5/24/2019

Biology and Scientific Inquiry

Biological Organization: levels of biological organization

Chap. 1

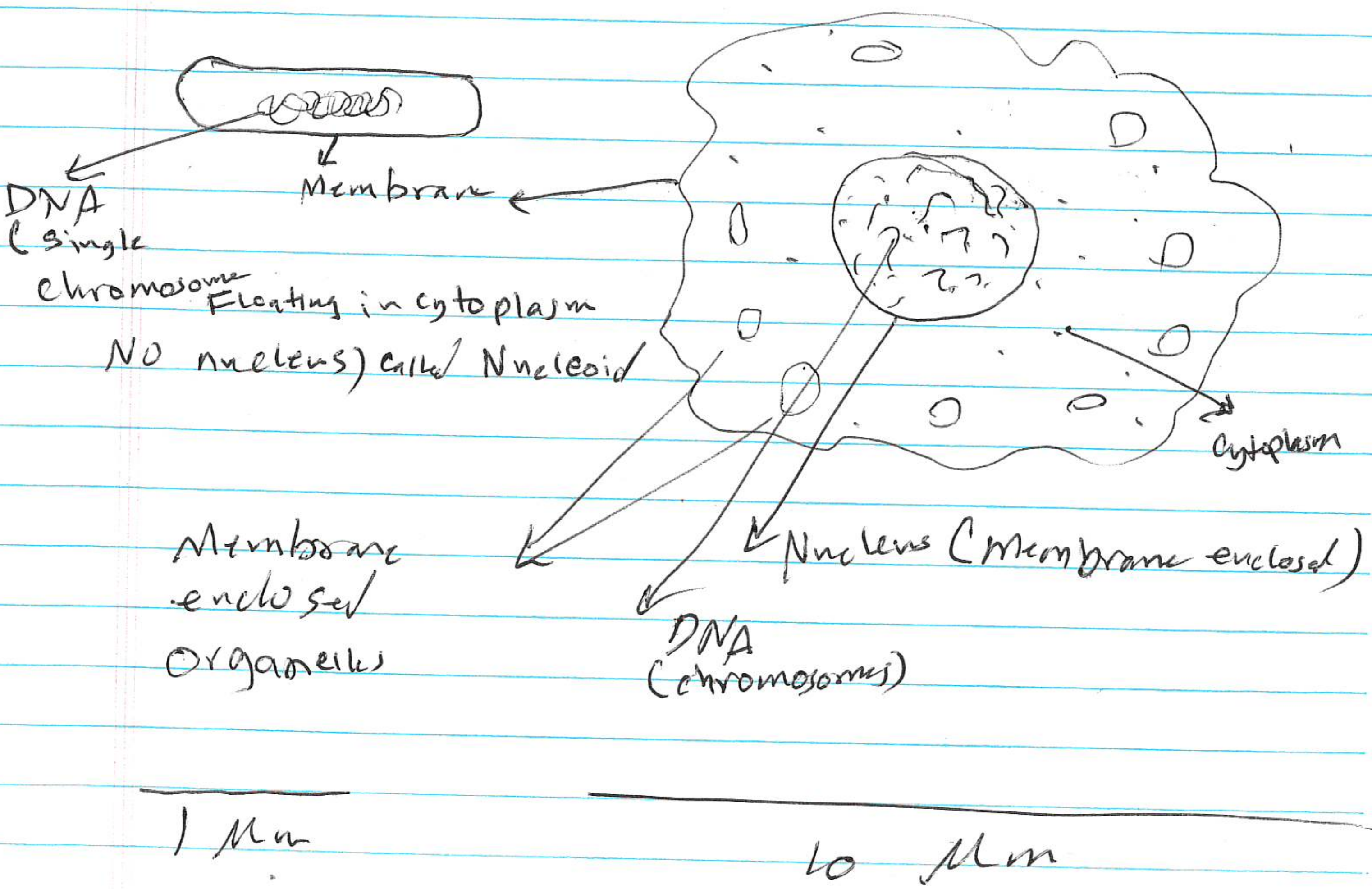
The Cell: An Organism's Basic Unit of Structure and Function:

- Structure and function always related

A) Organization Theme: Cell is the smallest unit of life.

Two main forms

- Prokaryotes
  - Bacteria
  - Archaea
  - No Nucleus
  - Examples
- Eukaryotes
  - Plants
  - Animals
  - Fungi
  - Protozoa
  - Nucleus present



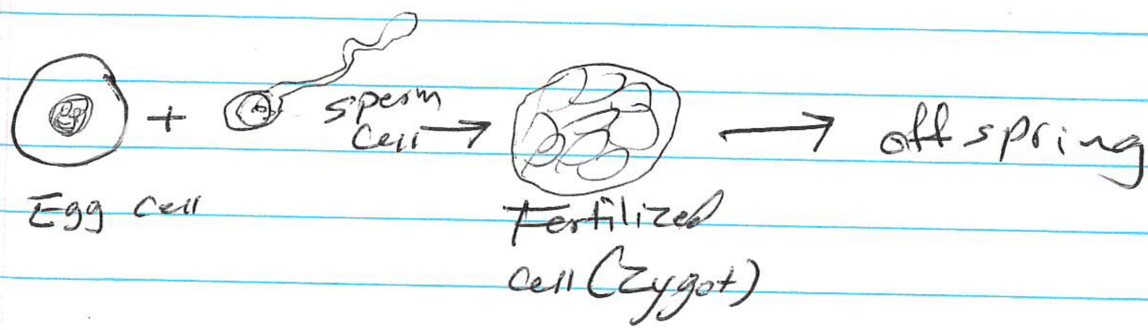
B) Information Theme:

Life's Processes involve expression and transmission of genetic material encoded in the DNA

- Before a cell divides, DNA is first replicated (synthesized) → offspring cells inherits or receives a complete set of DNA.

DNA: Deoxyribonucleic acid → 100–1,000 genes

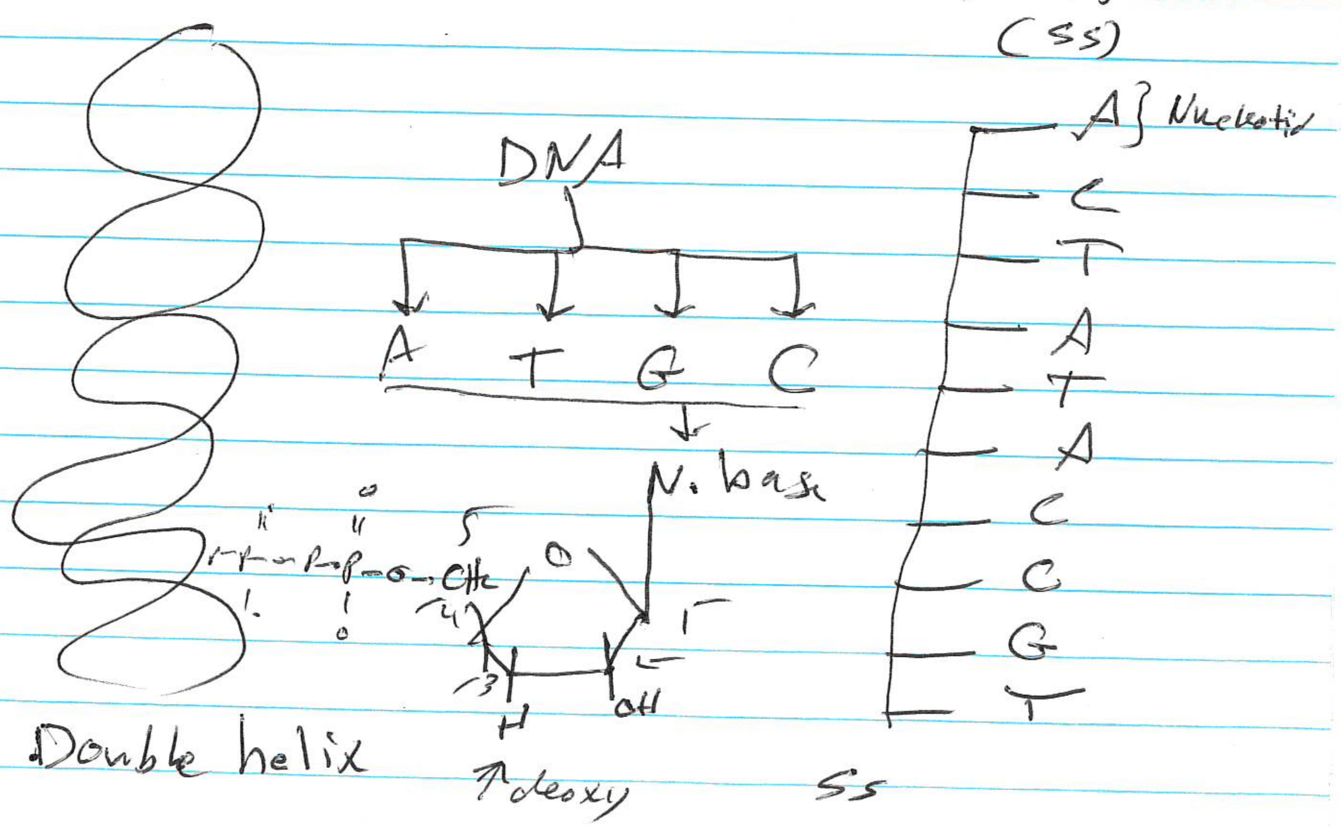
DNA: Master file of the Cell



- DNA the genetic material

DNA double strand (DS)

DNA Single strand (SS)



A C C A A C C
T G G T T G G — DNA (Part of a gene)

↓

Transcription (Synthesis of new RNA)

↓

mRNA

↓

Translation (Synthesis of new Protein)

↓

Chain of amino acids

↓

Protein folding

↓

Functional Protein

C: Energy Transformation

Living organisms use energy for

moving | growing | reproducing | all other activities

- One way of energy flow

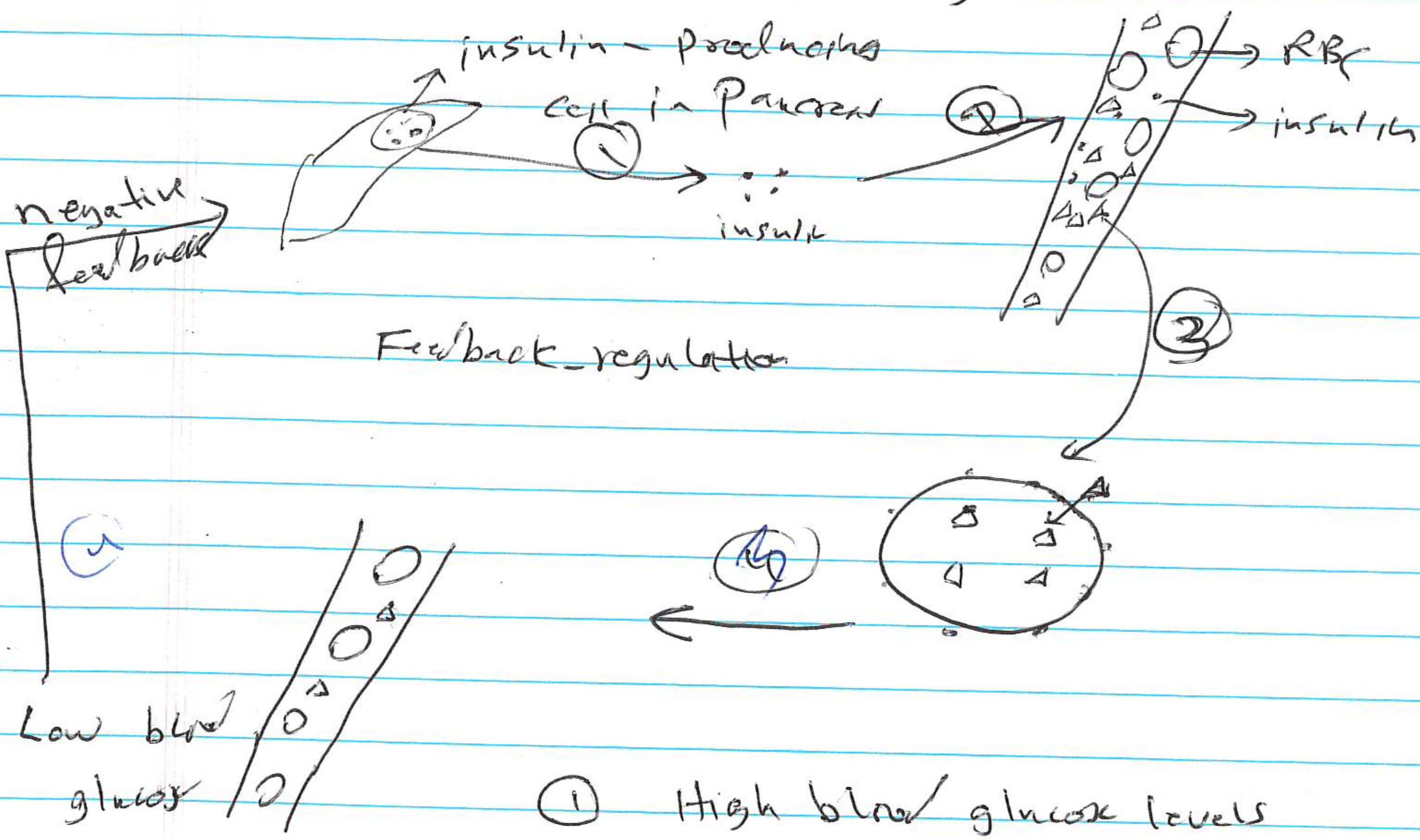
Photosynthesis (Convert sunlight energy → chemical Energy)

