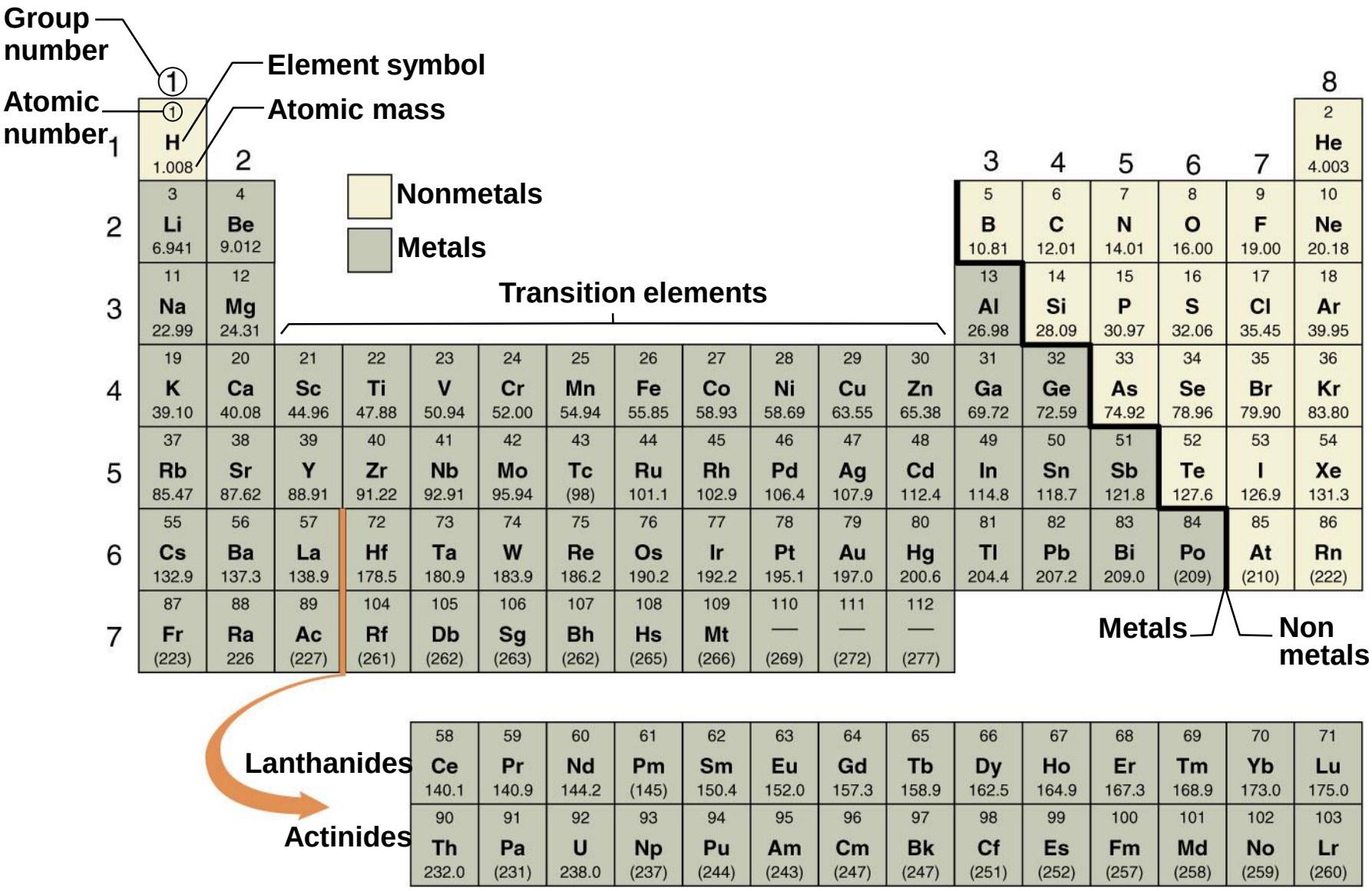
Chemistry

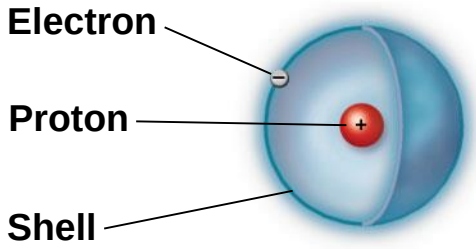
All Matter Consists of Elements

- **Chemistry** is the study of matter
- **Matter is:**
  - Anything that has mass and occupies space
  - Composed of elements
- **Elements**
  - Cannot be broken down to a simpler form
  - Periodic table of elements – lists all known elements

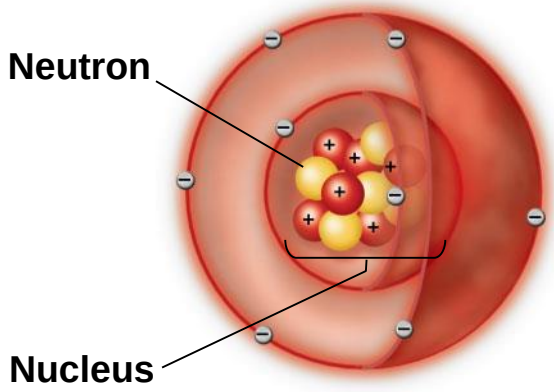

Group number
Atomic number
Element symbol
Atomic mass
Nonmetals
Metals
Transition elements
Metals
Non metals
Lanthanides
Actinides

Atoms – Smallest Functional Unit of Elements

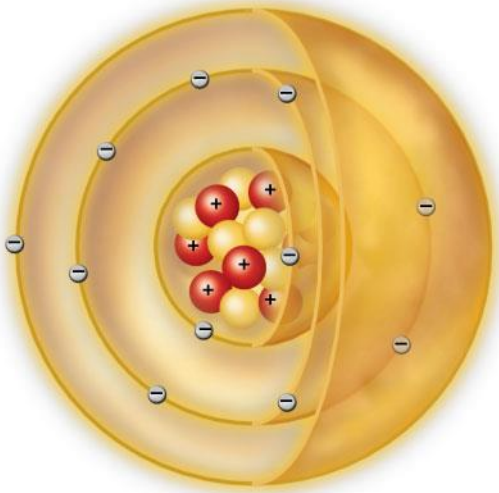
- Atoms consist of
  - Nucleus (central core)
    - **Protons**
      - positive charge
      - have mass
    - **Neutrons**
      - no charge
      - have mass
  - Shells (surrounding nucleus)
    - **Electrons**
      - negative charge
      - no discernable mass



