Inorganic Molecules

~2/3rd 's of body consists of inorganic molecules

general characteristics:

small molecules: only a few atoms & bonds

little or no carbon atoms

usually dissolve easily in water

usually resist decomposition

undergo rapid chemical reactions

usually more likely to ionize

Major kinds of inorganic molecules inside cells:

1. Water

perhaps most important and most abundant molecule in the body

some animals up to 95% of body mass; average is 65-75%

can live for several weeks or a month without food but not more than a few days without water

its unique properties relate to its structure, strong

polar nature and hydrogen bonds it can form

a. Universal solvent

can only have chemical reactions (metabolism) if the chemicals are dissolved in some liquid (=**solvent**)

more things dissolve in water than in any other solvent

polar→ forces ions and polar molecules to disperse(ie. dissolve)

substances that dissolve readily in water = hydrophilic (water loving)
substances that do not dissolve in water = hydrophobic (water hating)
uncharged or nonpolar molecules
hydrophobic molecules tend to cluster together
→ not 'bond' but important in shape of some molecules and cellular structures

b. chemical reactant

water molecules are directly used in some important chemical reactions

eg. synthesis and decomposition of most organic polymers

acts as main source of H atoms for organic molecules

also donates O atoms in some reactions

c. ability to stabilize temperature

water absorbs and releases heat slowly

contributes to temperature homeostasis

eg. sweating → cooling

high heat capacity: requires a much greater heat input to raise temp of water 1º C than any other substance

also gives up heat slowly
because of tight hydrogen bonds takes more E to get them to comparable degree of motion (ie. cause an increase in T)
takes 539 C to heat 1g of water past its boiling point – hydrogen bonds resist separation (this is 2x's ethanol, 5x's chloroform)
as molecule of water evaporates it takes this heat along with it therefore cools the rest of the liquid

d. acts as lubricant

prevents friction and damage to moving parts

eg. heart, lungs, joints, stomach, intestine, etc

e. cushioning

water protects organs from physical damage if jostled

water baths brain and spinal cord

fluid surrounds each cell

f. transport medium

blood, lymph

moves things from place to place

The human body is made up mostly of water; ~60 - 65% (40 L)

Where is this water located?

This water can be visualized as occurring in several "compartments":

intracellular	62%	40% (25 L)	
extracellular	(38%)	20% (15 L)	
interstitial	30%	16% (12 L)	[80% of ecf]
intravascular	8%	4% (3 L)	[20% of ecf]

<u>**Intracellular**</u>

most of the fluid in the body = 2/3rd's inside all body cells

<u>**Extracellular**</u>

all fluid outside cells
~1/3rd of body water

some is in tissue spaces between cells = **interstitial** (= intercellular)

30% of total fluids

some is circulating in vessels
= **intravascular**
(blood and lymphatic systems)
8% of total fluids

These compartments are interconnected:

outside ⟷ intravascular ⟷ interstitial ⟷ intracellular

maintaining water and salt balance in each compartment means maintaining a balance in body as a whole

they interact with the environment by specialized organ systems:

respiratory system
excretory system
digestive system

Fluid inputs:

digestive tract	2000ml
metabolism	500ml
TOTAL:	2500ml

Fluid outputs:

kidneys	1300ml
lungs	450ml
skin	650ml
intestine	100ml
TOTAL:	2500ml

2. Electrolytes (ions)

molecules that tend to disperse in solution into charged atoms

[some organic molecules are also electrolytes]

ions; eg Ca^{++}, Na^{+}, Cl^{-}, K^{+}, et
salts; NaCl, carbonates, phosphates
acids and bases; HCl, NaOH

organisms are extremely sensitive to changes in electrolyte composition

general functions of electrolytes:
a. help maintain salt/water balance
b. acid/ base balance
c. bone and teeth formation
d. functioning of nerve and muscle cells
e. enzyme activation

cations and **anions**
salts → cations and anions (but not H^{+} or OH^{-})

salt=any acid in which the H ion has been replaced by a metal ion

HCl →
- NaCl
- KCl
- Mg→epsom salt
- Ca→calcium carbonate

a. Calcium
99% of Ca^{++} is in bones as reservoir (eg.Calcium phosphate)
1% circulates in body fluids

functions:
- blood clotting
- synapses
- hormone secretion
- nerve impulses
- muscle contractions

b. Sodium
main cation (+) in extracellular fluid (ECF)
main regulator of its volume
also helps in acid/base balance
nerve transmission
muscle contractions

c. Potassium
main cation in intracellular fluid
nerve impulse transmission
muscle contraction
steady heartbeat

