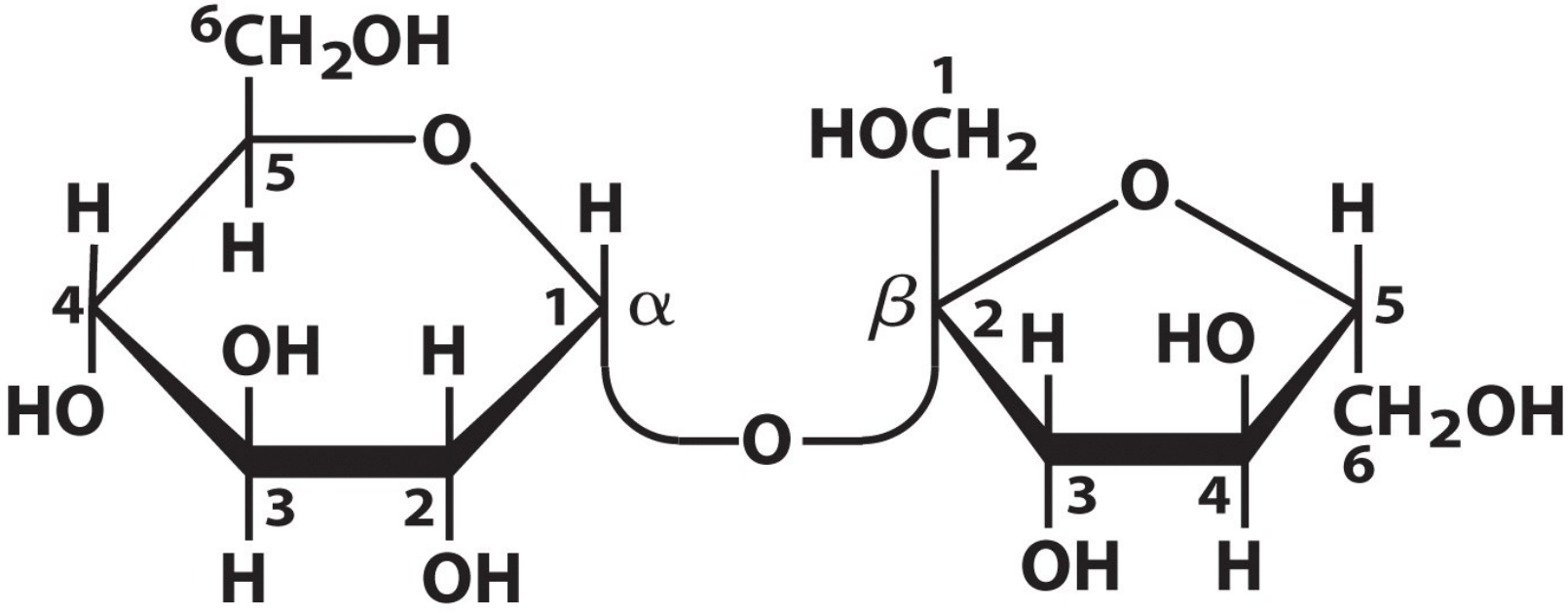



# Cyclization of six carbon sugar to form α or β pyranose






**Sucrose**

**α-D-glucopyranosyl β-D-fructofuranoside**

**Glc(α1↔2β)Fru**

Sugars are frequently packaged as complex carbohydrates, here shown as the disaccharide sucrose, but also as polysaccharides such as glycogen (D-glucose α1→4 linkages plus occasional branches α1→6) or cellulose (D-glucose β1→4)

# Job Description for a Biological Membrane

- **Control the ionic composition** of the cytoplasm by highly specific transporters (act as a barrier to diffusion)
- **Form a dynamic matrix** for enzymatic reactions, receptor processes and immunological recognition (act as a surface)
- **Guarantee the integrity** of the cell and influence its shape and movement as well as the displacement of organelles (act as a mechanical structure)
- **Contain a mosaic of various passive and active electrical devices**, control the potential at and near the membrane, control electrodynamic conditions (act as an electrically isolating leaflet)

