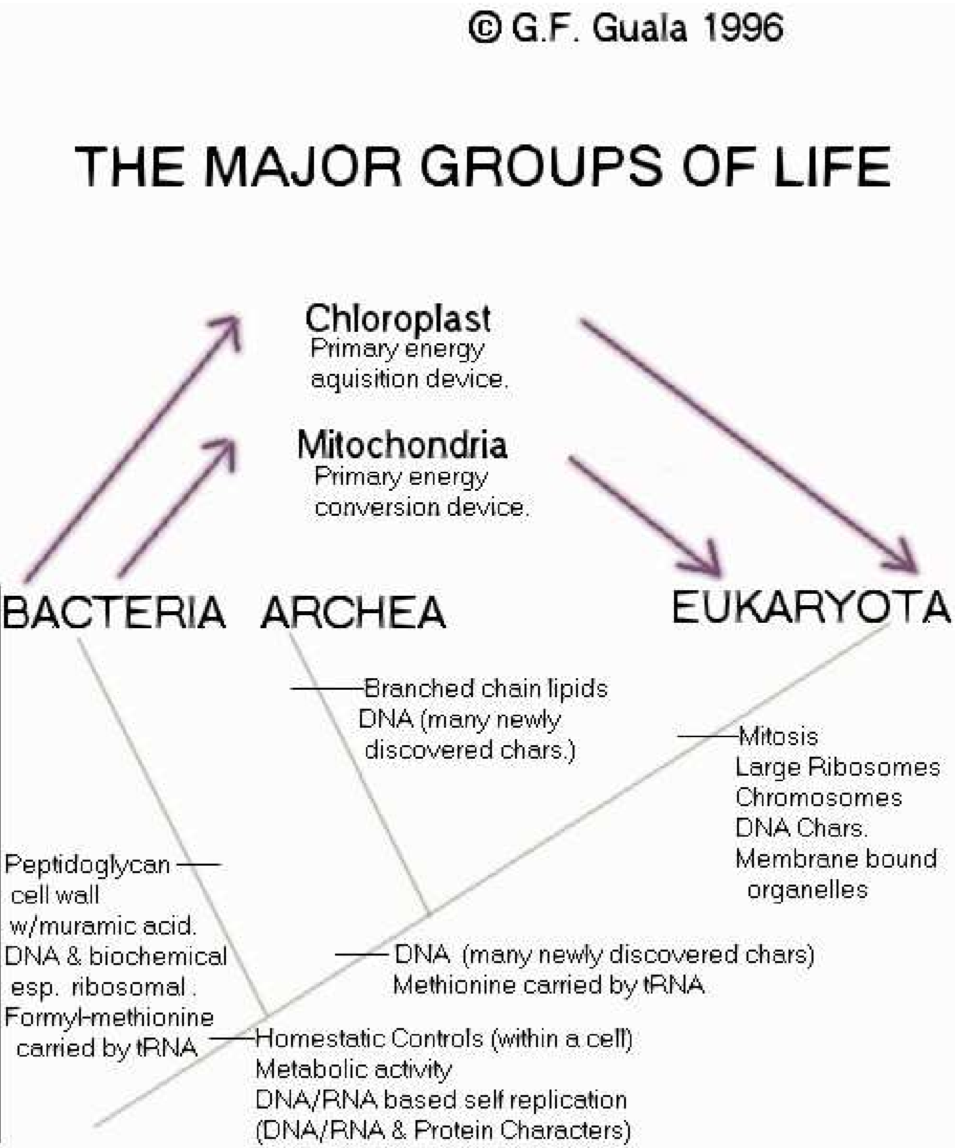
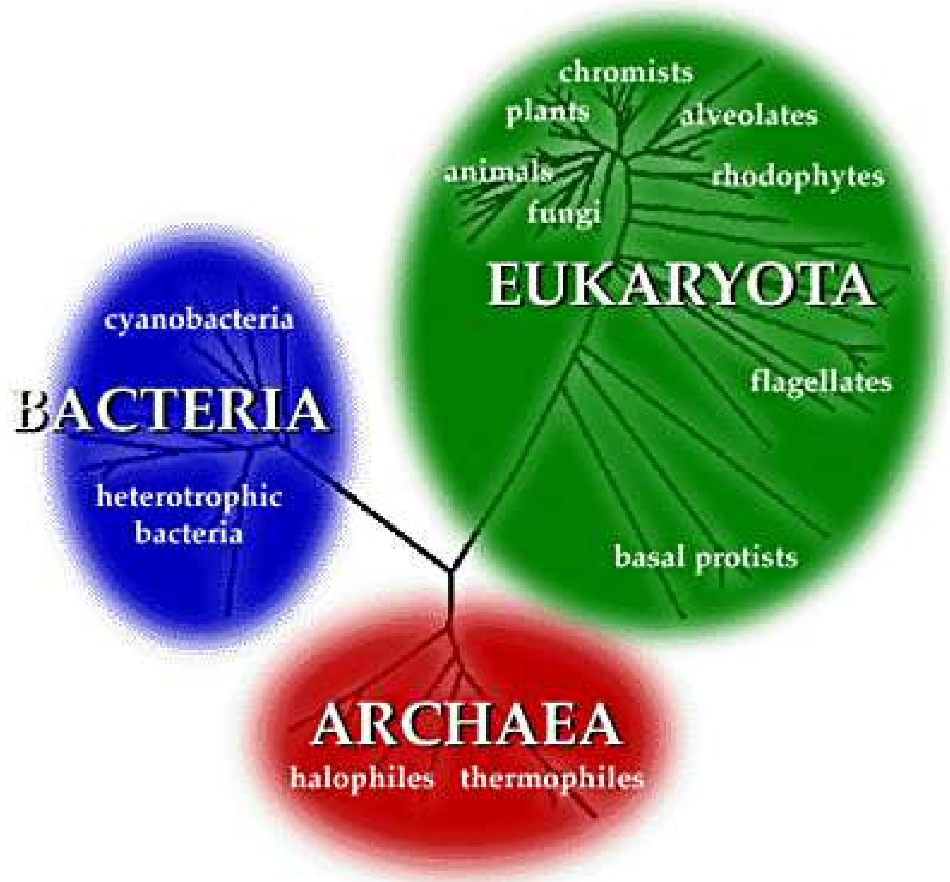