a) Hydrogen
1 proton



b) Oxygen
8 protons
8 neutrons
8 electrons
in 2 shells



c) Sodium
11 protons
11 neutrons
11 electrons
in 3 shells

More About Atoms

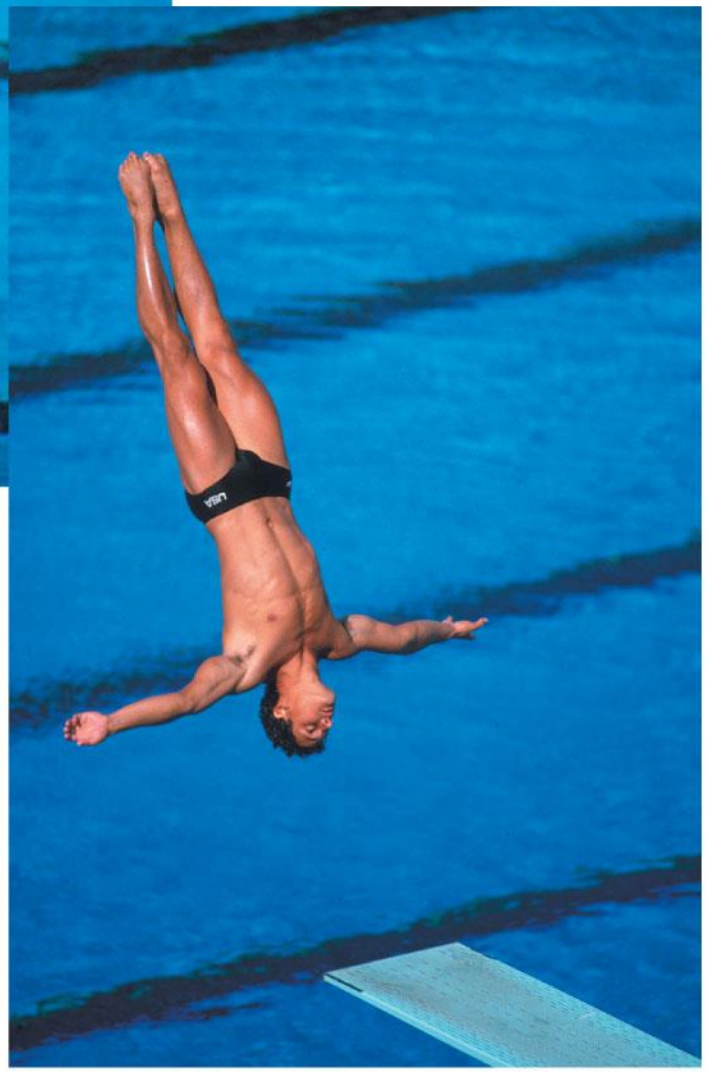
- **Atomic symbol**: one or two letters
  - Na: sodium
  - O: oxygen
- **Atomic number**
  - Number of protons
- **Atomic mass**
  - Roughly equal to number of protons plus neutrons

Energy Fuels Life's Activities

- **Energy**: the capacity to do work
- **Potential energy**: stored energy
- **Kinetic energy**: energy in motion, doing work

- Potential energy can be transformed into kinetic energy

a) Potential energy is locked up in the chemical bonds of energy-storage molecules in Greg Louganis' tissues.



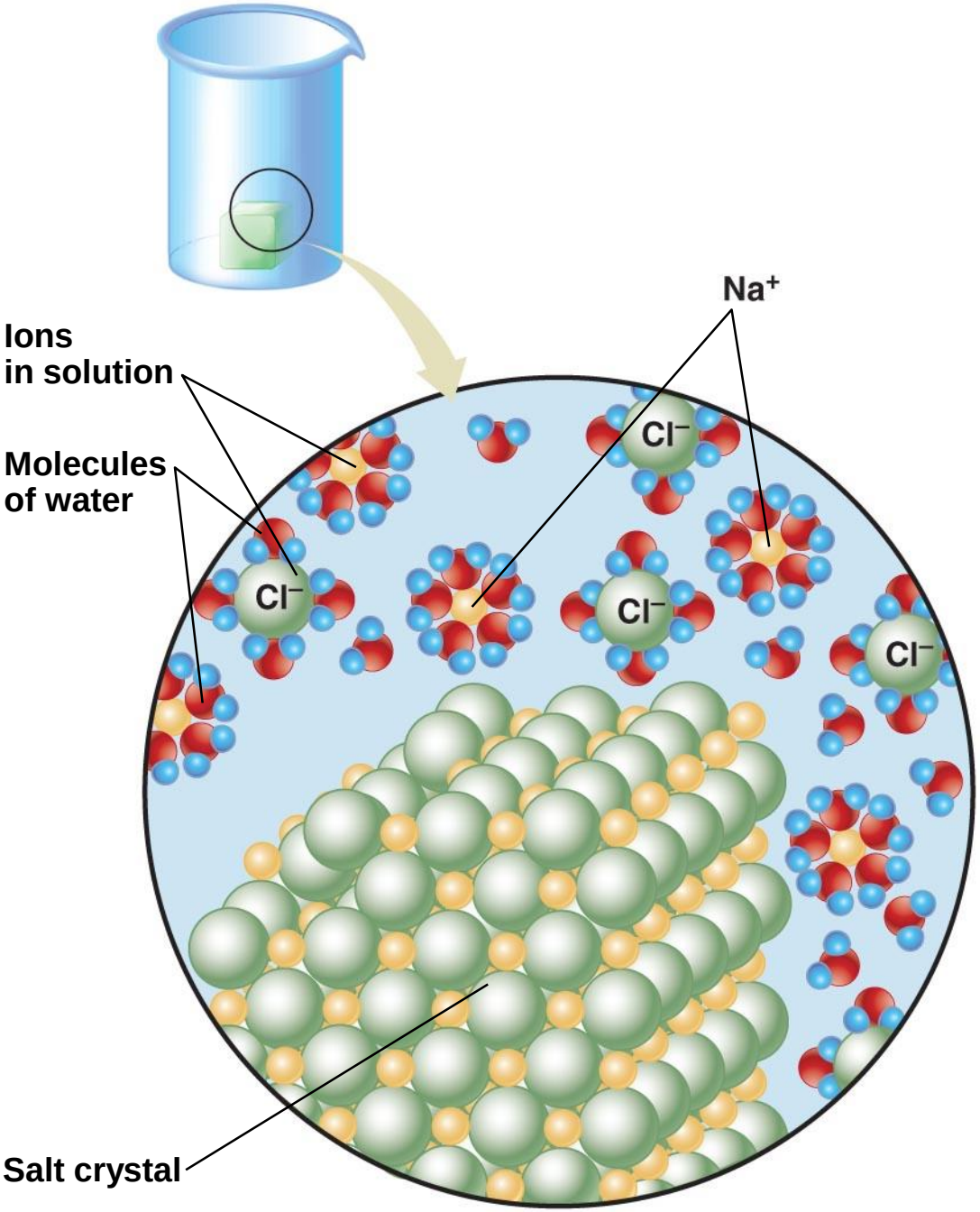
b) Kinetic energy is energy in motion.

Life Depends on Water

- Water molecules are polar
- Water is liquid at body temperature
- Water can absorb and hold heat energy
- Water is the biological solvent
- Water helps regulate body temperature