d. Iron
most of body's iron is in form of hemoglobin and myoglobin
→oxygen transport and storage
also used as cofactor in enzymes
→ ETS energy pathways
→enzymes for AA, hormone and neurotransmitter synthesis

e. Iodine
I_2 (=iodine gas) is a poison, but I is essential for life
integral part of 2 hormones of thyroid
→regulate body temperature
metabolic rate
reproduction
blood cell formation
nerve and muscle function

acids and **bases**
acids → release H^{+} (proton donors)

bases → releases OH^{-} (proton acceptors)

pH =-log [H^{+}]
pure water: #H^{+} = #OH^{-} → neutral, pH=7

pH = 7 = .0000001 gm H^{+}/liter

pH 6 is 10x's more acidic than pH of 7

body is protected from drastic pH changes by the presence of buffers

3. Gasses

O_2 gas
comprises about 20% of atmosphere
essential for aerobic respiration
waste product of photosynthesis
not same thing as oxygen atoms

CO_2 gas
comprises 0.03% of earth's atmosphere
source of carbon in organic molecules
waste product of respiration

NO gas (nitric oxide)
acts as neurotransmitter and hormone
eg. relaxes smooth muscles (Viagra)

CO
poison

Organic Molecules

~1/3[rd] of body consists of organic molecules

major kinds of organic molecules:

1. **carbohydrates**
2. **lipids**
3. **proteins**
4. **nucleic acids (include ATP)**
5. **vitamins**

large – made of 100's, 1000's 10,000's atoms

contain lots of carbon = **carbon backbone**
carbon can form 4 covalent bonds
easily forms chains, rings, branching structures

also usually contain lots of H, O, N & P atoms

most larger organic molecules are **polymers** of smaller units:

carbohydrates	→ monosaccharides (simple sugars)
proteins	→ amino acids
fats	→ fatty acids & glycerol
nucleic acids	→ nucleotides

most organic molecules can be used for energy production (but not vitamins)

Carbohydrates

sugars and starches, fiber

comprise 1-2% of total body mass

larger ones contain long chains of carbon atoms
→ many chemical bonds
→ huge store of chemical energy

general formula: $(CH_2O)n$

Kinds of Carbohydrates:

Simple Carbohydrates = sugars

Complex Carbohydrates = starches and fiber

complex carbohydrates are **polymers** of sugars

eg. cellulose → most abundant natural polymer
eg. chitin → second most abundant natural polymer

a. simple sugars (monosaccharides)

simplest kinds of carbohydrates

5or 6 carbon atoms

many kinds based on arrangement of atoms

[-ose = sugar]

eg. glucose, fructose, ribose, deoxyribose

glucose ($C_6H_{12}O_6$)
is one of two sugars in every disaccharide
most polysaccharides are made from units of glucose

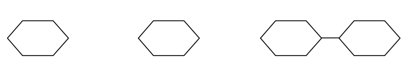
fructose ($C_6H_{12}O_6$)
the sweetest of sugars
same chemical formula as glucose, different structure
this different arrangement stimulates taste buds for sweet even more than does glucose
occurs naturally in fruits and honey
is an additive in high fructose corn syrup

galactose ($C_6H_{12}O_6$)
rarely occurs by itself in nature
usually part of a disaccharide

b. disaccharides

are polymers of monosaccharides

hook two monosaccharides together
eg.



glucose + glucose = maltose

in process of forming disaccharide, a molecule of water is removed = **dehydration synthesis**

addition of water to break bond = **hydrolysis**

eg. sucrose, lactose

sucrose
fructose-glucose
fruits, veggies, grains
table sugar: refined from sugar cane, sugar beets

lactose
galactose-glucose
main carbohydrate in milk (30 – 50% of milks energy)

c. polysaccharides (=starches =complex carbohydrates)

starches are large polymers of simple sugares

consist of many glucose units and sometimes a few other kinds of sugars

= polysaccharides

eg. "starch", glycogen, "fiber"

General Functions of Carbohydrates:

1. decomposition to provide most energy for cell in form of ATP

most cells in body get most of their energy from carbohydrates in the form of simple sugars (esp brain and RBC's)

breakdown of sugar releases energy for day to day activities

the body cannot **store** large amounts of carbohydrates most are used immediately or lost; small amounts can be converted to other kinds of carbohydrates:

2. some simple sugars (ribose & deoxyribose) can be used to make DNA and RNA

3. synthesis of glycoproteins and glycolipids
   cell markers, transport

4. some carbs are converted to **glycogen** and

   stored in the **liver** and **muscles**

Lipids

fats and oils, waxes

oils → liquid at room temperature
fats → solid at room temperature

one of most abundant organic molecules in body

(14 - 20% in lean adult)

most fats are **polymers** of **fatty acids**,

(also glycerol & sometimes phosphates)

3 main kinds:
1. triglycerides
2. phospholipids
3. sterols

1. Triglycerides:

90% of dietary fats and oils are triglycerides

also are predominant lipid found in body

responsible for much of the flavor, tenderness, aroma and palatability of foods

saturated fats

(less healthy: tend to raise LDL ("bad" cholesterol))

eg. esp animal tissues

eg. also some plant oils: cocoa, palm, coconut

unsaturated fats

(more healthy: tend to lower LDL ("bad" cholesterol, and raise HDL "good" cholesterol))

eg. olive oil, peanut oil, corn oil, safflower oil, sunflower oil, sesame oil

eg., linoleic acid & linolenic acid are **essential nutrients**

2. Phospholipids

replace one fatty acid with phosphate group

the Phosphorus group makes them dissolve in water

3. Sterols/Steroids

lipid compound with multiple rings

characteristic 4-ring structure

both plant and animal foods contain sterols but only animal food contains the sterol **cholesterol**

<u>Function of Lipids in The Body</u>

1. fats carry with them **fat soluble vitamins: ADEK**

2. store excess food energy:

   2x's energy/gm than carbohydrates contain

3. insulation from heat and cold

4. "electrical" insulation around neurons = **myelin**

5. used to synthesize some "tissue hormones"

6. **Phospholipids** are needed for all **cell membranes**

7. many fats are used to synthesize hormones

   eg. sex hormones, cortisol

8. cholesterol is essential for cell membranes

Proteins

second most abundant organic molecules in body (15-18%).

much more complex structure than either carbohydrates or lipids

proteins are often **polymers** of 100'x or 1000's of **amino acids**

some proteins are so large that their exact structure has not yet been determined

20 different kinds of amino acids are needed to make proteins

each protein is composed of a unique combination of these amino acids

the body can synthesize ~ half of the 20 AA's

8 AA's are **essential nutrients** and must be gotten in diet (10 in children)

all amino acids have the same basic structure:

amino group: $-NH_2$
acid group: -COOH
R group → unique for each AA

→ small chains of amino acids = **polypeptides**

→ long chains of amino acids = **proteins**

normally the AA's released in digestion are used to synthesize new proteins in the body

but they can also be used as an alternate energy source

the **sequence of amino acids** in each protein determines its **shape** and therefore its **function**

their different 3-D shapes determine their function:

eg. some form hollow spheres amd store other molecules inside

eg. some form long, redline fibers such as collagen, actin, myosin

eg. specific shape of enzyme proteins determines which reactions they will facilitate

sequence of amino acids
→ conformation
→ function

1º structure
→ specific sequence of AA's
small changes in AA alters shape and therefore their function
eg. sickle cell anemia (1 AA different)

2º structure
few proteins exist as straight chains of amino

acids
most are coiled or twisted into secondary structure
eg. spiral, helices, pleated sheets
most common secondary structures are spirals or helices
→ created mainly by hydrogen bonds

3º structure
some proteins have additional coiling, looping and twisting
hydrogen and sulfide bonds cause molecule to bend back upon itself in characteristic fashion

proteins are very sensitive to environmental changes

→ changes in temp, pH, salts, etc can cause them to "denature" and become nonfunctional

they uncoil or loose their shape and function

eg. albumin in cooked egg turns solid

dietary protein is needed mainly to provide amino acids for synthesis of new proteins in body

not generally used for energy but can be if needed

<u>Functions of Proteins</u>

the AA's of a protein are used to synthesize:

1. **structural elements or fibers**

   eg. collagen in bones and teeth, tendons and ligaments, arterial walls
   eg. actin and myosin in muscle cells

2. **hormones**

   messenger molecules
   eg. insulin

3. **transport proteins**

   oxygen → hemoglobin
   lipids (Hold's, LDL's)
   hormones
   iron

4. **membrane carriers**

   facilitated diffusion
   active transport

5. **antibodies**
   = globulins = immunoglobins
   attaches to antigen in inactivate or kill it

6. **buffers**

   can absorb and release H^+

7. **regulate salt/water balance**

   osmotically active → attract water
   as proteins build up draws water in (edema)

8. **clotting**

fibrinogen

9. photoreceptors

eg. rhodopsin is light sensitive changes shape with light hits it to generate a nerve impulse

