Introduction to Biochemistry

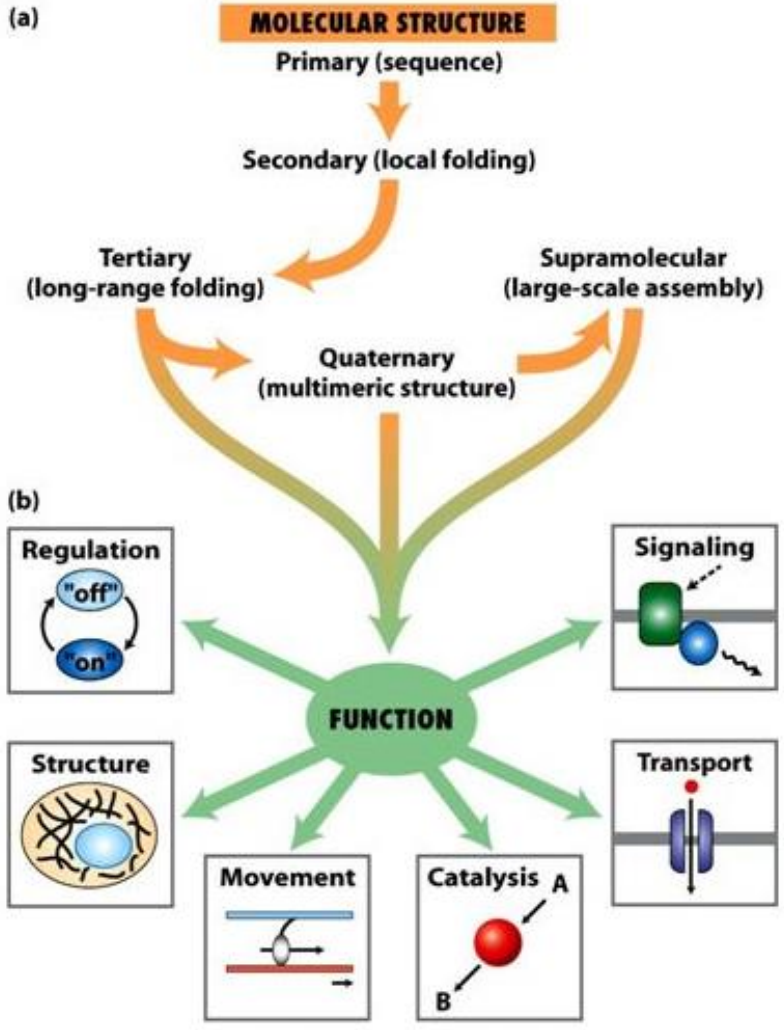
Part 1: Review of General Chemistry and Organic Chemistry

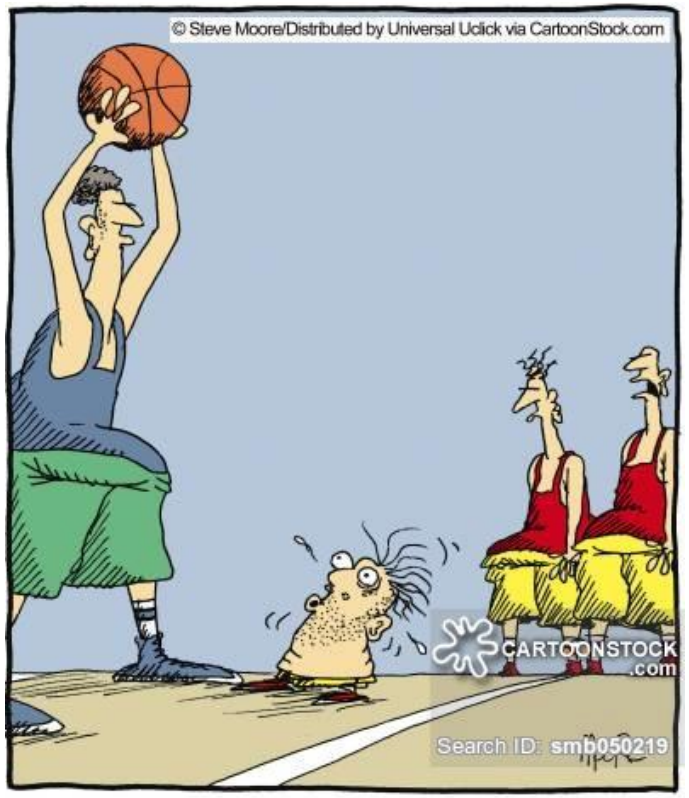
Dr. Matthew Lafrenière

16 May 2019

The Fundamental Concept of Biochemistry

Structure → **Function**

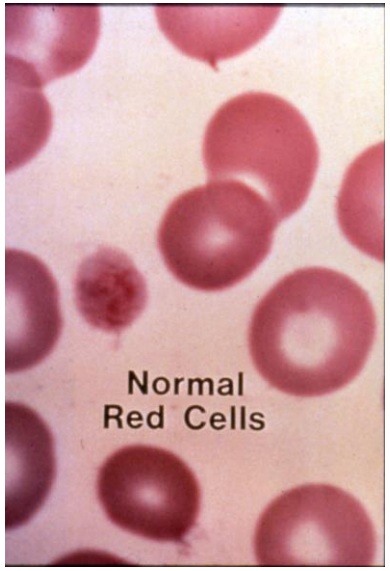




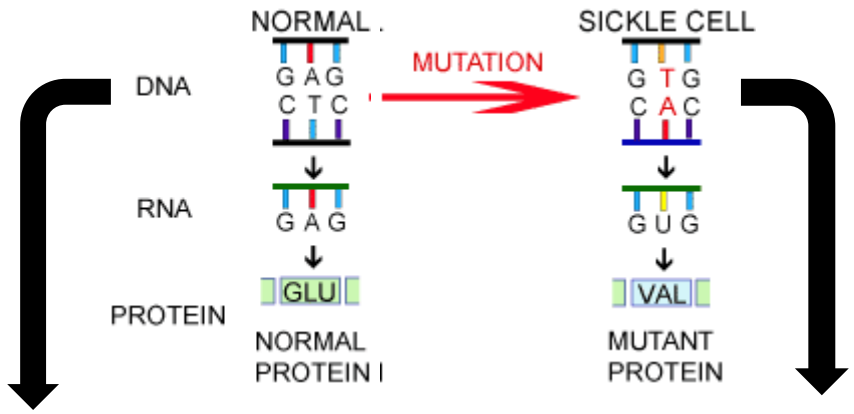
"He can't dribble or shoot, but he's got a good head for the game."

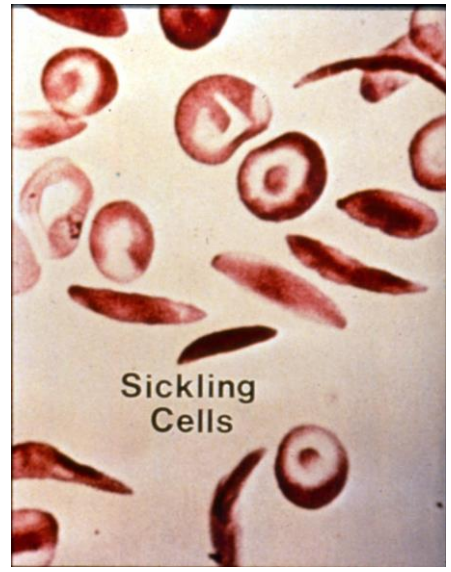
Photo Credits: University of Pennsylvania; *Nature Reviews Molecular Cell Biology* **volume 15**, pages 384–396 (2014)