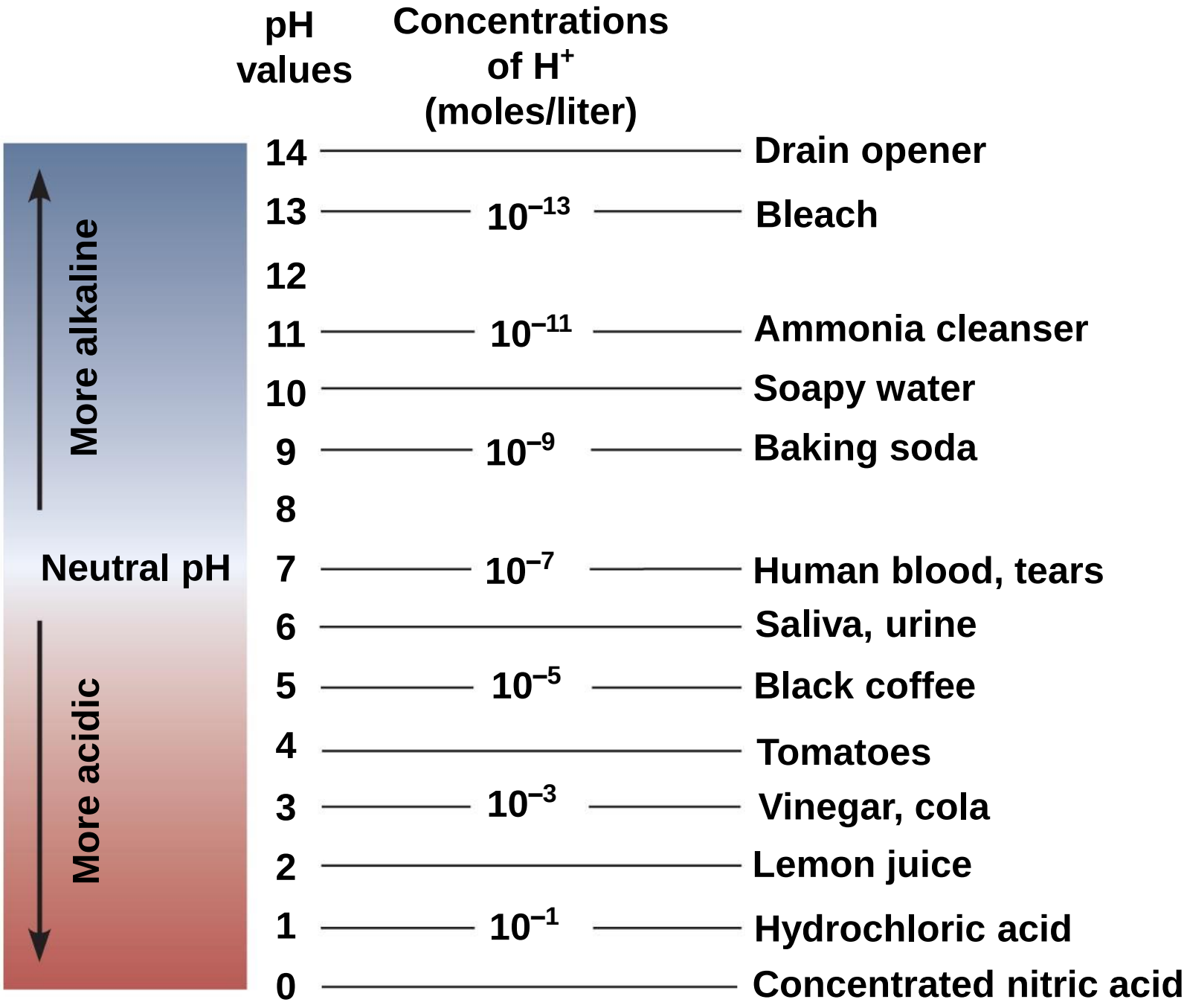
Water Is the Biological Solvent

- **Solvent**: liquid in which other substances dissolve
- **Solute**: any dissolved substance
- **Hydrophilic**: molecules that are attracted to water and interact easily with water
- **Hydrophobic**: molecules that do not interact with or dissolve in water


Ions
in solution
Molecules
of water
Salt crystal
Na+
Cl–
Cl–
Cl–
Cl–

The Importance of Hydrogen Ions

- Acids:
  - Donate hydrogen ions (protons)
  - Increase hydrogen ion concentration in solutions
- Bases
  - Accept hydrogen ions (protons)
  - Lower hydrogen ion concentration in solutions
- pH Scale
  - A measure of hydrogen ion concentration


pH values
Concentrations of H^+ (moles/liter)
More alkaline
Neutral pH
More acidic
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
10^{-13}
10^{-11}
10^{-9}
10^{-7}
10^{-5}
10^{-3}
10^{-1}
Drain opener
Bleach
Ammonia cleanser
Soapy water
Baking soda
Human blood, tears
Saliva, urine
Black coffee
Tomatoes
Vinegar, cola
Lemon juice
Hydrochloric acid
Concentrated nitric acid

Buffers

- Minimize pH change
- Help maintain stable pH in body fluids
- Carbonic acid and bicarbonate act as one of the body's most important buffer pairs
  - $HCO_3^- + H^+ \longrightarrow H_2CO_3$

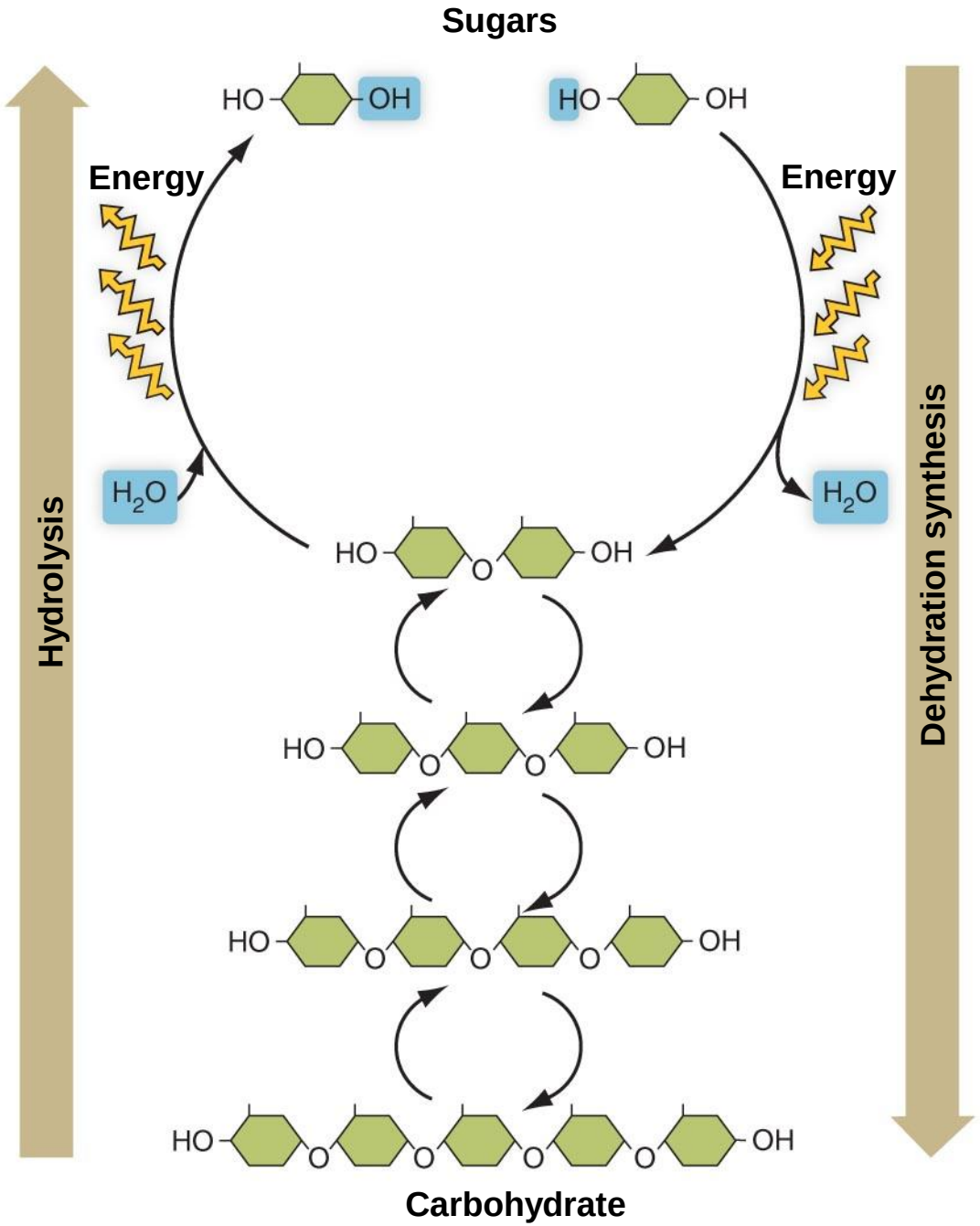
The Organic Molecules of Living Organisms

- Carbon
  - The building block of living things
  - Comprises ~18% of the body by weight

Macromolecules Are Synthesized and Broken Down within the Cell

- Dehydration synthesis
  - Removes equivalent of a water molecule
  - Requires energy
  - Builds macromolecules from smaller subunits
- Hydrolysis
  - Adds the equivalent of a water molecule
  - Releases energy

- Dehydration synthesis is the reverse of hydrolysis

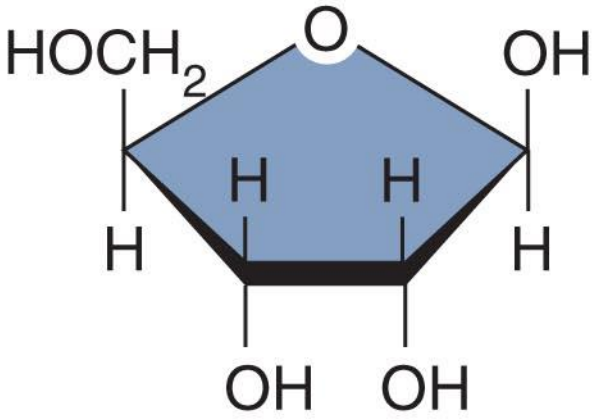

Sugars
HO
OH
HO
OH
Energy
Energy
H_2O
H_2O
HO
O
OH
HO
O
O
OH
HO
O
O
O
OH
HO
O
O
O
O
OH
Hydrolysis
Dehydration synthesis
Carbohydrate