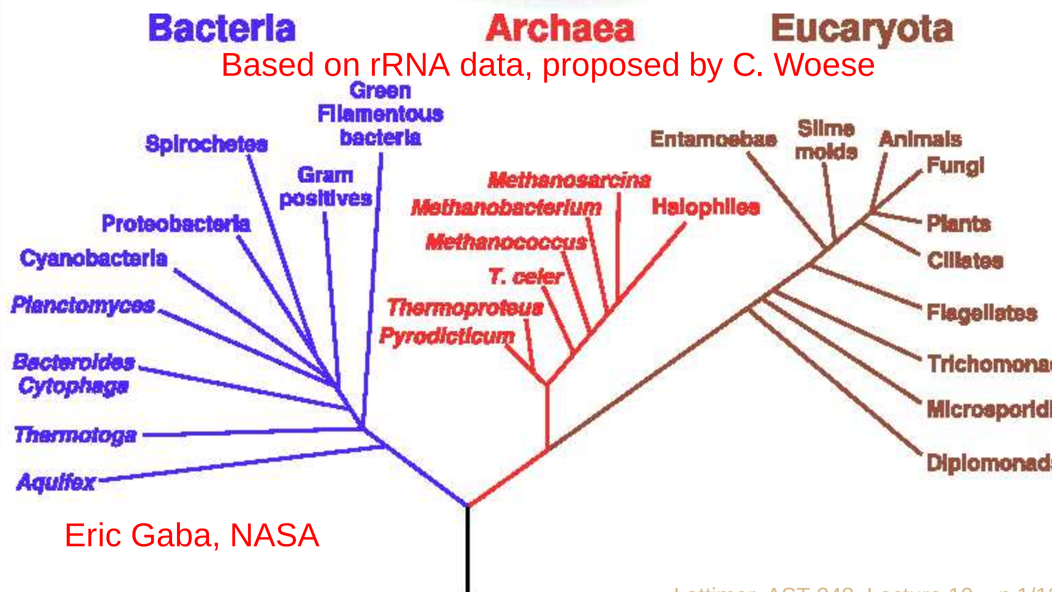
Major Domains of Life