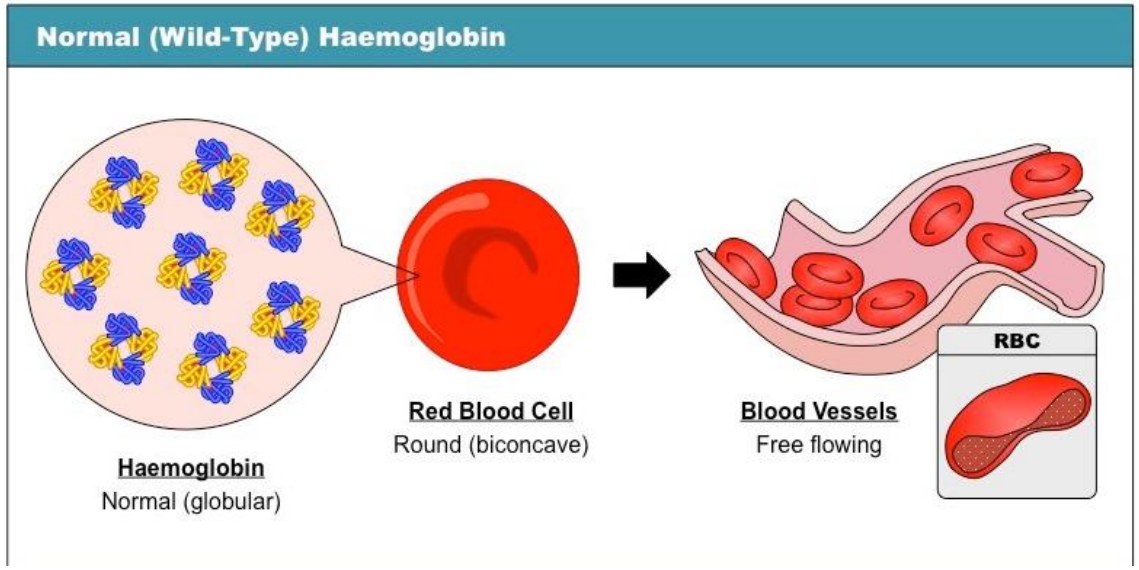
The Fundamental Concept of Biochemistry



Structure → **Function**







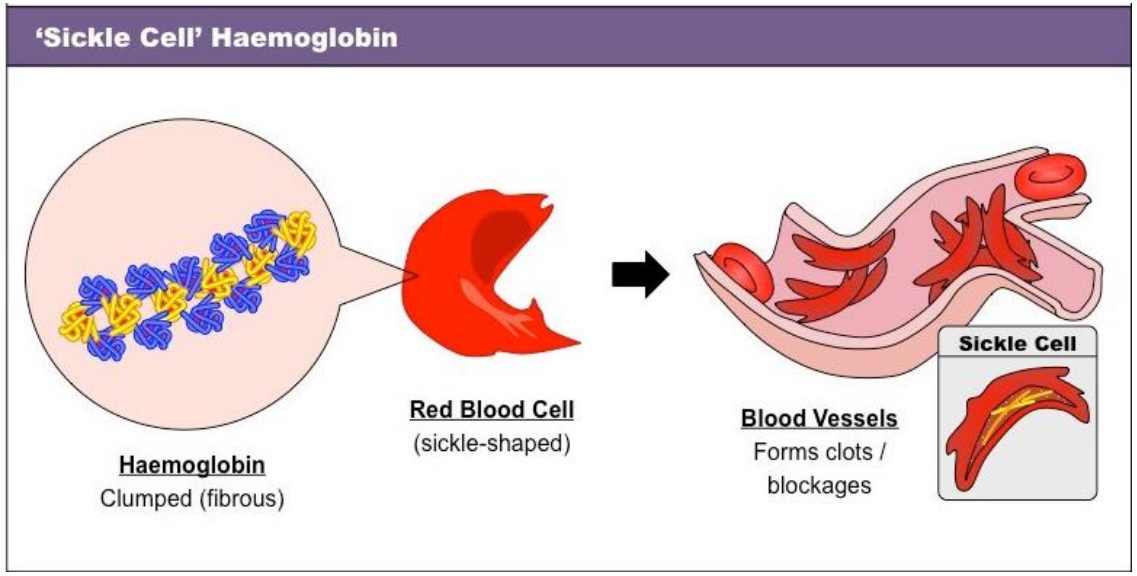
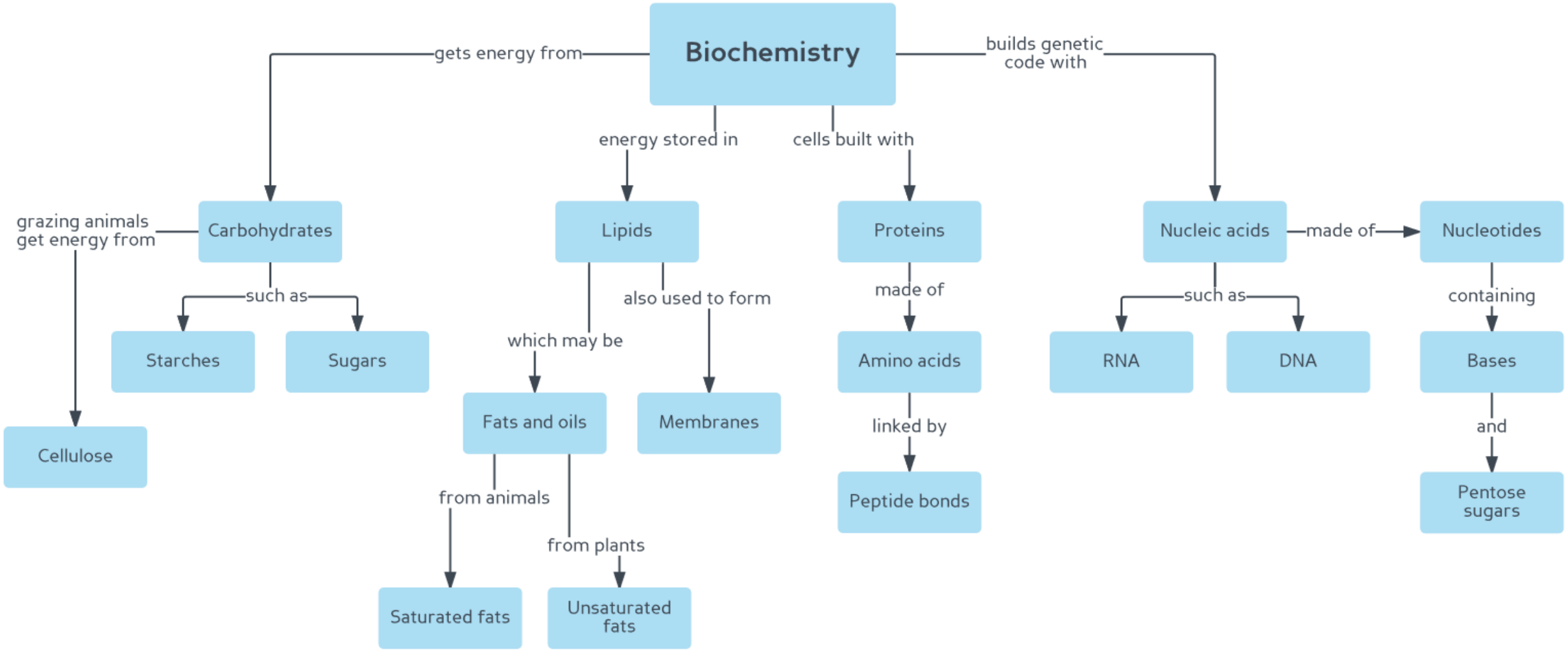


Photo credits: https://www.gemssforschools.org/conditions/sickle-cell-disease/default/learn-more-scd ; https://ib.bioninja.com.au/standard-level/topic-3-genetics/31-genes/mutations.html ;

What is biochemistry?

- **Biochemistry:** the study of the chemical and physiochemical processes and substances that occur in life!



https://www.lucidchart.com/pages/templates/concept-map/biochemistry-concept-map-template

The Origins of Life: Version I

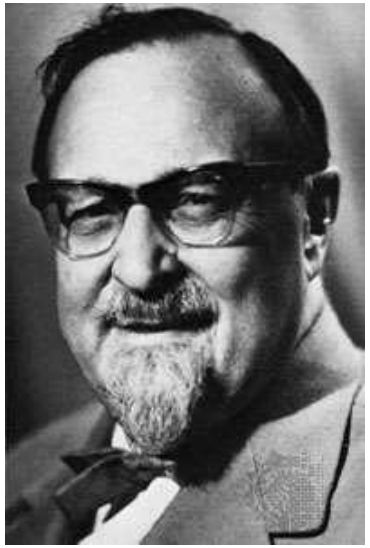
- The primordial earth had:
- 1. A reducing atmosphere
- 2. No complex organic molecules

- Alexander Oparin and John Haldane (1920s) proposed the **Primordial Soup Theory**

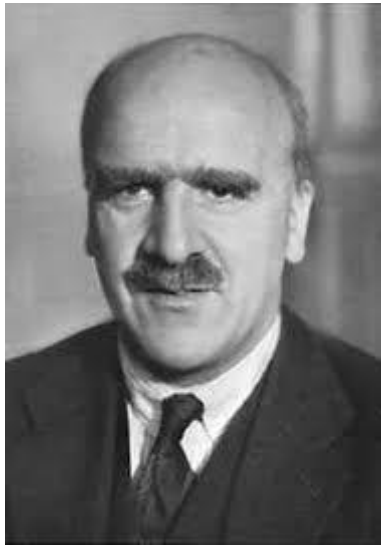
https://i.ytimg.com/vi/CCwBRfBHeag/maxresdefault.jpg

The Origins of Life: Version I

- In 1924, Alexander Oparin hypothesized that organic molecules could undergo a series of chemical reactions to become more complex
  - These coacervates, which are complex molecules, could be capable of absorption and assimilation of organic compounds in the environment.
  - He called this the "**primordial soup**" theory



- Independent of Alexander Oparin, J.B.S. Haldane proposed that a primordial sea could provide vast amounts of chemical energy – due to solar energy



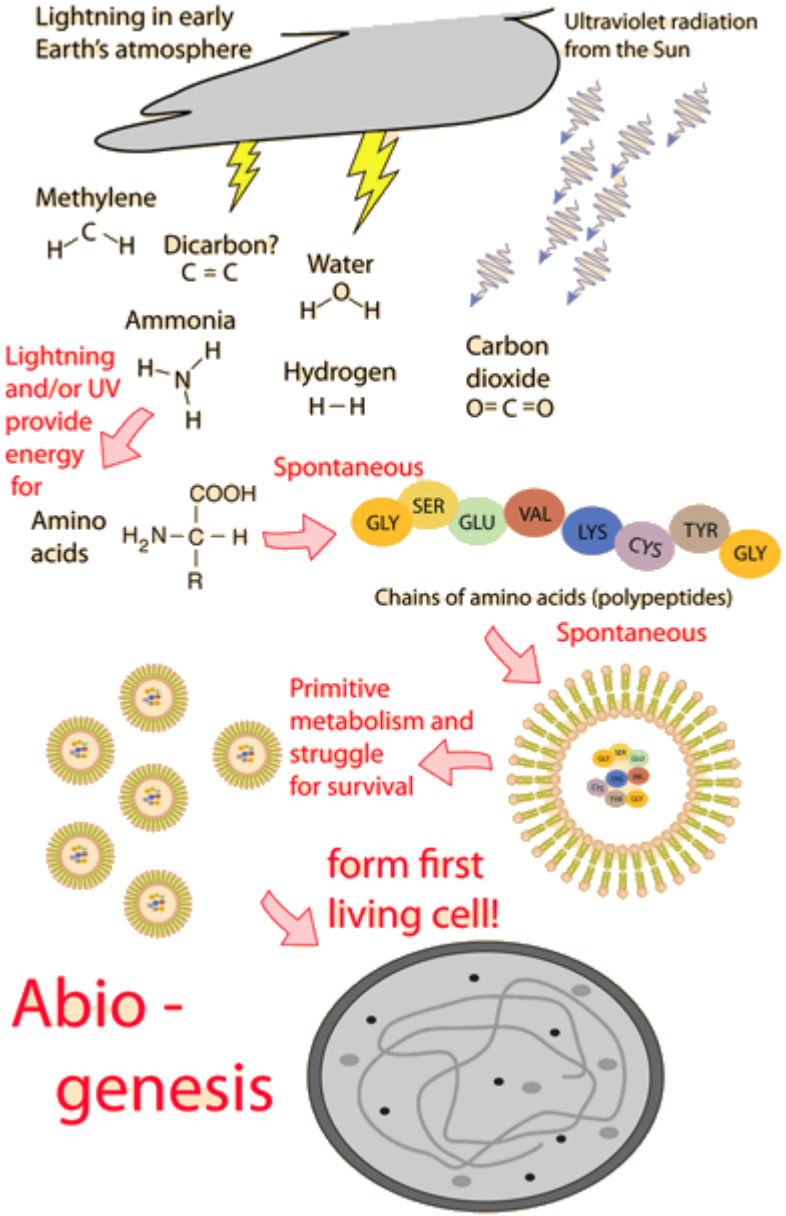
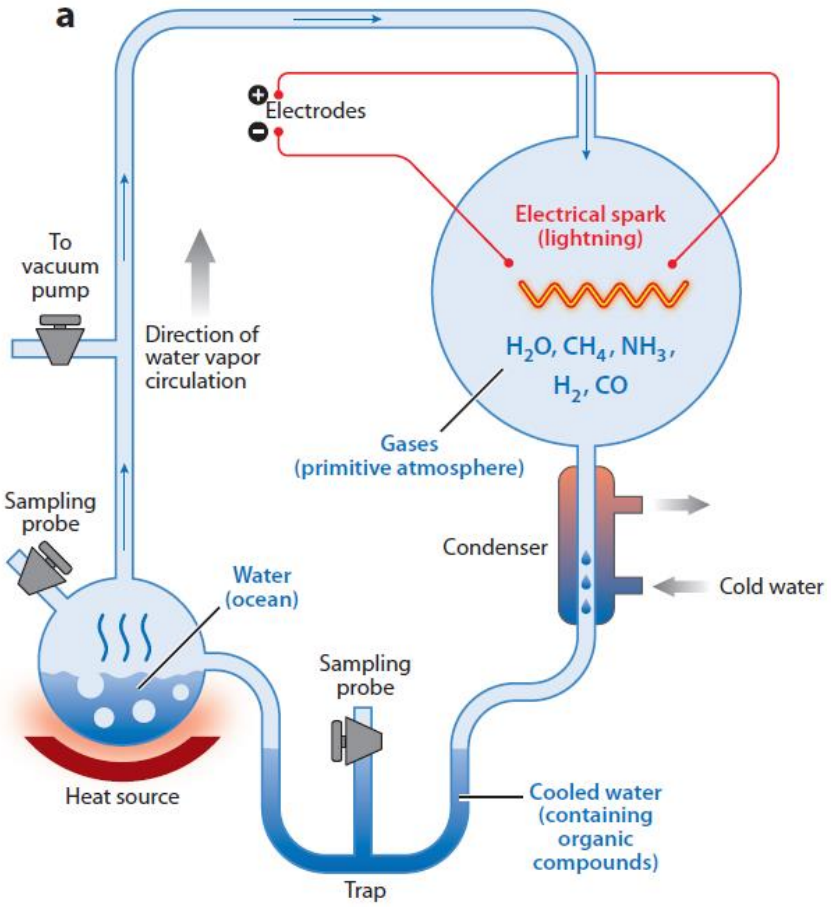