Carbohydrates: Used for Energy and Structural Support

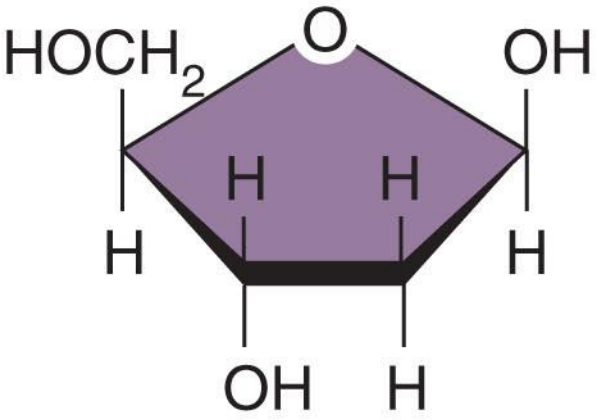
- General formula: $C_n(H_20)_n$
- Monosaccharides: simple sugars
  - Glucose
  - Fructose
  - Galactose
  - Ribose
  - Deoxyribose

Oligosaccharides: More than One Monosaccharide Linked Together

- Monosaccharides can be linked together via dehydration synthesis
- Disaccharides: two monosaccharides linked together
  - Sucrose: glucose + fructose
  - Maltose: glucose + glucose
  - Lactose: glucose + galactose

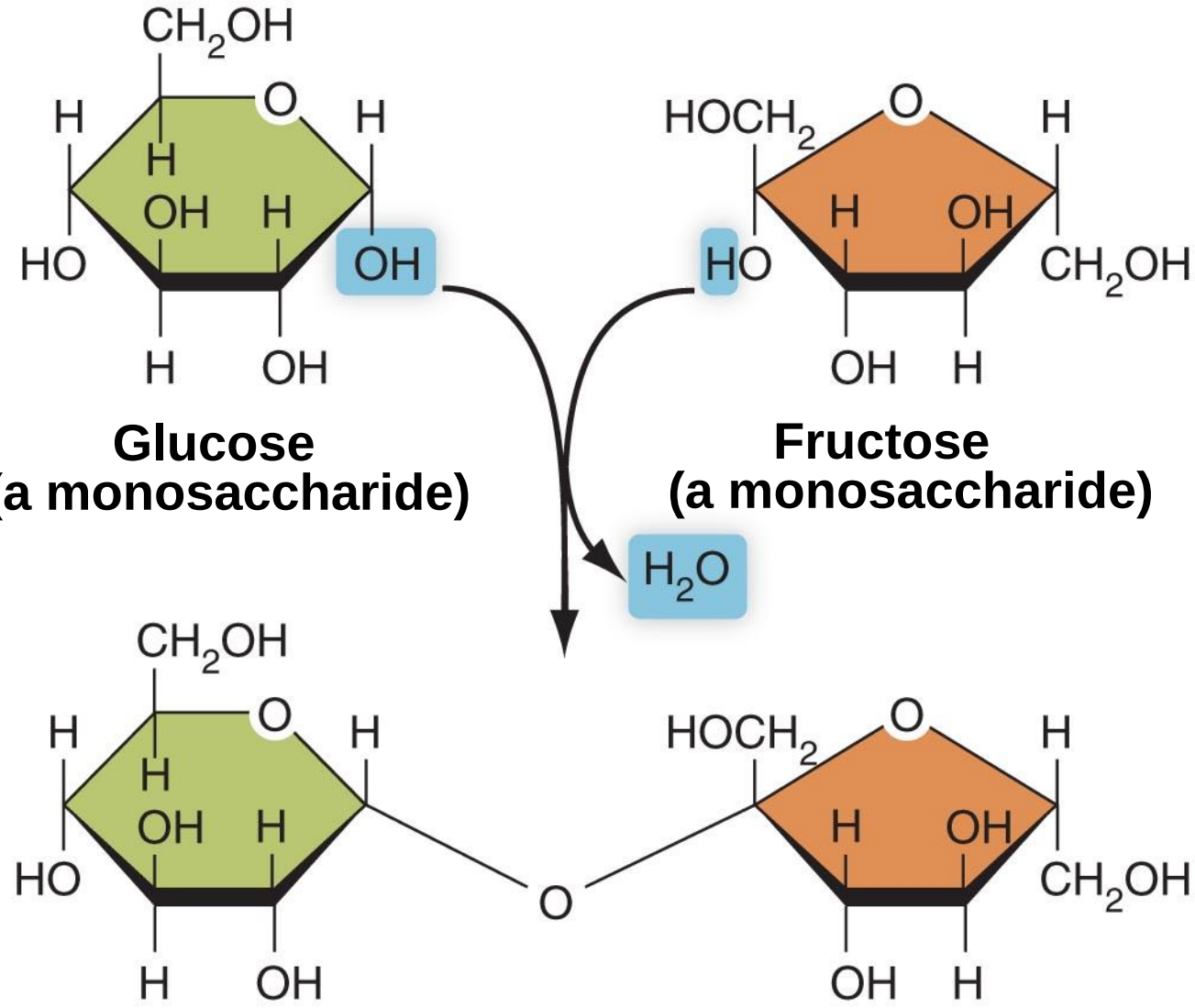


Ribose



Deoxyribose

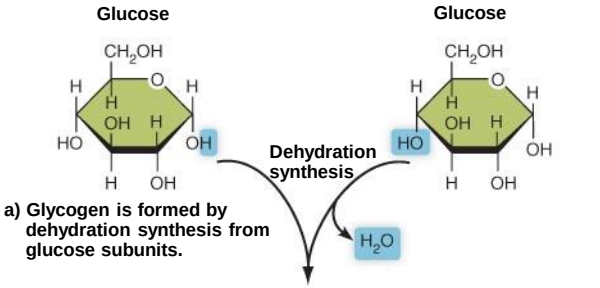
a) The five-carbon monosaccharides ribose and deoxyribose.



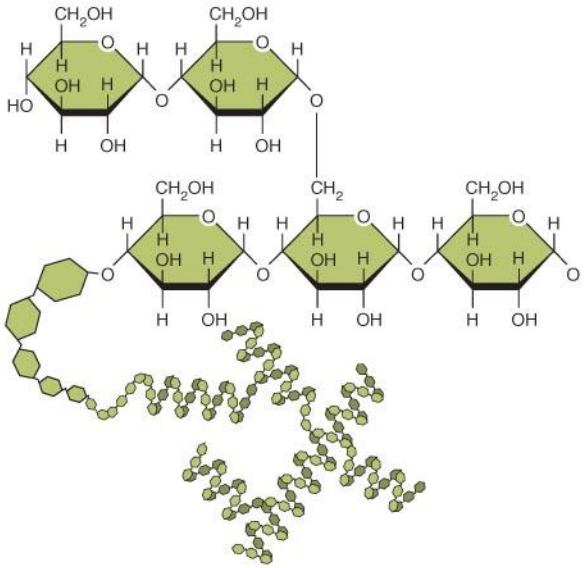
b) Two 6-carbon monosaccharides (glucose and fructose) are joined together by dehydration synthesis, forming sucrose.

Polysaccharides Store Energy

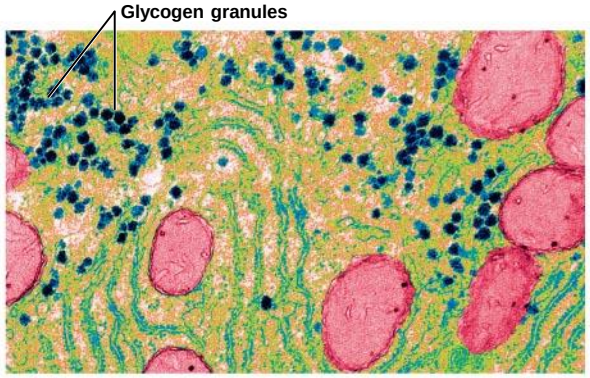
- Polysaccharides: thousands of monosaccharides joined in chains and branches
  - Starch: made in plants; stores energy
  - Glycogen: made in animals; stores energy
  - Cellulose: indigestible polysaccharide made in plants for structural support



a) Glycogen is formed by dehydration synthesis from glucose subunits.



b) A representation of the highly branched nature of glycogen.



