

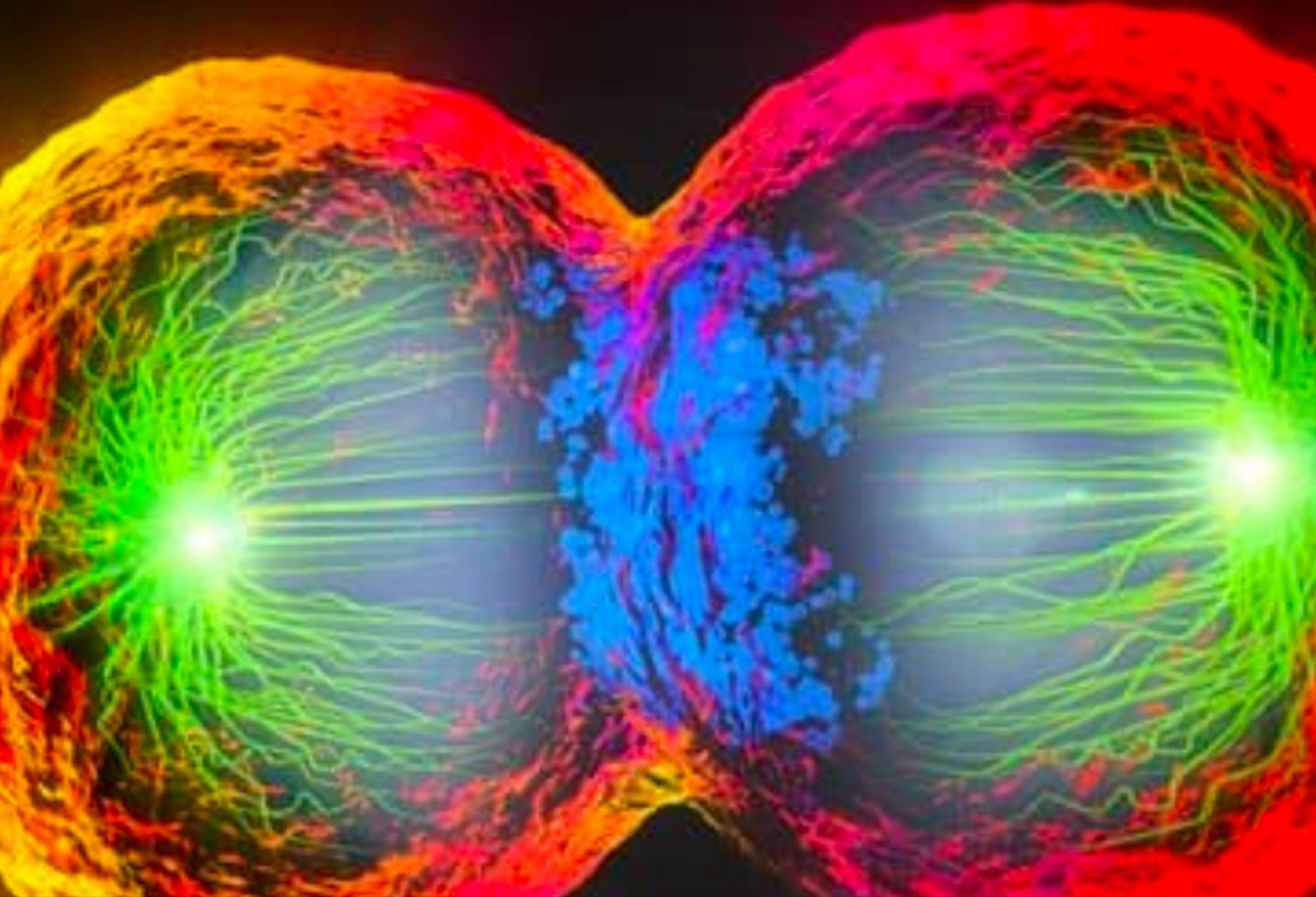
CELL BIOLOGY & BIOCHEMISTRY

NOTES

FOURTH EDITION

**PRE-SUMMARIZED
READY-TO-STUDY
HIGH-YIELD NOTES**

**FOR THE TIME-POOR
MEDICAL, PRE-MED,
USMLE OR PA STUDENT**



152 PAGES

A Message From Our Team

Studying medicine or any health-related degree can be stressful; believe us, we know from experience! The human body is an incredibly complex organism, and finding a way to streamline your learning is crucial to succeeding in your exams and future profession. Our goal from the outset has been to create the greatest educational resource for the next generation of medical students, and to make them as affordable as possible.

In this fourth edition of our notes we have made a number of text corrections, formatting updates, and figure updates which we feel will enhance your study experience. We have also endeavoured to use only open-source images and/or provide attribution where possible.

If you are new to us, here are a few things to help get the most out of your notes:

- 1. Once saved, the notes are yours for life!** However, we strongly advise that you download and save the files immediately upon purchasing for permanent offline access.
- 2. Sharing notes is prohibited.** All files are share-protected and our system will automatically revoke access to and lock files if it detects a customer attempting to share or distribute our notes.
- 3. Your license permits you to do the following:**
 - a. You may download/save/view files on up to 2 simultaneous devices.
 - b. You may save the files to an external hard drive for backup purposes only.
 - c. You may print your notes to hard copy on any home printer/photocopier.
- 4. Once saved, you do not need to download the notes again.** You can simply transfer your file/s to your second personal device (eg: your iPad/tablet) without the need to re-download your files. If you wish to retire an old device, simply transfer your files to your new device, then delete the files from your old device.

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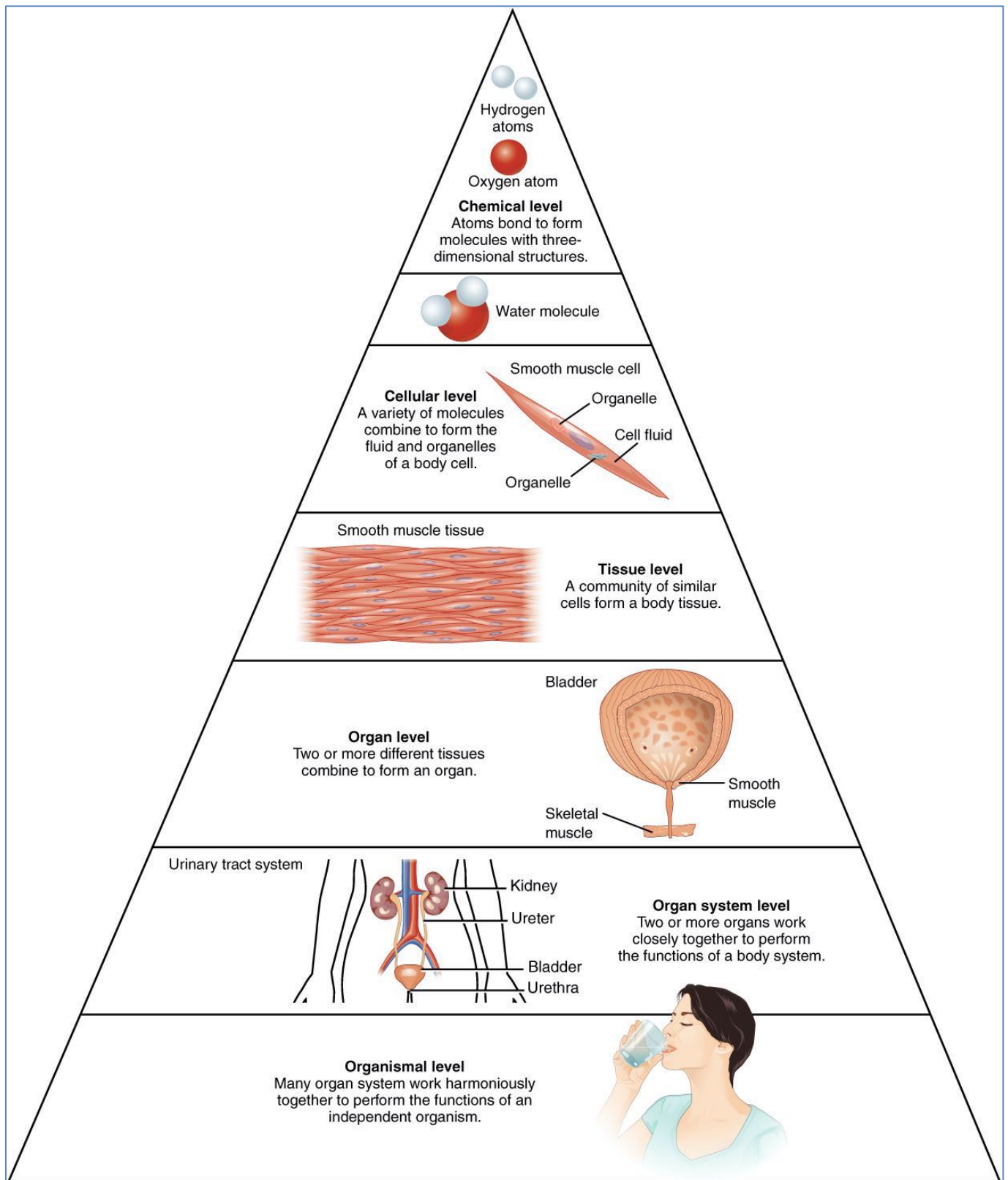
What's included: Ready-to-study summaries of a broad range of cellular physiology and biochemical topics, presented in succinct, intuitive and richly illustrated downloadable PDF documents. Once downloaded, you may choose to either print and bind them, or make annotations digitally on your iPad or tablet PC.

Cellular Physiology & Biochemistry Topics:

- **5 LEVELS OF ORGANIZATION IN THE BODY**
- **MOLECULAR BUILDING BLOCKS OF LIFE:**
 - o **CARBOHYDRATES:**
 - o **LIPIDS / FATS:**
 - o **PROTEINS**
 - o **NUCLEIC ACIDS**
- **CELL STRUCTURE:**
- **CELL MEMBRANE & TRANSPORT**
- **CELLULAR METABOLISM**
 - o **CARBOHYDRATE METABOLISM**
 - o **THE CITRIC ACID CYCLE (TCA) / 'KREBS CYCLE':**
 - o **ELECTRON TRANSPORT CHAINS / OXIDATIVE PHOSPHORYLATION:**
 - o **AMINO ACID METABOLISM & THE UREA CYCLE**
 - o **THE UREA CYCLE:**
 - o **FATTY ACID METABOLISM**
- **CELLULAR SIGNALLING**
- **THE 'CELL CYCLE' & CELLULAR REPLICATION**
- **REGULATION OF CELL FATE**
- **CANCER, CELL DEATH & CELLULAR AGEING**
- **EPITHELIAL TISSUES (MEMBRANES & GLANDS)**
- **CONNECTIVE TISSUE:**
- **MUSCLE TISSUE:**
- **NERVOUS TISSUE**
- **MEMBRANE POTENTIAL & EXCITABLE TISSUES**
- **TISSUE INJURY & CELLULAR ADAPTATIONS**
- **MICROBIAL DIVERSITY**