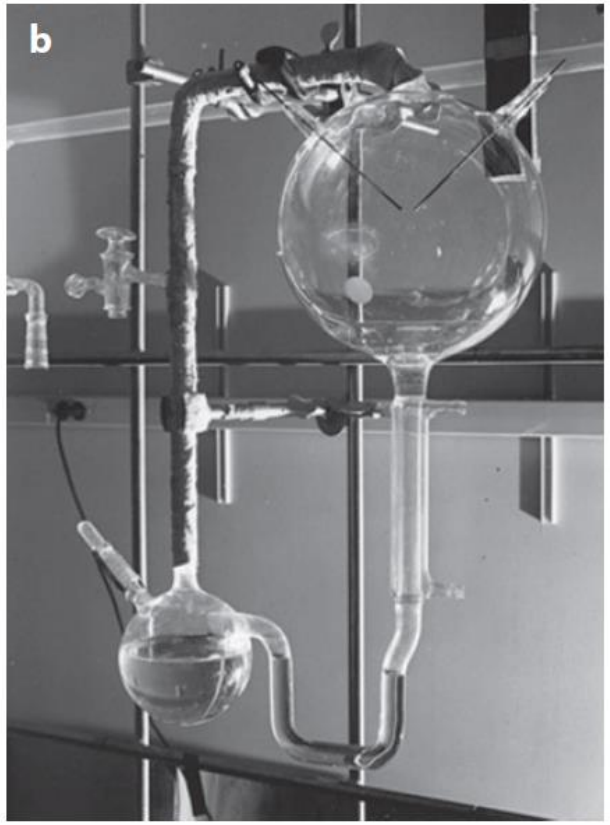
Photo credit: Britannica ; http://hyperphysics.phy-astr.gsu.edu/Nave-html/Faithpathh/lifelab.html

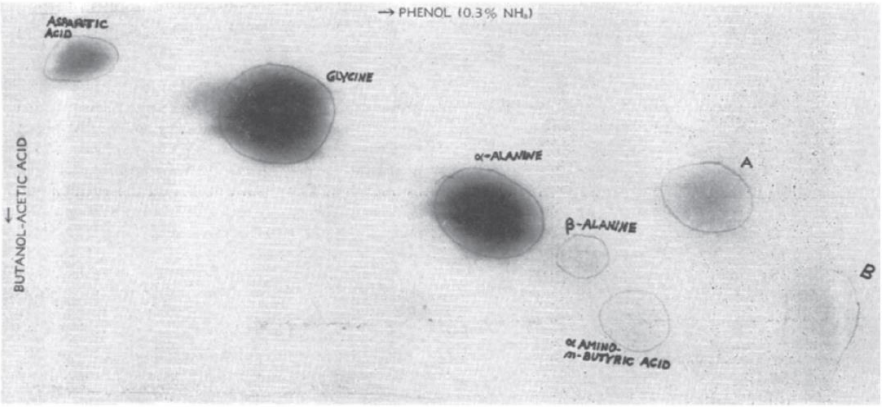
Origins of Life Version 1: Urey-Miller Experiments

- To test the primordial earth theory, Stanley Miller and Harold Urey

Stanley Miller
(1930-2007)







- The Urey-Miller experiment marked the beginning of prebiotic chemistry

Photo credit:**Annual Review of Earth and Planetary Sciences** Vol. 41:207-229 (Volume publication date May 2013) First published online as a Review in Advance on March 7, 2013 https://doi.org/10.1146/annurev-earth-040610-133457

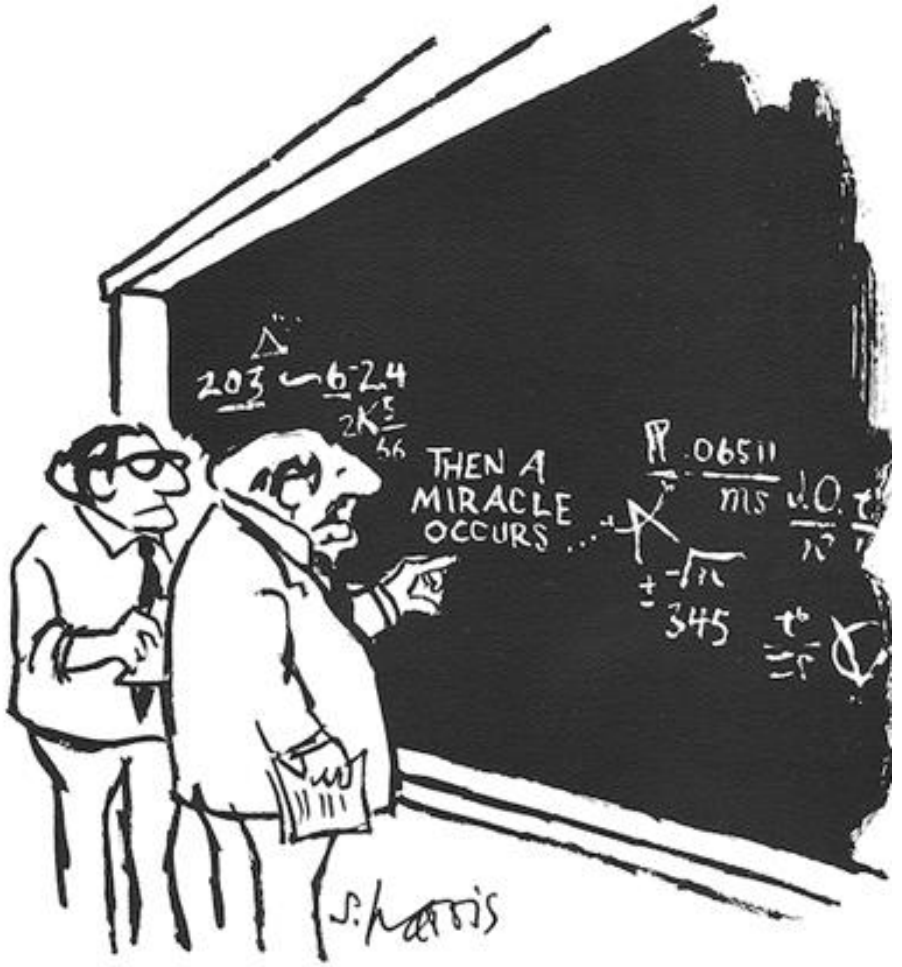
Origins of Life Version 1: Urey-Miller Experiments

- But…… there are limitations to the Urey-Miller experiments:

Limitation #1: Debate about whether the brown soup can even support life

Limitation #2: Unsure of the exact composition of early Earth's atmosphere

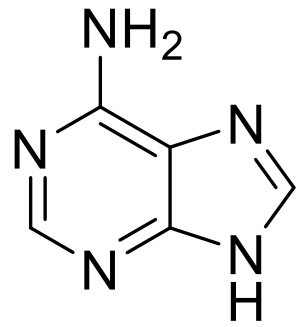
Limitation #3: No organisms were formed in this experiment



https://carbonpilgrim.wordpress.com/2013/01/21/carbon-soup/ ; https://www.deviantart.com/lorysdisneyworld/art/Primordial-earth-volcano-105484942

Origins of Life Version 1: Joan Oro Experiments

- The first attempt at showing that nucleobases could be produced in the prebiotic world were done by Joan Oro (1960) and Kimball (1961)

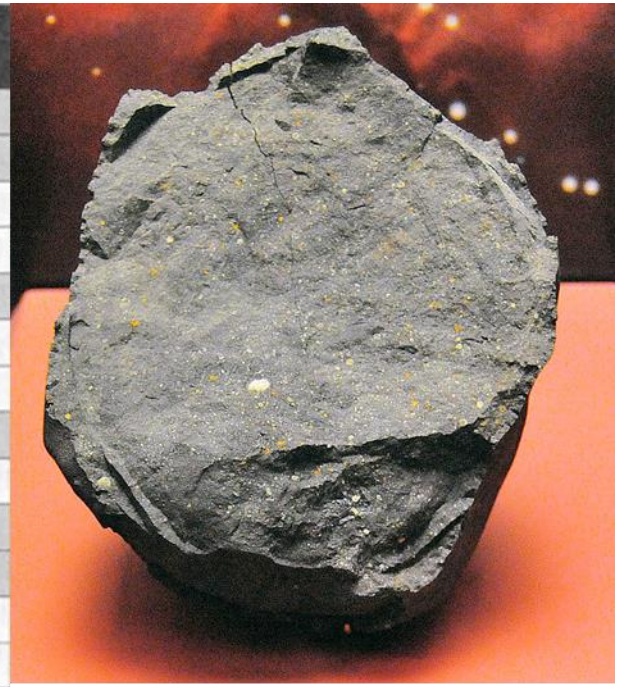


- Challenge with this?

The Origins of Life: Version 2

- An additional theory of the source of organic molecule on earth related to the idea that meteorites could have “seeded” early life.