Chemical energy in food molecules such as sugars, proteins, etc → used by organisms eat plant

- Heat is lost from the ecosystem (photosynthesis)
- Decomposers: Fungi + bacteria break down dead organisms + trash → returning chemicals to soil

D: Molecules Interactions within organisms

- Interactions between living organism: tissues, cells, and molecules → are crucial
- The key for self-regulation called feedback
- Feedback regulation:
  Product of a process or a reaction regulates or inhibits that process or reaction
- Example insulin signaling



① High blood glucose levels stimulate cells in the Pancreas to secrete insulin into the blood

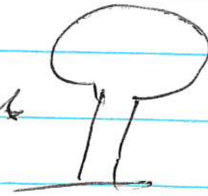
② Insulin circulates in the blood throughout the body and cells

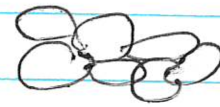
③ Insulin binds to cells causing them to take up glucose and liver cells to store glucose → glycogen

④ Lowered blood glucose levels do not stimulate secretion of insulin

The three Domains of life

a) Domain Bacteria : most divers
b) " Archaea : Extreme environment
c) " Eu Karya

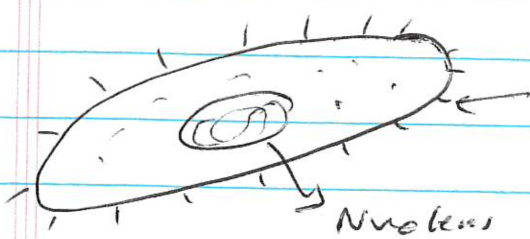




Protists — Kingdom plantae — Kingdom Fungi — Kingdom Animalia

mostly unicellular

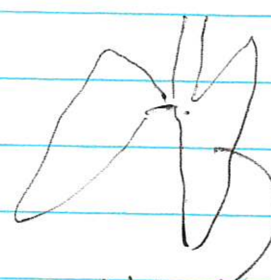
↓ Example: Paramecium: an example of unity underlying the diversity of life: Cilia in eukaryotes



Paramecium: found in pond water

VS

Human Cilia of windpipe:



Cells that line the human windpipe are equipped with cilia that help keep the lungs clean by sweeping a film of debris-trapping mucus. →

The chemistry of life

Chap. 2

There are 92 natural elements

- Essential elements
  - Human needs = 25 element
  - Plants need = 17 "
- Trace elements
  - required in a minute quantities

Elements in human body

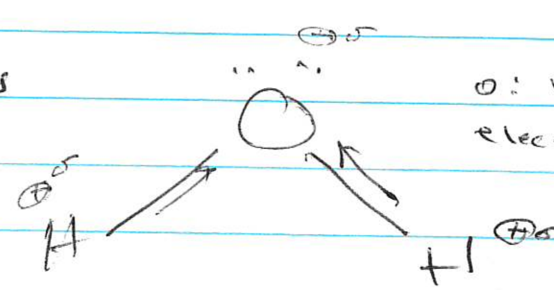
Element	% of body mass (including H_2O)	
Oxygen: O	65.0	96.3
Carbon: C	18.5	
Hydrogen: H	9.5	
Nitrogen N	3.3	
Calcium Ca	1.5	3.7%
Phosphorous P	1.0	
Potassium K	0.4	
Sulfur S	0.3	
Sodium Na	0.2	
Chlorine Cl	0.2	
Magnesium Mg	0.1	

Trace elements less than 0.01% of mass such as Boron (B), Cobalt (Co), copper (Cu), flourine (F) etc, iodine (I), iron (Fe).

Chemical Bonding:

1) Covalent bonds

e.g.: H_2O



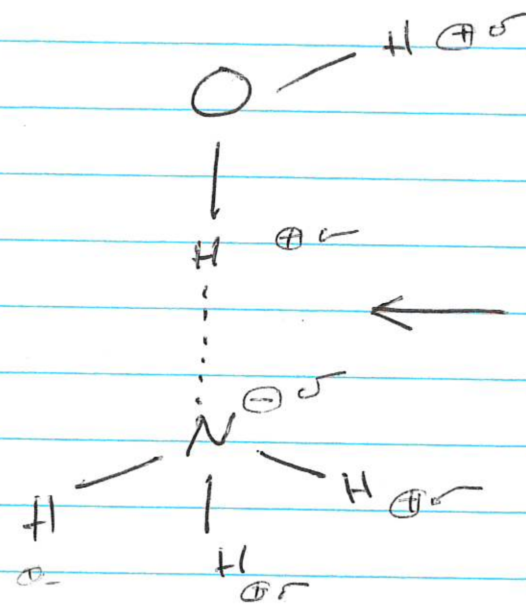
O: more electronegative

2) Ionic bonds:

⊕ ion = Cation
⊖ " = anion } Opposite charge

— Because opposite charge, cations & anions attract each others and called ionic bond
eg: Na^{+} Cl^{-}

3) Hydrogen bonds: are central in life chemistry



This attraction is important in living cells
e.g: Stabilizing DNA structure, protein-structure, etc.

3) Van der Waals forces:
attraction and repulsion between atoms, Molecules, and surfaces

4) Hydrophilic interactions: important in aqueous solutions, including charged molecules

5) Hydrophobic interactions: polar vs nonpolar interactions, eg: mixing ~~fat~~ and water

* Dissolve like dissolve

Molecular Structure of Life

Acids and Bases: important in living organisms

Chap. 3

a) Strong:

$HCl \rightarrow H^+ + Cl^-$

$NaOH \rightarrow Na^+ + OH^-$ Complete ionization

b) Weak:

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

$H_2CO_3 \rightleftharpoons HCO_3^- + H^+$

Partial ionization

c) PH:

$H_2O \rightleftharpoons H^+ + OH^-$

$(H^+)(OH^-) = 10^{-14}$ M Kw: ionization water product constant

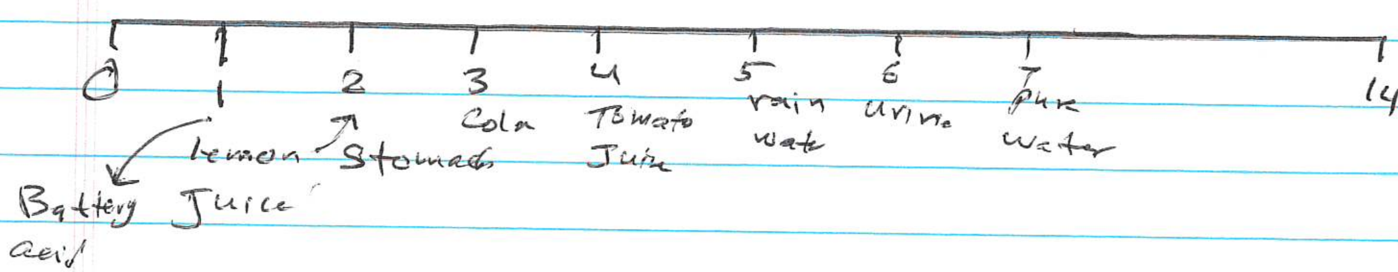
$(H^+) = 10^{-7}$ M, $(OH^-) = 10^{-7}$ M

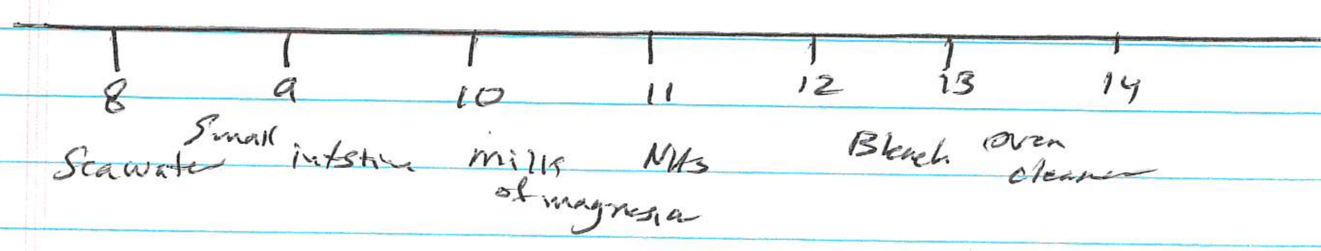
$PH = -\log(H^+)$

For neutral aqueous solution

$-\log(10^{-7}) = -(-7) = 7$

PH scale





CO_2 — atmosphere
↓
$CO_2 + H_2O \rightarrow H_2CO_3$ carobic acid
$H_2CO_3 \rightarrow H^+ + HCO_3^-$ bicarbonate
$H^+ + CO_3^{-2} \rightarrow HCO_3^-$ CO_3^{-3} Carbonate ions
$CO_3^{-2} + Ca^{+2} \rightarrow CaCO_3$ Calcium Carbonate

↑ seawater acidifies → $H^+ + CO_3^{-2} \rightarrow HCO_3^-$
bicarbonate

— Year 2100 : Carbonate ion concentrations decrease by 40% → coral beach and animal shells will be affected (less $CaCO_3$ forms)

$H_2CO_3 \xrightarrow[\text{a rise in PH}]{\text{response to}} HCO_3^- + H^+$

H^+ donar acid — H^+ acceptor (base) conjugate — Hydrogen ion (acid) Conjugate

$OH^- + NH_4^+ \rightleftharpoons H_2O + NH_3$
base — acid — Conjugate acid — Conjugate base

Buffer maintain pH
— The most important buffer in our bloodstream is the carbonic acid — bicarbonate buffer which prevents drastic PH changes when CO2 is introduced into blood.

$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$
Carbonic acid — bicarbonate

Carbon: the backbone of life

Chap. 4

Carbon atoms can form diverse molecules by bonding to four other atoms

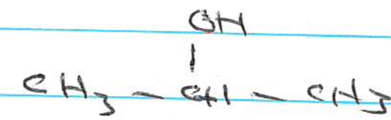
— isomers: same elements but different structure and different properties

e.g.:

a) structural isomers:

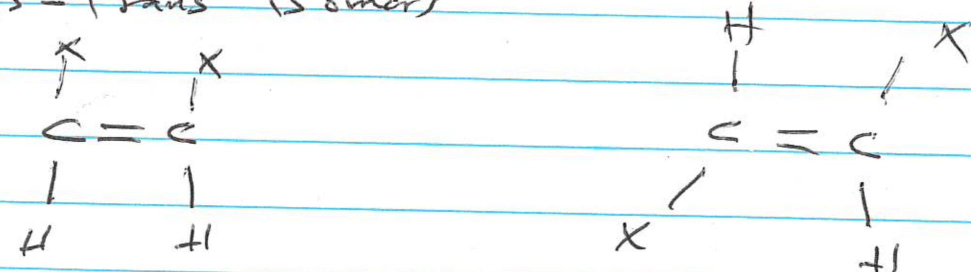
$CH_3-CH_2-CH_2-OH$

propyl alcohol



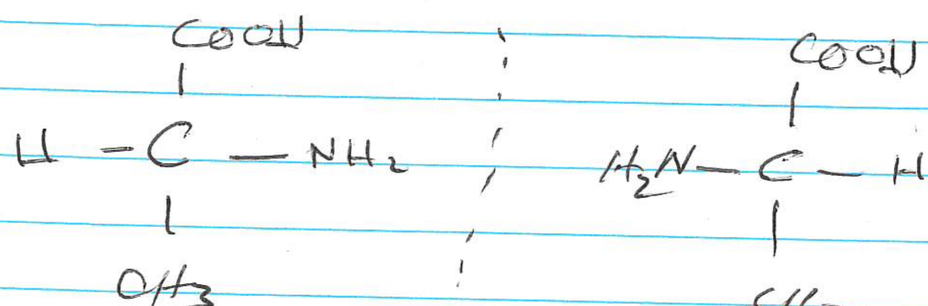
isopropanol

b) Cis-trans isomers



Cis-isomer　　　　Trans-isomer

c) Enantiomers:

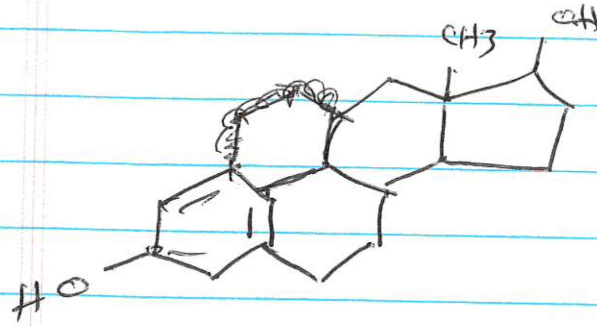


L-isomer　　　mirror image　　　D-isomer

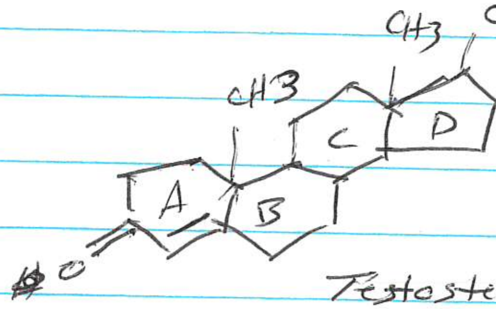
alanine enantiomers

Chemical groups are most important

Examples: Sex Hormones



Estrogen = Estradiol



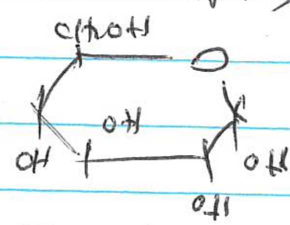
Testosterone

7 - Chemical groups most important in biological systems

1 - Hydroxyl group — OH

Polar due to oxygen (electronegative) → forms H bonds helping sugars dissolve in H_2O

e.g.:

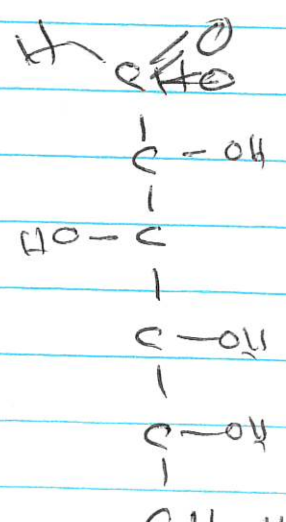


D_glucose

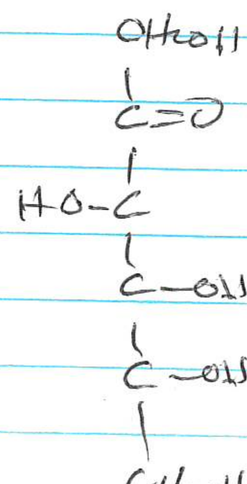
2 - Carbonyl group $>C=O$

Sugars → with Keton groups → Ketose
→ " aldehyde " → aldoses

aldehyde →



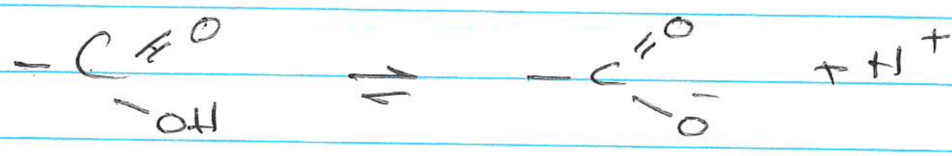
D_Glucose



← Keto

D_Fructose

3- Carboxyl group — COOH
act as an acid, donates H^+

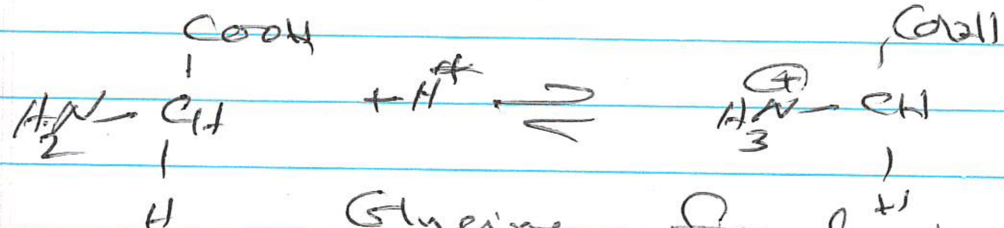


$$-COOH \rightleftharpoons -COO^- + H^+$$

ionized form

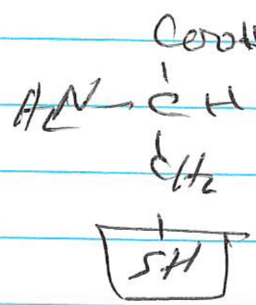
Found in organic acids

4- Amino group: — NH_3
act as a base, can pick up an H^+



Glycine found in cells

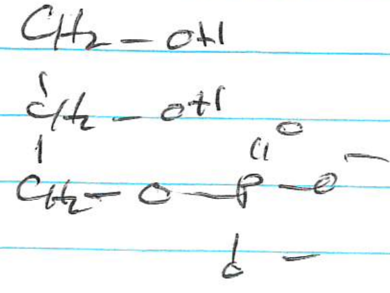
5- Sulfhydryl group: — SH
can form cross-link - stabilize proteins



Cysteine

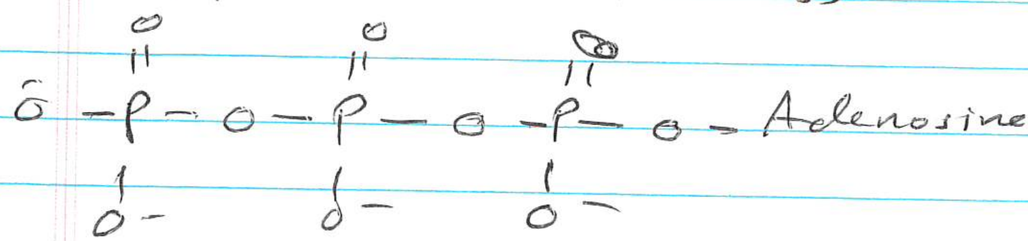
Sulfhydral gp.

6- Phosphate group: — PO_4^{-2}



Glycerol Phosphate

ATP: source of energy



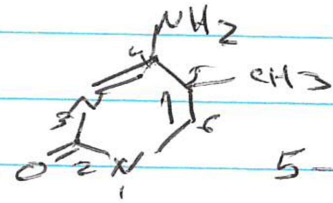
ATP $\longrightarrow$ ADP + Pi + Energy

inorganic phosphate

6 — Methyl groups: — CH_3

DNA — methylation

protein — "



5-methyl cytosine

Biological Molecules

Chap. 5

- Carbohydrates
- Lipids
- Proteins → Proteomics
- Nucleic acids → DNA, RNA
  - DNA → RNA
  - Genomics

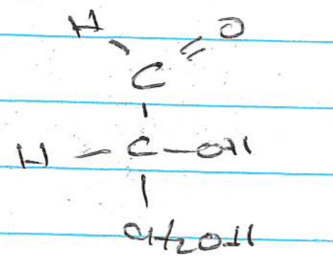
Carbohydrates

- Fuel
- building material

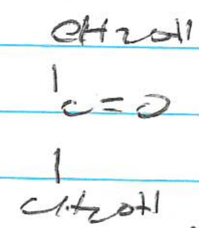
Monosaccharides

- Structure:
  - a) Aldoses: Carbonyl group (C=O) at the end of carbon structure
  - b) Ketoses: Carbonyl group within structure
- Classes

1) Trioses: 3 carbons

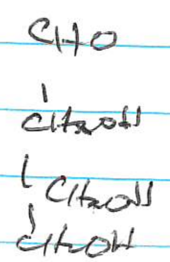


Glyceraldehyde

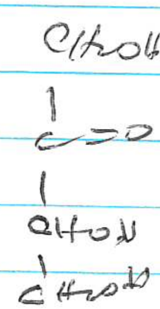


Dihydroxyaceton

2) Tetroses: 4 – C

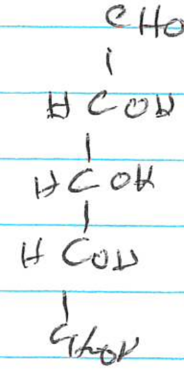


Erythrose



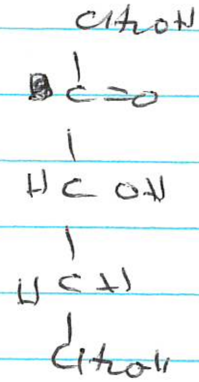
Erythrulose

3- Pentoses : 5 C



Ribose

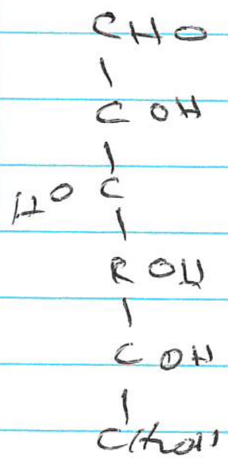
Component of RNA



Ribulose

(substrate in photosynthesis)

4- Hexoses : 6-C



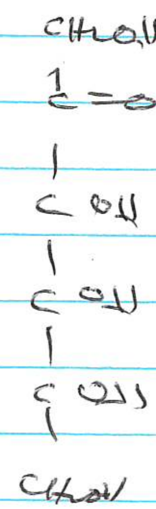
Names ⇒ a) Glucose

b) Grapes sugar

c) blood sugar

d) Dextrose

e) Energy source in metabolism (cell respiration)



Fructose

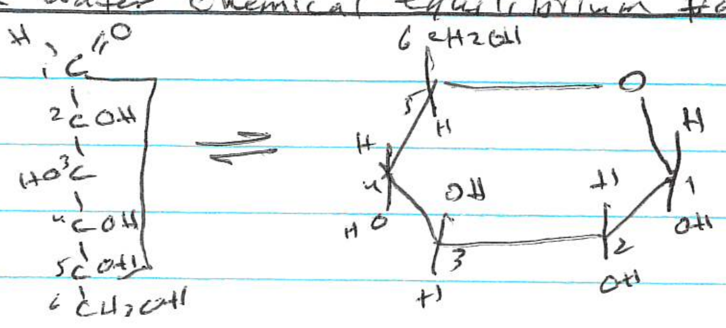
Sweeter than glucose

1970s: corn Glu → Fru

corn syrup

In water chemical equilibrium favors ring structure

open chain



Glu

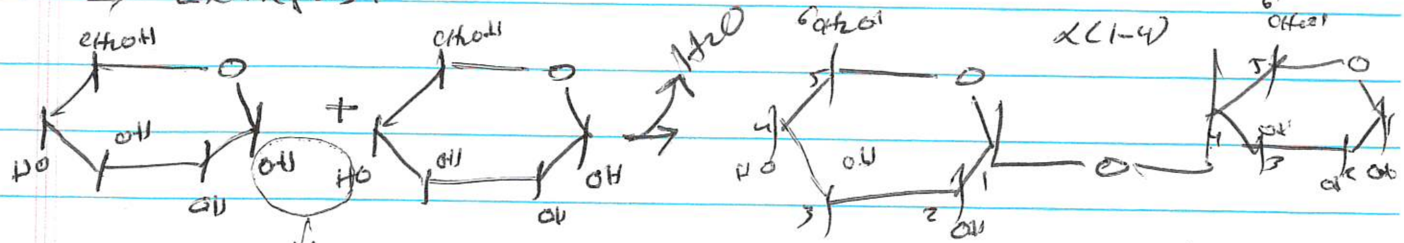
cyclic

Glu

Disaccharides

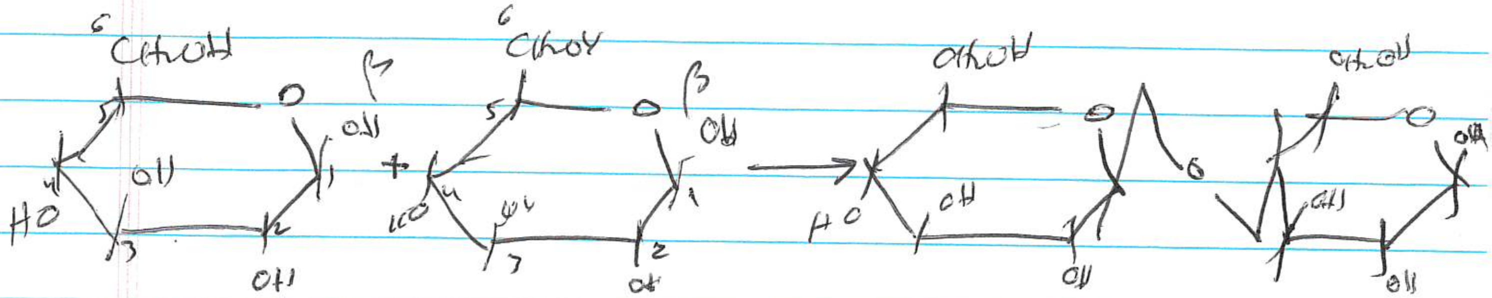
- Two monosaccharides joined by a glycosidic bond

→ Examples:



Maltose

- OH down, its an α-bond
- Adding more glucose units results in starch



β-Glucose

Cellobiose

- Adding more β-glucose ⟶ Cellulose

Not digested by humans, forms fibers

Polysaccharide

Monosaccharides ⟶ hundreds or thousands monosaccharides

Examples:

① Starch: potato starch only in plant

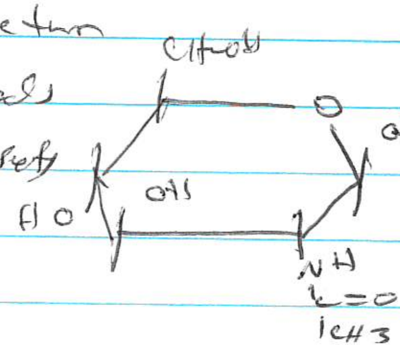
② Glycogen: Animal liver ; ; animals

③ Cellulose: found in fruits, vegetable and woods

Structural polysaccharides

- Cellulose in plant structure
- Chitin in arthropods

exoskeleton in arthropods + insects

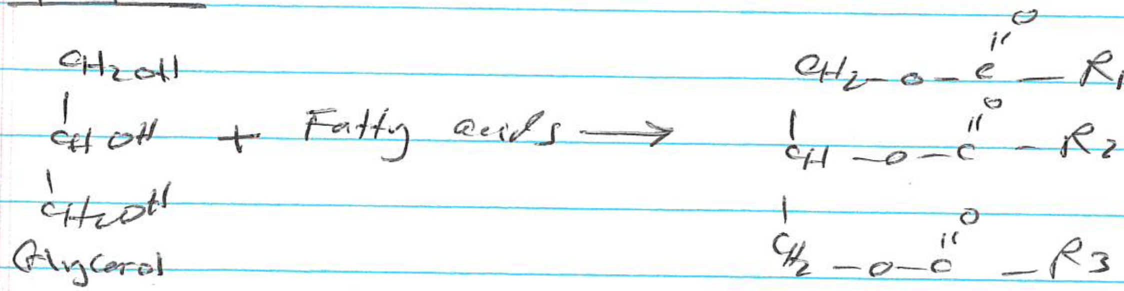


Chitin

Lipids

- important biological lipids are fats, phospholipids, and steroids.