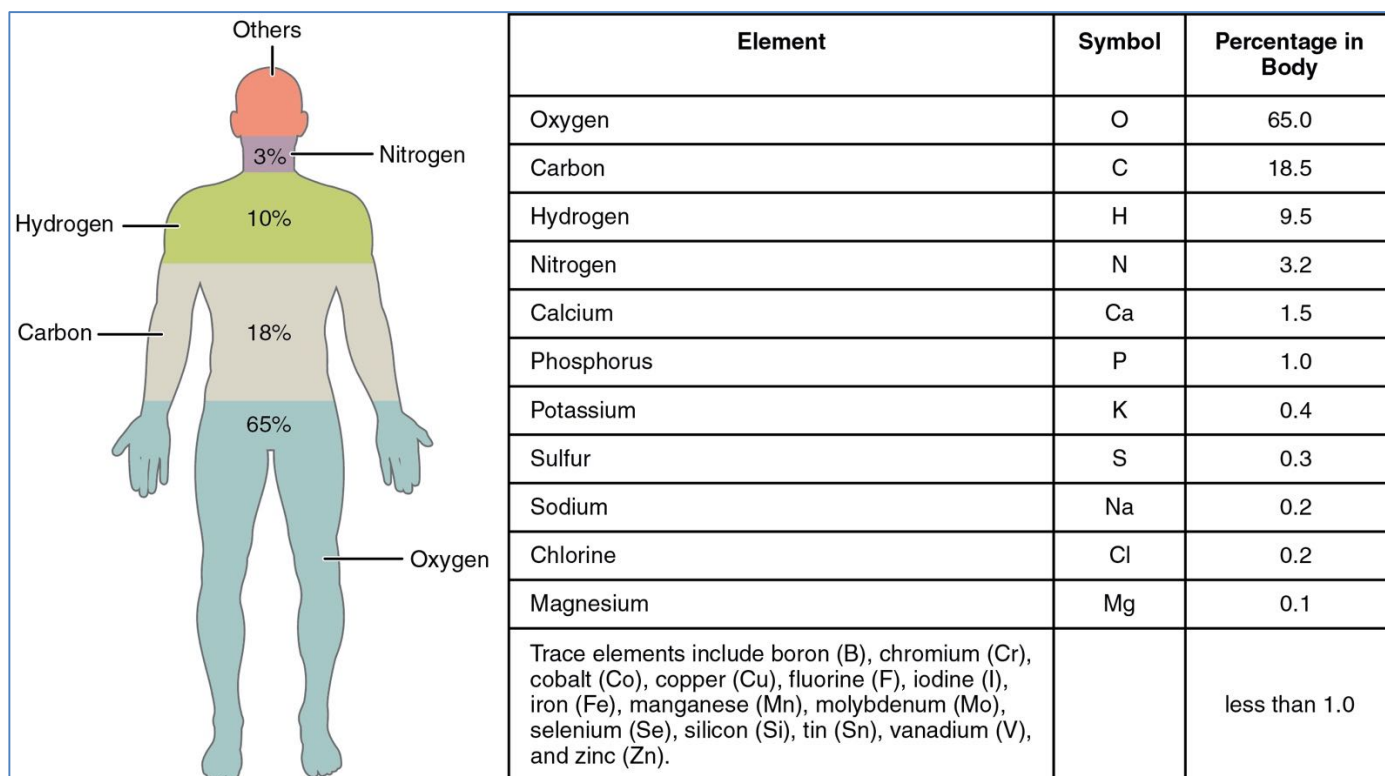
5 LEVELS OF ORGANIZATION IN THE BODY

5 LEVELS OF ORGANIZATION IN THE BODY:



1: The Chemical Level:

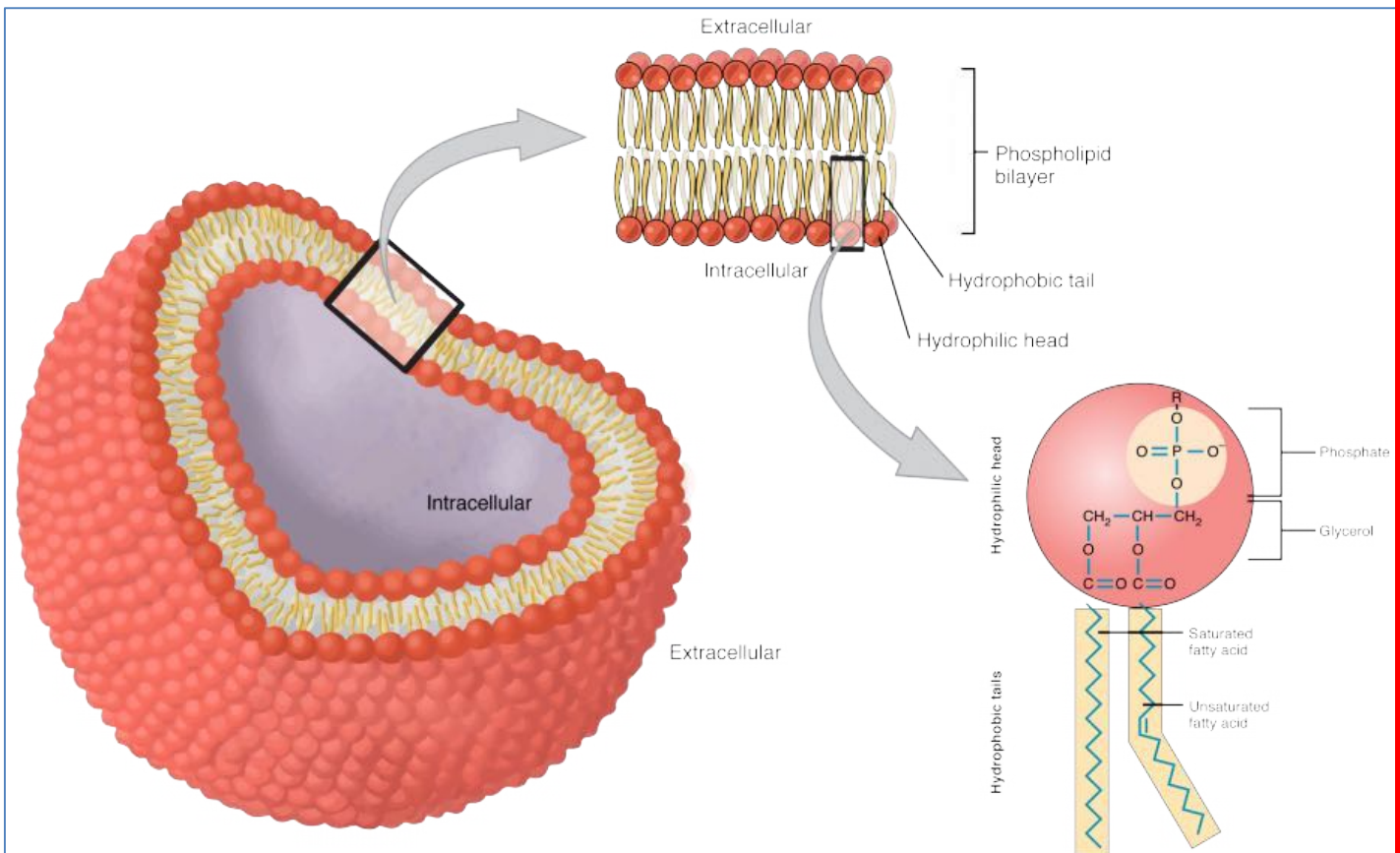
- All matter is made up of atoms & molecules
- 4 Biological Elements account for 96% of living matter:
 - o Carbon
 - o Oxygen
 - o Hydrogen
 - o Nitrogen
- These 4 elements combine to form the 4 major Macromolecules of life:
 - o Proteins
 - o Carbohydrates
 - o Fats
 - o Nucleic Acids



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2: The Cellular Level:

- **Cells are the basic functional units of life**
 - o I.e: There are no *sub*-cellular 'living things'
 - o The cell is the smallest unit capable of carrying out the processes associated with life
 - o Single-celled organisms (eg: Bacteria & amoebas) are the simplest forms of life
 - o Multi-cellular organisms (eg: Humans) are structural aggregates of trillions of cells
- **All cells are bound by a *Plasma Membrane*:**
 - o A bilipid membrane (hydrophilic on outer & inner surfaces; hydrophobic tails facing inwards)
 - o Encapsulates all internal cellular machinery
 - o Contains many proteins necessary for all types of functions:
 - Eg: Transporter proteins (control movement of materials into & out of the cell)
 - Eg: Antigen proteins (allows the body's immune cells to identify 'self' vs 'foreign' cells)
 - Eg: Cell membrane receptors (allows the cell to respond to outside chemical signals)
- **All cells perform certain basic functions:**
 - o Obtain food/nutrients from the environment
 - o Obtain oxygen from the environment
 - o Extract useful energy from food via respiration
 - o Eliminate its own waste products
 - o Synthesize macromolecules necessary for its own maintenance & functions
 - Eg: Proteins for growth
 - Eg: Enzymes for functions
 - Eg: Fats for energy & membrane repair/maintenance
 - Eg: Carbohydrates for energy
 - o Control the exchange of materials between itself and its surroundings
 - o Move materials internally from one part of the cell to another
 - o Sense and respond to changes in surrounding environment
 - o Self-replication (Except nerve and muscle cells)

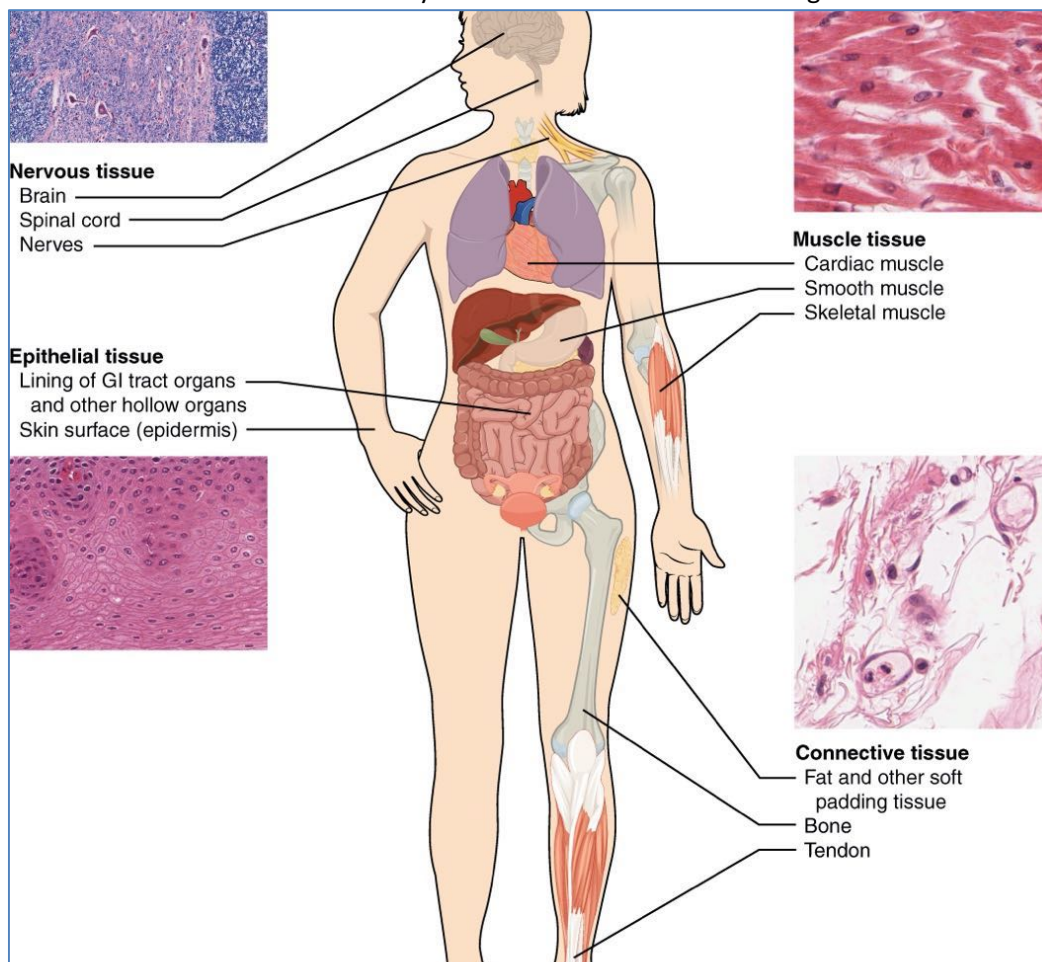


3: The Tissue Level:

- **Cells of similar structure and/or function, combine to form tissues**

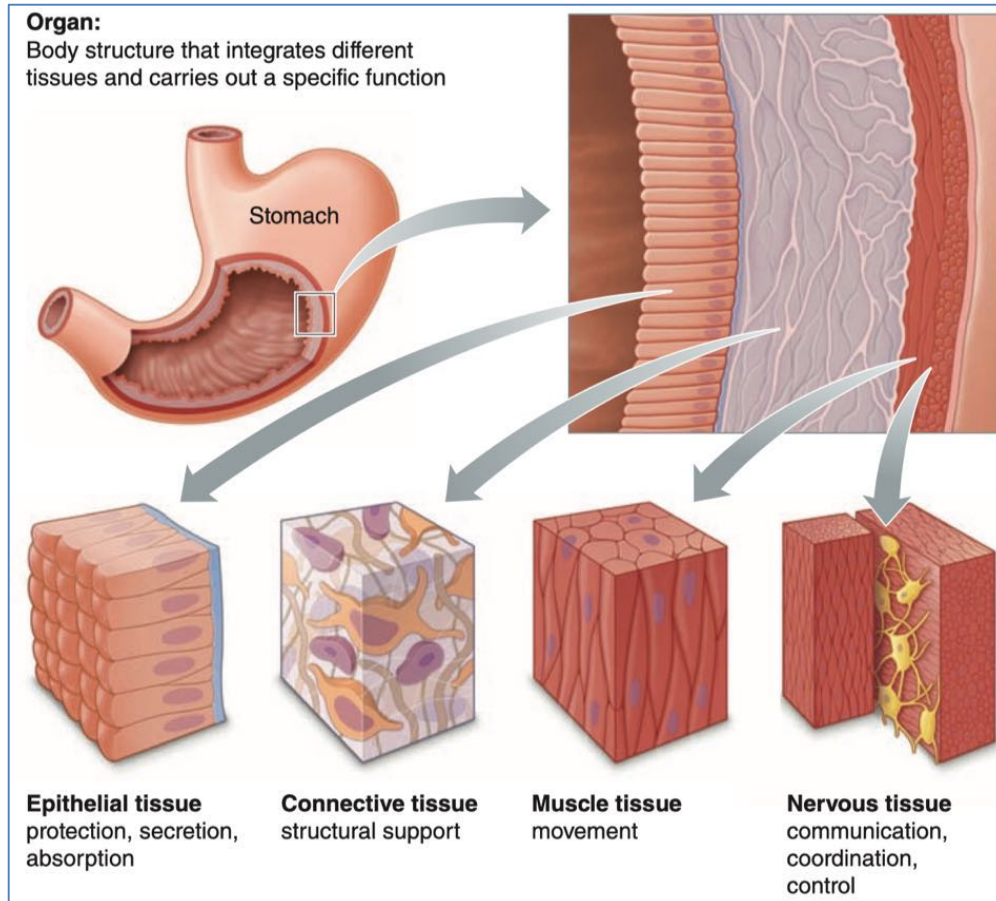
- **4x Primary Tissue Types:**

- **Muscle Tissue:**
 - Consist of contractile cells capable of generating tension & movement
 - 3 Types of Muscle Tissue:
 - Skeletal Muscle
 - Cardiac Muscle
 - Smooth Muscle
- **Nervous Tissue:**
 - Consist of cells specialized for initiating and transmitting electrical impulses
 - Electrical impulses = 'Action Potentials'
 - Signals relay information from one part of the body to another
- **Epithelial Tissue:**
 - Consist of cells specialized for exchanging materials between the cell & its environment
 - ANY substances that ENTERS or LEAVES the body, does so via an Epithelia Membrane
 - 2 Types of Epithelial Tissue:
 - Epithelial Sheets (Membrane)
 - Secretory Glands (Exocrine or Endocrine)
- **Connective Tissue:**
 - Consist of relatively few cells dispersed in an abundant extracellular matrix
 - Role: Connects/supports/anchors various body parts
 - 4 Types of Connective Tissue:
 - Connective Tissue Proper
 - Loose connective tissue
 - Dense connective tissue
 - Cartilage
 - Bone
 - Blood - technically a 'connective tissue' even though it's a fluid



4: The Organ Level:

- **Organ = 2 or more types of primary tissue organized to perform specific functions**
- **Eg: The Stomach:**
 - **Overall function** – To store food, digest food, and move it down the digestive tract
 - **Tissue Types:**
 - **Epithelial** – secrete digesting juices into the lumen
 - **Connective** – Binds together all other tissues
 - **Muscle** – Smooth muscle contractions mix ingested food
 - **Nervous** – controls muscle contraction & gland secretion



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5: The Body System Level:

- **Body System = 2 or more organs organized to perform related functions**
- **Eg: Digestive System; contains:**
 - Stomach
 - Small intestine
 - Large intestine
 - Salivary glands
 - Exocrine pancreas
 - Liver & Gallbladder
- **Body has 11 Systems:**
 - Cardiovascular (Circulatory)
 - Digestive (Gastrointestinal)
 - Respiratory
 - Urinary
 - Skeletal
 - Muscular
 - Integumentary (Skin)
 - Immune
 - Nervous
 - Endocrine
 - Reproductive

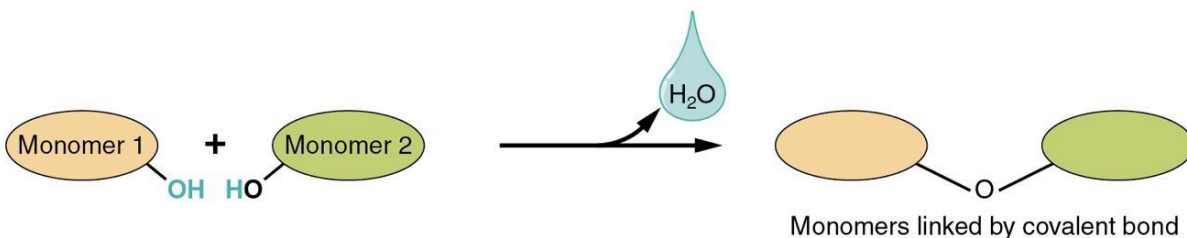
MOLECULAR BUILDING BLOCKS OF LIFE:

MOLECULAR BUILDING BLOCKS OF LIFE:

- All matter is made up of atoms & molecules
- 4 Biological Elements account for 96% of living matter:
 - o Carbon
 - o Oxygen
 - o Hydrogen
 - o Nitrogen
- These 4 elements combine to form the 4 major Macromolecules of life:
 - o Carbohydrates (Sugars)
 - o Fats (Polymers of Fatty Acids)
 - o Proteins (Polymers of Amino Acids)
 - o Nucleic Acids (Polymerizes to form DNA & RNA)
- Most of them are polymers
 - o Made by stringing together many smaller molecules (monomers)
 - o Monomers bond (polymerise) by dehydration reactions and break down by hydrolysis:

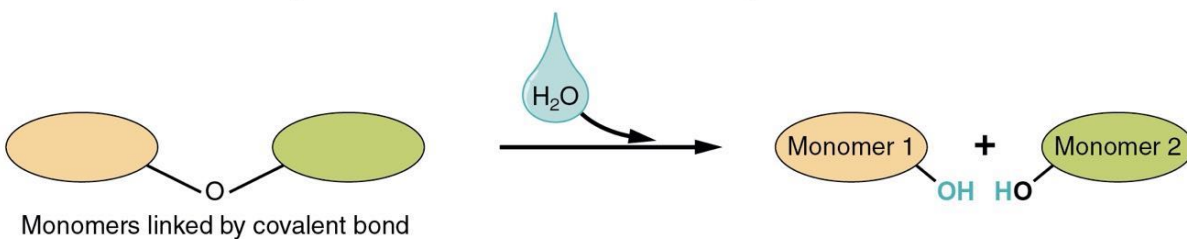
(a) Dehydration synthesis

Monomers are joined by removal of OH from one monomer and removal of H from the other at the site of bond formation.



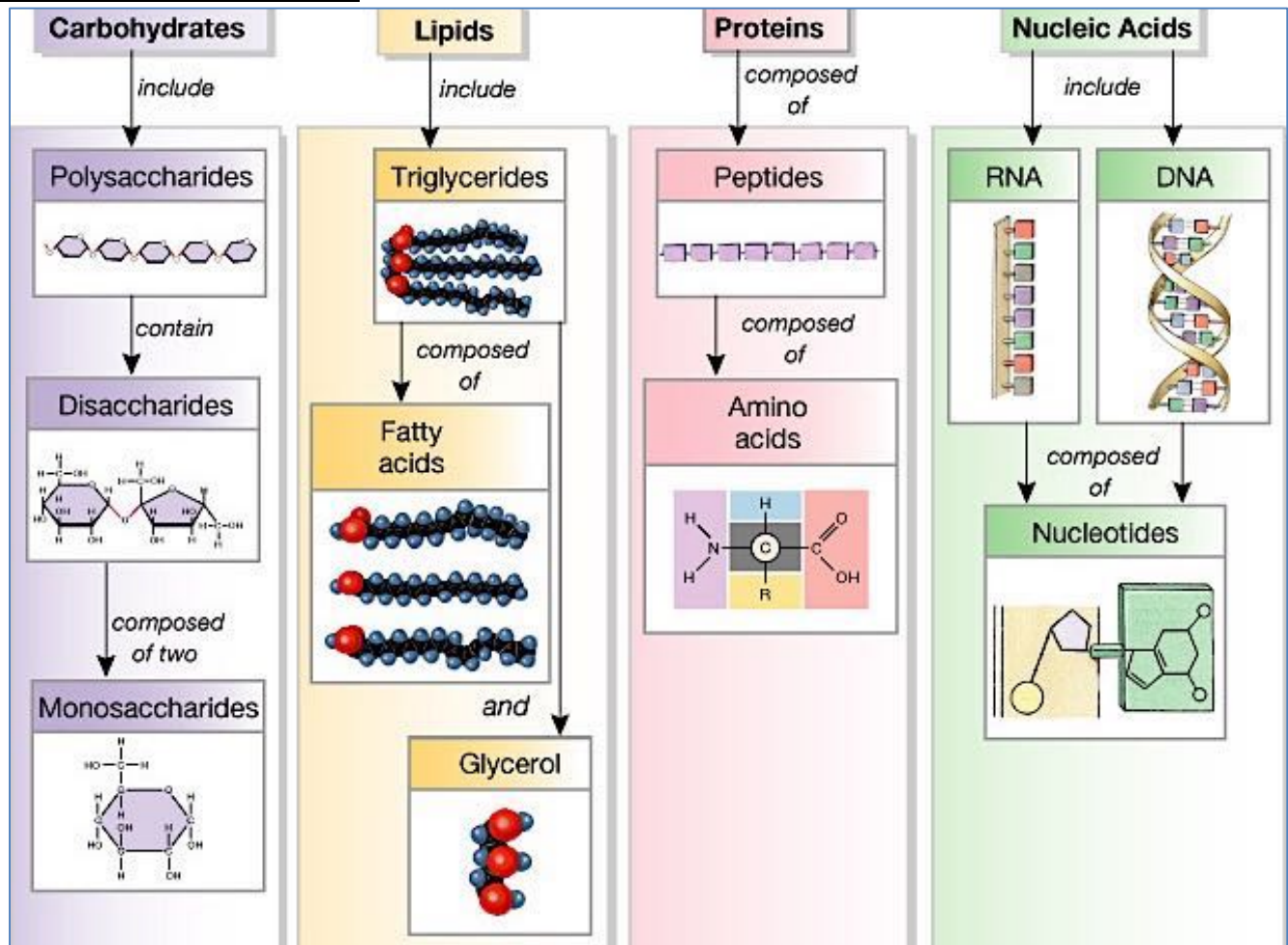
(b) Hydrolysis

Monomers are released by the addition of a water molecule, adding OH to one monomer and H to the other.