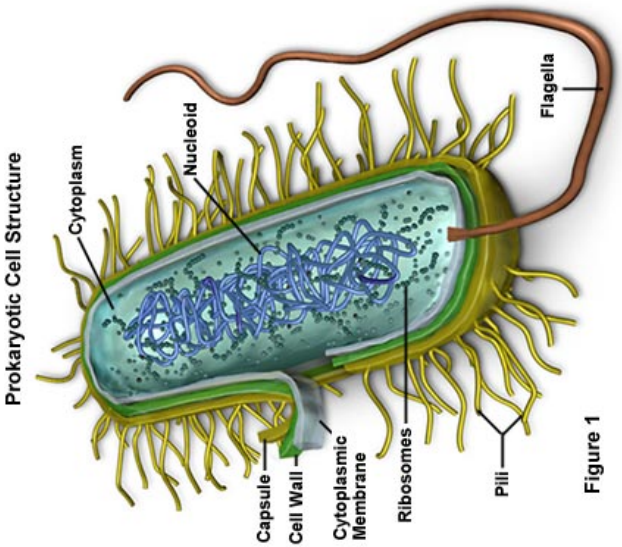
Glaser Biophysics p80

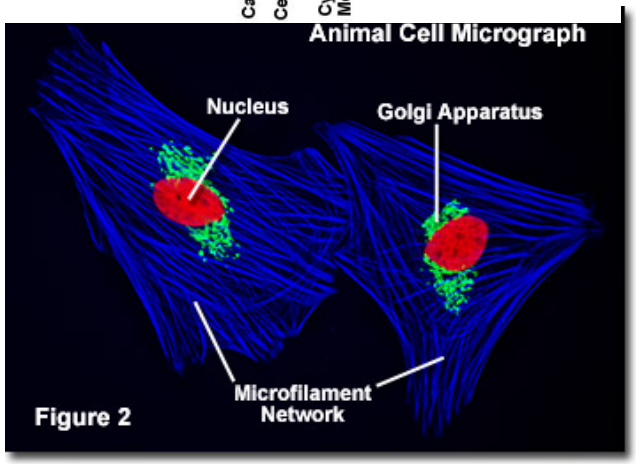
# Barriers to the world outside

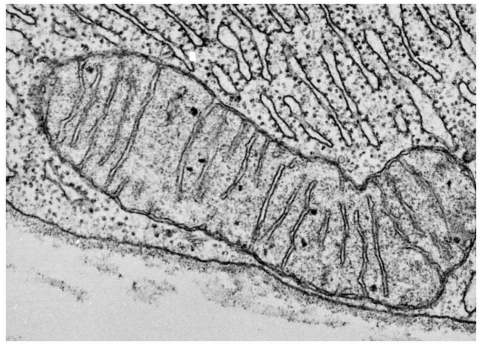
- Prokaryotes lack inner organelles, but have much more complicated outer walls, with capsules, cell walls that can be several layers thick and a cytoplasmic membrane (1 micron)

- Eukaryotic cells can be larger (10 microns-0.1 m) and the lipid bilayer is the plasma membrane that separates inside from outside. Inside are organelles many of which such as the nucleus, also have their own lipid bilayers Plant cells have chloroplasts and an outer wall

- Mitochondrion organelles within the eurkaryotic cells have a double wall. These inner and outer membranes, vestigial remnant of their former prokaryotic origin (electron micrograph at right)