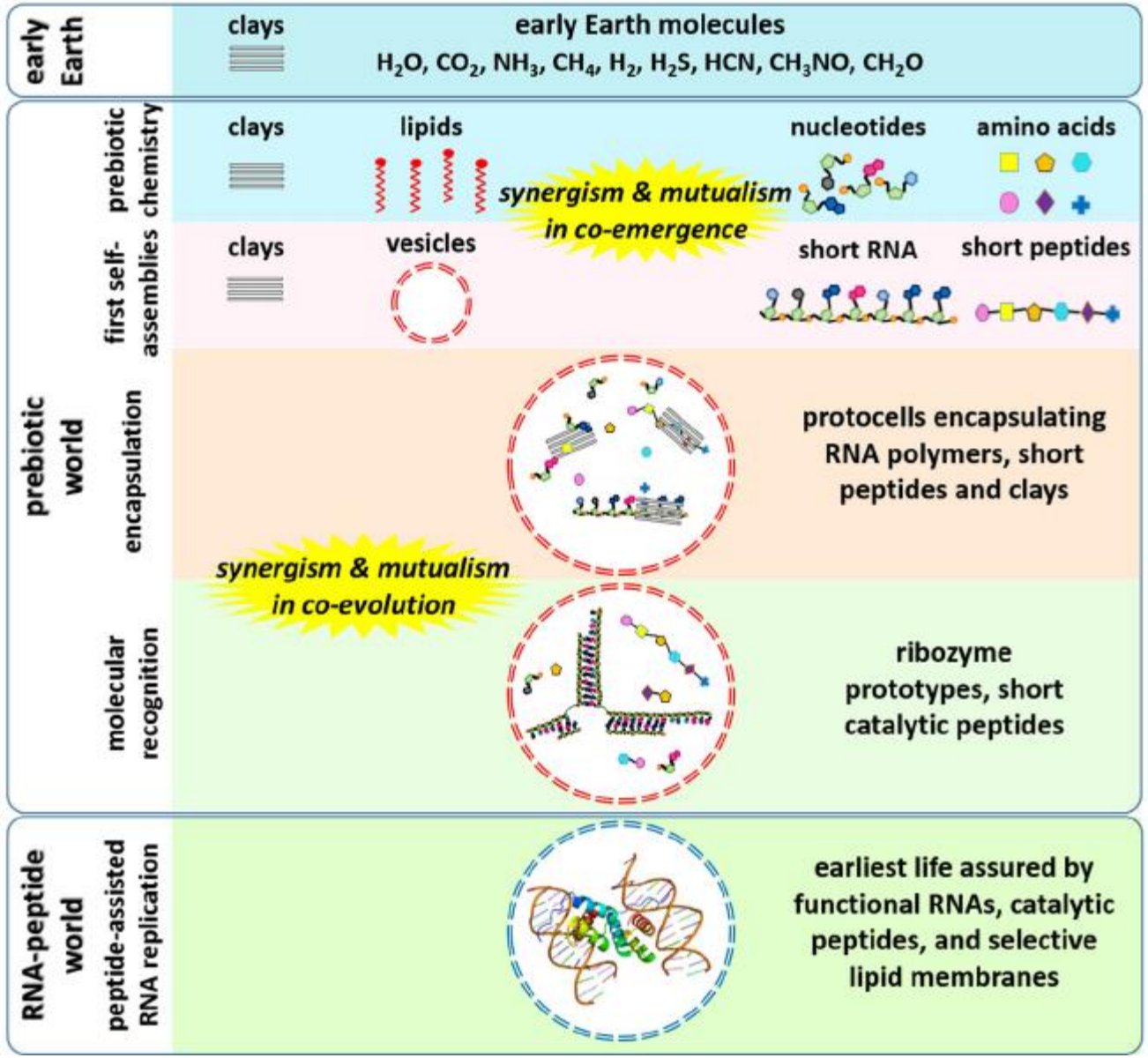
AMINO ACID	MURCHISON METEORITE	DISCHARGE EXPERIMENT
GLYCINE	• • • •	• • • •
ALANINE	• • • •	• • • •
α-AMINO-*N*-BUTYRIC ACID	• • •	• • • •
α-AMINOISOBUTYRIC ACID	• • • •	• •
VALINE	• • •	• •
NORVALINE	• • •	• • •
ISOVALINE	• •	• •
PROLINE	• • •	•
PIPECOLIC ACID	•	•
ASPARTIC ACID	• • •	• • •
GLUTAMIC ACID	• • •	• •
β-ALANINE	• •	• •
β-AMINO-*N*-BUTYRIC ACID	•	•
β-AMINOISOBUTYRIC ACID	•	•
γ-AMINOBUTYRIC ACID	•	• •
SARCOSINE	• •	• • •
N-ETHYLGLYCINE	• •	• • •
N-METHYLALANINE	• •	• •



From Prebiotic Chemistry to Chemical Evolution

- Chemical evolution extends to the association of individual polymers, which increases complexity and diversity of biochemical reactions

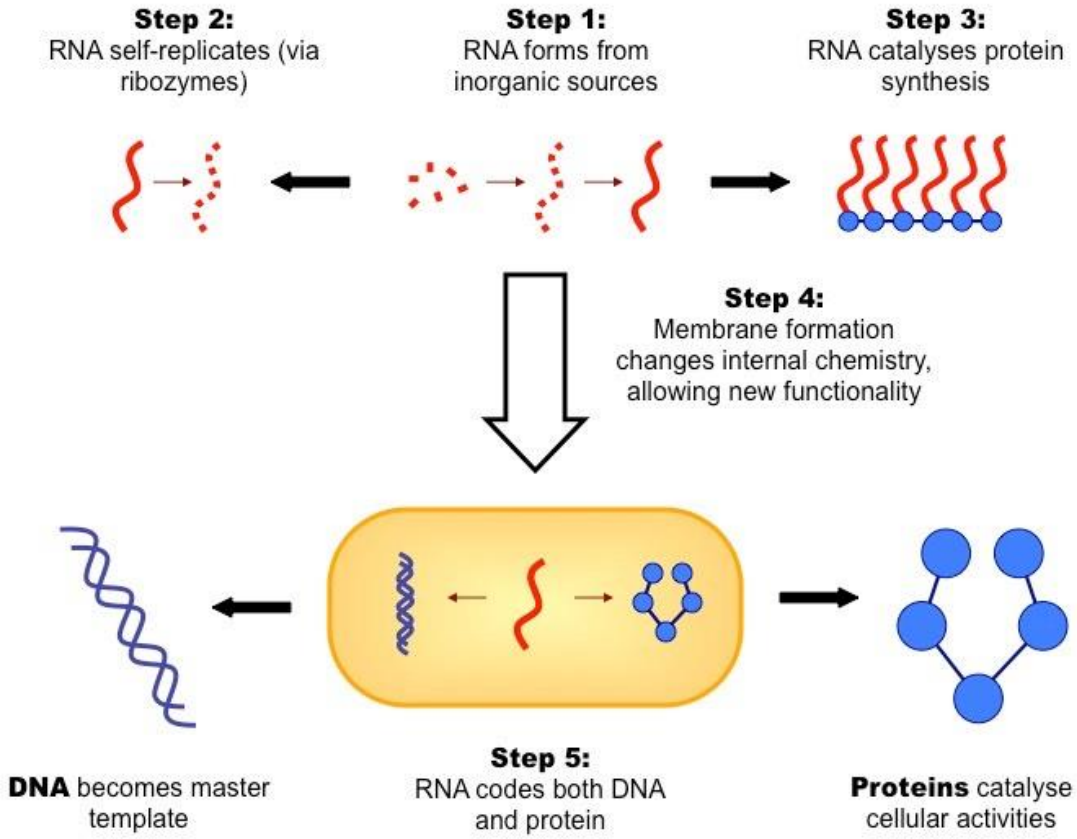
- There are many kinds of biological monomers available to polymerize with other monomers, increasing the functional versatility of condensation products



Life (Basel). 2014 Nov 3;4(4):598-620. doi: 10.3390/life4040598.

The Process of Chemical Evolution

- The “RNA World” hypothesis suggests that RNA molecules may have been both the first polymer and the first catalyst.



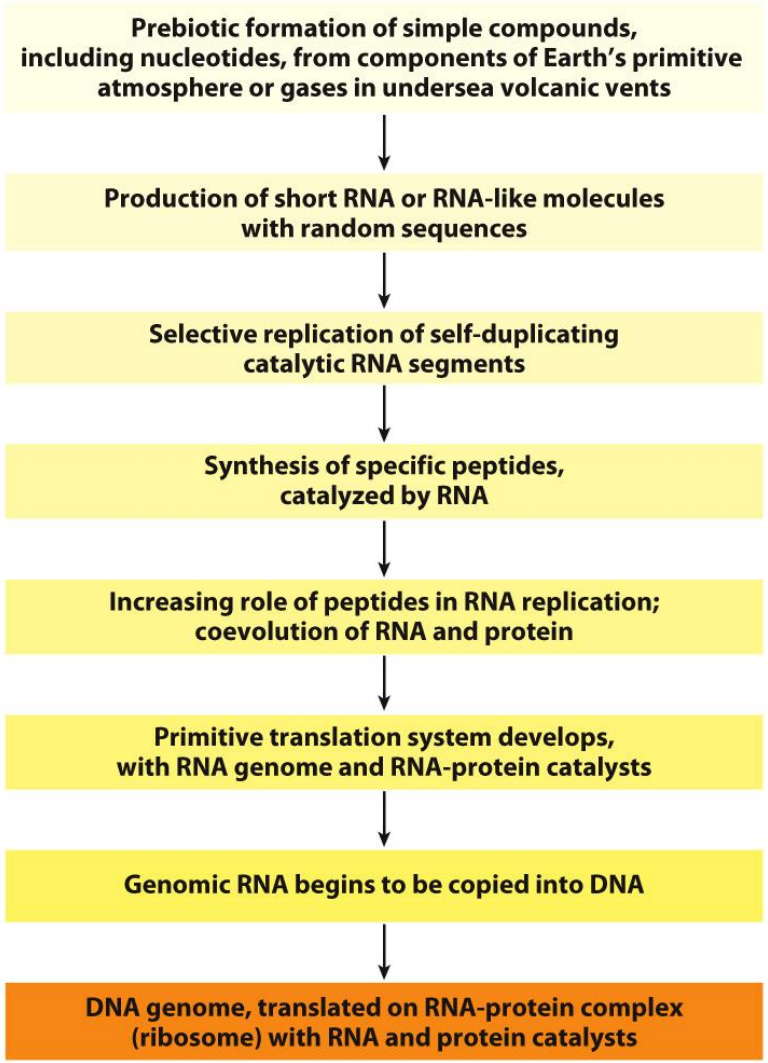
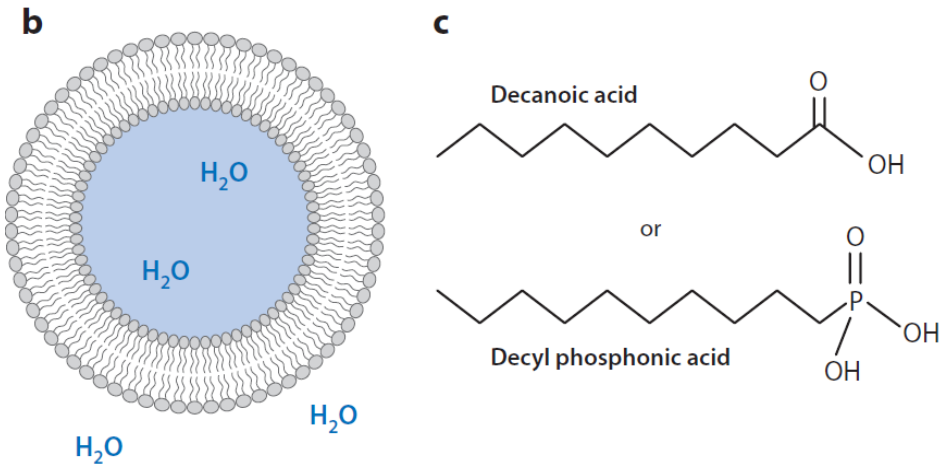
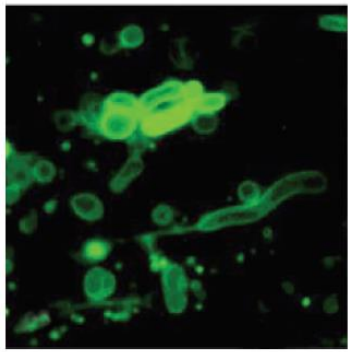


Figure 1-37
Lehninger Principles of Biochemistry, Seventh Edition

The Process of Chemical Evolution

- The origin of life is linked to the ability to compartmentalize chemical reaction networks, which will promote reactivity.