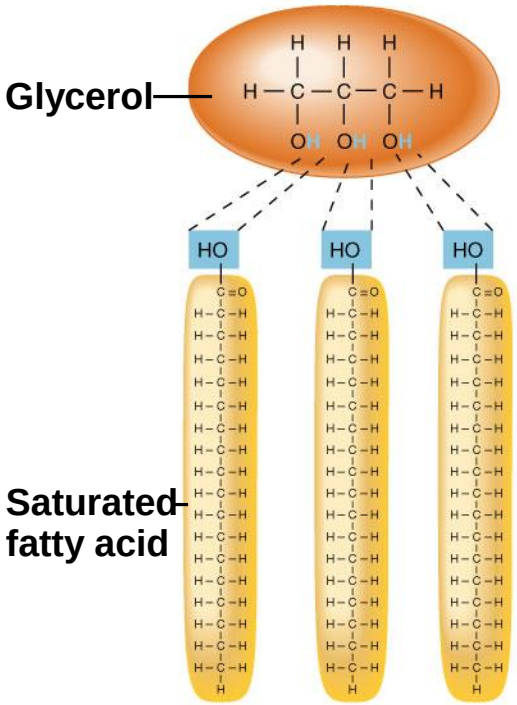
c) A portion of an animal cell showing granules of stored glycogen (blue). The large pink structures are mitochondria.

Lipids: Insoluble in Water

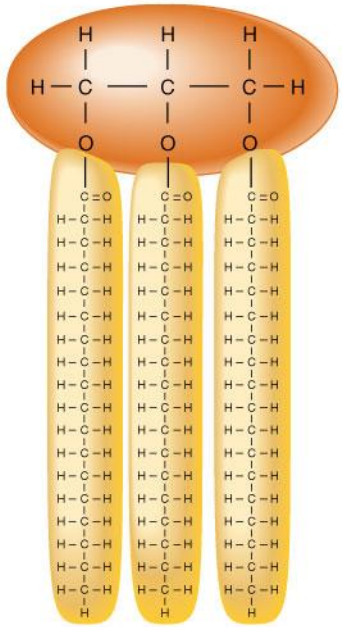
- Three important classes of lipids
  - **Triglycerides**: energy storage molecules
  - **Phospholipids**: cell membrane structure
  - **Steroids**: carbon-based ring structures

Triglycerides

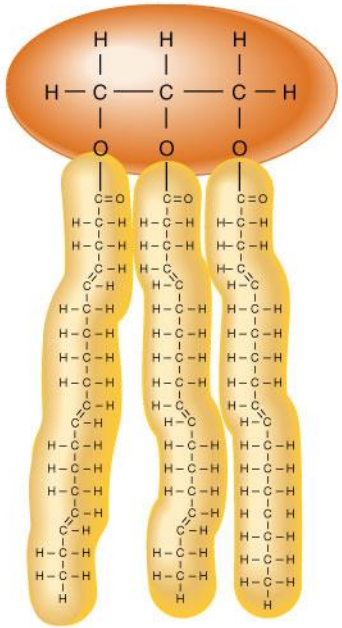
- Also known as fats and oils
- Composed of glycerol and three fatty acids
  - Fatty acids
    - Saturated (in fats)
    - Unsaturated (in oils)
- Energy storage molecules



a) Triglycerides (neutral fats) are synthesized from glycerol and three fatty acids by dehydration synthesis.



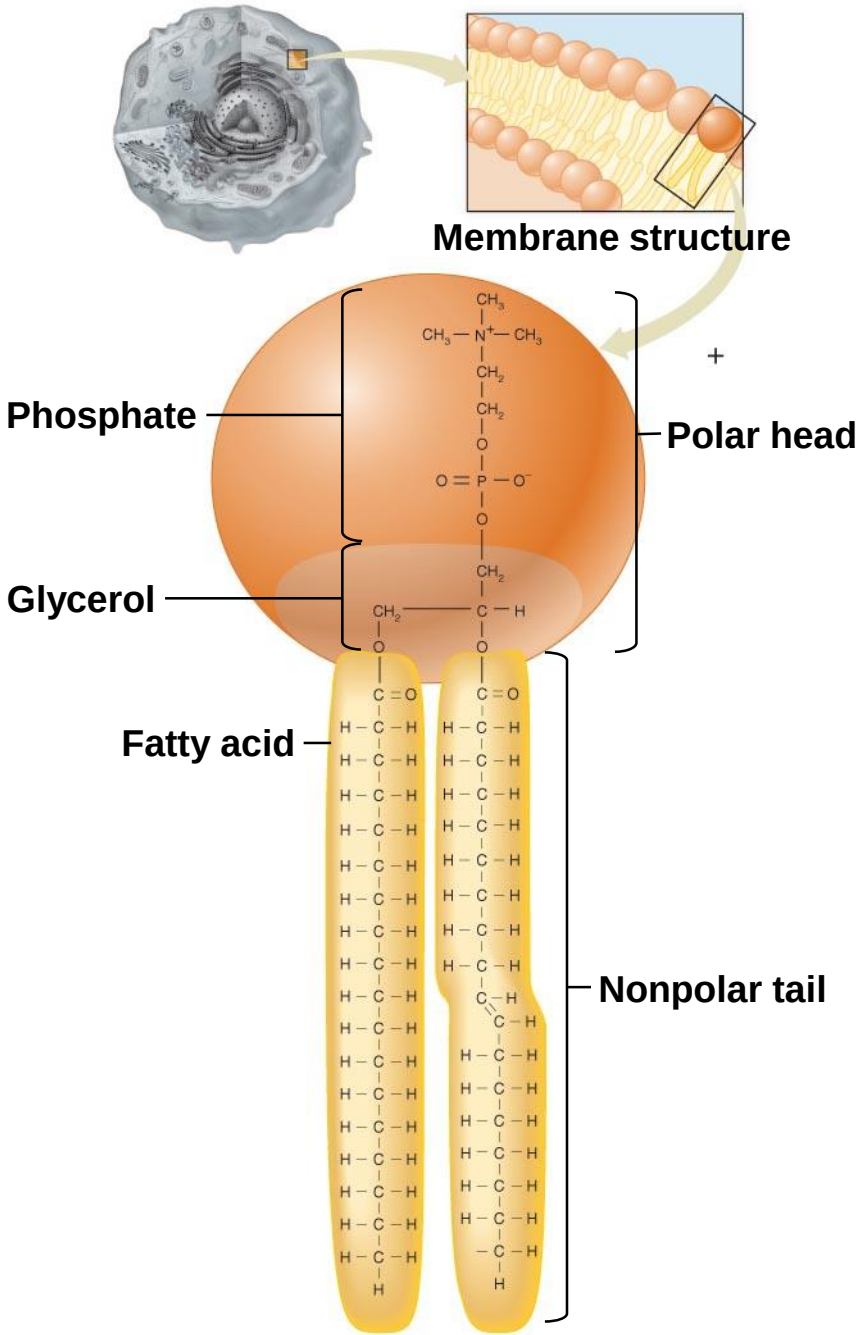
b) Triglycerides with saturated fatty acids have straight tails, allowing them to pack closely together.



c) Triglycerides with unsaturated fatty acids have kinked tails, preventing them from packing closely together.