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The Biological MACROmolecules:



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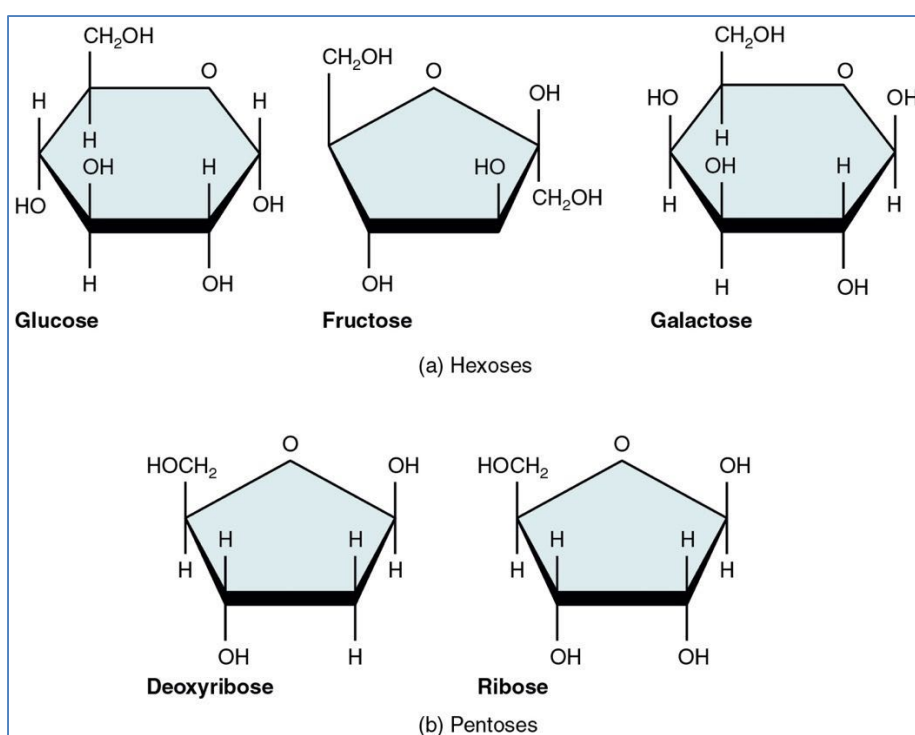
CARBOHYDRATES:

General Info About Carbohydrates:

- **What Are They?**
 - o Biological compounds containing covalently bonded **carbon, hydrogen, and oxygen** (in a 1:2:1 ratio)
- **Importance:**
 - o Monosaccharides = important cellular nutrients
 - o Metabolised by cells to produce usable energy
 - o Important store of energy reserves
- **Structural Classifications:**
 - o **Monosaccharides** = Single-Sugar units:
 - Glucose
 - Fructose
 - Galactose
 - o **Disaccharides** = Double-Sugar units:
 - Sucrose
 - Lactose
 - Maltose
 - o **Polysaccharides** = Multi-Sugar Polymers:
 - Glycogen
 - Starch
 - Cellulose (Plants)

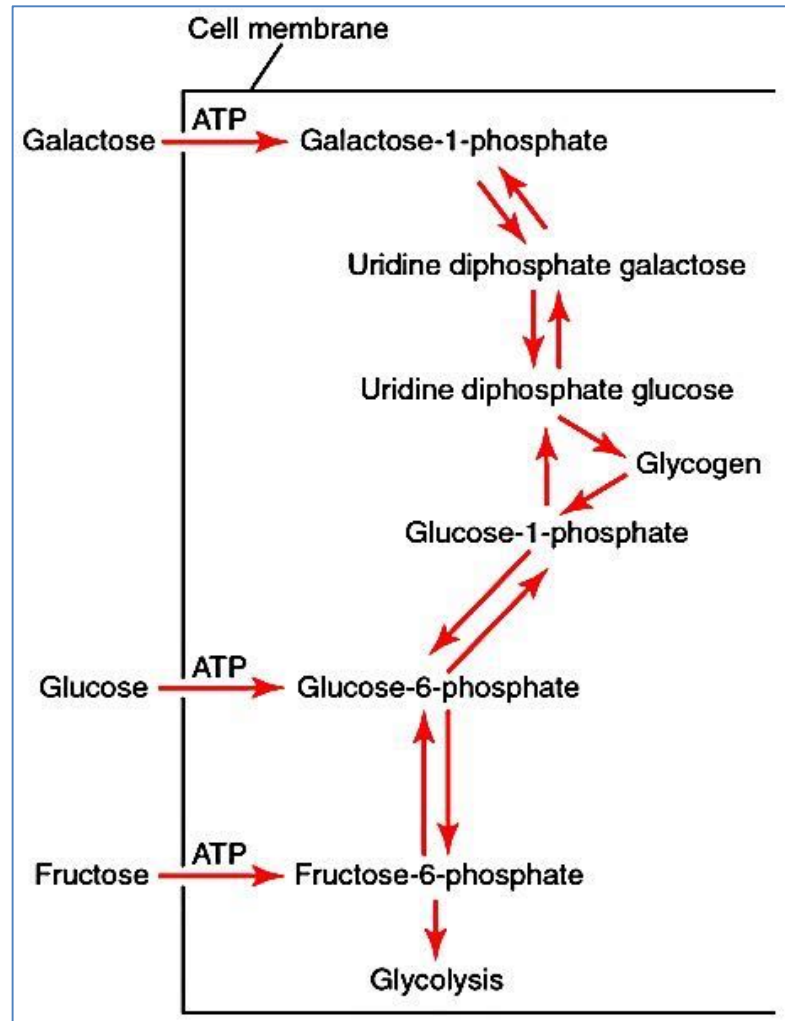
Monosaccharides (Simple Sugars):

- **Monosaccharide Literally Means: “single” “Sugar-unit”**
 - o Cannot be broken down into simpler sugars
- **Examples:**
 - o Glucose
 - o Fructose
 - o Galactose
- **Monosaccharides are Isomers:**
 - o I.e: Have the same chemical formulae but different structural arrangements
 - o Still contain exactly the same amount of energy
- **In aqueous solutions, monosaccharides form rings**
 - o Are the main fuel used by cells



- **Each Monosaccharide Has Its Own Metabolic Pathway:**

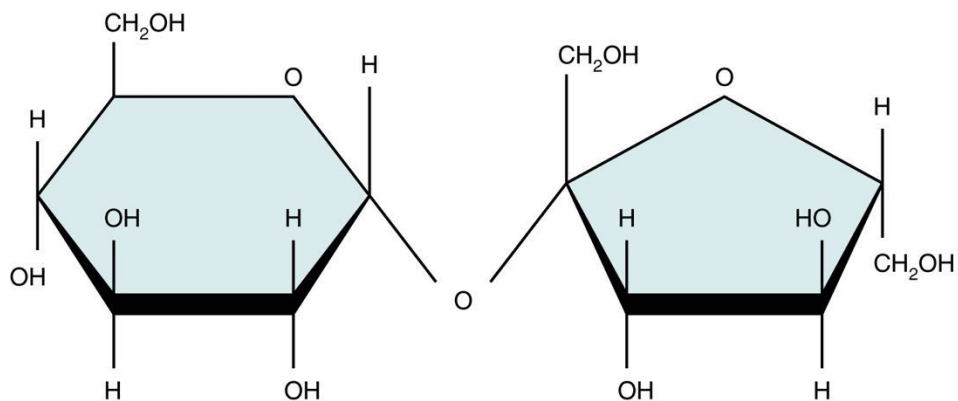
- Glucose → **Glycolysis** → ATP
- Fructose → **Fructolysis** → Glycolysis → ATP
- Galactose → **Leloir Pathway** → Glycolysis → ATP
- (Note how ALL 3 eventually feed into Glycolysis)



Disaccharides:

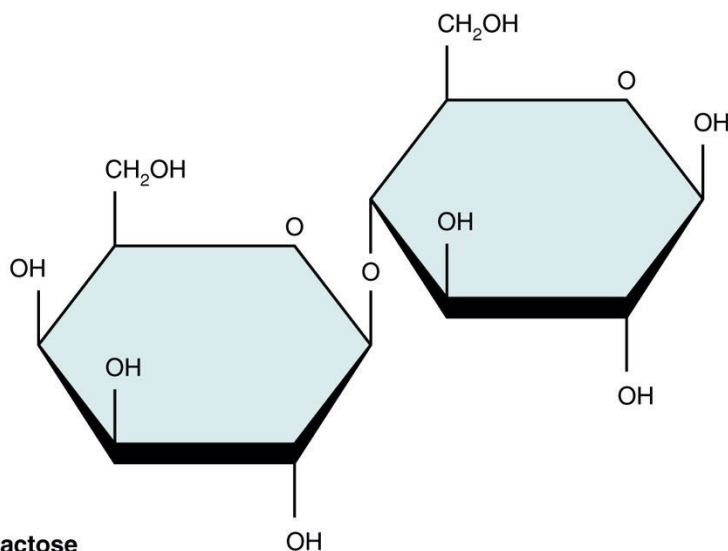
- “Double-Sugar Units”
 - I.e: Consist of 2 monosaccharides
- **3x Digestible Disaccharides:**
 - **Maltose:** Glucose + Glucose
 - **Lactose:** Glucose + Galactose
 - **Sucrose (table sugar):** Glucose + Fructose

(a) The monosaccharides glucose and fructose bond to form sucrose



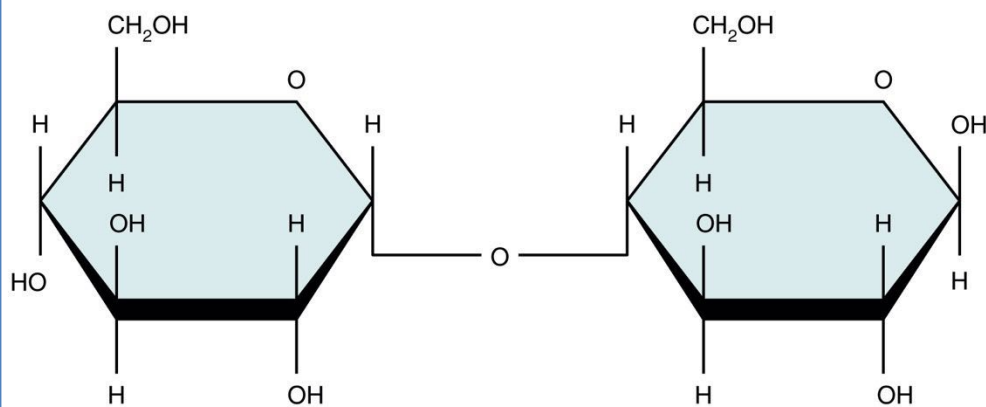
Sucrose

(b) The monosaccharides galactose and glucose bond to form lactose.



Lactose

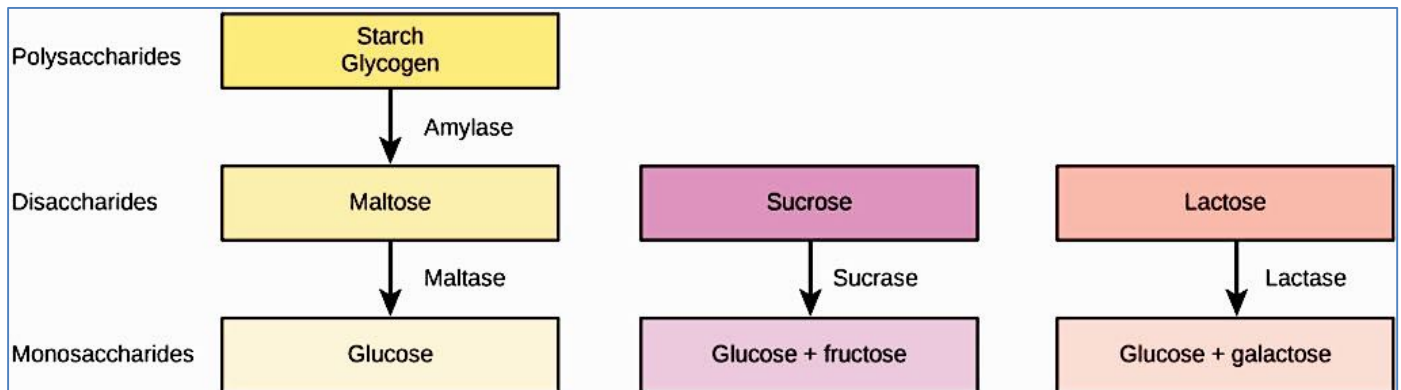
(c) Two glucose monosaccharides bond to form maltose.