Decanoic acid

Meteorite extracts

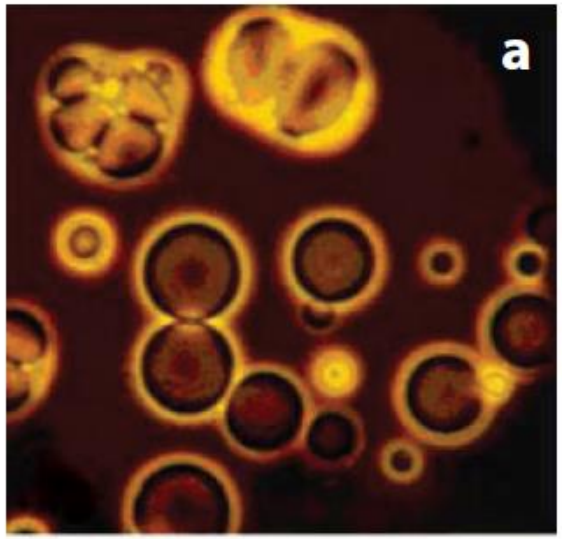
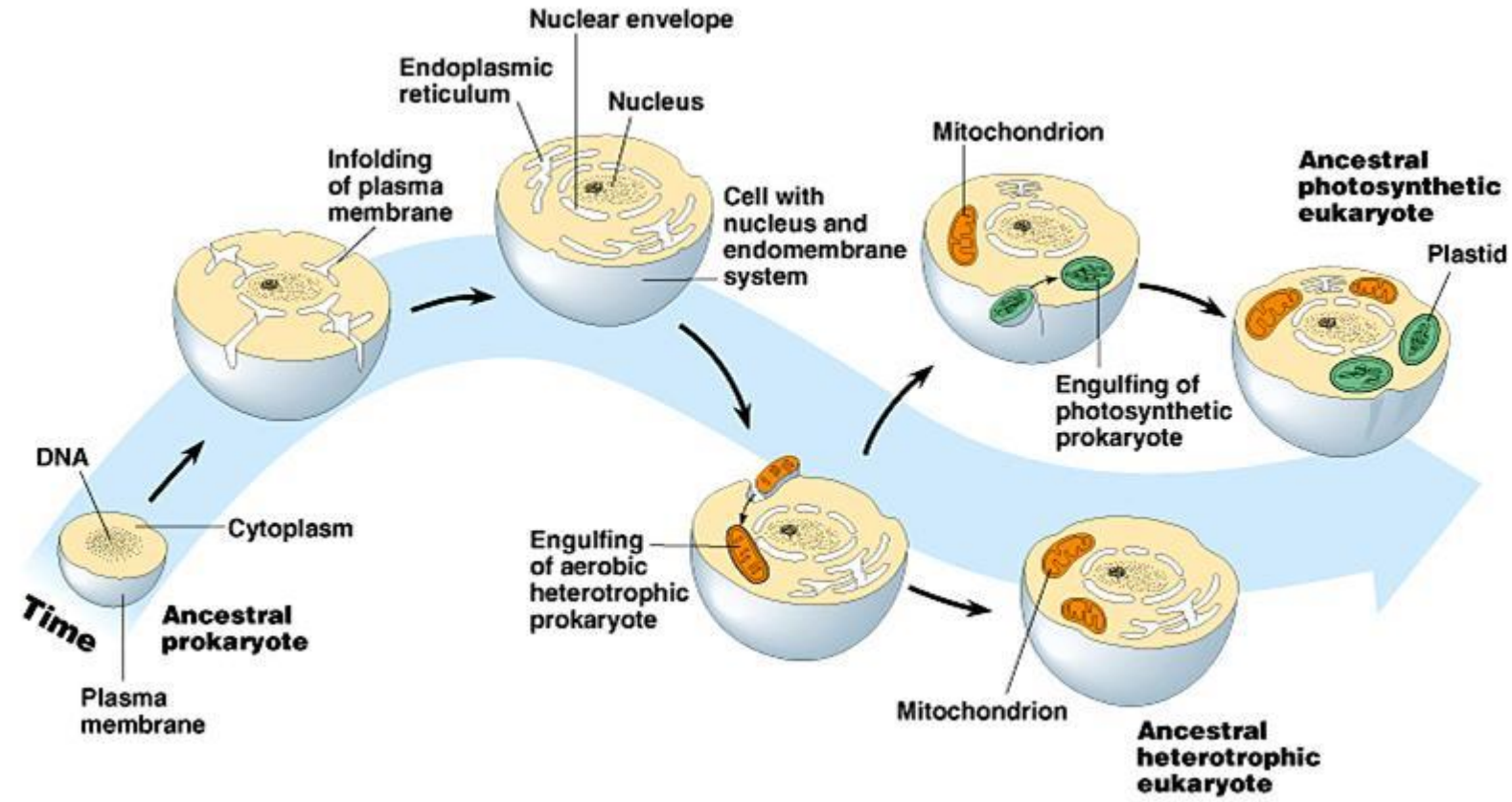


Photo credit:**Annual Review of Earth and Planetary Sciences** Vol. 41:207-229 (Volume publication date May 2013) First published online as a Review in Advance on March 7, 2013 https://doi.org/10.1146/annurev-earth-040610-133457

Prokaryotic vs. Eukaryotic Cells

- Around 1.5 billion years ago, fossil evidence started to show more complex organisms
  - Cells required more DNA
  - Large cells required large organelles
  - **Endosymbiosis!**
- Lynn Margulis proposed that early eukaryotic cells (anaerobic) enveloped aerobic bacteria or photosynthetic bacteria in order to adapt to the new aerobic environment on earth



Prokaryotic and Eukaryotic Cells

- There are two major cell types: eukaryotes and prokaryotes
  - Eukaryotes have a membrane enclosed nucleus encapsulating their genomic DNA
  - Prokaryotes do not have a nucleus

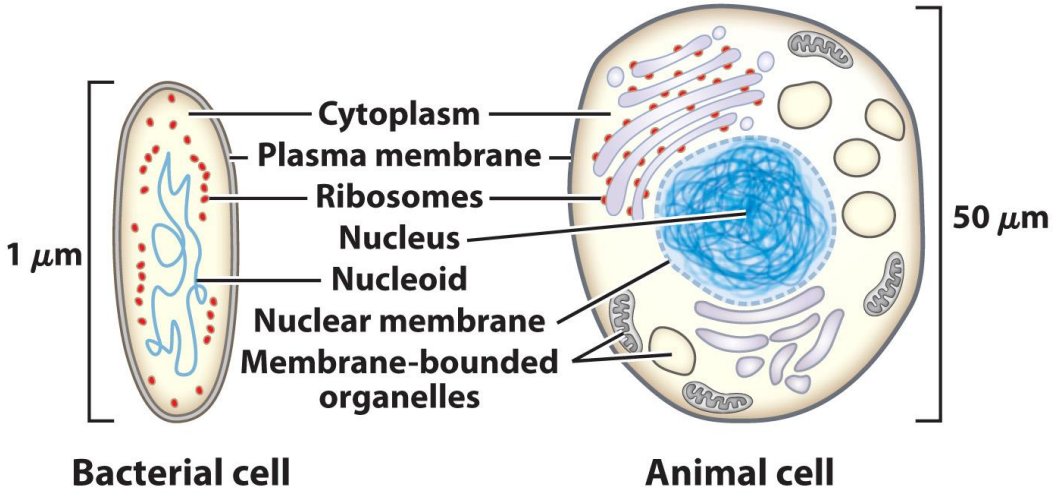


Figure 1-3
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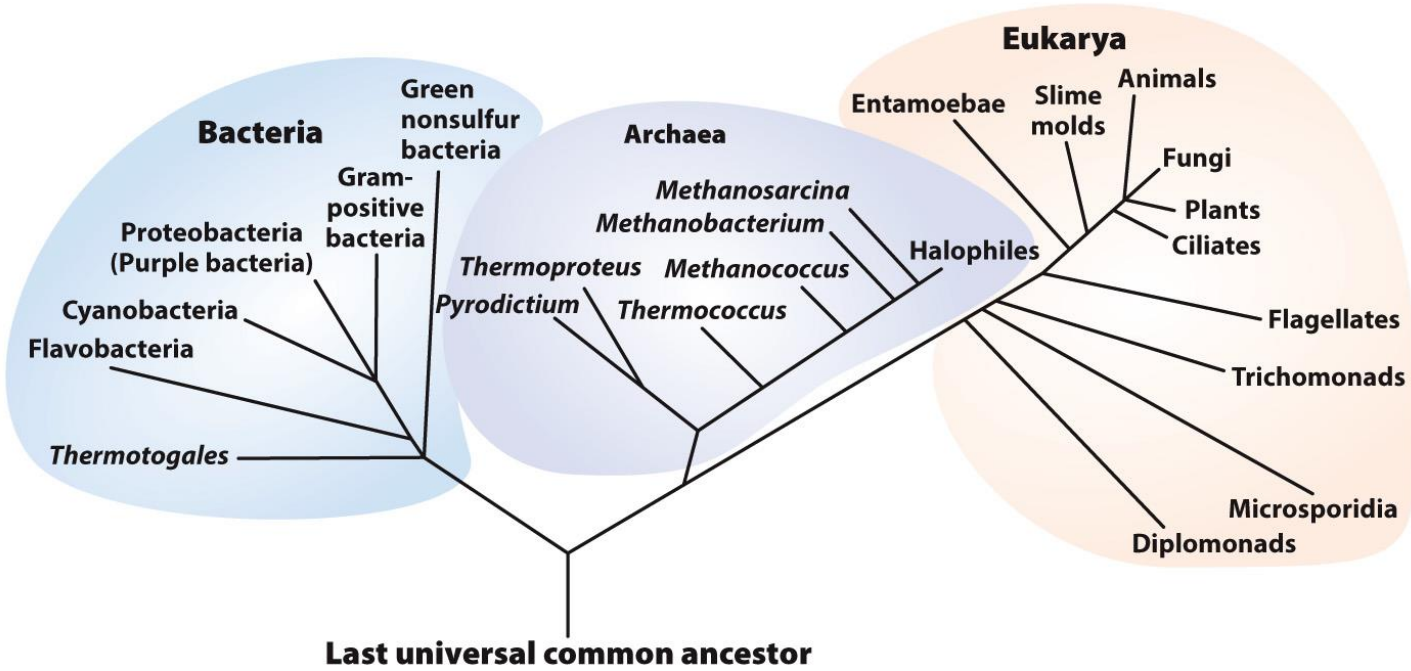