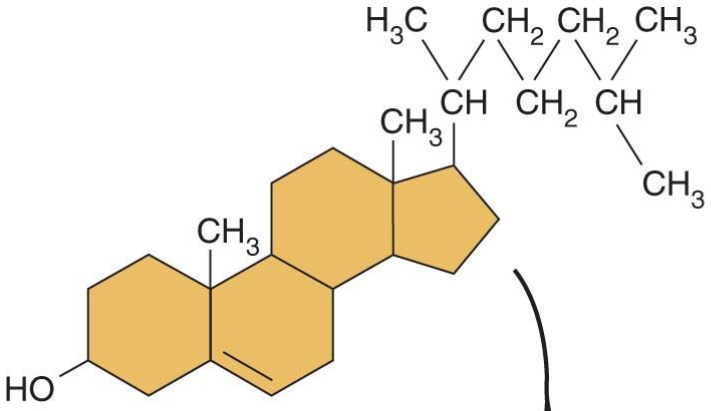
Phospholipids

- Structure
  - Glycerol + two fatty acids and phosphate group
  - One end of molecule is water soluble (hydrophilic)
  - Other end of molecule is water insoluble (hydrophobic)
- Function
  - Primary component of cell membranes


Membrane structure
Phosphate
Glycerol
Fatty acid
Polar head
Nonpolar tail
+

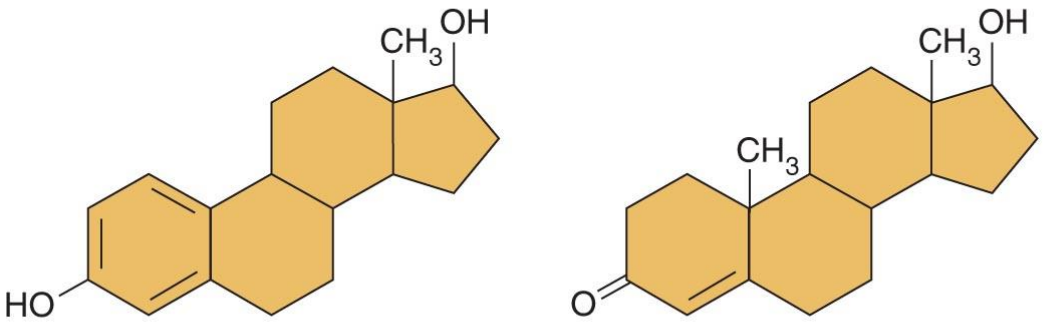
Steroids

- Structure
  - Composed of four carbon rings
- Examples:
  - Cholesterol
  - Hormones
    - Estrogen
    - Testosterone



a) Cholesterol:
A normal component of the cell membrane.

c) Testosterone:
Male sex hormone synthesized from cholesterol.



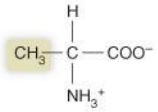
b) Estrogen (estradiol):
Female sex hormone synthesized from cholesterol.

Proteins

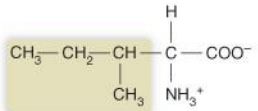
- Long chains (polymers) of subunits called amino acids
- Amino acids
  - 20 different types
  - Amino end, carboxyl end, R group
- Amino acids are joined by peptide bonds
  - produced by dehydration synthesis reactions

Amino acids with nonpolar R groups

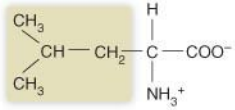
Alanine (Ala)



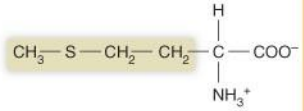
Isoleucine (Ile)



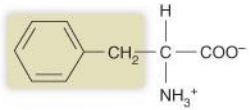
Leucine (Leu)



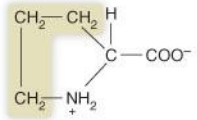
Methionine (Met)



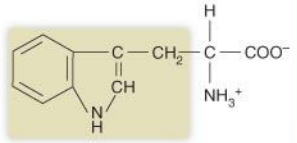
Phenylalanine (Phe)



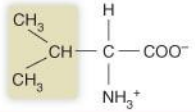
Proline (Pro)



Tryptophan (Trp)

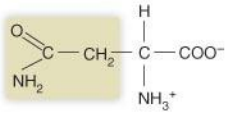


Valine (Val)

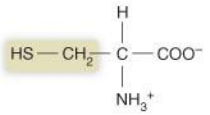


Amino acids with uncharged polar R groups

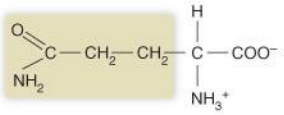
Asparagine (Asn)



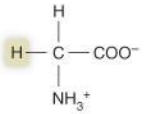
Cysteine (Cys)



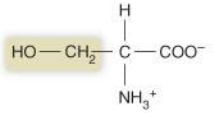
Glutamine (Gln)



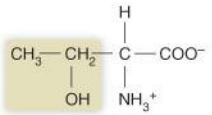
Glycine (Gly)



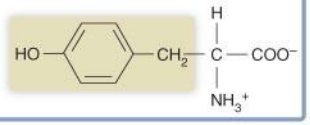
Serine (Ser)



Threonine (Thr)

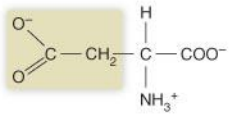


Tyrosine (Tyr)

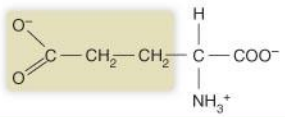


Amino acids with negatively charged R groups

Aspartic acid (Asp)

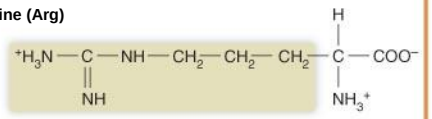


Glutamic acid (Glu)

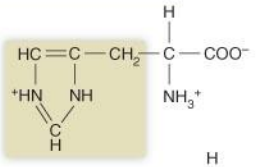


Amino acids with positively charged R groups

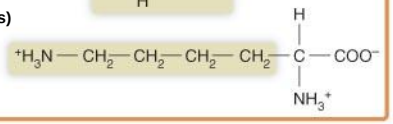
Arginine (Arg)



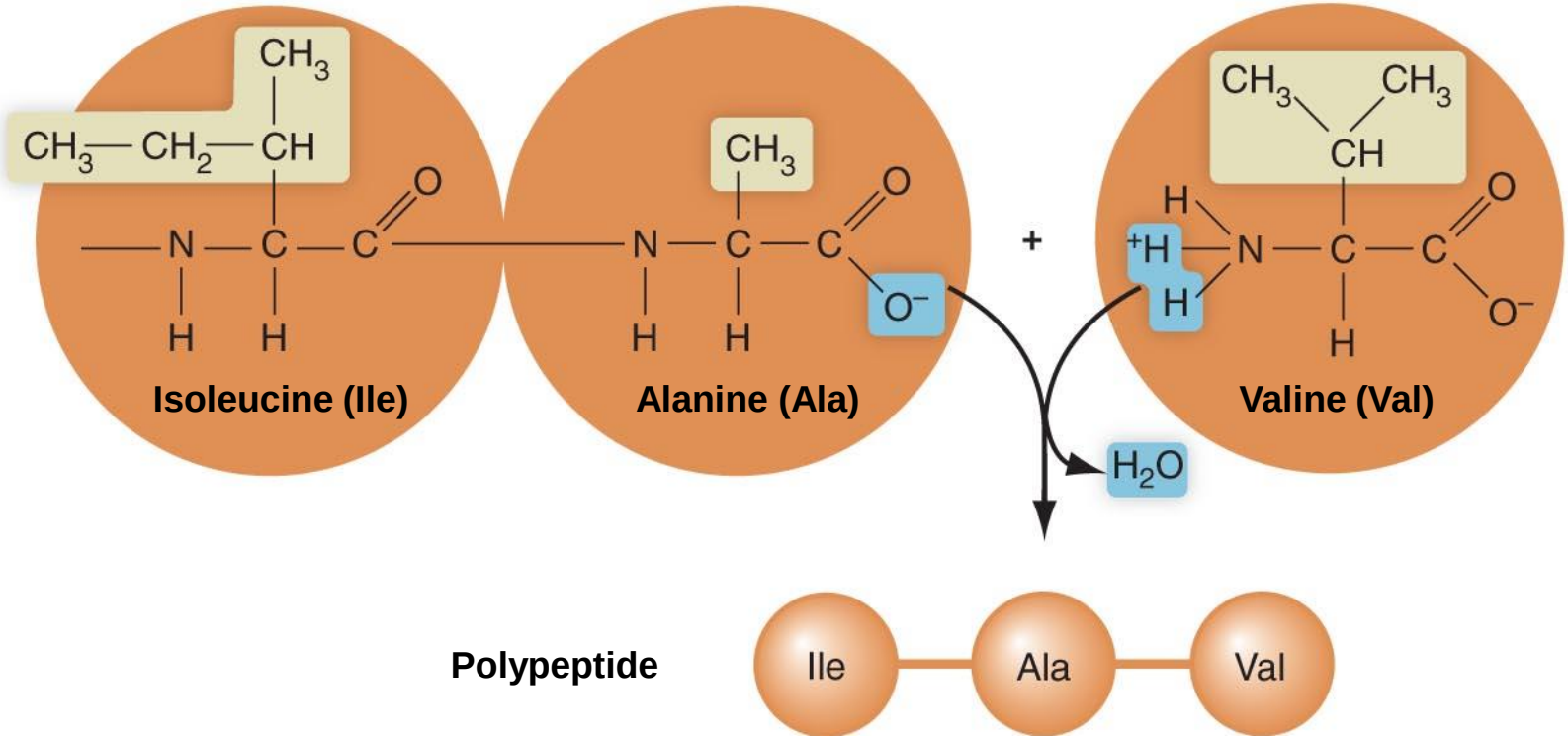
Histidine (His)