Based on rRNA data, proposed by C. Woese

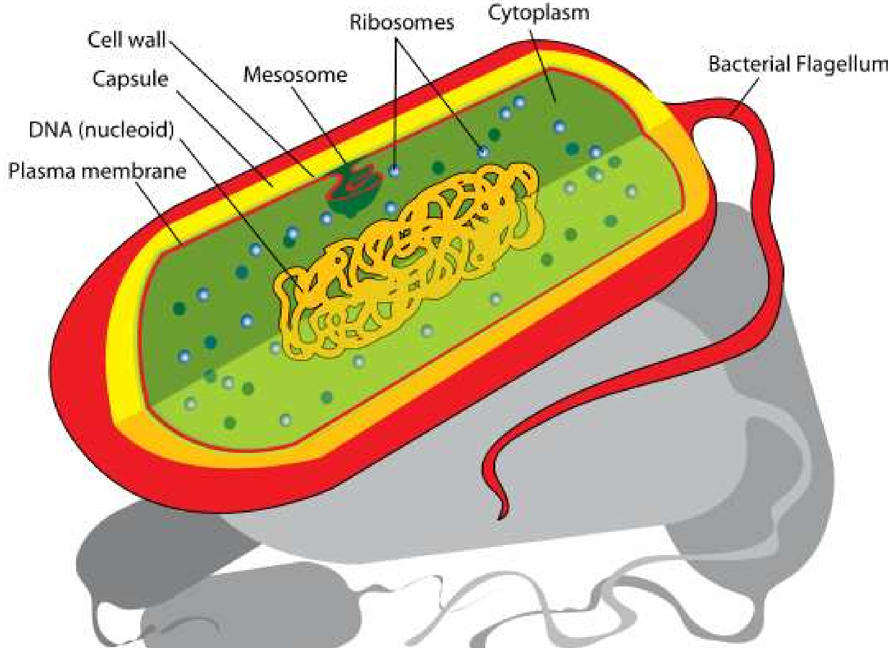
Eric Gaba, NASA

Types of Cells

Prokaryotes Cells without nuclei

Eukaryotes Cells with nuclei

Viruses



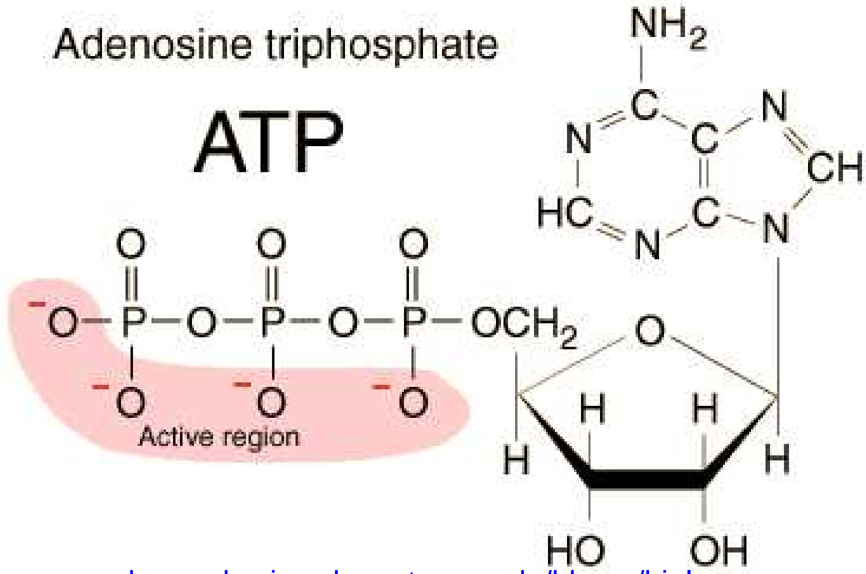
Mariana Ruiz

Major Differences:

- Prokaryotes form domains of bacteria or eubacteria and archaea.
- Prokaryotes form single-celled organisms, but can cluster into colonies.
- Prokaryotes are enclosed by a cell wall ma peptidoglycan (amino acids + sugar) which maintains size and shape of cell.
- Metabolism in prokaryotes is complex and more diverse.
- Prokaryotic genome is smaller, and its DNA is not attached to histone proteins.
- Most prokaryotic DNA is present in a single circular chromosome, and replication begins at a single point and proceeds around the circle in both directions.
- Prokaryotes obtain new genes by conjugation (transferral), transformation (absorbed from environment) and transduction (transferral by viruses or phages.
- Ribosomes of eubacteria differ in molecular detail from those of eukaryotes and archaea.