Figure 1-5
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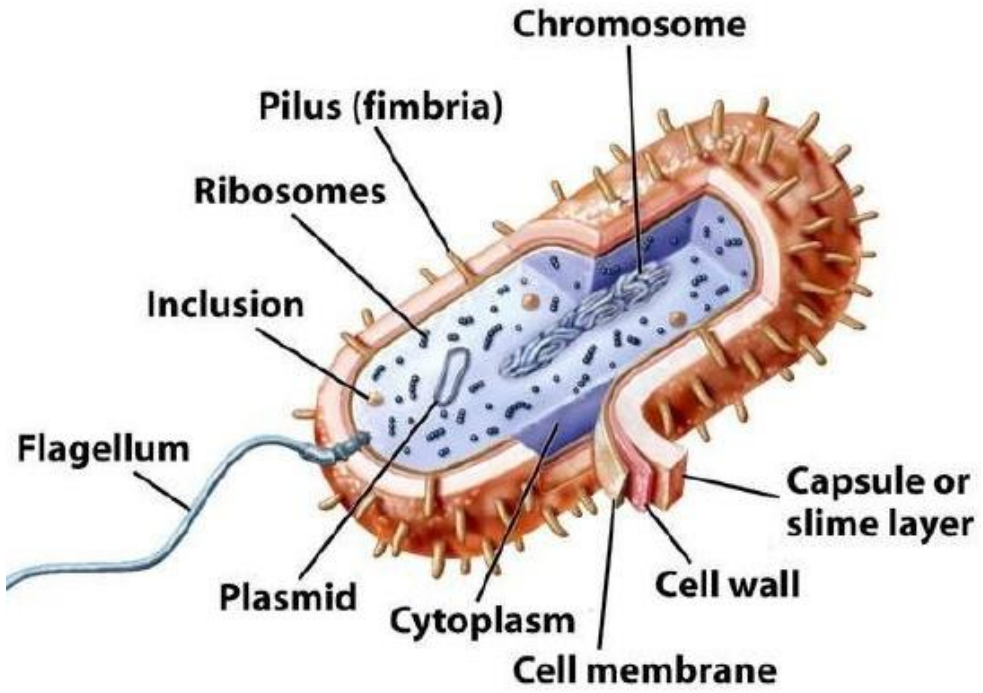
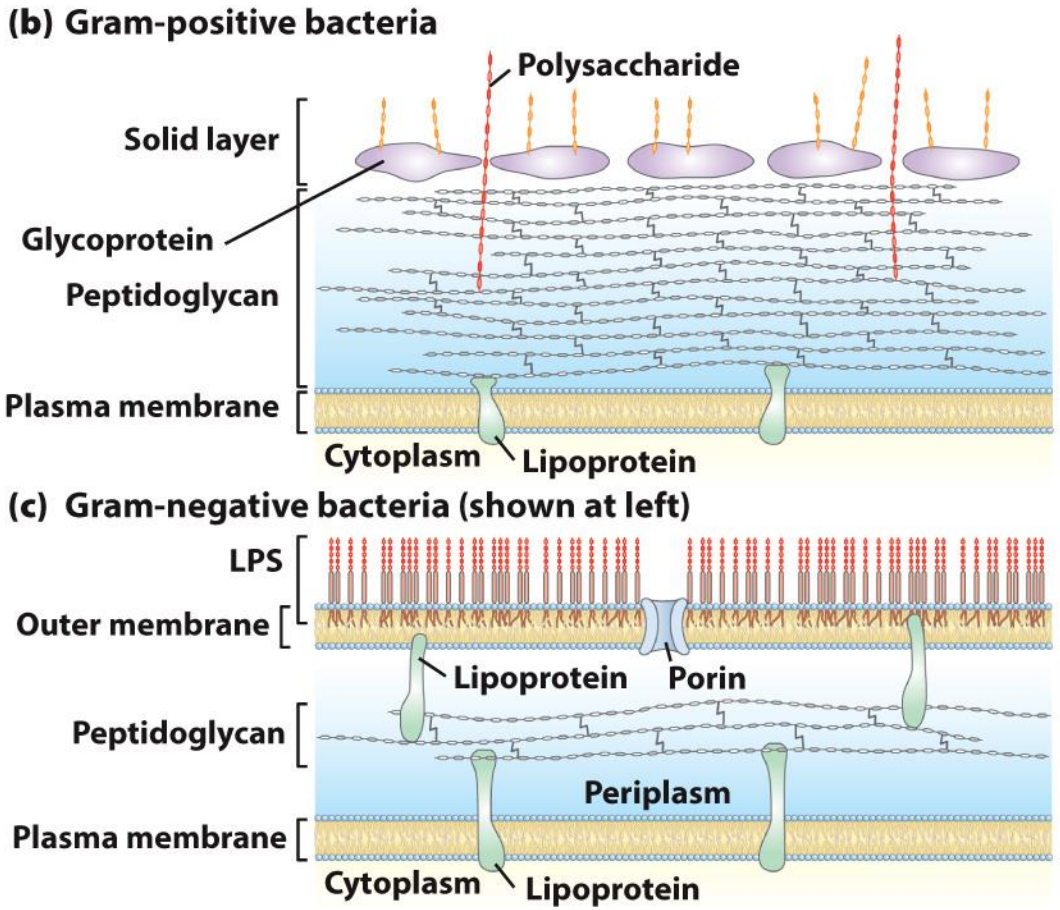
Prokaryotic Cell