Maltose

- **Disaccharide Metabolism:**

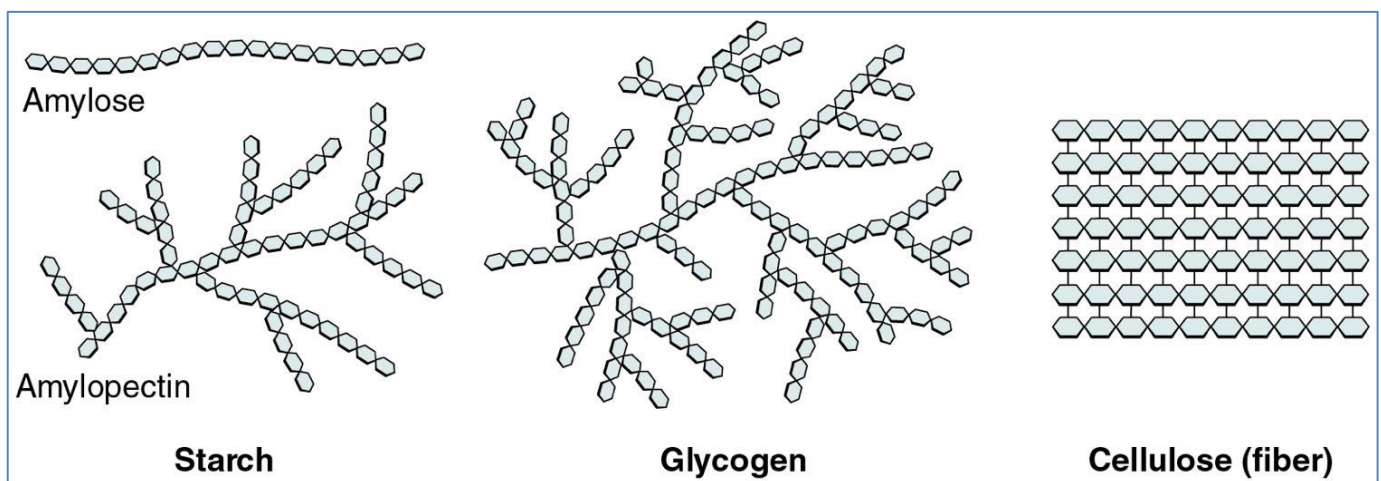
- First requires breakdown into constituent Monosaccharides In order for the body to utilise
- **Requires Specific Enzymes**
 - Sucrase → Hydrolyzes Sucrose into **Glucose + Fructose**
 - Lactase → Hydrolyzes Lactose into **Glucose + Galactose**
 - Maltase → Hydrolyzes Maltose into **Glucose + Glucose**



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Polysaccharides:

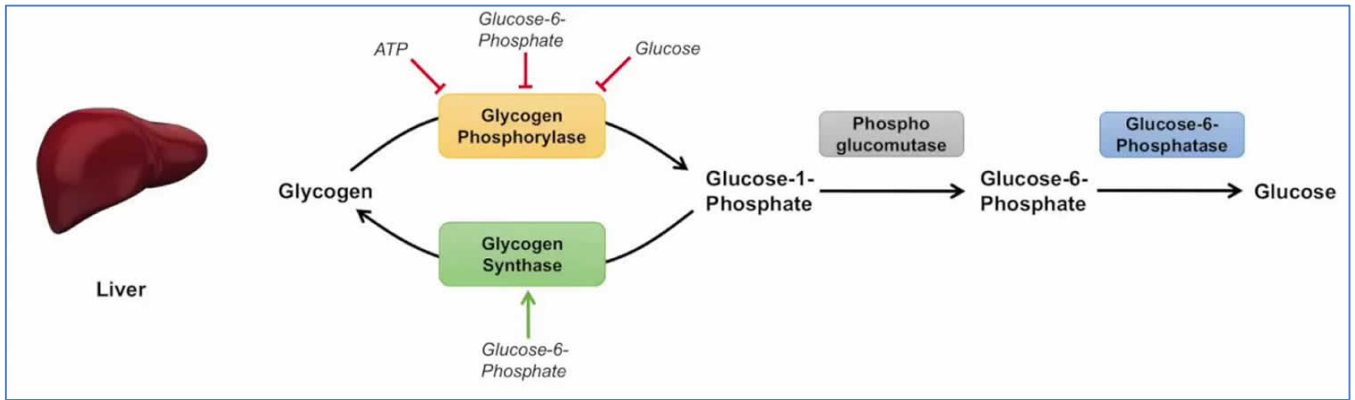
- **AKA: Complex Carbohydrates**
 - Long Polymers of Monosaccharides (Single Sugar Units)
- **3x Polysaccharides:**
 - **Starch**
 - Stores energy in plant cells (potatoes/grains)
 - Made of many Glucose monomers
 - **Glycogen (animal starch)**
 - Animals store excess sugar as glycogen
 - Made of many Glucose monomers
 - Contains many branches
 - **Cellulose**
 - Makes up the structure of plant-cell walls
 - Major component of wood
 - Is a dietary fibre
 - Can only be broken down by grazing animals due to prokaryotes in their digestive system



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- **Glycogen Metabolism & Storage In The Body:**

- **Glycogenesis** = Creating glycogen from excess glucose following a meal
- **Glycogenolysis** = Tapping into glycogen to liberate glucose in times of fasting

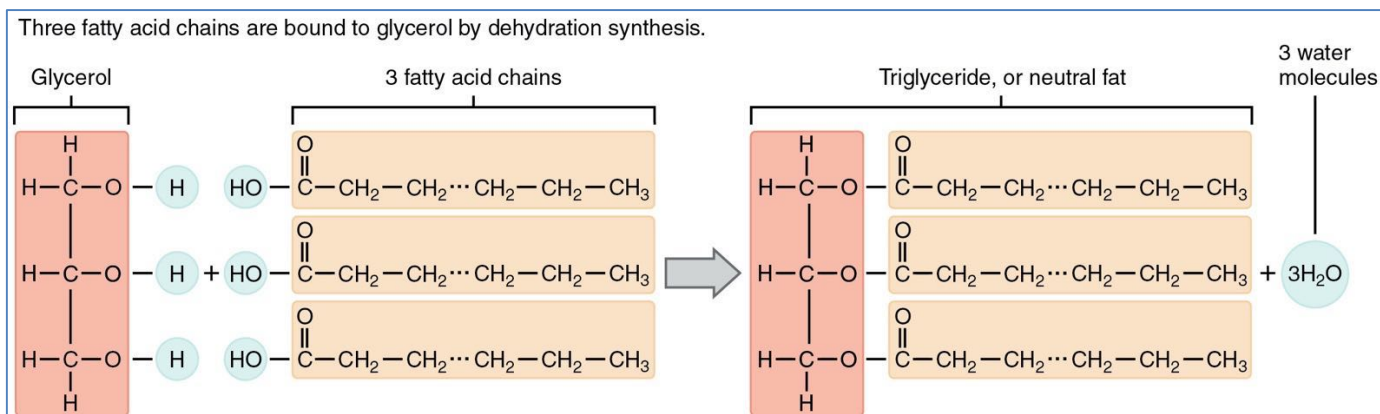


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LIPIDS / FATS:

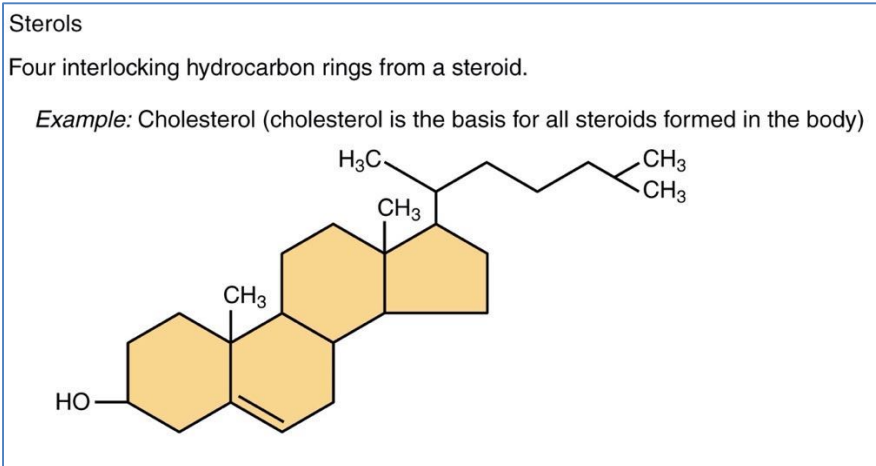
General Info About Lipids/Fats:

- **What are they?**
 - o Biological compounds containing **hydrocarbons**
 - o Not soluble in water (**hydrophobic**)
 - o Eg: Fats/waxes/oils/sterols/triglycerides/phospholipids
- **Importance:**
 - o Major structural component of cell membranes (lipid bilayer)
 - o Major class of chemical messenger (Eg: Steroid hormones)
 - o Major store of energy (triglycerides)
 - o Major source of energy (fatty acids)
 - o Major solvent for certain vitamins (Vitamins A, D, E & K)
 - o Major functional barriers (Eg: Skin oils, ear wax, cerumen)
 - o Major source of insulation/cushioning of vital organs (Eg: Kidneys and heart)
- **3 Relevant Types:**
 - o **Fatty Acid:** A long hydrocarbon chain with a carboxyl group end
 - **Saturated** fatty acids are **straight**
 - Pack tightly together
 - Solid @ Room Temperature
 - **Unsaturated** fatty acids are **kinked**
 - Pack loosely together
 - Liquid @ Room Temperature
 - o **Triglycerides:** 3 x fatty acids bonded to a glycerol through dehydration (ester linkage)



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- o **Steroids:**
 - = any fatty substances containing four carbon rings
 - cholesterol is the “base steroid” from which your body produces other steroids (sex hormones)



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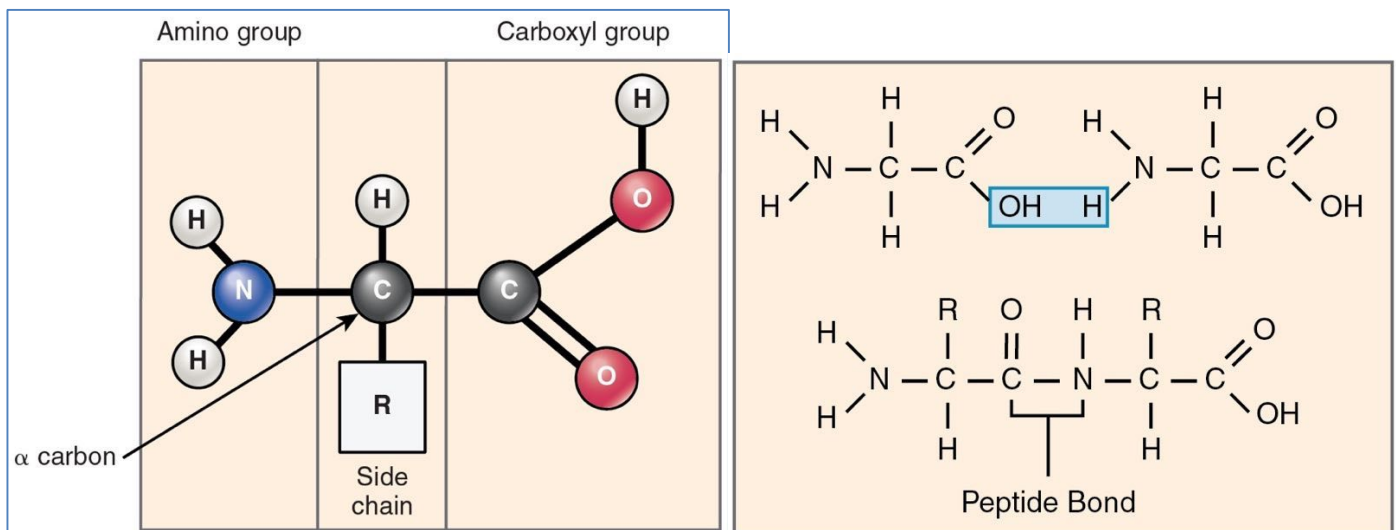
PROTEINS

General Info About Proteins:

- **What are they?**
 - o Biological polymers of linked **amino acid** monomers (via a peptide bond)
 - o The most complex and functionally diverse molecules of living organisms
- **Important Roles Of Proteins In The Body:**
 - o Protein Enzymes (Eg: Digestion, metabolism, cellular repair)
 - o Protein Hormones
 - o Carrier Proteins (Eg: Albumin)
 - o Cellular Receptor Proteins
 - o Membrane Transporter Proteins (Eg: Na/K/ATP-ase)
 - o Contractile Proteins (muscle tissue)
 - o Structural Proteins
 - o Storage Proteins
 - o Defensive Proteins
 - o Sensory Proteins
 - o Gene Regulatory Proteins
 - o Etc etc
- **Think about this:**
 - o The **ONLY** reason DNA exists, is to encode the creation of all the proteins necessary for you to exist
 - o Proteins are created from DNA Transcription and Translation
- **Base elements:**
 - o **Carbon**
 - o **Hydrogen**
 - o **Oxygen**
 - o **Nitrogen**

Amino Acids:

- **Each amino acid consists of:**
 - o **A central carbon** covalently bonded to 4 partners
 - o **An amino group**
 - o **A carboxyl group**
 - o **A side group** (Variable among all 20 amino acid types)
- **ALL proteins are constructed from Amino Acids**
 - o Amino acids join together by dehydration reactions forming peptide bonds:



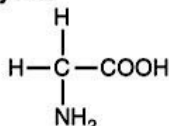
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- **There are 20 relevant amino acids**

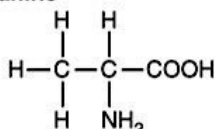
- **Some are Essential** (Either cannot be synthesized at all or cannot be synthesized in sufficient quantities in the body; Therefore, must be consumed in food)
- **Some are Non-Essential** (Body can synthesize them & in sufficient quantity)
- **Note:** There is broad disagreement among textbooks of exactly which are essential or not, some even further classifying certain amino acids as 'conditionally non-essential', so below is Guyton's list:

AMINO ACIDS

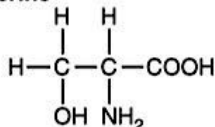
Glycine



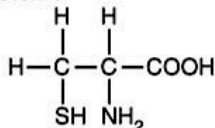
Alanine



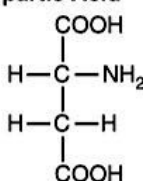
Serine



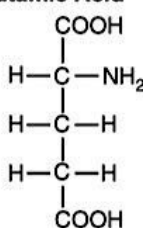
Cysteine



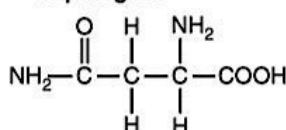
Aspartic Acid



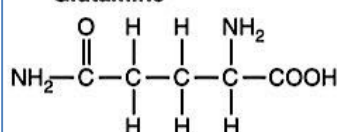
Glutamic Acid



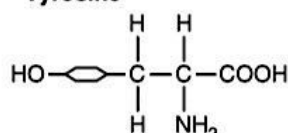
Asparagine



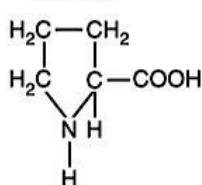
Glutamine



Tyrosine

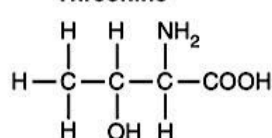


Proline

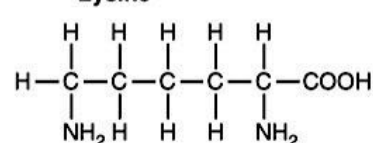


ESSENTIAL AMINO ACIDS

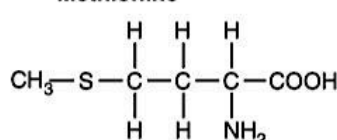
Threonine



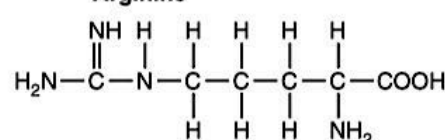
Lysine



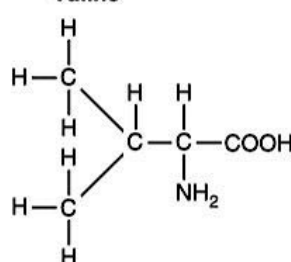
Methionine



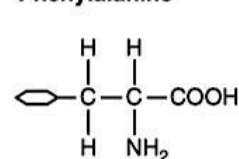
Arginine



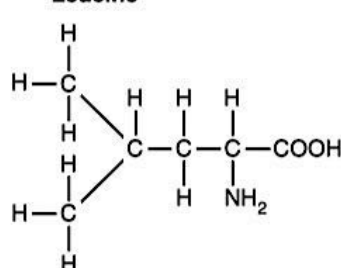
Valine



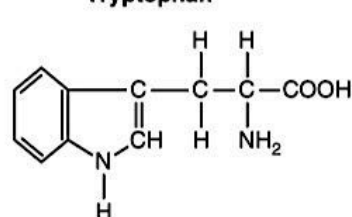
Phenylalanine



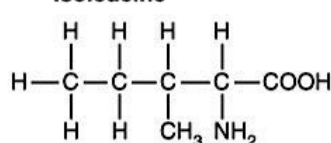
Leucine



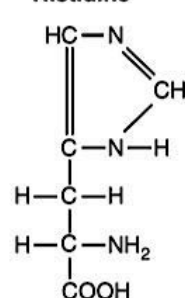
Tryptophan



Isoleucine

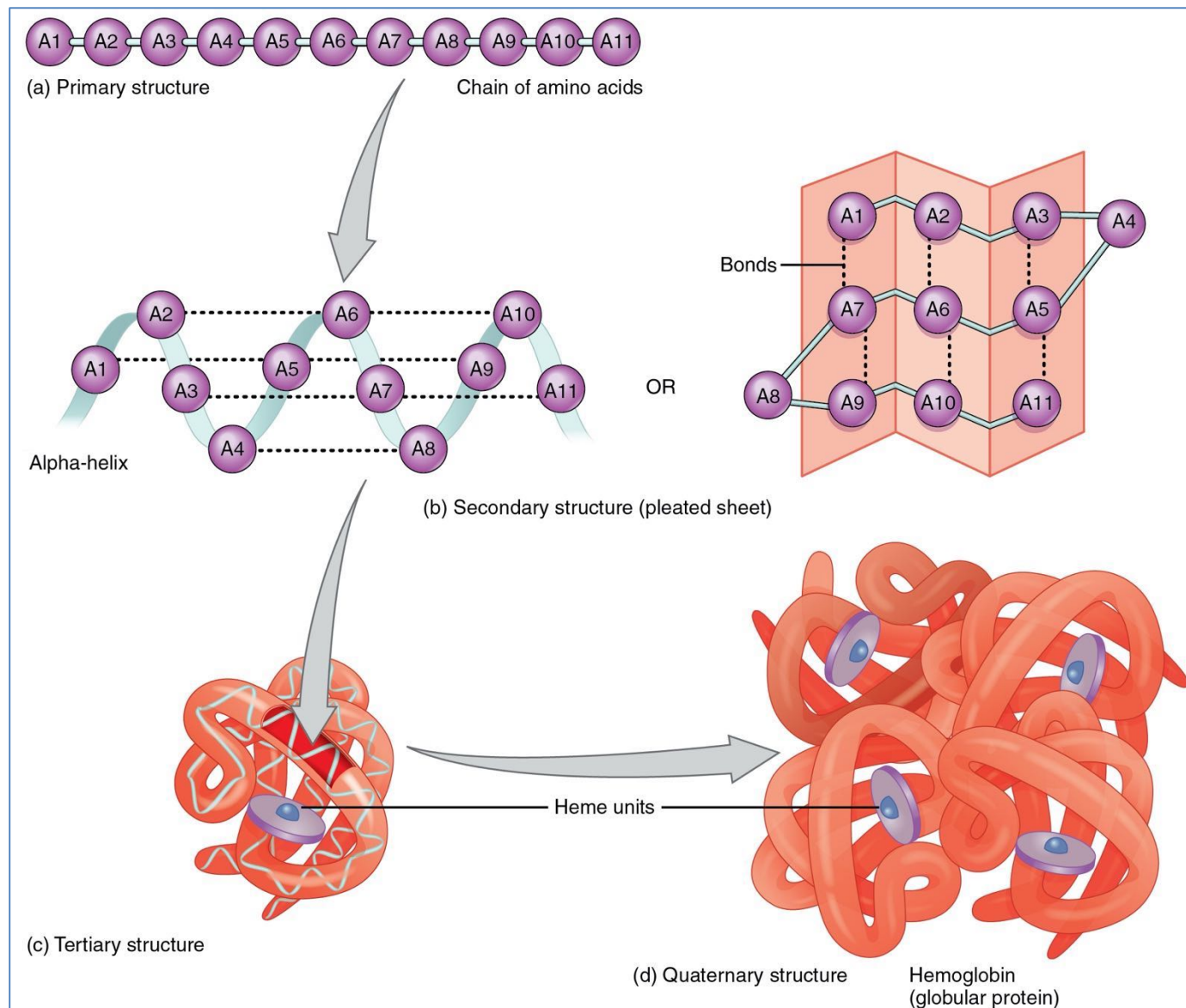


Histidine



Protein Shape/Structures:

- **Primary Protein Structure** (multiple peptide bonds = **polypeptide** *chains*)
 - Written L→R from amino end to carboxylic acid end
- **Secondary Protein Structure**
- **Tertiary Protein Structure**
- **Quaternary Protein Structure**
 - Complete functional protein



The Shape of Proteins (a) The primary structure is the sequence of amino acids that make up the polypeptide chain. (b) The secondary structure, which can take the form of an alpha-helix or a beta-pleated sheet, is maintained by hydrogen bonds between amino acids in different regions of the original polypeptide strand. (c) The tertiary structure occurs as a result of further folding and bonding of the secondary structure. (d) The quaternary structure occurs as a result of interactions between two or more tertiary subunits. The example shown here is hemoglobin, a protein in red blood cells which transports oxygen to body tissues.

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Note: A protein's shape is sensitive to the environment and can be denatured by change in temperature and pH

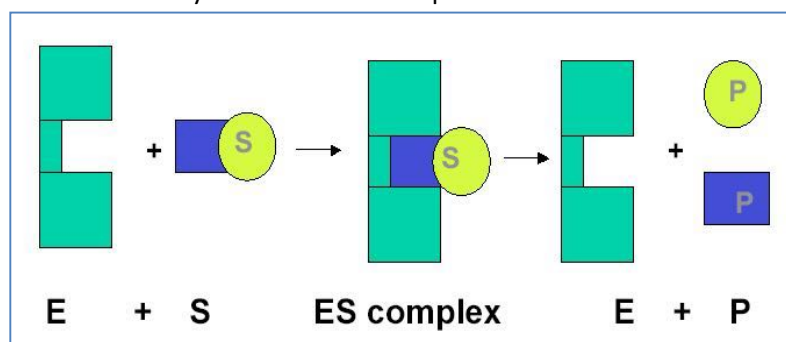
Proteins as Enzymes:

- **What are Enzymes:**
 - Compounds that **Catalyse biological reactions**
 - Almost all enzymes are proteins
 - Act to Lower the activation energy of a reaction
 - May contain cofactors (metal ions for vitamins)
- **Most Enzyme Names end in “-ase”**
 - Is specific for the chemical that it reacts
 - Eg: Sucrase – reacts sucrose
 - Eg: Lipase – reacts lipids
 - Describes the function of that enzyme
 - Eg: Oxidase – catalyses oxidation
 - Eg: Hydrolase – catalyses hydrolysis
 - NOTE: some don't conform: (pepsin, trypsin)

Enzyme Mechanisms:

- Lock & Key Model:

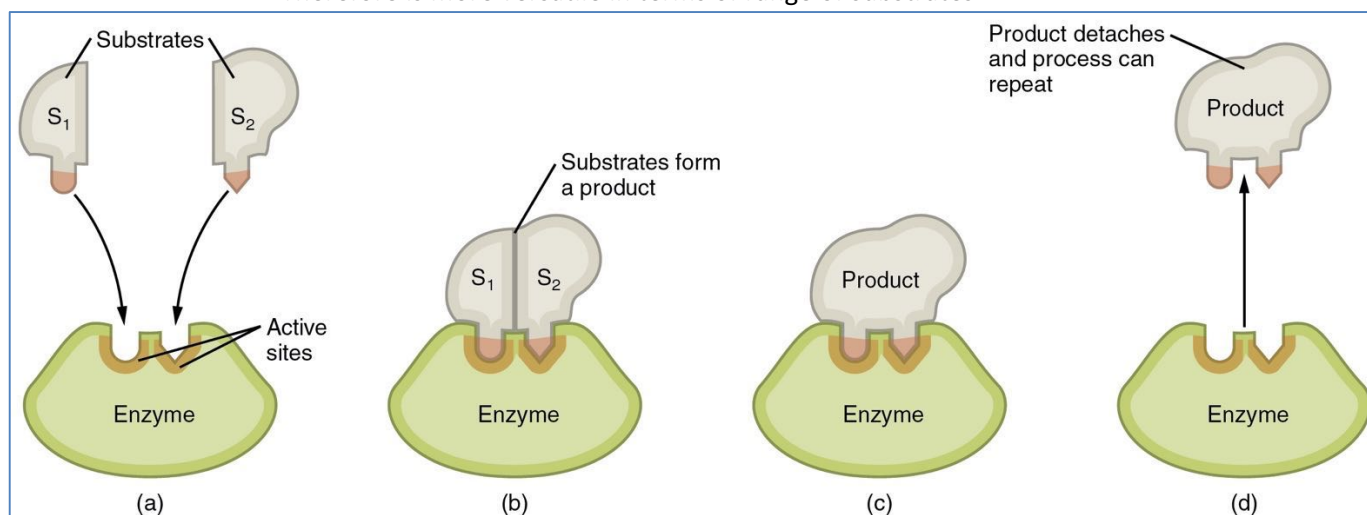
- The active site of the enzyme is the same shape as the substrate that it reacts



“E” = Enzyme; “S” = Substrate

- Induced Fit Model:

- The enzyme and active site adjust shape to bind to the substrate
 - Therefore is more versatile in terms of range of substrates



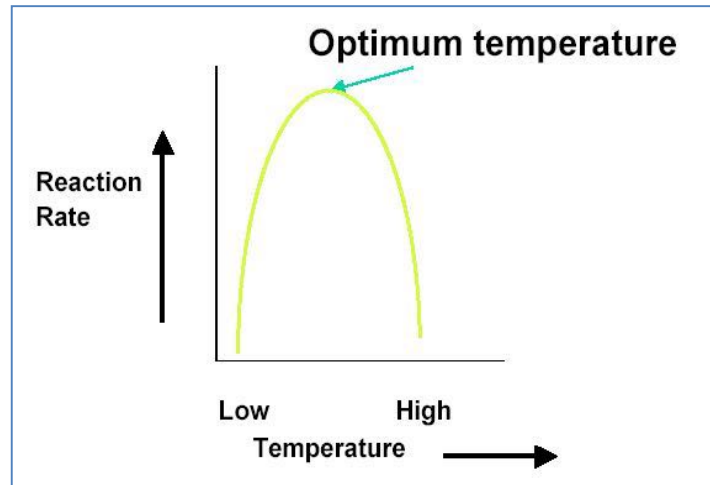
Steps in an Enzymatic Reaction According to the induced-fit model, the active site of the enzyme undergoes conformational changes upon binding with the substrate. (a) Substrates approach active sites on enzyme. (b) Substrates bind to active sites, producing an enzyme–substrate complex. (c) Changes internal to the enzyme–substrate complex facilitate interaction of the substrates. (d) Products are released and the enzyme returns to its original form, ready to facilitate another enzymatic reaction.