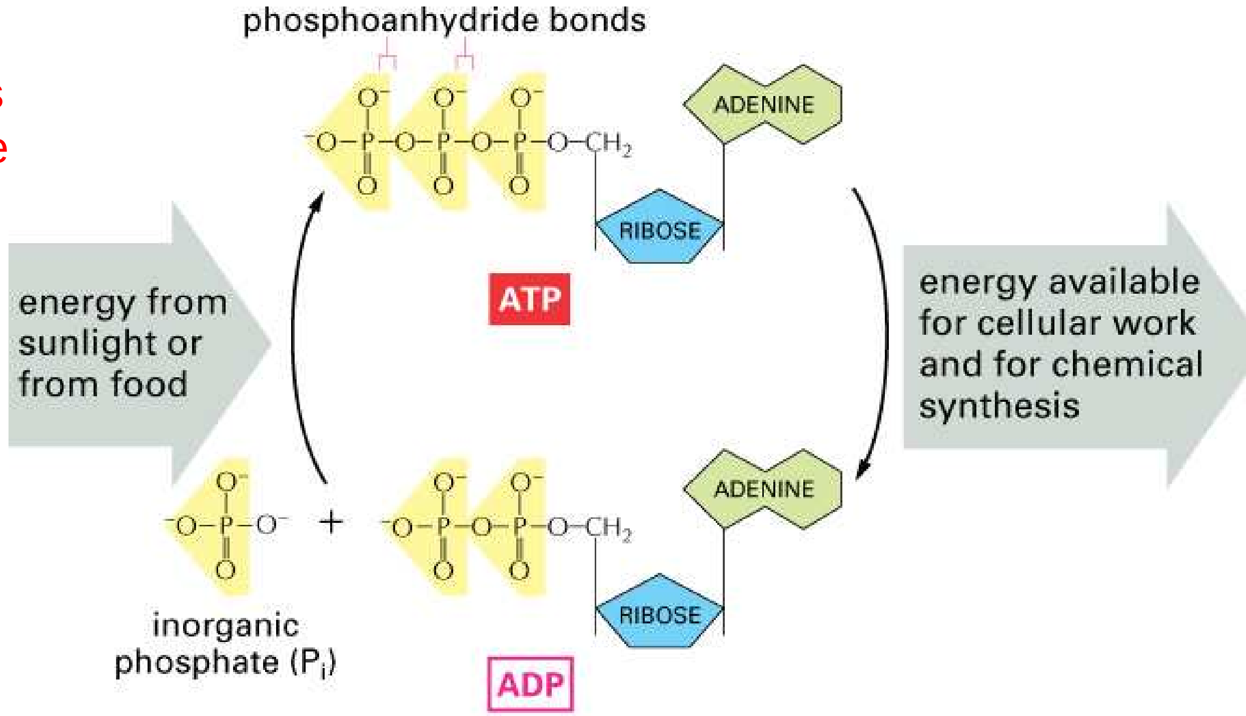
Metabolism

- Chemical processses that provide energy and nutrients to cells. Without cell's presence, these reactions would occur too slowly to be useful. Cell's primary purpose is to speed up these reactions.
- Metabolism requires both sources of raw materials and energy to break down old molecules and manufacture new ones.



hyperphysics.phy-astr.gsu.edu/hbase/biology

- Cells have the ability to produce a large variety of products from a very limited set of starting materials, utilizing a diverse array of enzymes.
- Regardless of where energy comes from, cells utilize the same molecule (ATP, adenosine triphosphate) to store and release energy. ATP is completely recyclable.



Alberts, Bray, Johnson, Lewis, Raff, Roberts, Walter, Garland Publishing: Taylor Francis Group

Metabolic Sources

Carbon sources

Heterotroph Organism which gets its carbon by eating (animals, many microscopic organisms)

Autotroph Organism which gets its carbon from CO_2 in the atmosphere or dissolved in water (most plants)

Energy sources

- Sunlight (photosynthesis) photo-
- Organic (food) chemo-
- Inorganic (chemicals) chemo-

Metabolic class	Carbon source	Energy source
photoautotroph	CO_2	sunlight
chemoautotroph	CO_2	inorganic chemicals (*e.g.,* Fe, S, NH_3)
photoheterotroph	organic compounds	sunlight
chemoheterotroph	organic compounds	organic compounds

Metabolic class	Examples
photoautotroph	plants, photosynthetic bacteria
chemoautotroph	extremophile archaea and bacteria
photoheterotroph	some bacteria and archaea
chemoheterotroph	animals, many microbes

Metabolism and the Implications for Life

Structures like cells are a probable basis for extraterrestrial life.