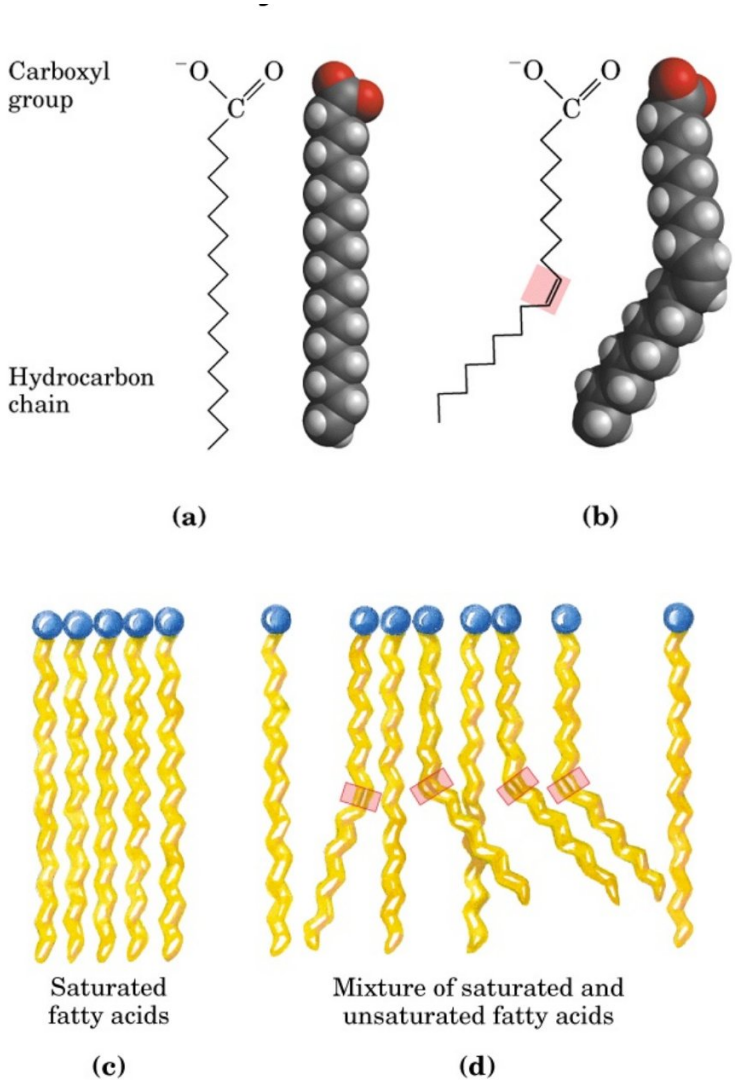



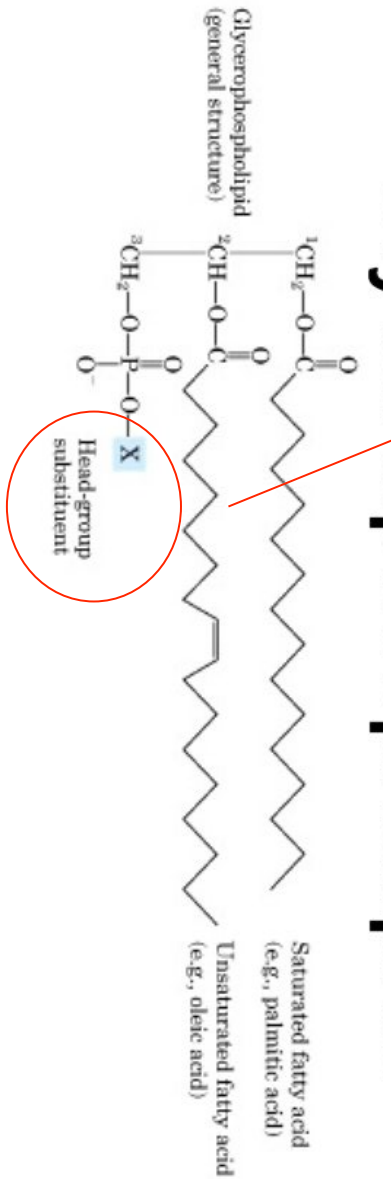
http://www.molecularexpressions.com/cells

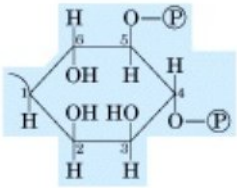
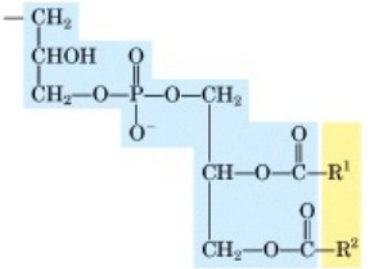
# Fatty acids self assemble into bilayers and micelles

- Polar head group (acid component) orients towards aqueous phase
- Non-polar tail (long hydrocarbon chain) orients towards inside (micelle) or towards other layer in a bilayer (shown)



