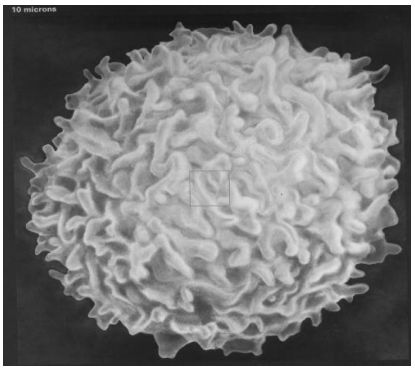
The Road to DNA:
A review of chemistry and biology

Chem 210

1/28/00

The cell is the fundamental unit of life

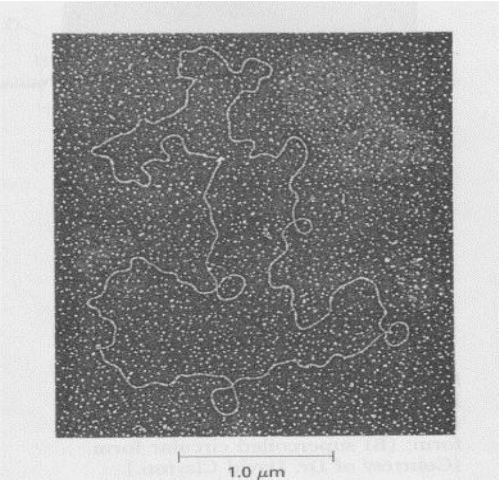


- The size of cells are measured in microns (10^{-6} meters = 10^{-3} mm)
- Cells can be studied by light microscopy or electron microscopy
- The genetic material of a cell is contained in the chromosomes

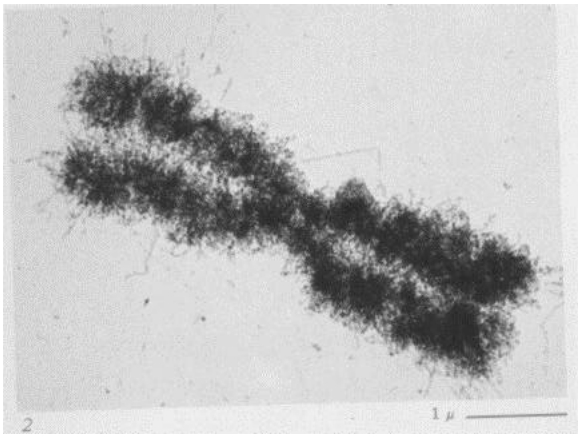
Two main types of cells: prokaryotes and eukaryotes

Eukaryotes	Prokaryotes
• Cell is subdivided into small membrane bound bodies • Chromosomes (the genetic material) are enclosed in the **nucleus** • Chromosomes are linear strands • General: complex cells	• No internal membrane bound subcompartments • Chromosomes are free in the cytoplasm (no nucleus) • Chromosomes are circular • General: simple cells

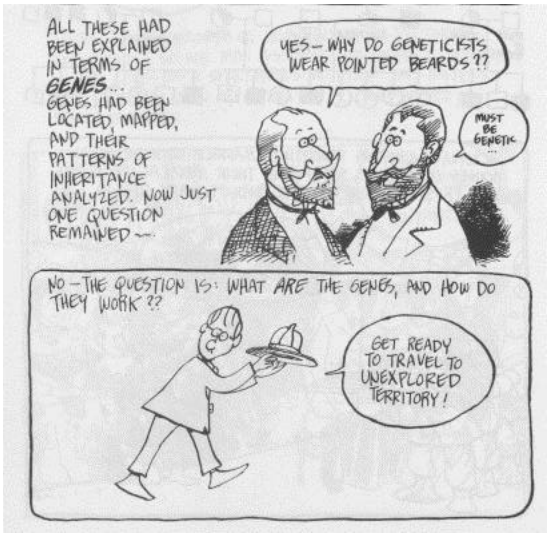
Prokaryotes have circular chromosomes



Eukaryotes have linear chromosomes



The state of the gene c.1940



The constituents of a cell can be described in terms of *chemistry* (c. 1940)

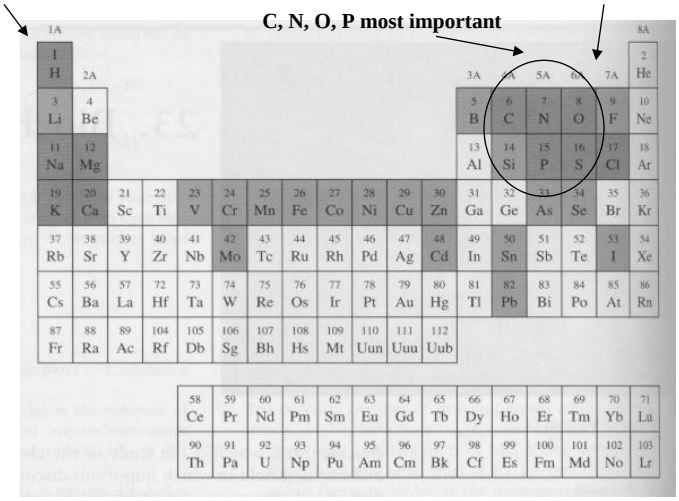
- A physical model for the structure of molecules is available
  - Linus Pauling and others described *The Nature of the Chemical Bond;*
  - Important forces holding atoms together include:
    - *Covalent bonds*
    - *Hydrogen bonds*
    - *Electrostatic interactions*
    - *Hydrophobic interactions*
- The chemical entities which make up the cell are known
  - Carbohydrates
  - Lipids
  - Proteins
  - Nucleic acids