- General nature of metabolic classes suggest they could apply to extraterrestrial life.
- Any type of complex metabolism requires existence of some kind of structure that allows carbon and energy to come together and manufacture or break down molecules.

Water plays key roles and might be universally required.

- Organic chemicals are readily available for reactions by being dissolved in water.
- Water provides the medium for transporting chemicals to and within cells and transporting waste products away.
- Water is essential in cellular metabolic reactions, such as the ATP-ADP cycle.

Abundances of the Elements

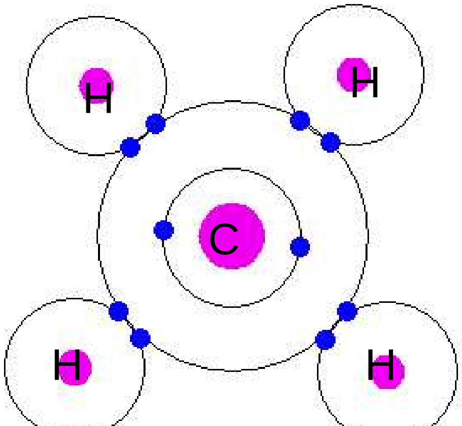
Element	Stars & Universe	Earth Crust	Earth Ocean	Life
H	93.4	0.14	66.2	61
He	6.5	0	0	0
O	0.06	47	33.1	26
C	0.03	0005	0.001	10.5
N	0.011	0.0003	0	2.4
Ne	0.01	0	0	0
Mg	0.003	2.1	0.03	0.011
Si	0.003	28	0	0
Fe	0.002	5	0	0.01
S	0.001	0.026	0.017	0.13
Al	0.0002	8.1	0	0
Ca	0.0002	3.6	0	0.23
Na	0.0002	2.8	0	0.01
Ni	0.0001	0.1	0	0
Cr	0.00004	0	0	0
P	0.00003	0.1	0	0.13

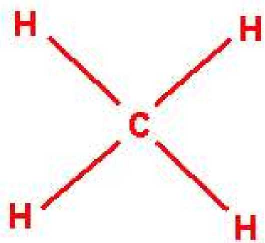
Composition of Biological Compounds

- Organisms are made from polymers, which are long chains of monomers.
- A monomer is a molecule made from individual atoms.
- An atom is one of the approximately 100 stable elements, or which 4 are ultra-important and 2 more are moderately important.

Element	# bonds	Element	# bonds	Element	# bonds
H	1	C	4	N	3
O	2	P	5	S	2

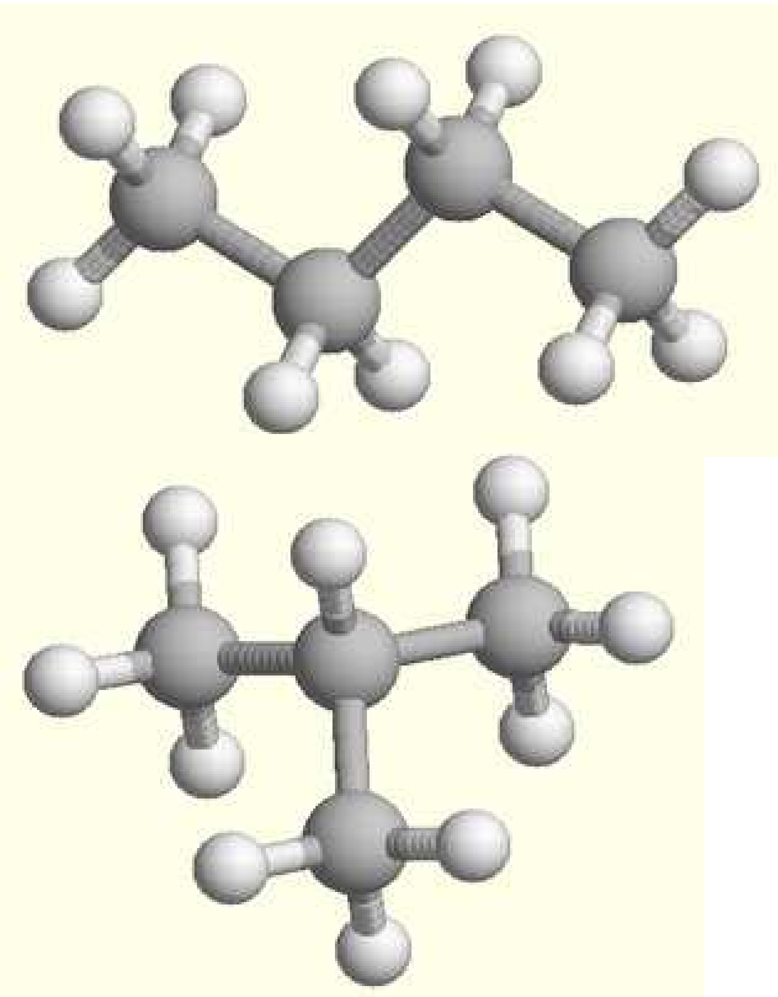
- The number of bonds are the maximum number of covalent bonds elements can form. A covalent bond is formed when electrons are shared among atoms.
- Even though some elements can share more electrons, *e.g.*, P, C has the most flexibility in forming molecules of different shapes and sizes.
- Most molecules that are carbon-based are called organic molecules and can be very complex. Elemental carbon, cabonates, CO_2 and cyanides are considered inorganic.