Fats



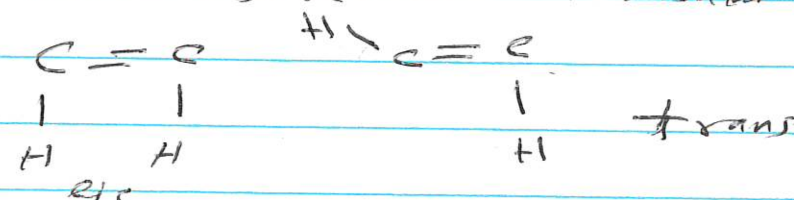
Fat or Triglyceride

Fatty acids: Two types

1) Saturated: Hydrocarbon chains, No double bonds
 e.g.: Palmitic acid $CH_3(CH_2)_{14}COOH$

2) Unsaturated: Hydrocarbon chains with one or more double bonds
 e.g.: Oleic acid : C18:1   one double bond

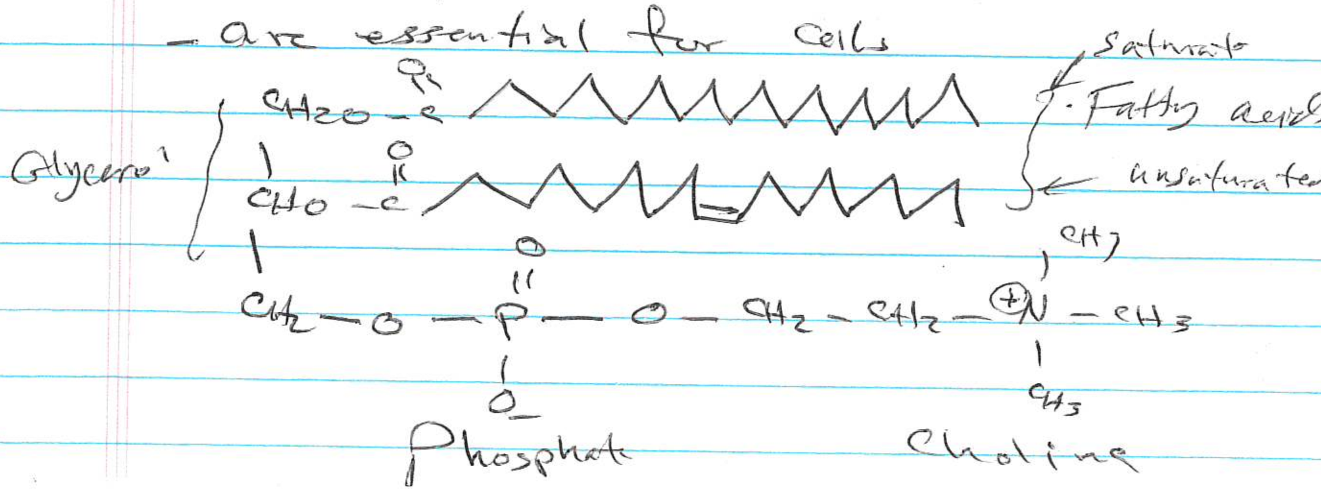
- Trans fatty acids → can contribute to coronary heart disease and cardiovascular diseases



- trans fats are banned/removed from diet

Phospholipids:

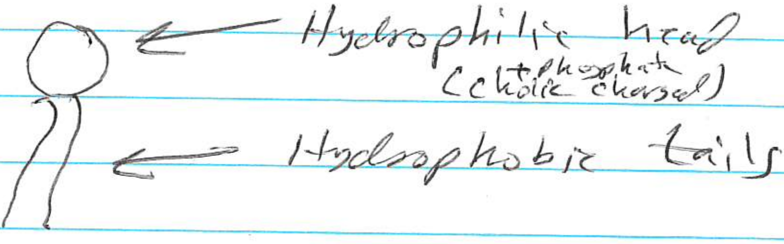
- are essential for cells



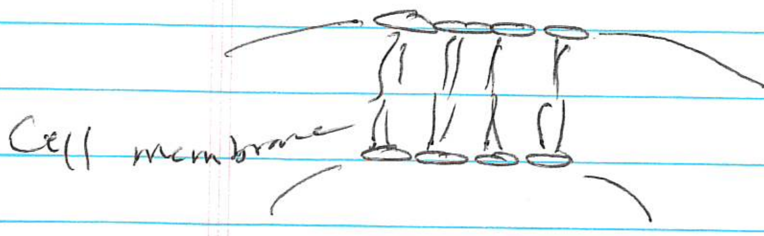
— Phospholipid structure:

a) Hydrophilic (polar) head

b) two hydrophobic (non-polar) fatty acids tails

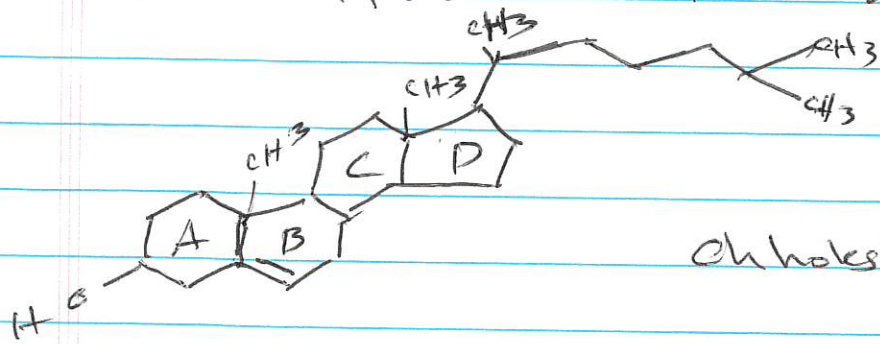


→ This makes lipid bilayer in cell membranes



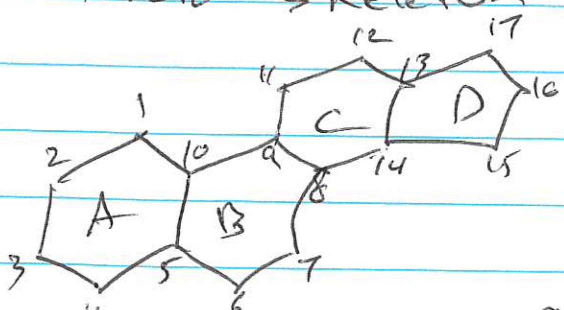
Steroids

— are lipids with 4- fused rings



Chholesterol

Steroid skeleton



steroid

cholesterol

↓ bile acids, Progesterone, Glucocorticoids, mineralocorticoids, androgens, estrogens

Chap. 6 **Cells**

Cells can be seen by microscopes

Ligh microscope (LM) — Scanning electron microscope (SEM)

→ The size range of cells measured by using the metric system

1 meter : 1 m = 100 cm

1 cm = 10 mm (millimeter)

1 mm = 1000 μm (micrometer)

1 μm = 1000 nm (nanometer)

cm = 10^{-2} m = 0.4 inch, inch = 2.54 cm

1 mm = 10^{-3} m

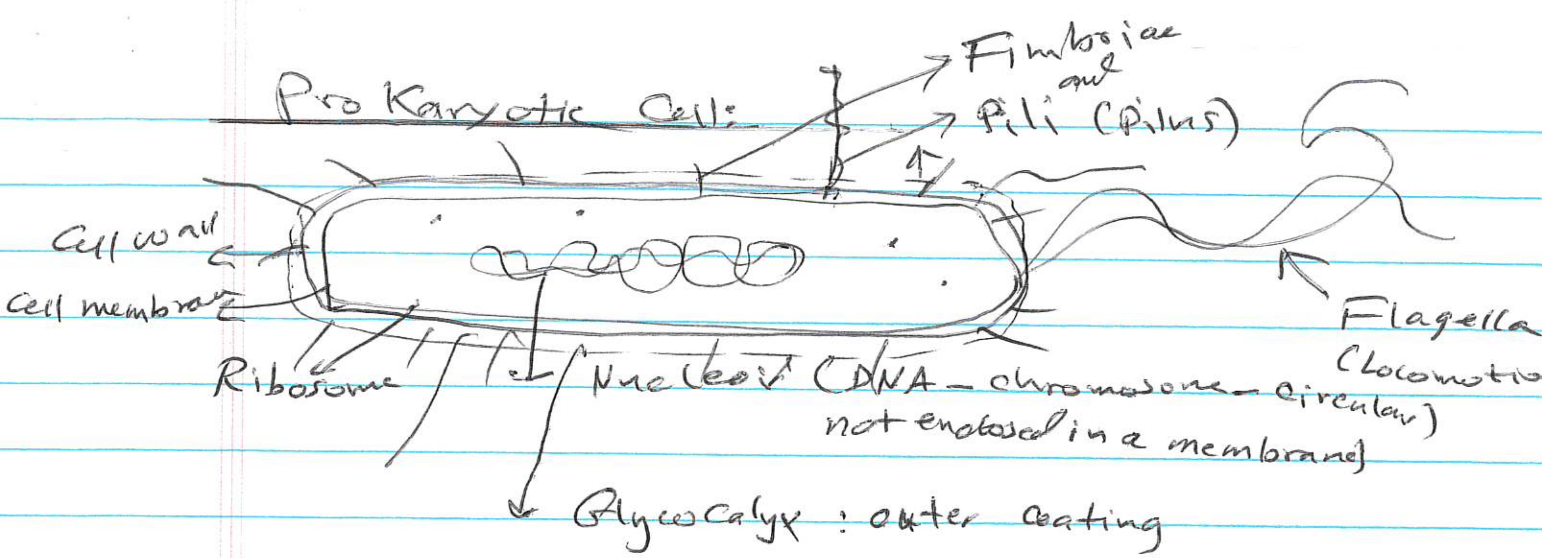
1 μm = 10^{-3} mm or 10^{-6} m

1 nm = 10^{-3} μm or 10^{-9} m

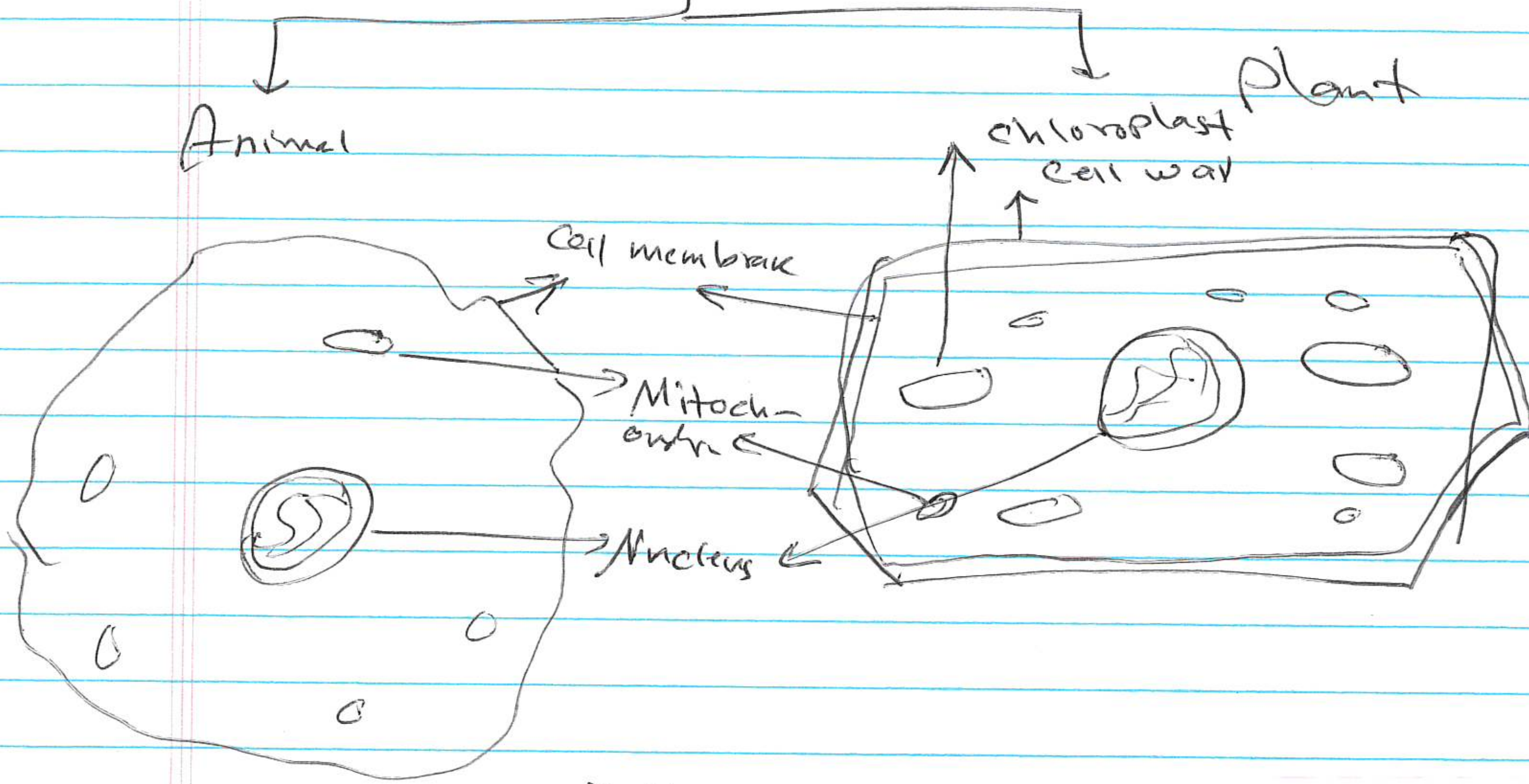
Cell types

Prokaryotes	Eukaryotes
— NO nucleus	+ nucleus
e.g: Bacteria	e.g: Human
— Cell wall	No cell wall
— ~ 1.0 μ size	~ 10 μ size
— 1 chromosome	— many chromosomes
— No compartments (e.g: No mitochondria, nucleus)	→ membrane surrounded organelles: compartments + (mitochondria, nucleus)
— Simple cell division called cell fission	— Mitoses and Meioses: complicated
— large surface/volume ratio: increase material exchange	— Small surface/volume ratio