Common elements in biological systems

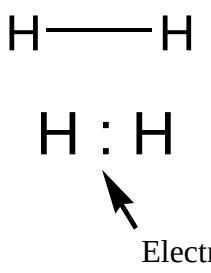
Electropositive: give up electrons

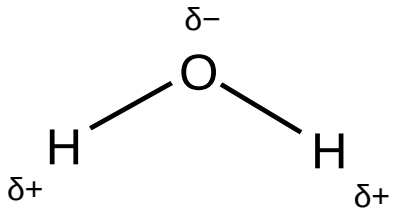
Electronegative: want electrons

C, N, O, P most important



Molecules held together by covalent bonds

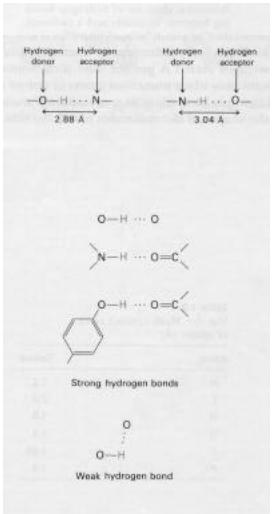




Polar bonds

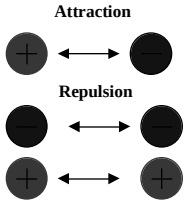
- Covalent bonds are shared electron pairs
- If atoms have different electronegativities, the electrons are shared unequally, creating a *polar* bond
- A molecule with polar bonds can have a *dipole moment*

Hydrogen bonds are weak interactions



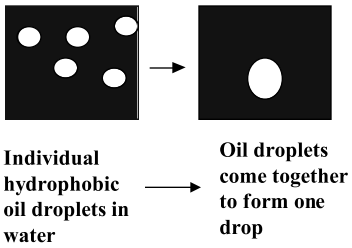
- Formed by hydrogen bonded to an electronegative atom (N or O -- the hydrogen bond *donor*)
- The electrons are shared unequally between the hydrogen and the donor atom; the hydrogen has a partial positive charge.
- This hydrogen can interact with a partial negative charge on another electronegative atom (the hydrogen bond acceptor).
- Hydrogen bonds are weaker than covalent bonds, with energies around 12 - 28 kJ/mol

Charged species (ions) interact via electrostatic attraction/repulsion



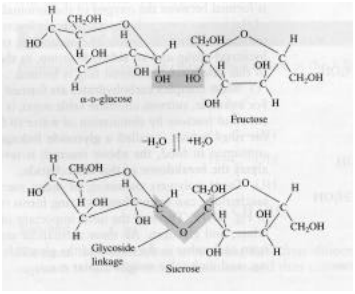
- Molecules with a net charge are called *ions;* positively charged species are *cations,* negatively charged species are called *anions.*
- Positive and negative charges are attracted by the Coulomb force(opposite charges attract, like charges repel).
- Ions also interact strongly with water, since water is a *dipolar* species (it has a dipole moment).

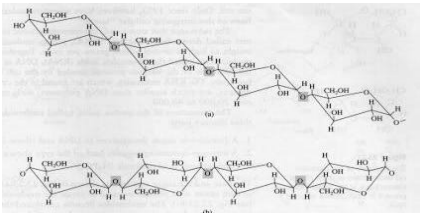
Nonpolar groups tend to associate in water



- Common experience: think of mixing oil and vinegar salad dressing.
- This association occurs primarily because water prefers to interact with itself (through hydrogen bonds), not because the nonpolar species have a high affinity for one another.

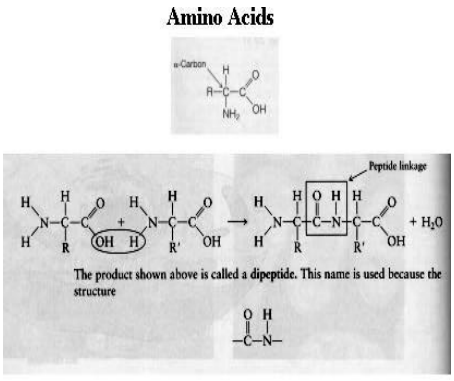
Carbohydrates are a source of energy





- Carbohydrates are polymers of five or six carbon units called monosaccharides, or simple sugars.
- Contain only C,H,O
- Used as an energy source, energy storage, and structural support

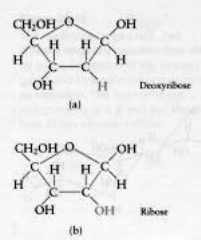
Proteins are polymers of amino acids



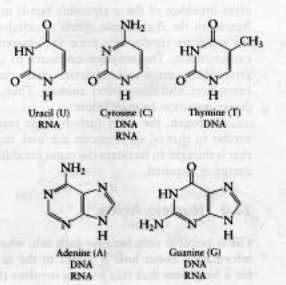
- Cells have thousands of proteins involved in metabolism, signaling/hormones, structural features, regulation--just about everything!
- There are twenty “essential” amino acids-each differing in the R group
- Each protein type folds into a unique three dimensional shape-the 3-D structure is responsible for the proteins function.