Lysine (Lys)



Amino acids



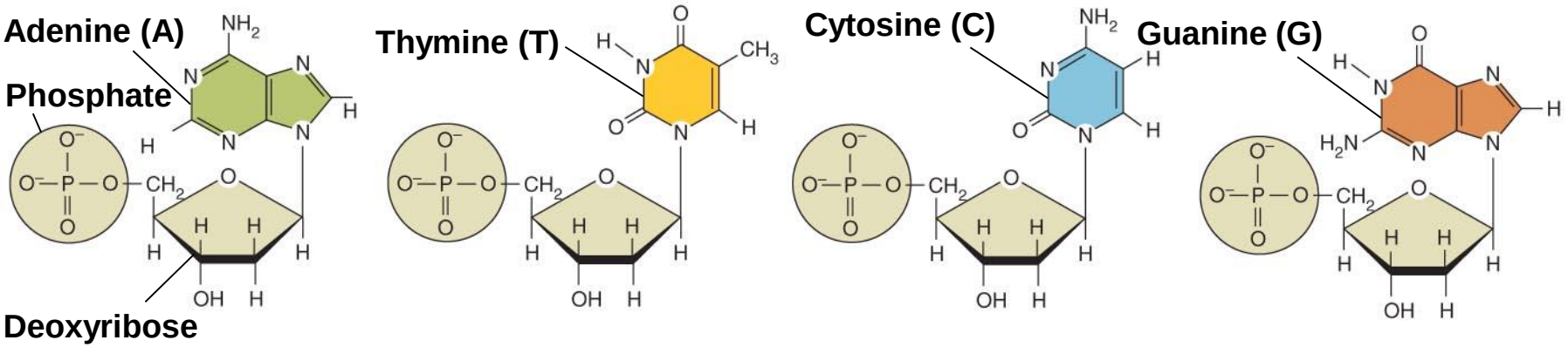
Polypeptide

Nucleic Acids Store Genetic Information

- Two types
  - DNA: deoxyribonucleic acid
  - RNA: ribonucleic acid
- Functions
  - Store genetic information
  - Provide information used in making proteins
- Nucleic acids are long chains containing subunits known as nucleotides

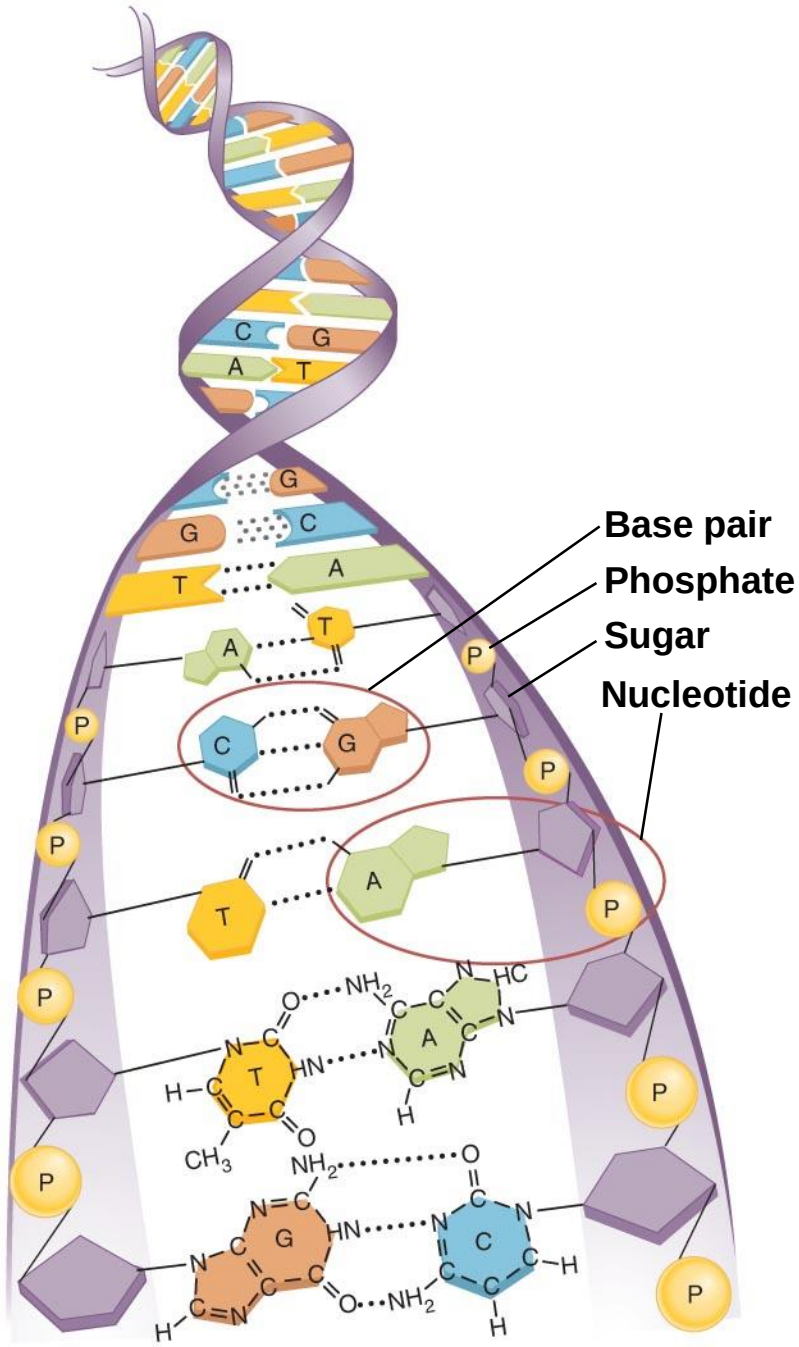
Nucleic Acids Store Genetic Information

- **Nucleotides**: building blocks of nucleic acids
- Each nucleotide contains
  - 5 carbon sugar
    - DNA nucleotides: deoxyribose
    - RNA nucleotides: ribose
  - Nitrogenous base
  - Phosphate group


Adenine (A)
Phosphate
Deoxyribose
Thymine (T)
Cytosine (C)
Guanine (G)