ProKaryotic Cell:



EuKaryotic Cells



Both contain organelles such as

- mitochondria : Power house of the cell
- Golgi apparatus (Visicle) : Protein export
- peroxisome : detoxification
- Endoplasmic reticulum (ER) : Protein shipment
- Ribosomes : Protein synthesis
- Nucleus : chromosome contains cell components
- Cytoskeleton : reinforce cell shape, organize

Cellular Organelles ; Compartments

1) Cell membrane

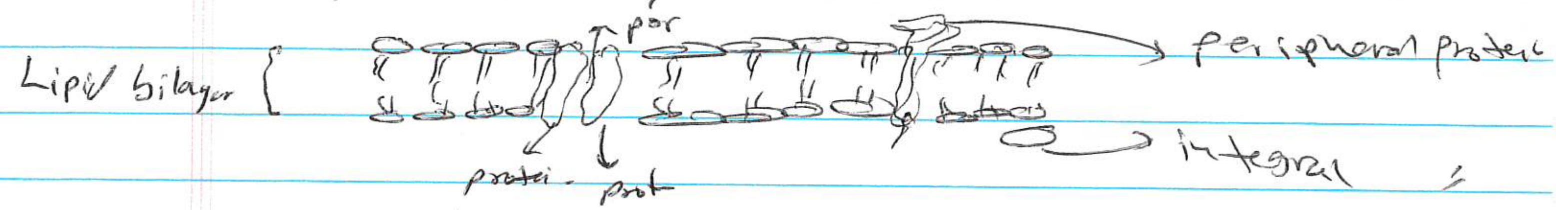
a. Cell morphology: mechanical structure, defines/encloses the cell components

b: Selective permeability

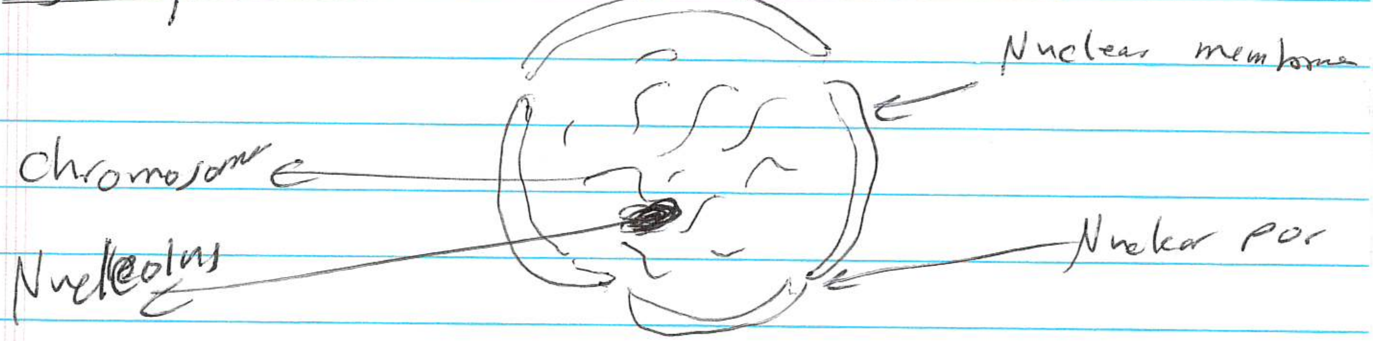
c: Active transport

d: Bulk transport: endocytosis & exocytosis

e: Markers and signalling: recognition of its own cell, communication with other cells

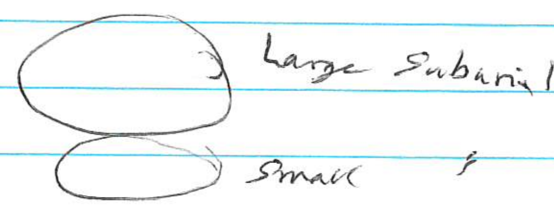


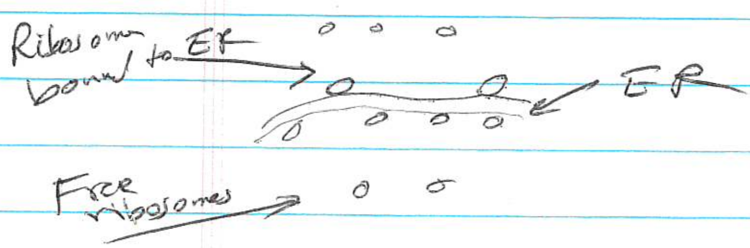
2) Nucleus



- Nuclear membrane: is a double-layered structure, encloses the contents of nucleus
- chromosomes: DNA - master file of the cell
- Nucleolus: rRNA synthesis

3) Ribosomes





Endoplasmic Reticulum (ER):

Network of membranous tubules

Smooth ER

Lack ribosomes

↓

Detoxify drugs + poisons

Rough ER

\+ Ribosomes

↓

Proteins produced by ribosomes

↓

e.g.: Insulin → blood Transport ← enters ER lumen

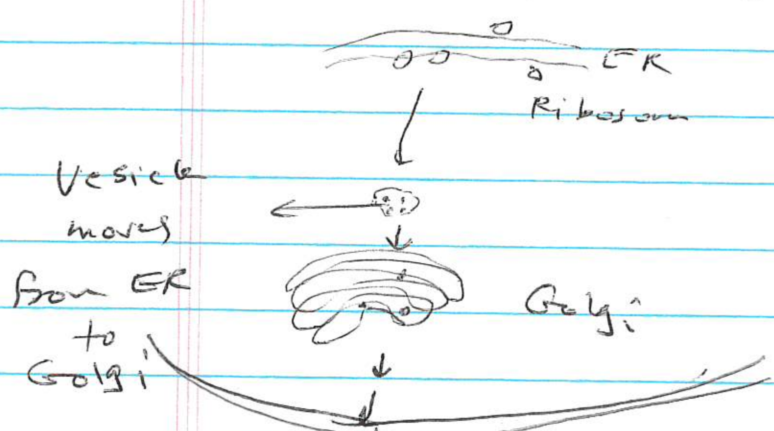
Free ribosomes: proteins used inside cell

Bound ribosomes: secretory proteins depart from ER

Golgi Apparatus:

\- Receiving - sorting - shipping, and manufacturing synthesized proteins.

ER → proteins → Golgi (→ Modified, sorted and sent to destinations, export).



protein secretion via plasma membrane,

Golgi: a) Sorting → proper folded proteins continue for export, misfolded degraded

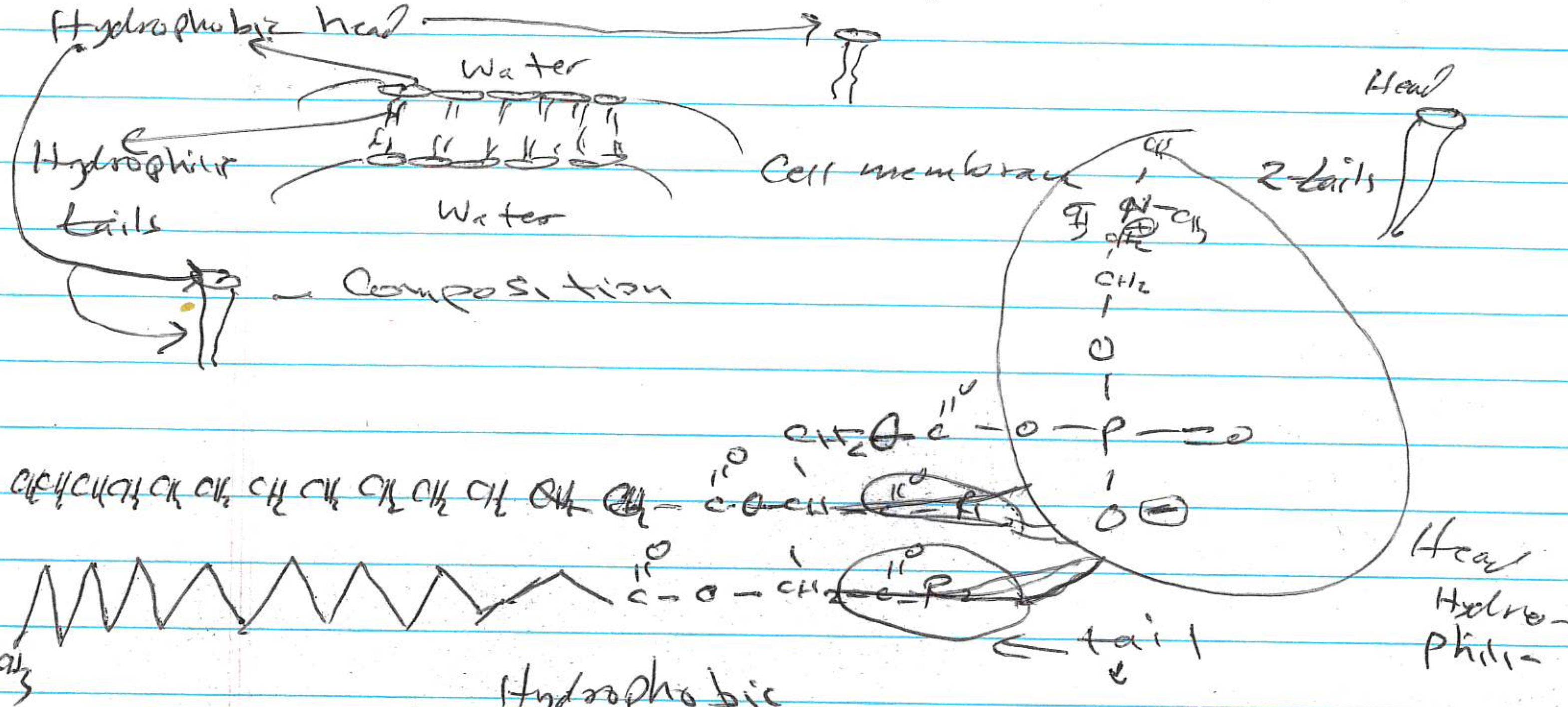
b) tags added, eg phosphate groups

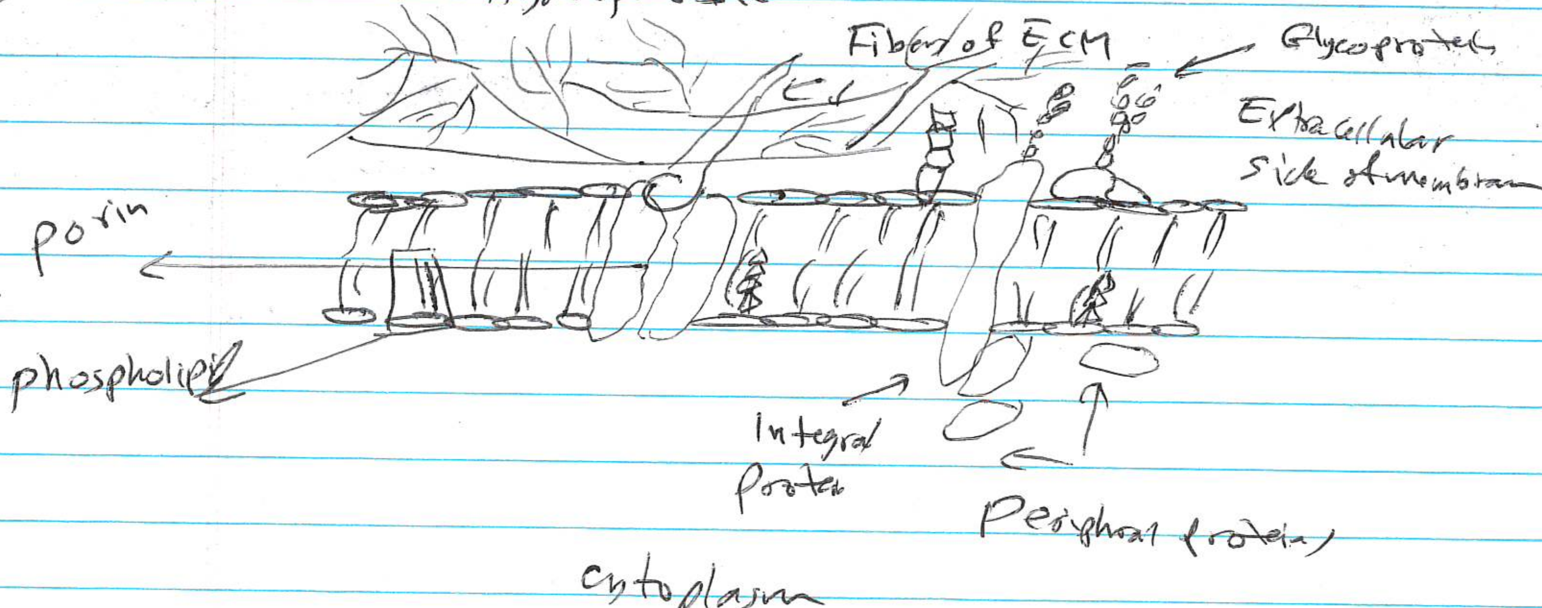
c) plasma membrane → export

Chap. 7 — 8/19/19

Membrane Structure & Function:

Fluid Mosaic: membrane is a mosaic of proteins in a fluid bilayer of phospholipids





: Glycolipid

: Carbohydrates (sugars)

: cholesterol

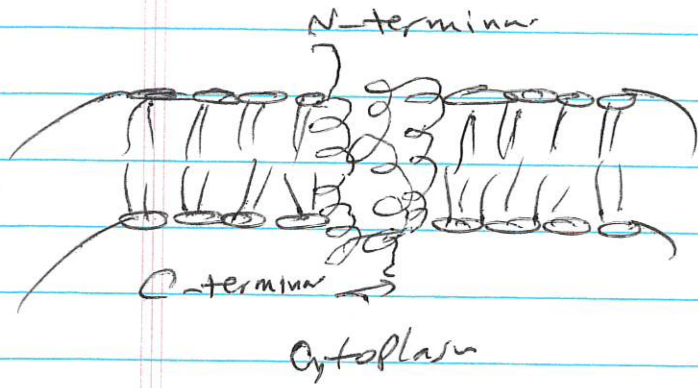
Fibers of ECM

Membrane Proteins:

- In RBC more than 50 kinds of proteins have been found.
- Proteins determine most of membrane function

two major membrane protein

Integral: transmembrane proteins, span the membrane



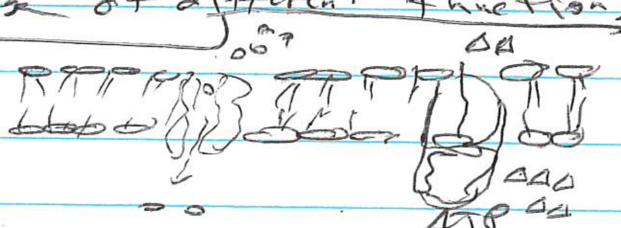
20-30 aa's coiled into α-helix, hydrophilic parts exposed to the aqueous solution.

Peripheral

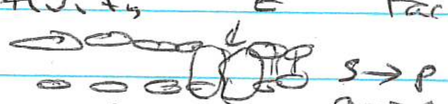
Not embedded. Loosely bound to external surface of membrane.

Mosaic: many proteins embedded in the membrane with a range of different functions

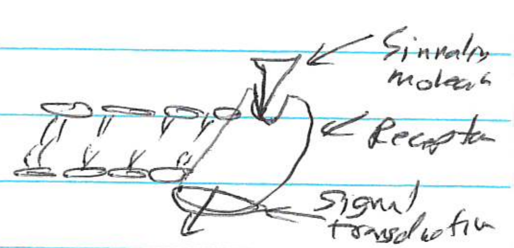
a) Transport



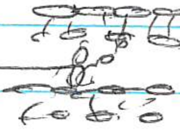
b) Enzyme activity



c) Signal transduction

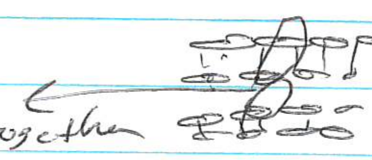


d) Cell-Cell recognition



e) Intercellular joining

in adjacent cells Proteins hooked together

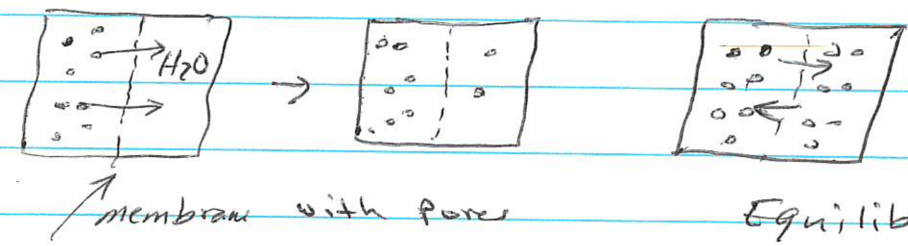


f) Attachment to cytoskeleton & ECM: Stability & cell shape

Transport & Membrane structure

① Passive transport, for H_2O is called Osmosis
— Diffusion of a substance across a membrane with no energy requirement.
— A substance will diffuse from [High] — [low]

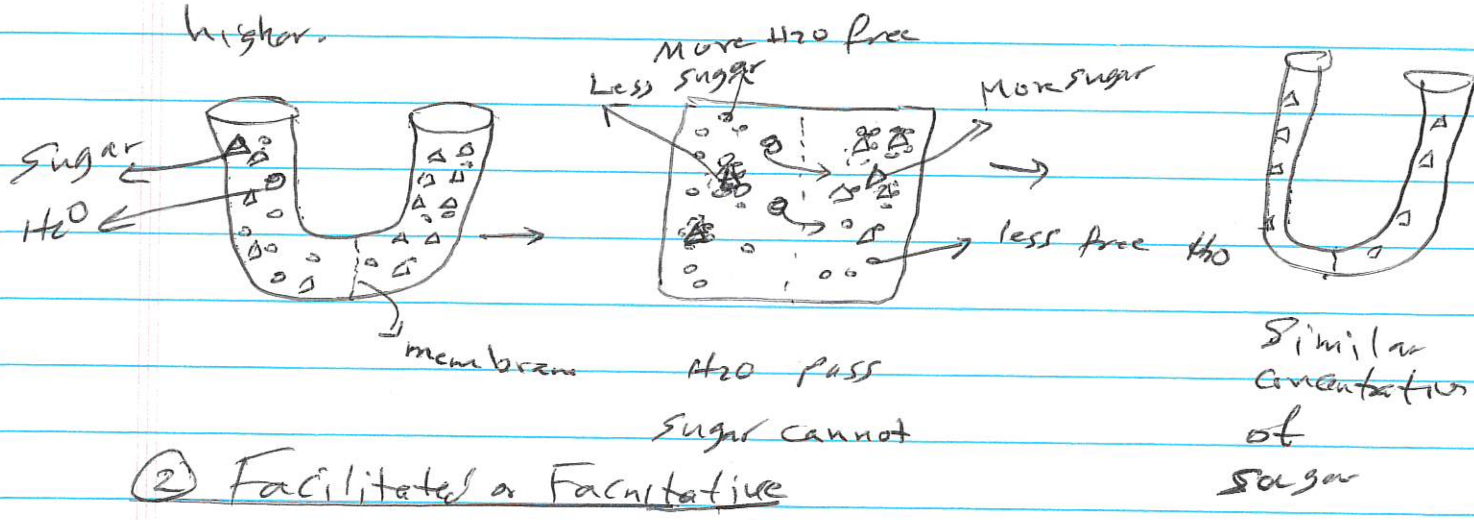
o : dye



— Dye pass through pores from high to low concentration until reaches equilibrium

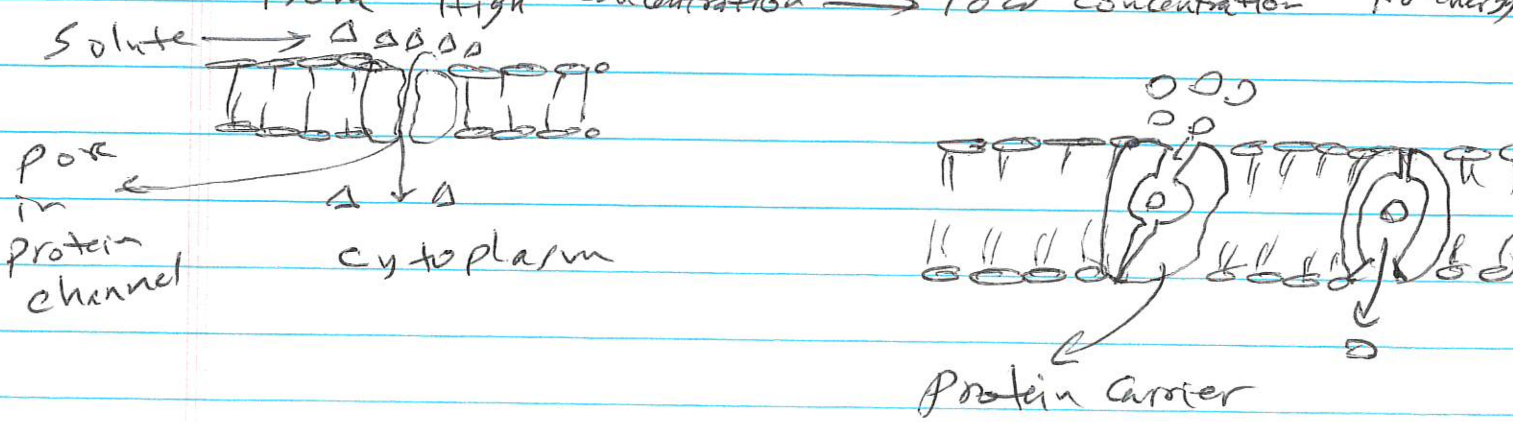
Osmosis

Water molecules pass from low concentration of solute to higher.



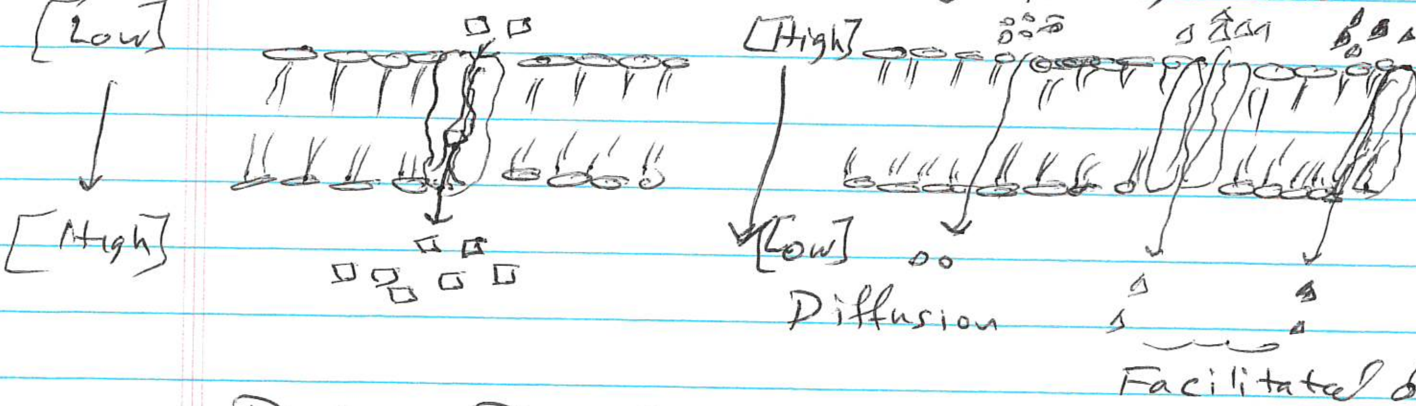
② Facilitated or Facultative

Passive transport aided by protein carriers
From High Concentration ⟶ low concentration No energy

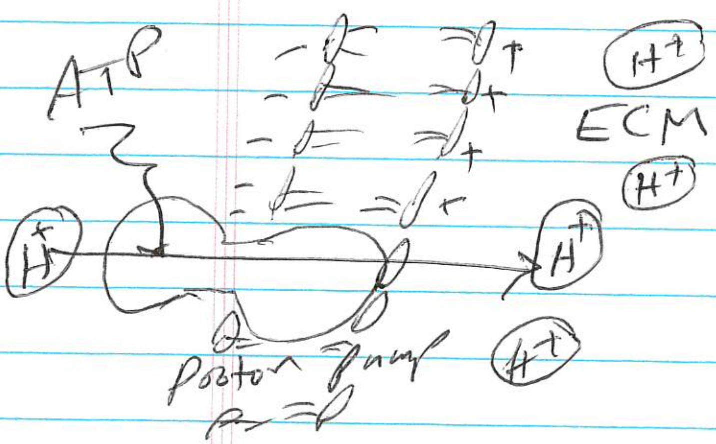


③ Active transport

- Energy in the form of ATP is required to move solute from low to high concentration