Nucleic acids are polymers of nucleotides

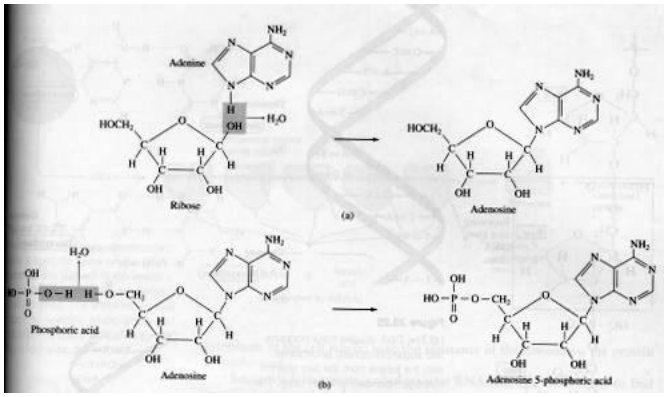
Nucleotides contain one of two sugars



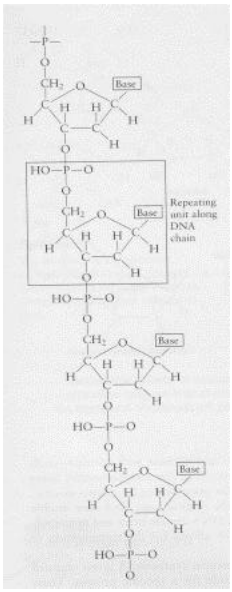
Nucleotides contain one of five nitogenous bases



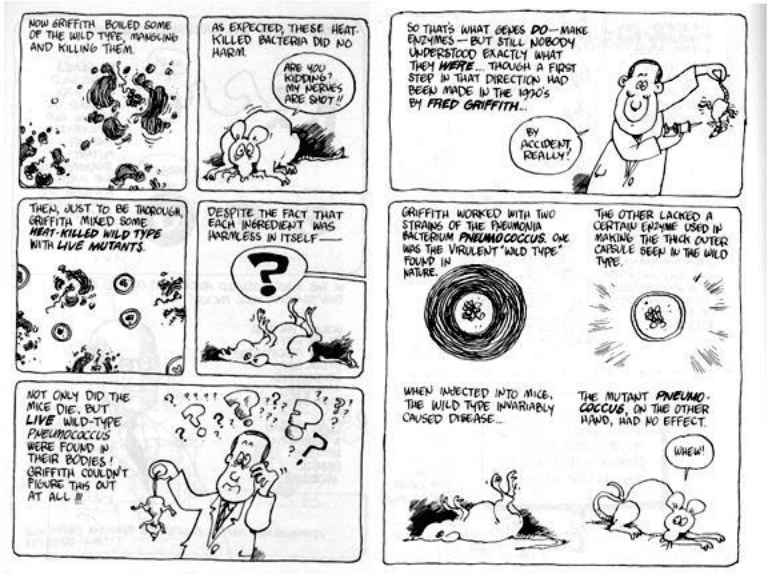
Nucleotides contain a sugar, a base, and a phosphate



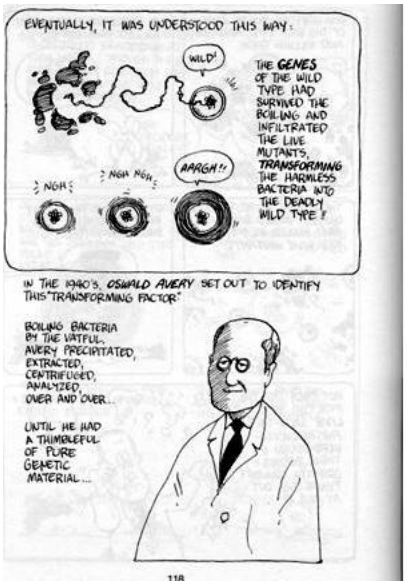
Nucleic acids are polymers of nucleotides



So, what are genes made of?



The answer: DNA (deoxyribonucleic acid)



Enter the physicists...

- In the first half of the 20th century, physicists "made order" of chemistry through the development and application of *quantum mechanics*…could the same be done of biology?
- In 1944, Erwin Schrodinger (one of the "founders" of quantum theory) published *What is Life?*, a challenge to physicists to understand the physical principles of life (and, most importantly, the physical principles behind genetics and self-replication).
- *What is Life?* inspires a generation of physicists to enter into biology.