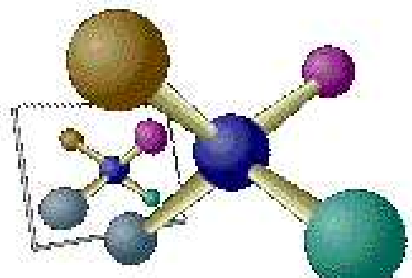




Isomers

- When larger groups of atoms are assembled, there may be multiple ways to bond the same number of atoms. Each of the different ways is called an isomer.
- Some isomers show handedness: these are called stereoisomers and are either left- or right-handed. They are mirror images of each other. In general, life utilizes only one handedness (*e.g.*, left-handed amino acids are used to make proteins).





Handedness

- Humans are 9:1 right-handed, but terrestrial biochemistry contains only left-handed amino acids.
- Meteorites contain amino acids in nearly equal proportions of left- and right-handed varieties. The ratio is left:right = 1.08:1, and no one know why. One possible explanation has to do with circularly polarized UV light in the stellar association where the Sun formed, as is observed in the Orion nebula.
- Left-and right-handed molecules can have very different properties. Drugs especially can be affected. Some examples are:
  - Orange and lemon peels get aromas from limonene, but it is left-handed in oranges and right-handed in lemons, which obviously smell distinct.
  - The molecule carvone produces the smells of mint (left) and caraway (right).
  - The drug ibuprofen, if left-handed, is 4 times as strong as the other kind.
  - The sedative Darvon is an isomer of the cough medicine ingredient Novrad.
  - The drug thalidomide is used to control morning sickness, but its mirror image causes birth defects.
  - Ethambutol: one handedness is used to treat tuberculosis, the other causes blindness.
  - Naproxen: one handedness is used to treat arthritis, but the other causes liver poisoning.
- Molecular activity can also be affected by handedness. Penicillin kills only bacteria in cell walls but not the cells themselves because of handedness.

Building Blocks and Selectivity

- Largest organic molecules are polymers, or long chains of monomers, which often containing repeating units or patterns.
- One could view monomers as lego blocks: an infinite variety are possible, but only a select few are actually used.
- Monomers tend to be simple, because otherwise it might be too difficult or take too long to form them, either deliberately or by chance.
- Examples: there are 35 isomers of C_9H_{20} and 60 trillion isomers of $C_{40}H_{82}$.
- Example of selectivity: About 20 different amino acids are found in living material although virtually billions are possible to be formed in the laboratory.
- Another example: Proteins are made of chains of about 100 amino acids. About 20 different amino acids are used. About 100,000 different proteins found in living material although it is possible to form $119!/(100!19!) = 5 \cdot 10^{21}$ combinations.
- Selectivity is extended by utilizing only a single handedness.

Kinds of polymers and their monomers:

- proteins – amino acids
- carbohydrates – sugars
- nucleic acids – bases, sugars, phosphates
- lipids – fatty acids