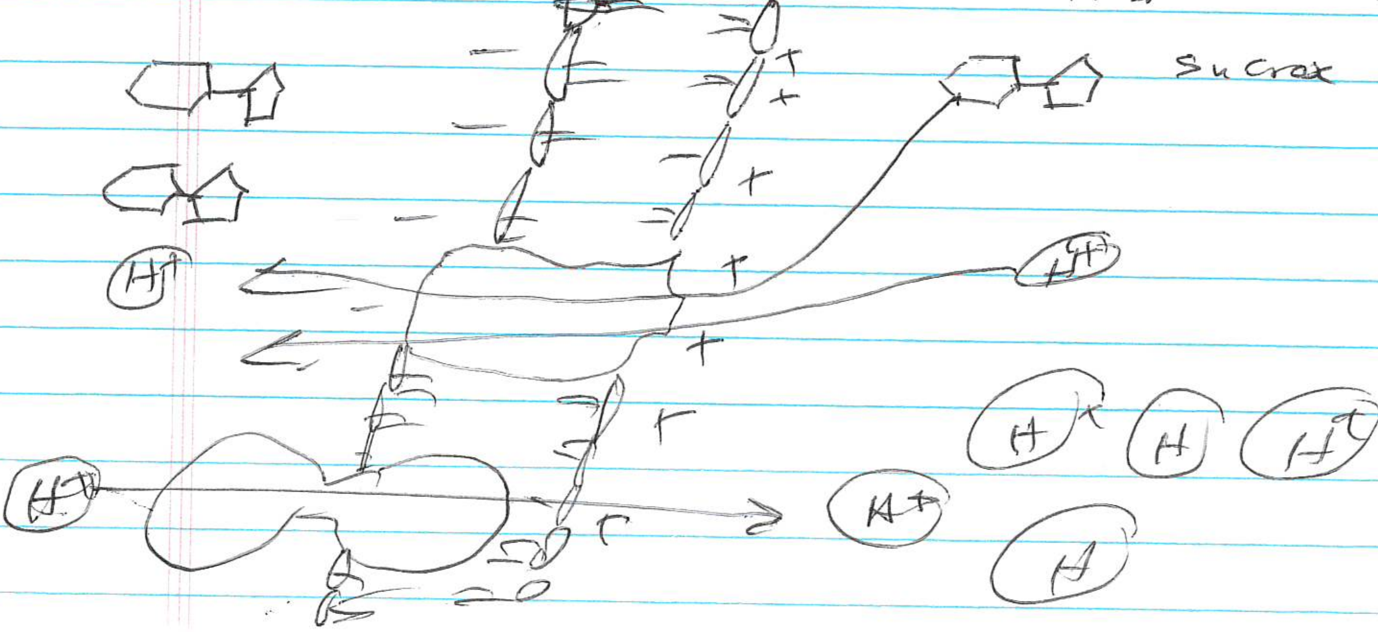


Proton Pump



- membrane with charge separation ⊕ & ⊖
- The voltage and H^+ concentration gradient drives mechanism

④ Cotransport: Active transport driven by a concentration gradient: ATP-driven proton pump → H^+ gradient → used for active transport of sucrose



Proteins

- Function of cells depend on proteins
- Accounts for more than 50% of the dry (mass) weight of most cells.

Protein Function

↓1 Enzymes ↓2 ~~Storage~~ ↓3 Hormones ↓4 Contraction (movement) ↓5 Defense ↓6 Transport ↓7 Receptors ↓8 Structure

- 10,000 tens of thousands in human of different proteins

1. **Enzymes**: accelerate chemical reactions

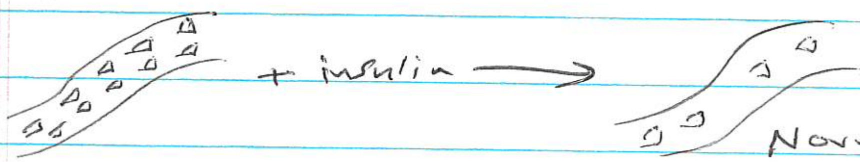
Hydrolyze bonds in food molecule

2 Storage

casein: milk protein → major source of amino acids for milking babies.

egg ovalbumin: " " " " for developing embryo

3. ~~Hormones~~



Normal blood sugar

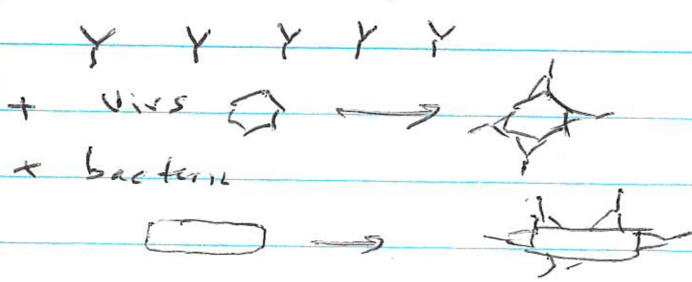
High blood sugar

4. Contraction

Actin & myosin proteins → muscle movements

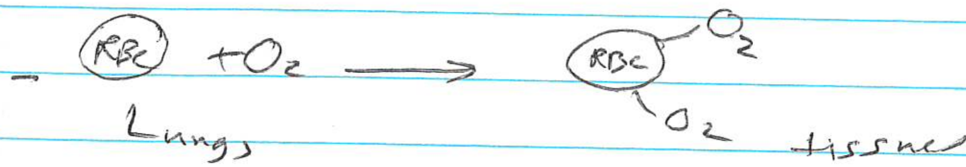
5. Defense

Antibodies: protection against diseases

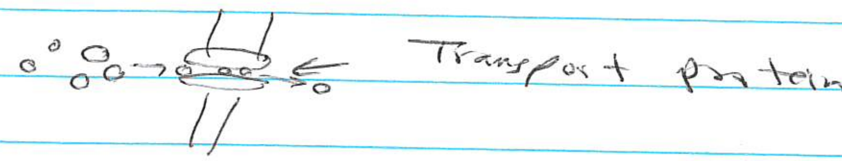


Antibodies neutralize invaders

6. Transport



- transport ions across membranes



7. Receptors

Cells response to chemical stimulus

Receptor ⟶ bind to specific chemical, hormonal, viral, bacterial, etc

8. Support

Keratin protein – skin & appendages

Collagen + elastin ⟶ connective tissues

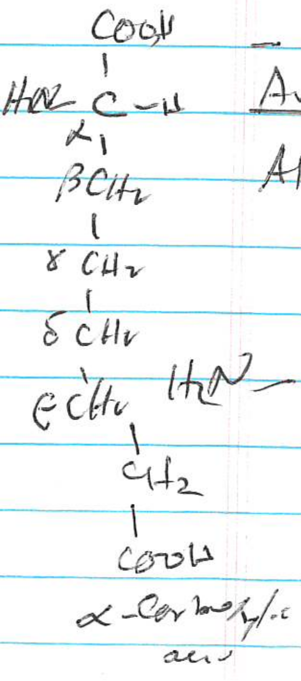
Protein Composition

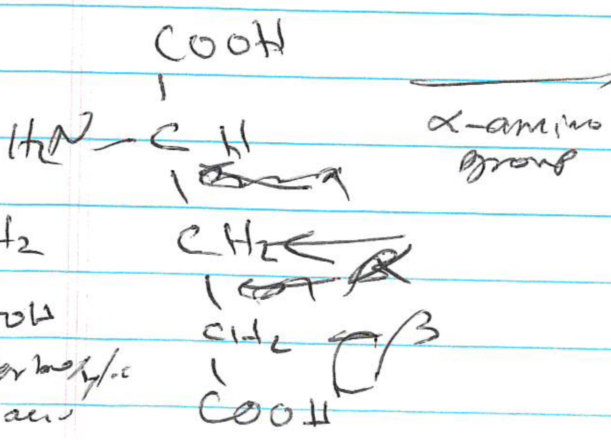
Viral + cell proteins all constructed from same set of 20 amino acids linked to unbranched polymer

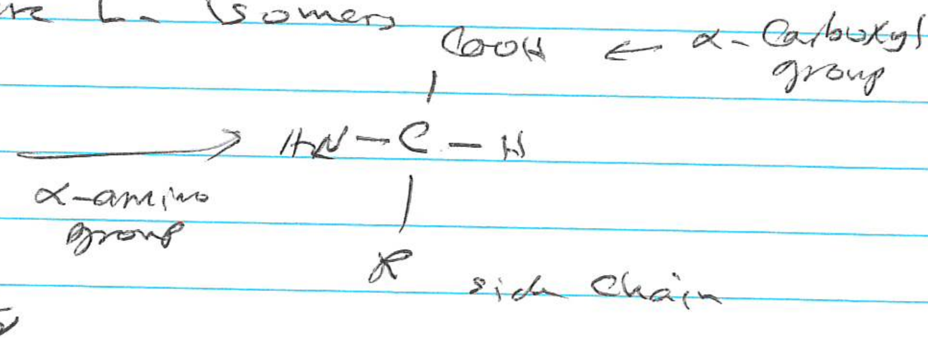
- Bonds between amino acids called peptide bonds

Amino acids monomers

All aa's are L- isomers

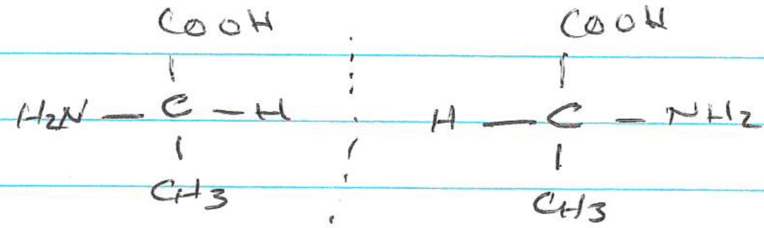






The 20 amino acids of Proteins

- All amino acids of Proteins are L- isomer
-



Enantiomers ("mirror-image")

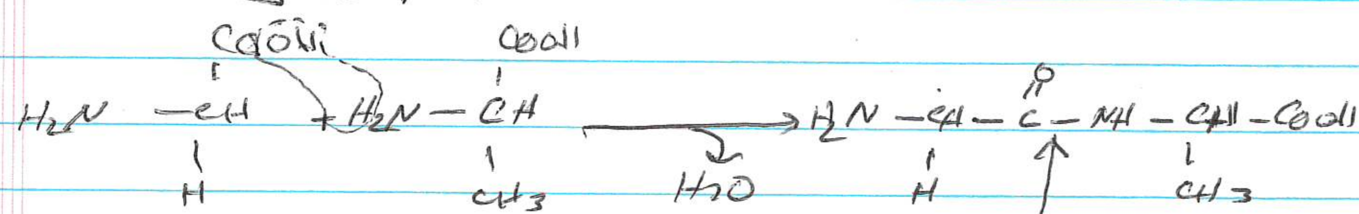
L- Alanine D- Alanine

20 - aa's

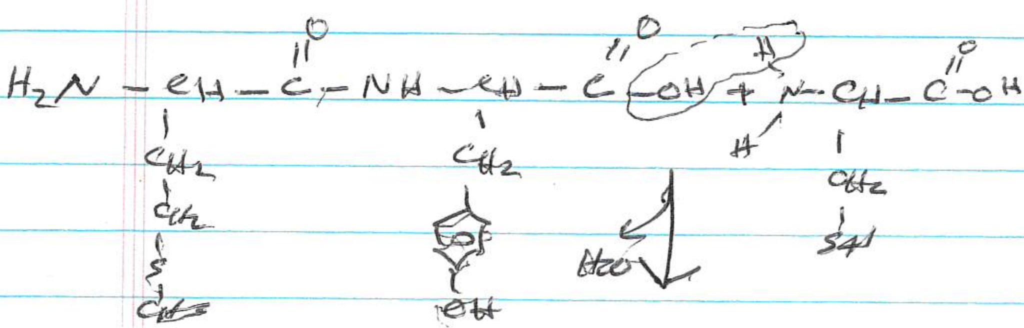
1 Glycine : Gly or G	2 Valine : Val or V
3 Alanine : Ala or A	4 Leucine: Leu or L
5 Isoleucine : Ile or I	6 Methionine: Met or M
7 Phenylalanine: Phe or F	8 Tryptophane: Trp or W
9 Proline: Pro or P	10 Serine : Ser or S
11 threonine : thr or T	12 Cysteine: Cys or C
13 Tyrosine: Tyr or Y	14 Asparagine: Asn or N
15 Glutamine: Gln or Q	16 Aspartic acid; Asp or D
17 Glutamin acid: Glu or E	18 Lysine: Lys or K
19 Arginine: Arg or R	20 Histidine: His or H

Polypeptides

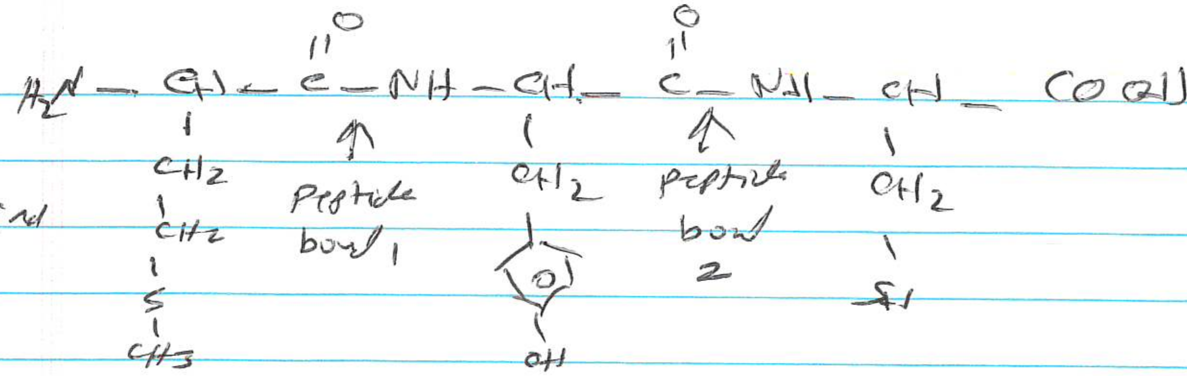
- Making a peptide:



Glycine Alanine peptide bond Glycyl-alanine (di-peptide)



Amino end
N-terminal



Carboxy end
C-Terminal

Methionine Tyrosine Cysteine

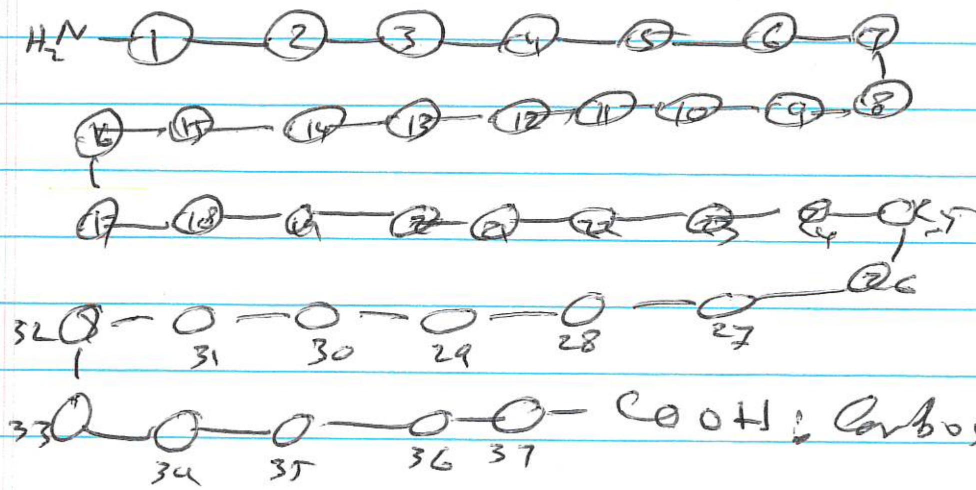
Protein Structure:

4 Levels
- Primary structure
- Secondary "
- Tertiary "
- Quaternary "

Primary Structure

- Linear chain of aa's

amino end

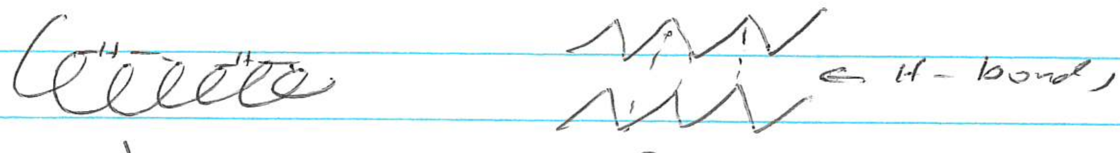


: Carboxyl end

Primary struc is the sequence of amino acids
- Order of aa's in the structure is inherited. Backbone of protein or polypeptide
- Gene or DNA codes for these aa's sequence order.

Secondary Structure:

Coiled or folded of Polypeptide

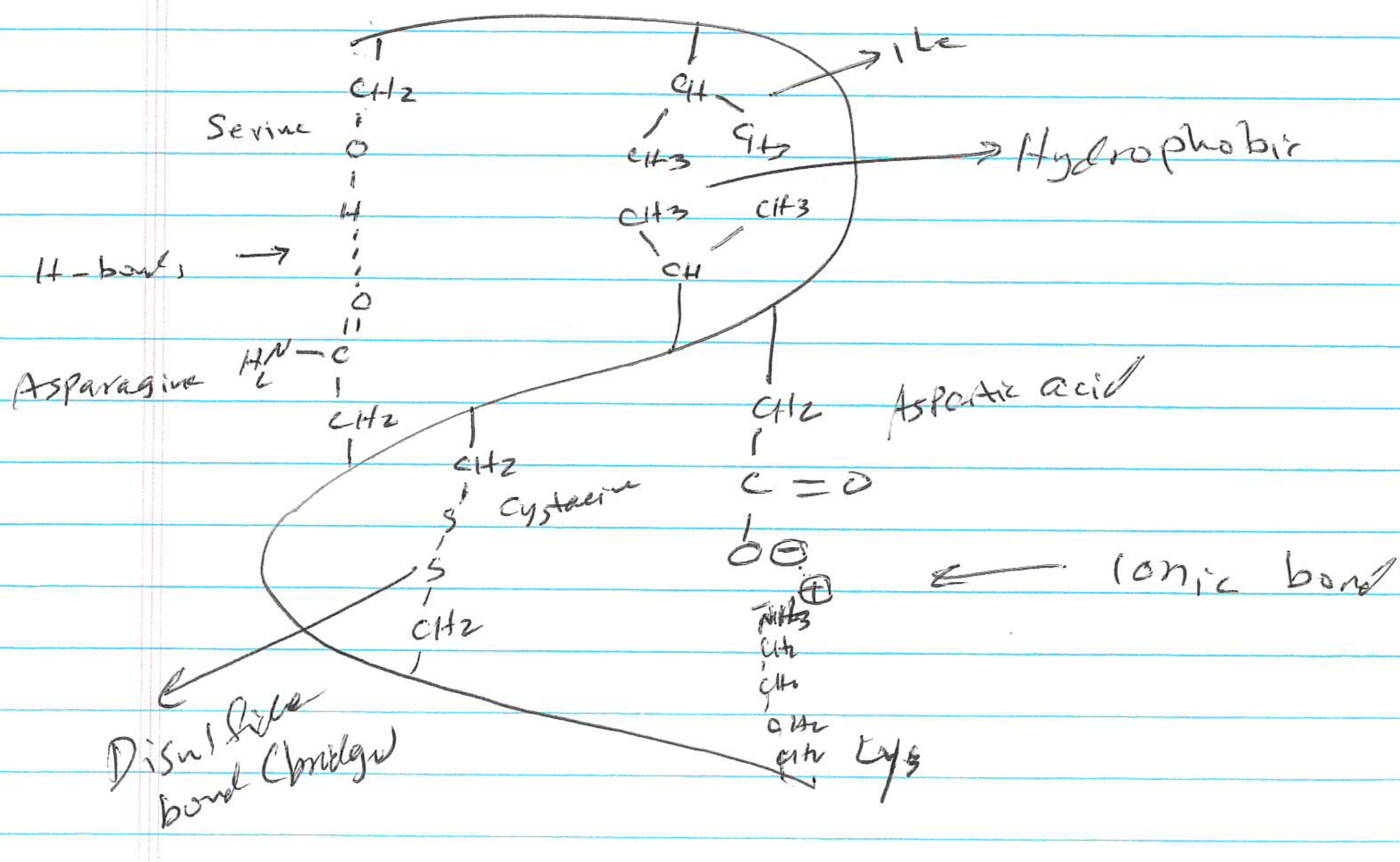


Regions stabilized by H-bonds between atoms of the polypeptide backbone

Tertiary Structure:

Three-dimensional shape of protein stabilized by interactions between aa's side chains.

- H-bonds
- S-S-bonds
- ionic bonds
- Hydrophobic interactions

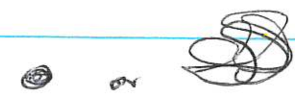


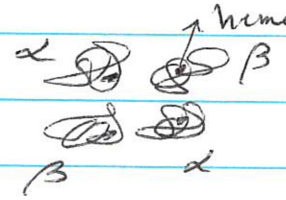
Quaternary Structure

Assocration of two or more polypeptides (if protein has more than one polypeptide)

One polypeptide → subunit

Examples

insulin hormone
or
- RNase enzyme
One polypeptied →  subunit

- Hemoglobin
4 - polypeptides → 

2α
2β } Subunits

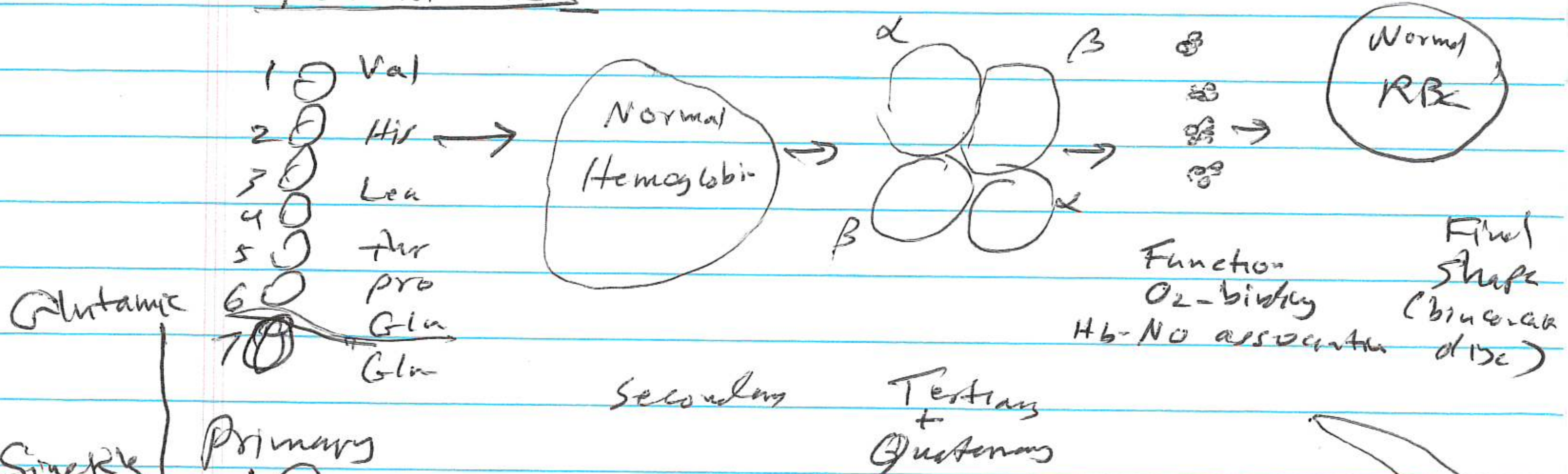
Hemoglobin

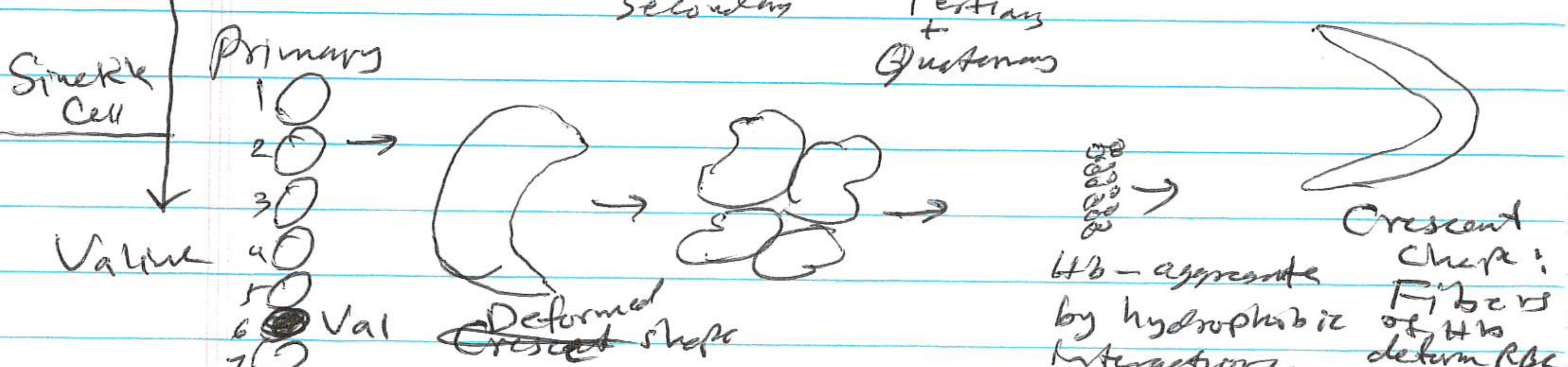
 → loaded with hemoglobin protein
RBC (O$_2$ - binding protein of RBC)

Assocration or aggregation of subunits, NO bonds between these Subunits.

Sickle cell disease: a change in primary structure → change shape

Normal RBC





Cohort:

~~What~~ determines Protein structure

DNA → Primary Structure → 2ndary → 3rtiery → 4 Structure
dictate dictate

protein Folding normally occurs as the protein is being synthesized by ribosomes in cells.

→ Protein Structure also depends on:

- Physical conditions
  e.g: Temperature, Sunlight
- Chemical condition
  e.g: pH, salt concentration

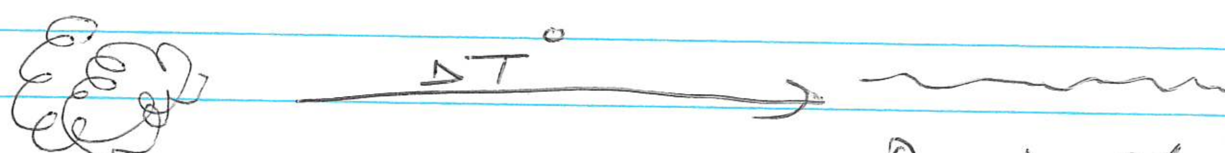
↓ Alterations may lead to

Protein Denaturation

Human body ↓ synthesize at least 30,000 proteins

e.g: 1) boiling or frying an egg
Liquid → solid egg content
(protein denatures)

2) Sunstroke → protein denaturation



Normal protein (native)
(Active)

Denatured Protein
(inactive)

cell pathology — Folding polypeptide while synthesized in ribosomes fold normally, if folding process is impaired → faulty Protein shape & structure results in impaired or inactive protein → human disease
e.g: autistic children, Prions, Alzheimer's, Parkinson's