# Biological Membranes are made up of Phospholipids



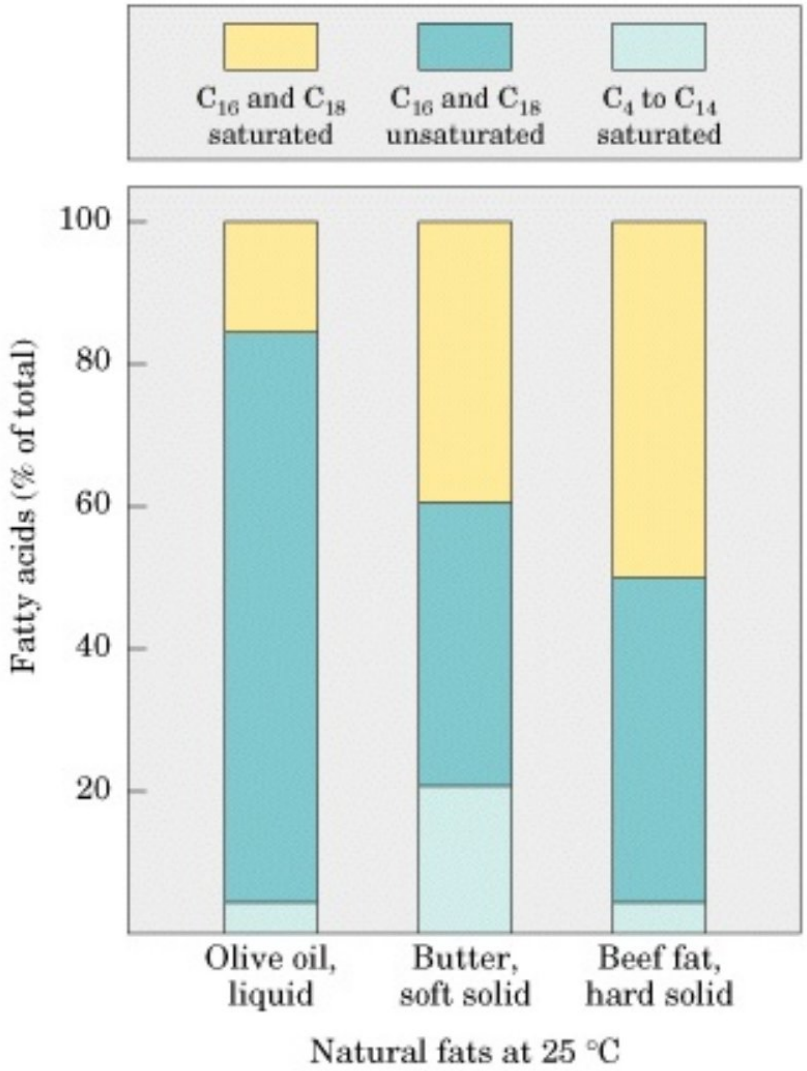

| Name of glycerophospholipid | Name of X | Formula of X | Net charge (at pH 7) |
|---|---|---|---|
| Phosphatidic acid | — | —H | −1 |
| Phosphatidylethanolamine | Ethanolamine | $-CH_2-CH_2-\overset{+}{N}H_3$ | 0 |
| Phosphatidylcholine | Choline | $-CH_2-CH_2-\overset{+}{N}(CH_3)_3$ | 0 |
| Phosphatidylserine | Serine | $-CH_2-\underset{COO^-}{CH}-\overset{+}{N}H_3$ | −1 |
| Phosphatidylglycerol | Glycerol | $-CH_2-\underset{OH}{CH}-CH_2-OH$ | −1 |
| Phosphatidylinositol 4,5-bisphosphate | *myo*-Inositol 4,5-bisphosphate |  | −4 |
| Cardiolipin | Phosphatidyl-glycerol |  | −2 |