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Factors Affecting Enzyme Action:

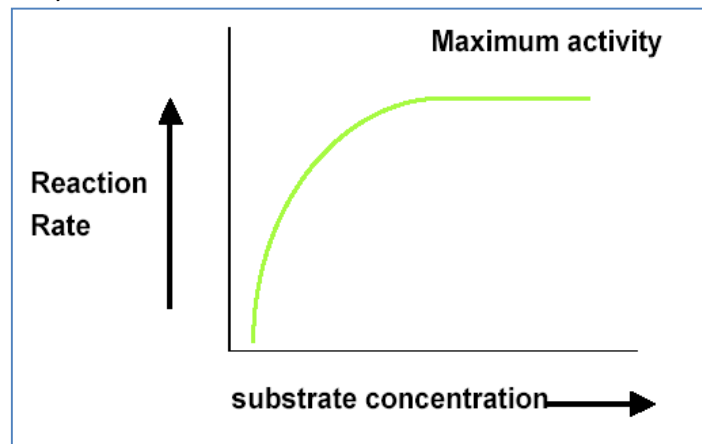
- Temperature:

- Little activity at low temp
- Rate increases with temp increases
- Reach optimum temp (37°C in humans)
- Activity lost @ high temps due to denaturation



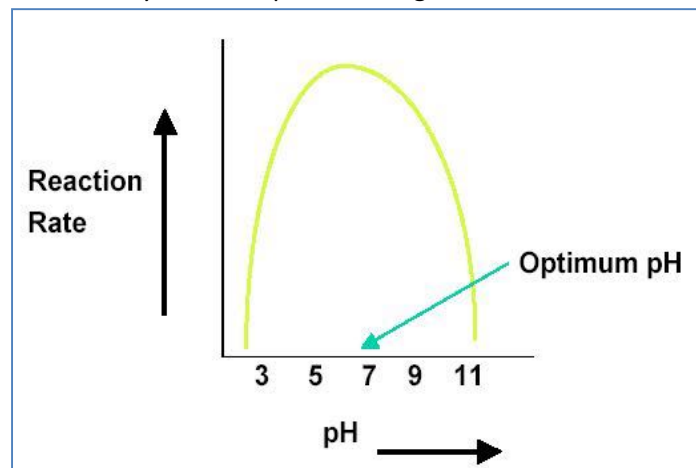
- Substrate Concentration:

- Activity increases with increasing substrate concentration
- Maximum activity reached when concentration of substrate = concentration of enzyme



- pH:

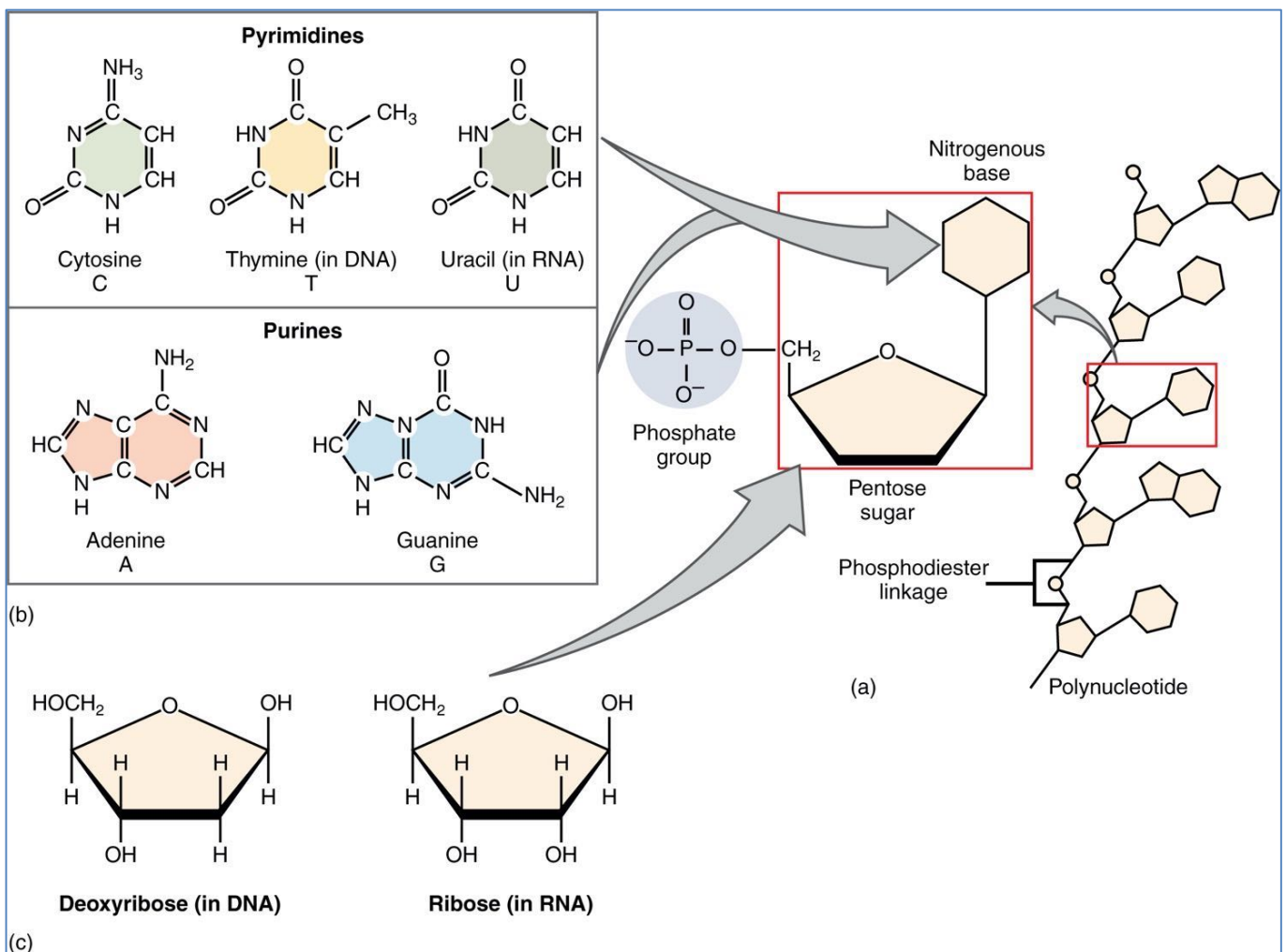
- maximum activity at optimum pH (narrow range)
 - R-groups have proper charge
 - Tertiary structure of enzyme is correct
 - Most lose activity outside optimum range

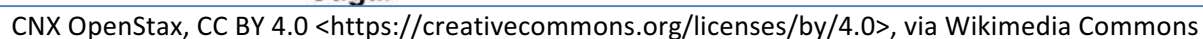


NUCLEIC ACIDS

General Info About Nucleic Acids:

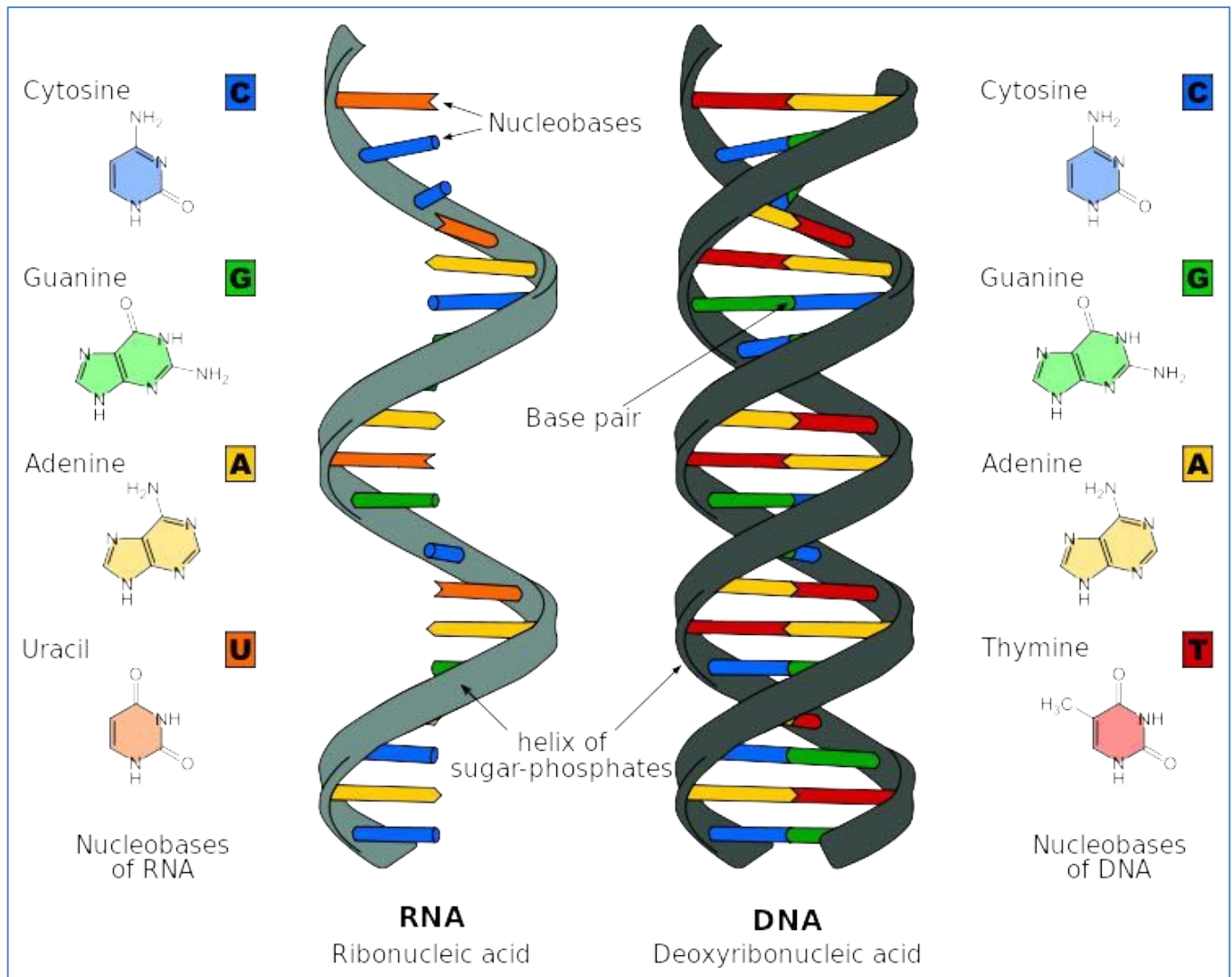
- **What Are They?**
 - "Nucleic acids" = a family of biopolymers, named for their role in the cell nucleus
 - **Composed of chains of monomeric nucleotides ('Bases')**
 - **Adenine (A)** (Only bonds to T)
 - **Guanine (G)** (Only bonds to C)
 - **Thymine (T)** (Only bonds to A)
 - **Cytosine (C)** (Only bonds to G)
 - **(Note: Uracil replaces Thymine in RNA)**
 - Form chains called **polynucleotides** or just **DNA strands**
 - **Joined by a sugar-phosphate backbone**
- **Importance:**
 - Provide the directions for building of all proteins necessary for life
 - Encodes Phenotypes/Traits in all animals
 - Central to the success of evolution (The genes that encode fitness get passed on)