10. enzymes

up to 50,000 different kinds of reactions in each cell
→ each requires specific enzyme
eg. digestive enzymes, enzymes needed for synthesis

many genetic diseases are the result of an error in a gene that substitutes the wrong amino acid into a critical part of a protein causing it to have the wrong shape and therefore doesn't function properly or at all

eg. hemophilia
eg. sickle cell anemia

Nucleic Acids

comprise <1% by wt of body but vitally important:

1. stores genetic code (genes on chromosomes)
2. controls cell division (mitosis and meiosis)
3. regulates metabolism
   → by controlling enzyme synthesis

two major kinds of nucleic acids
DNA
RNA

only a few different kinds of atoms make up the DNA or RNA molecule: C H O N P

both are polymers of **nucleotides**

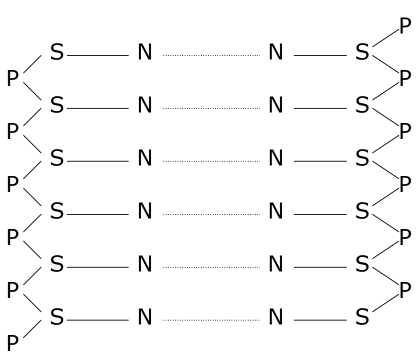
each **nucleotide** consists of three major parts:
sugar
phosphate
Nitrogen base

each DNA molecule consists of a double strand of these nucleotides

these two strand spiral around each other to form a double helix

the S and P alternate to form the backbone of each strand

the N bases are connected by hydrogen bonds to join the 2 strands together



there are 4 different kinds of N-bases possible in the DNA molecule:

adenine & guanine
A G

thymine & cytosine
T C

A only binds to **T**
C only binds to **G**

human chromosomes have ~3 Billion base pairs total in all their DNA

ATP & Energy Use

Energy used and released inside cell must be controlled

It is generally produced from the catabolism of organic molecules especially glucose

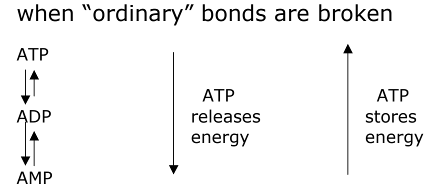
ATP is a special energy transfer molecule

exists mainly in two forms:
high energy ATP
lower energy ADP

=adenosine tri phosphate: A~P~P~P

high energy bonds

between the phosphorus atoms are "high energy" bonds
→ release 4-6 x's more energy than that released when "ordinary" bonds are broken



one form of AMP = cyclic AMP often controls the activity of other enzymes in cell → is a regulator molecule

ATP is the immediate source of energy for cells

food breakdown
→ releases energy from food and stores it as ATP until needed

The energy released by the catabolism of glucose is used for various energy requiring processes in cells:

eg. Active Transport and Bulk Transport

moving things in and out of cell against concentration gradients

eg. Movement

contraction of muscle cells requires large amounts of ATP

eg. Synthesis Reactions (biosynthesis)

the formation of new organic molecules requires ATP since new bonds are made

Vitamins - General

vitamins are:

1. small organic molecules

   other than proteins, carbohydrates, lipids and nucleic acids

2. used in very small amounts
3. don't form polymers
4. most cannot be made by body
5. cannot be broken down for energy

   [but may play an important role in energy pathways as coenzymes and cofactors]

vitamins are categorized as:

water soluble and **fat soluble** vitamins

→ affects:
a. what foods they are found in
b. if and where they are stored in body
c. toxicity
d. how they are eliminated

<u>**Water Soluble**</u> **(**B's, C)

dissolve easily in water, not fat

sensitive to heat and light
→generally don't store well
→lost in cooking

absorbed directly into blood and travel freely throughout the body

generally not stored well in body

→eliminated daily by kidneys
→fewer toxicities
→ needed in frequent, small doses

<u>**Fat Soluble vitamins**</u> **(**A, D, E, K)

dissolve easily in fat, not water

generally more heat and light stable
→not destroyed by cooking or storage

first enter lymphatic system

generally require protein transport molecules to travel in blood

blood concentrations are maintained because body retrieves them from storage as needed

stored in liver and fat cells and accumulate; not readily excreted

→don't need every day

→easier to have toxicity:
can reach toxic levels if consumed in excess
→ needed in less frequent doses

play major roles in growth and maintenance

their presence affects health and functions of
eyes
skin
GI tract
lungs
bones and teeth
nervous system
blood

tend to appear in different foods than water soluble vitamins