# Common fatty acid components of biological membranes

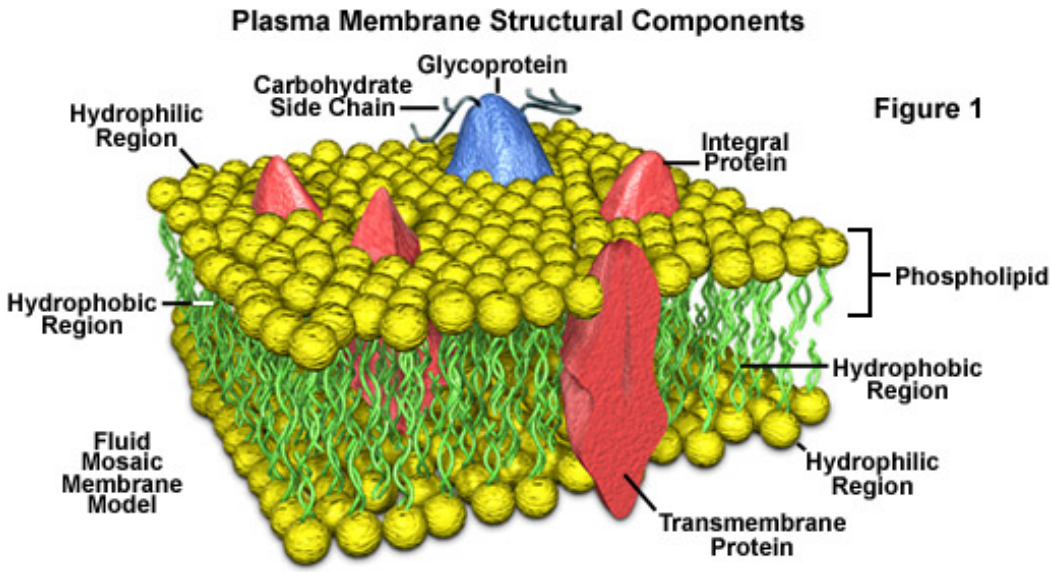
| Common Name | Systematic Name | Abbreviation | Structure | Melting Point (°C) |
|---|---|---|---|---|
| **Saturated Fatty Acids** | | | | |
| Capric | *n*-Decanoic | 10:0 | $CH_3(CH_2)_8COOH$ | 31.6 |
| Lauric | *n*-Dodecanoic | 12:0 | $CH_3(CH_2)_{10}COOH$ | 44.2 |
| Myristic | *n*-Tetradecanoic | 14:0 | $CH_3(CH_2)_{12}COOH$ | 53.9 |
| Palmitic | *n*-Hexadecanoic | 16:0 | $CH_3(CH_2)_{14}COOH$ | 63.1 |
| Stearic | *n*-Octadecanoic | 18:0 | $CH_3(CH_2)_{16}COOH$ | 69.6 |
| Arachidic | *n*-Eicosanoic | 20:0 | $CH_3(CH_2)_{18}COOH$ | 76.5 |
| Behenic | *n*-Docosanoic | 22:0 | $CH_3(CH_2)_{20}COOH$ | 81.5 |
| Lignoceric | *n*-Tetracosanoic | 24:0 | $CH_3(CH_2)_{22}COOH$ | 86.0 |
| Cerotic | *n*-Hexacosanoic | 26:0 | $CH_3(CH_2)_{24}COOH$ | 88.5 |
| **Unsaturated Fatty Acids** | | | | |
| Palmitoleic | *cis*-9-Hexadecenoic | 16:1cΔ9 | $CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$ | 0 |
| Oleic | *cis*-9-Octadecenoic | 18:1cΔ9 | $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$ | 16 |
| Linoleic | *cis,cis*-9,12-Octadecadienoic | 18:2cΔ9,12 | $CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$ | 5 |
| Linolenic | all-*cis*-9,12,15-Octadecatrienoic | 18:3cΔ9,12,15 | $CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$ | −11 |
| Arachidonic | all-*cis*-5,8,11,14-Eicosatetraenoic | 20:4cΔ5,8,11,14 | $CH_3(CH_2)_4CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_3COOH$ | −50 |
| **Branched and Cyclic Acids** | | | | |
| Tuberculostearic | *l*-D-10-Methyloctadecanoic | | $CH_3(CH_2)_7CH(CH_3)(CH_2)_8COOH$ | 13.2 |
| Lactobacillic | ω-(2-*n*-Octylcyclopropyl)-octadecanoic | | $CH_3(CH_2)_5CH(CH_2)CH(CH_2)_9COOH$ | 29 |

# Fatty acid compositions of fats

- Saturated (no double bonds)
  - Tend to form more rigid structures because hydrocarbon chains can be closely packed
  - Example animal fats (crisco, butter)
- Unsaturated (one or more double bonds)
  - Tend to form less rigid structures (higher Tm) because kinks due to double bonds resist packing
  - Examples plant fats (olive oil)
  - Can be cis or trans fats, **cis** fats can be more easily metabolized by fatty acid machinery in cell



# Membranes: fluid mosaic model




- Fluid mosaic model –
  - two dimensional lipid bilayer with random motion within layers, minimal diffusion between layers http://www.youtube.com/watch?v=Qqsf_UJcfBc (Singer and Nicholson 1972)
  - Embedded proteins can be integral or transmembrane, and many of them are glycosylated (that is they have complex carbohydrate groups added to the protein side chains).
  - Hydrophobic substances such as cholesterol further add rigidity to the membrane