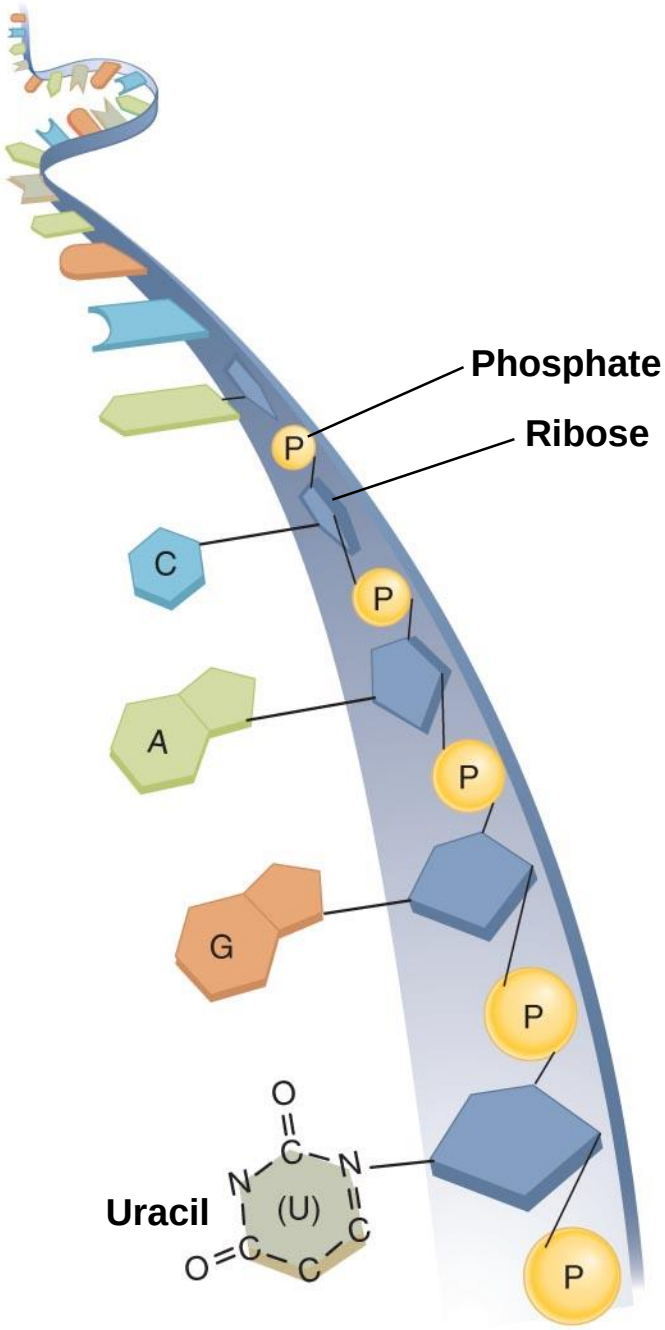
Nucleic Acids Store Genetic Information

- Structure of DNA (deoxyribonucleic acid)
  - Double–stranded
  - Nucleotides contain
    - Deoxyribose (sugar)
    - Nitrogenous bases
      - Adenine
      - Guanine
      - Cytosine
      - Thymine
  - Pairing
    - Adenine (A) – Thymine (T)
    - Guanine (G) – Cytosine (C)


C
G
A
T
G
C
G
C
T
A
T
A
P
P
C
G
P
P
T
A
P
P
P
P
P
P
Base pair
Phosphate
Sugar
Nucleotide

Nucleic Acids Store Genetic Information

- Structure of RNA (ribonucleic acid)
  - Single–stranded
  - Nucleotides contain
    - Ribose
    - Nitrogenous bases
      - Adenine (A)
      - Guanine (G)
      - Cytosine (C)
      - Uracil (U)

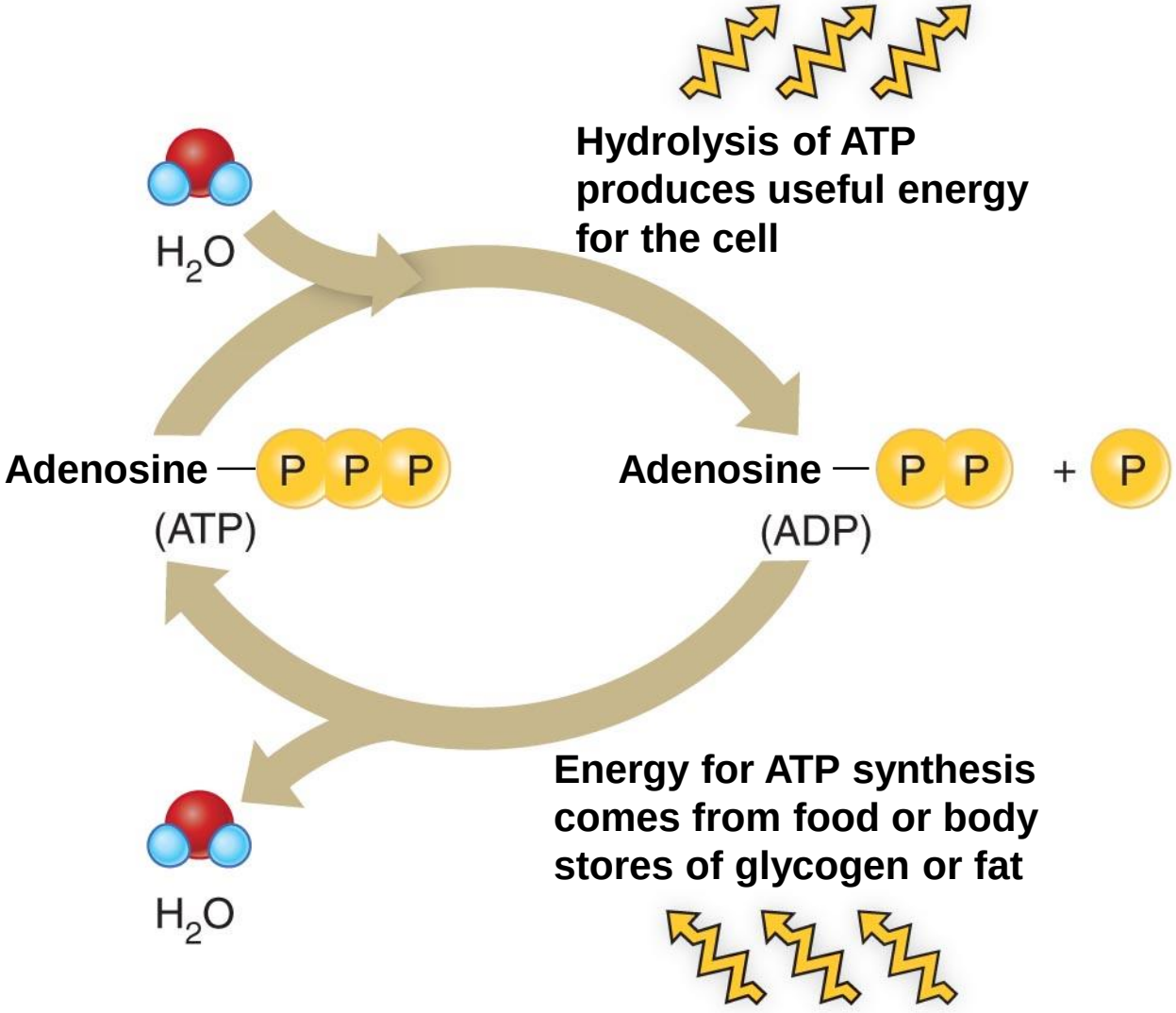

Phosphate
Ribose
P
C
P
A
P
G
P
P
Uracil
O
C
N
N
(U)
C
O
C
C

Nucleic Acid Function --- Nucleic Acids Store Genetic Information

- Nucleic acid function
  - DNA: instructions for making RNA
  - RNA: instructions for making proteins
  - Proteins: direct most of life's processes
  - DNA → RNA → Proteins

ATP Carries Energy

- Structure and function of adenosine triphosphate (ATP)
  - Universal energy source
  - Bonds between phosphate groups contain potential energy
  - Breaking the bonds releases energy
    - ATP → ADP + P + energy



b) The breakdown and synthesis of ATP.
The breakdown (hydrolysis) of ATP yields energy for the cell. The reaction is reversible, meaning that ATP may be resynthesized using energy from other sources.