https://www.slideshare.net/gaurav2481/bacterial-cell

Eukaryotic Cell

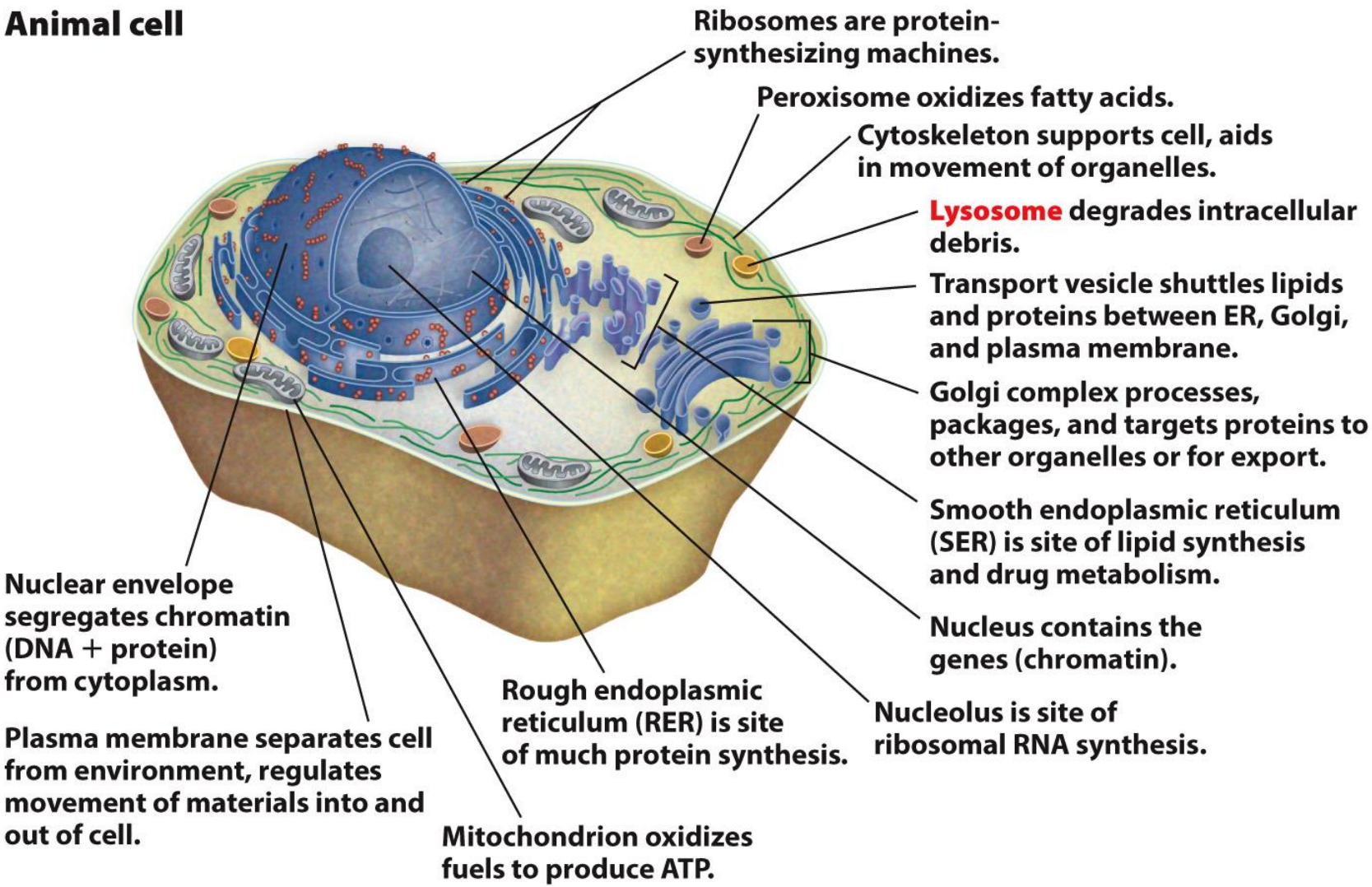


Figure 1-8a
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Eukaryotic Cell

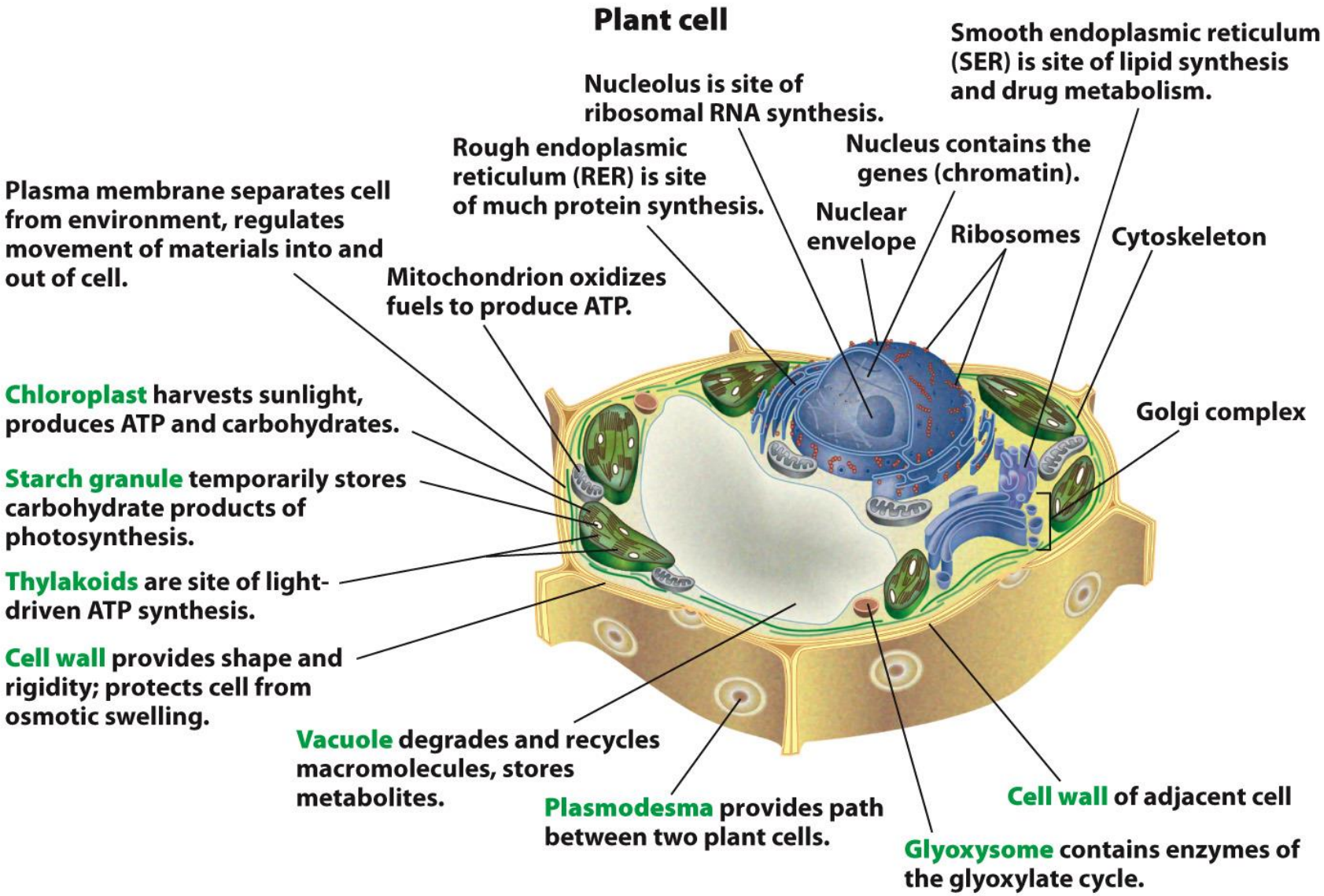

Figure 1-8b
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Biological Polymers are Important in Cell Function

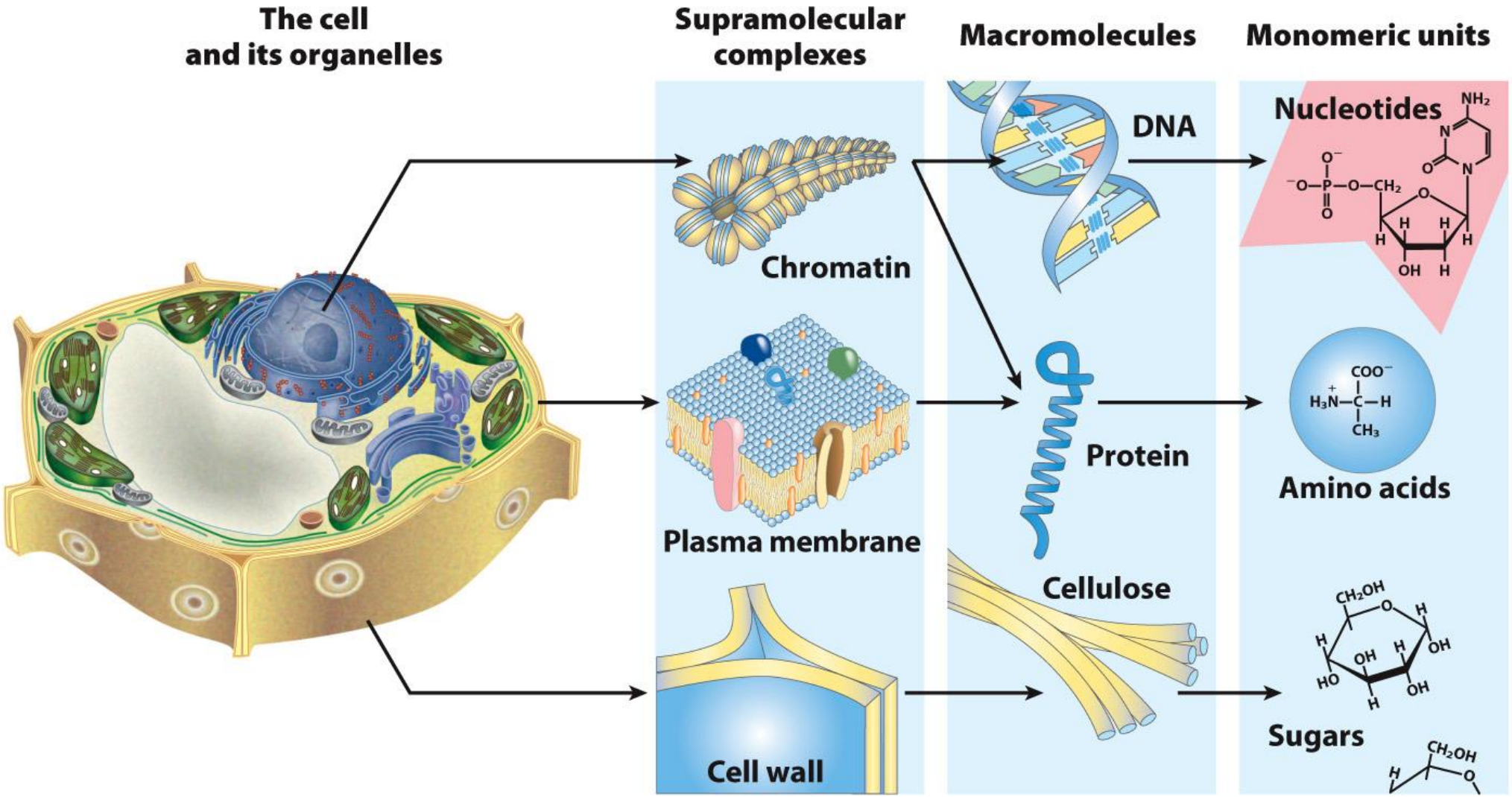

Figure 1-12
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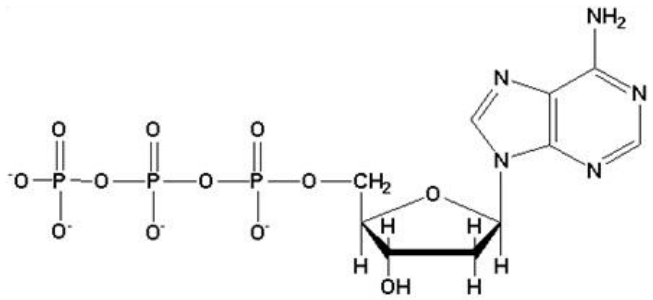
Nucleotides, DNA, and RNA