# Membrane Deformations

A. Translation and Rotation

B. Planar extension

C. Shear deformation

D. Translocation of membrane proteins by spectrin network

E. Mending of membrane by asymmetric lipids or proteins

F. Extrusion of membrane components with lower flexibility from bended areas

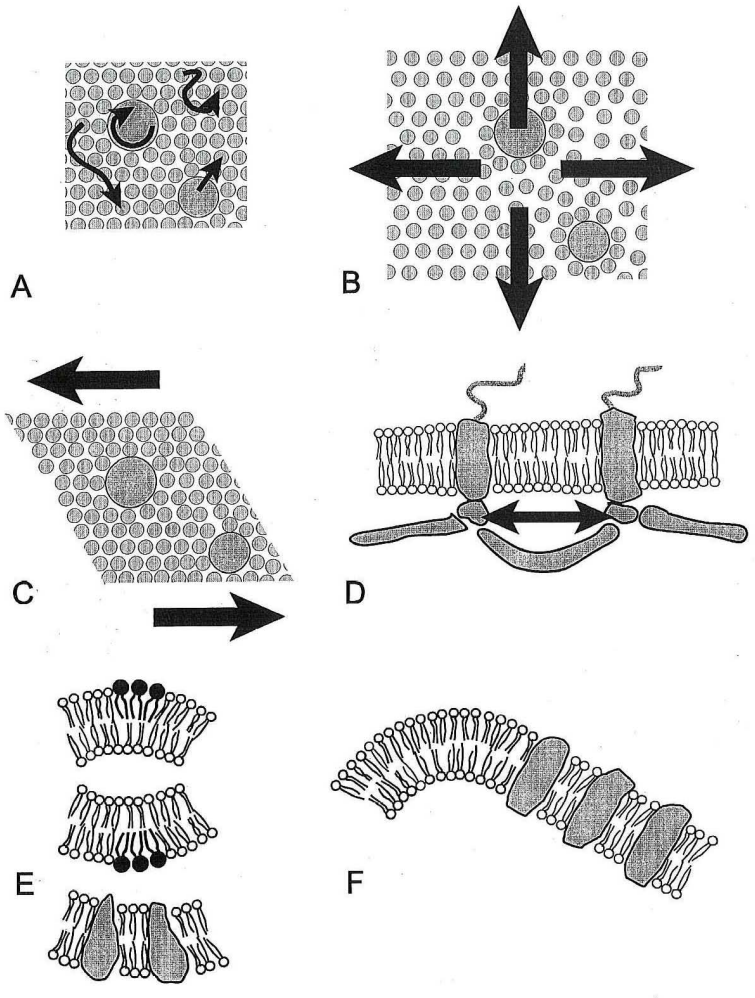



Figure 2.41 Glaser p 89

# Membrane Deformations

- Rapid lateral (within surface) diffusion for lipids (us to ms)
- Proteins (attached to cytoskeletal components) travel slowly or not at all
- Slower transverse diffusion between surfaces (min to hours) but can be assisted by lipid exchange systems

Glaser p 89

Easy deformation by sheering interactions (area is conserved)

Nearly impossible to extend the area of bilayer

Elasticity measured by property Y (Young's modulus)

Rubber: Y = 1 MPa

Erythrocytes: Y = 56 MPa

Bone: Y = 10,000 MPa

1-2 % stretching breaks cell, cell lysis by swelling common first step in protein purification

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Review

# Dynamics in the plasma membrane: how to combine fluidity and order

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**Cell membranes are fascinating supramolecular aggregates that not only form a barrier between compartments but also harbor many chemical reactions essential to the existence and functioning of a cell. Here, it is proposed to review the molecular dynamics and mosaic organization of the plasma membrane, which are thought to have important functional implications. We will first summarize the basic concepts of Brownian diffusion and lipid domain formation in model membranes and then track the development of ideas and tools in this field, outlining key results obtained on the dynamic processes at work in membrane structure and assembly. We will focus in particular on findings made using fluorescent labeling and imaging procedures to record these dynamic processes. We will also discuss a few examples showing the impact of lateral diffusion on cell signal transduction, and outline some future methodological challenges which must be met before we can answer some of the questions arising in this field of research.**

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*Keywords*: actin meshwork; cell membrane; fluorescence microscopy; lateral diffusion; membrane microdomain