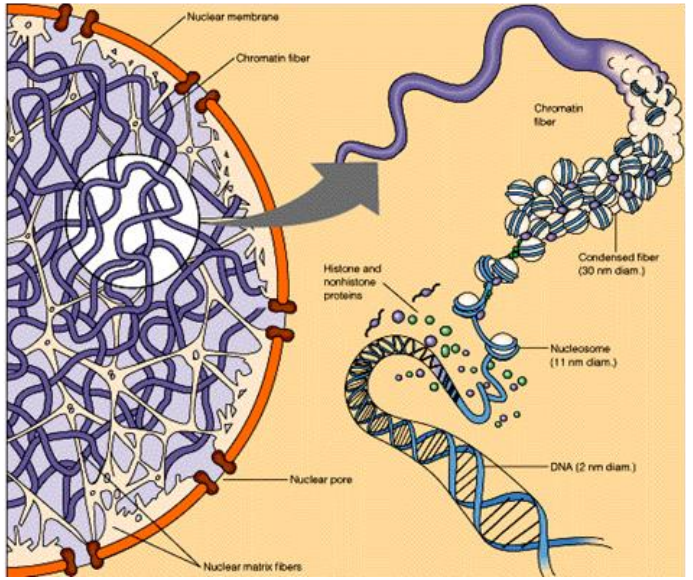
monomer — nucleotide

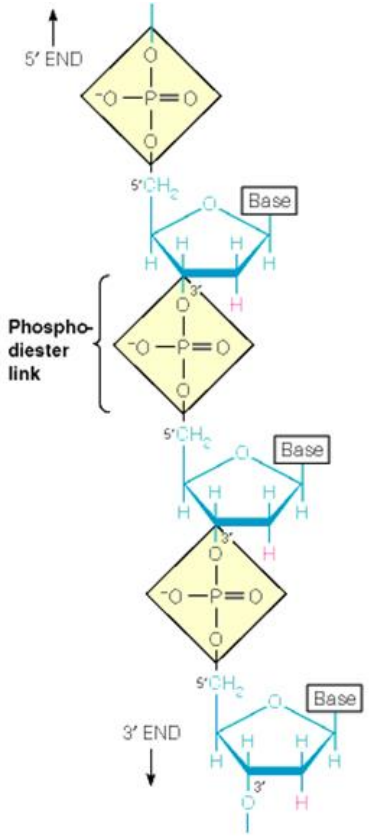
polymer — DNA

supramolecular structure — chromatin

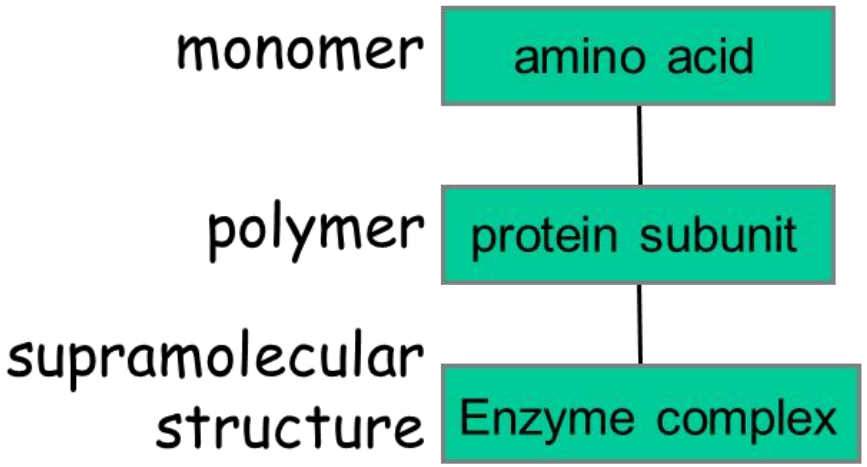


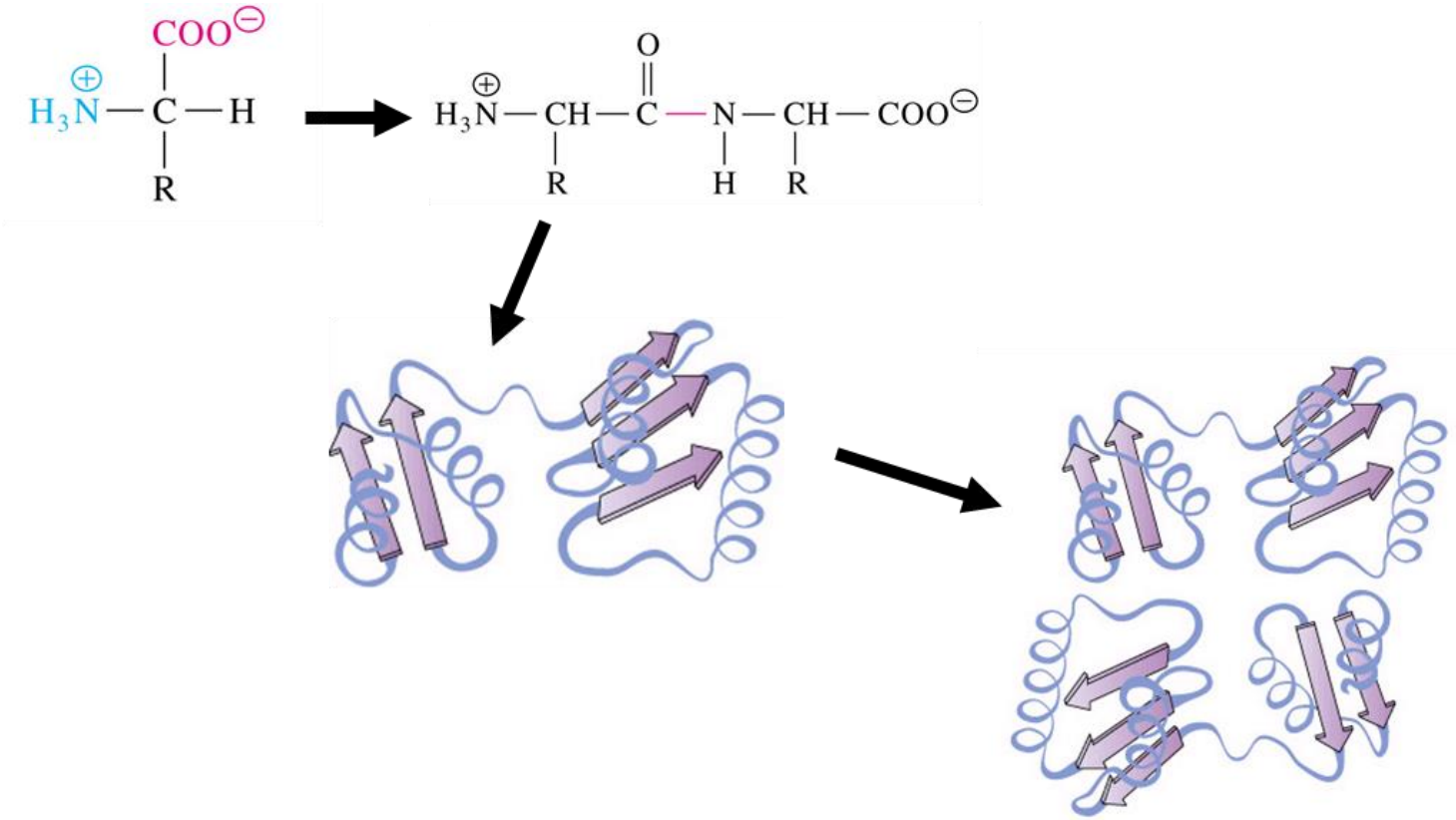
Deoxyadenosine Triphosphate (dATP)





Amino acids and Proteins



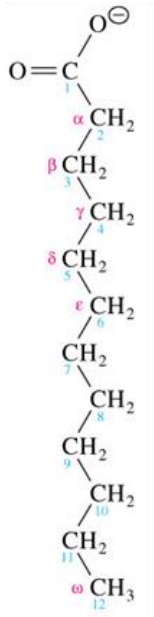


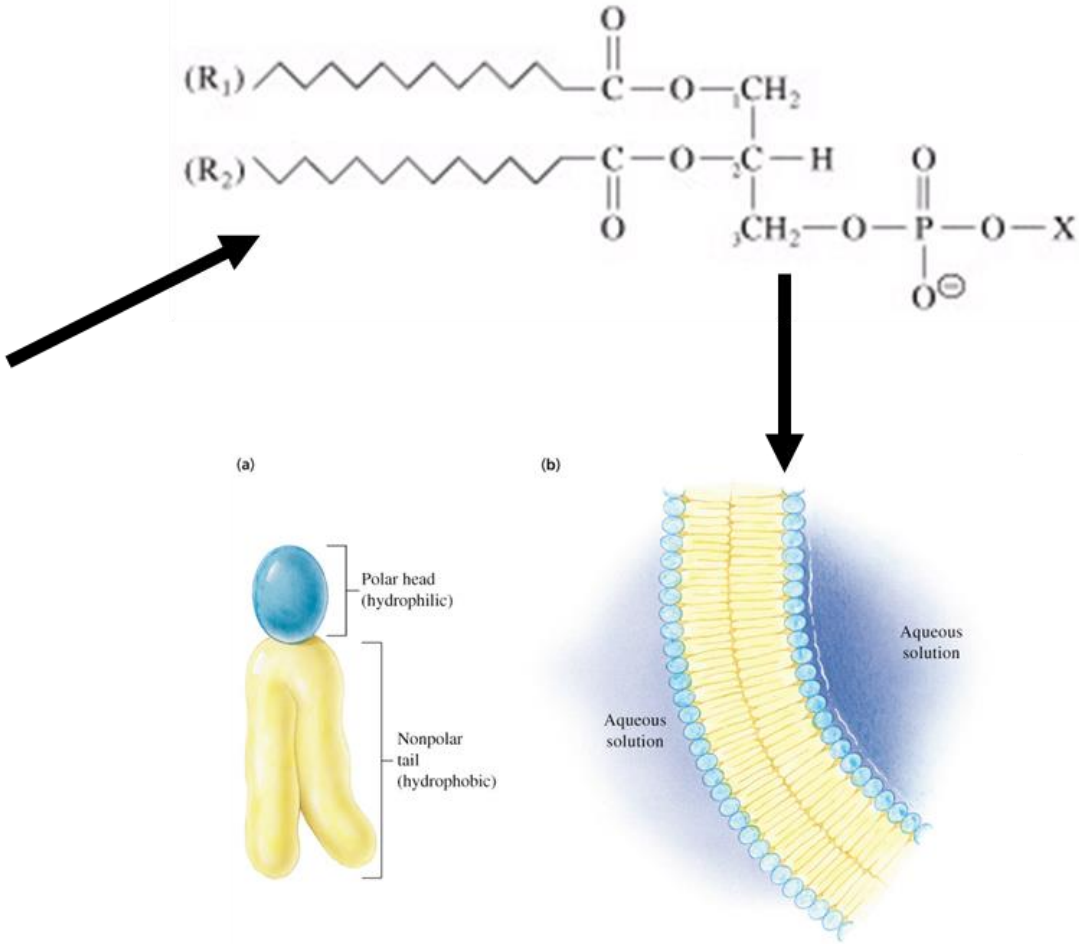
Lipids

monomer — fatty acid

polymer — phospholipid

supramolecular structure — membrane



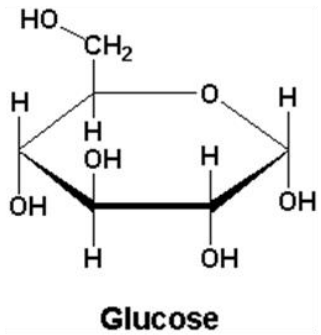


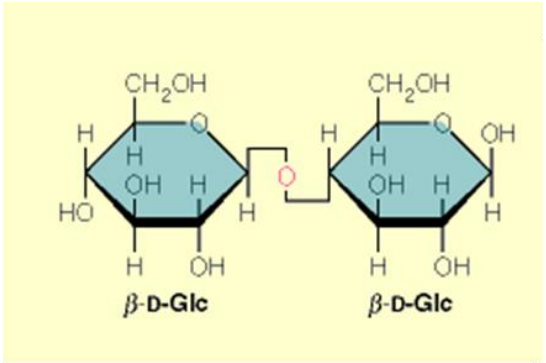
Carbohydrates

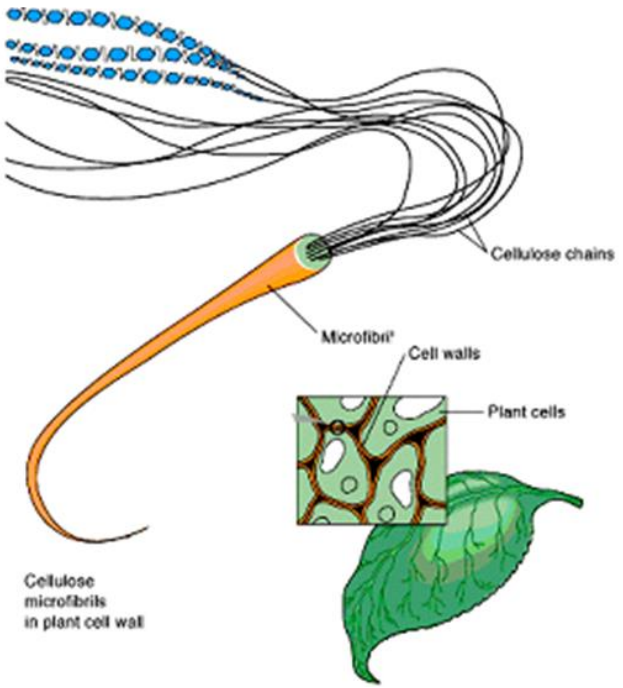
monomer — glucose

polymer — cellulose

supramolecular structure — cell wall







To Prepare For Tuesday's Class

Read

Chapter 2, all sections

Review

Chapter 1: sections 1, 2, 4, & 5