2 Types Of Nucleic Acids:

- **DNA:** Deoxyribonucleic Acid
 - The stable genetic code stored in the nucleus of cells
- **RNA:** Ribonucleic Acid
 - Translates genetic information from DNA into proteins
 - Acts as a messenger between DNA and the ribosomes (protein synthesis organelles)
 - Has the base **Uracil instead of Thymine**



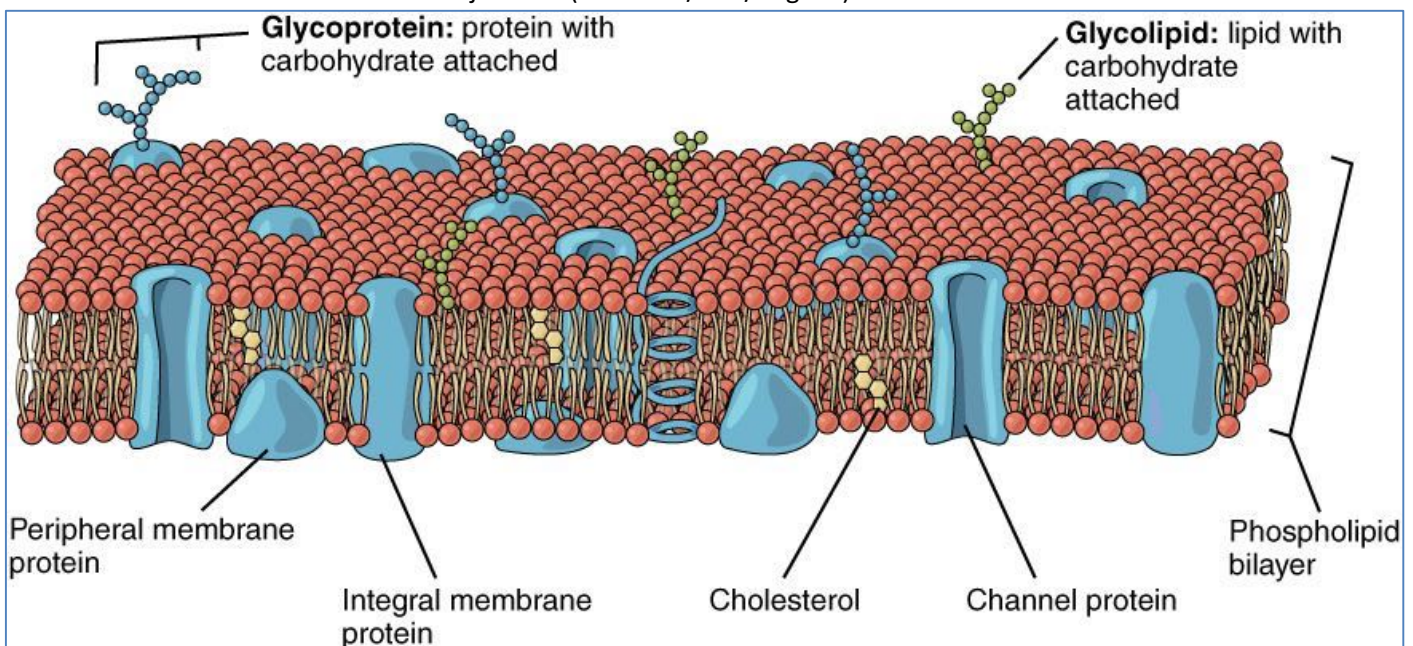
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CELL STRUCTURE:

CELL STRUCTURE:

Structure of a Typical Cell:

- **Plasma membrane**
 - Consists of a bi-lipid layer (diglycerides)
 - Is molten (has properties of both solid and liquid)
 - Contains Cholesterols
 - Contains **proteins**
 - Transportation
 - Catalysis
 - Reception of chemical signals
 - Intercellular joining (2 cells bonding)
 - Cell-Cell Recognition
 - Attachment to extracellular matrix
 - **Membrane Specialisations:**
 - Membrane Junctions (desmosomes/tight/gap)
 - Membrane Projections (microvilli/cilia/flagella)



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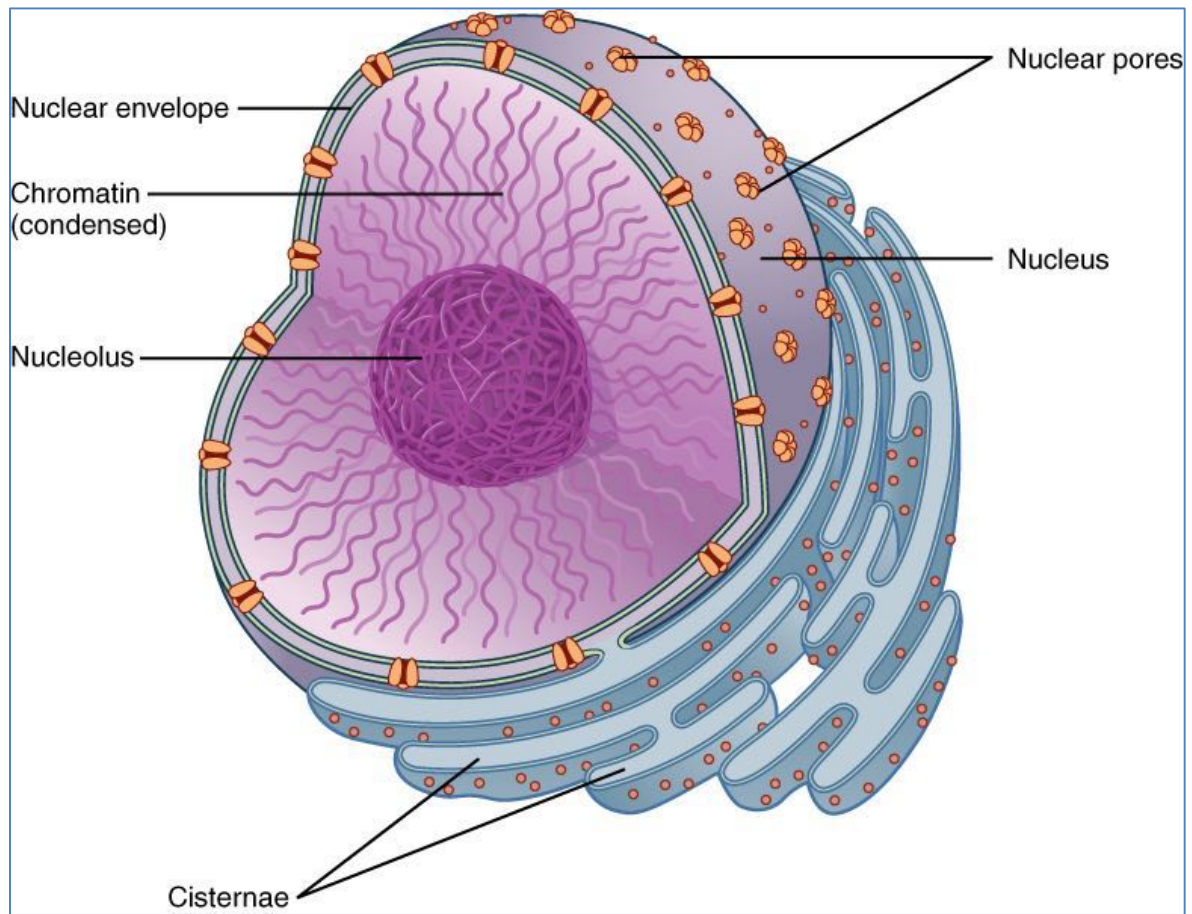
- **Cytoplasm**
 - Everything inside a cell bar the membrane and the nucleus
 - Includes all organelles + cytosol
- **Cytosol**
 - The fluid found within the membrane but outside the organelles
 - Largely water with dissolved protein, salts, sugars & other solutes
- **Inclusions**
 - Chemical substances
 - Glycosomes
 - Glycogen granules
 - Pigment

- **Cytoplasmic Organelles:**

- **Membranous Organelles:**

- **Nucleus**

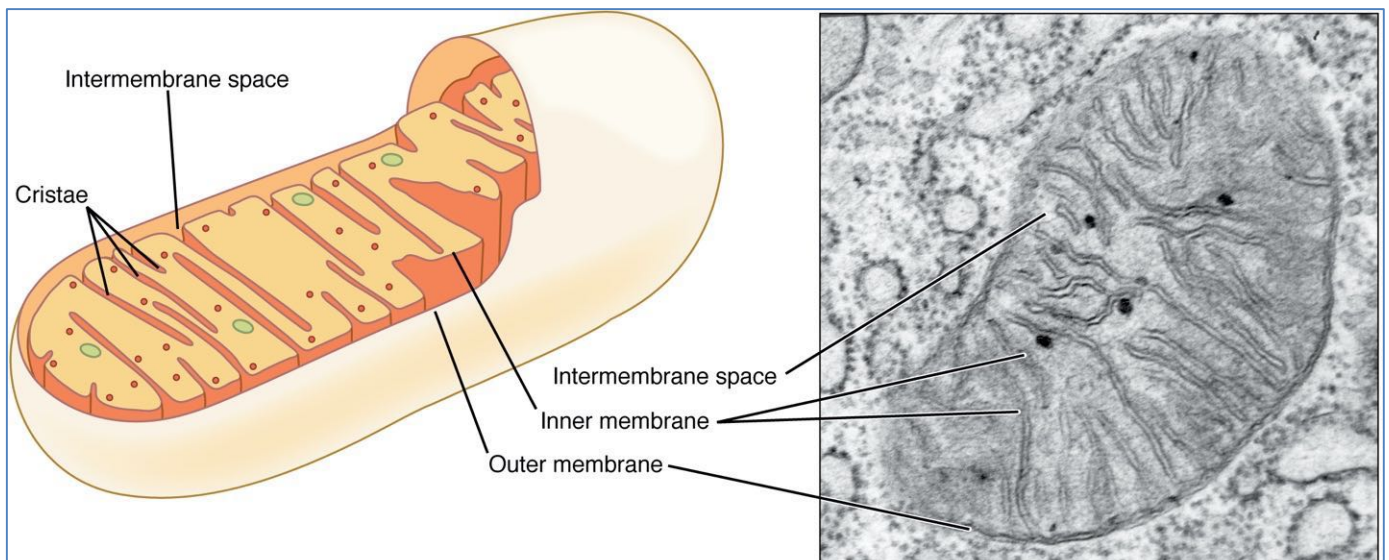
- Nuclear envelope, Nucleoli, Chromatin
 - Contains the genetic library for nearly all cellular proteins
 - Is the place where mitosis begins



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- **Mitochondria**

- Cell power station
 - Double Membrane
 - Synthesise ATP for energy



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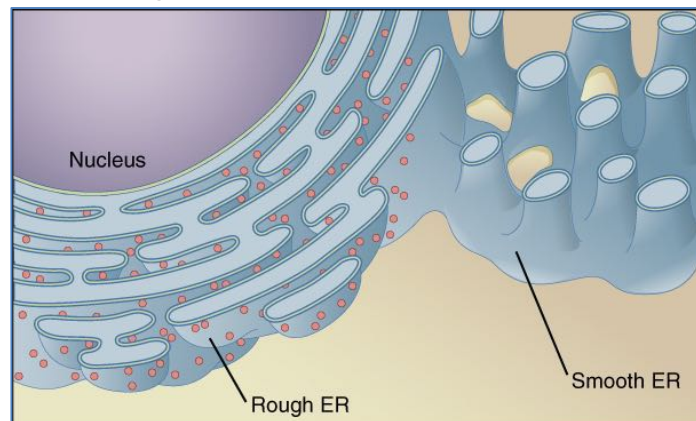
▪ **Endoplasmic reticulum (Rough/Smooth)**

• **Rough:**

- Covered with **ribosomes** (hence rough)
- Synthesis of all proteins secreted from cell + membrane proteins + protein hormones
- Proteins synthesised by ribosomes are then packaged in the Rough ER for export from the cell
- Assist in making cellular membranes

• **Smooth:**

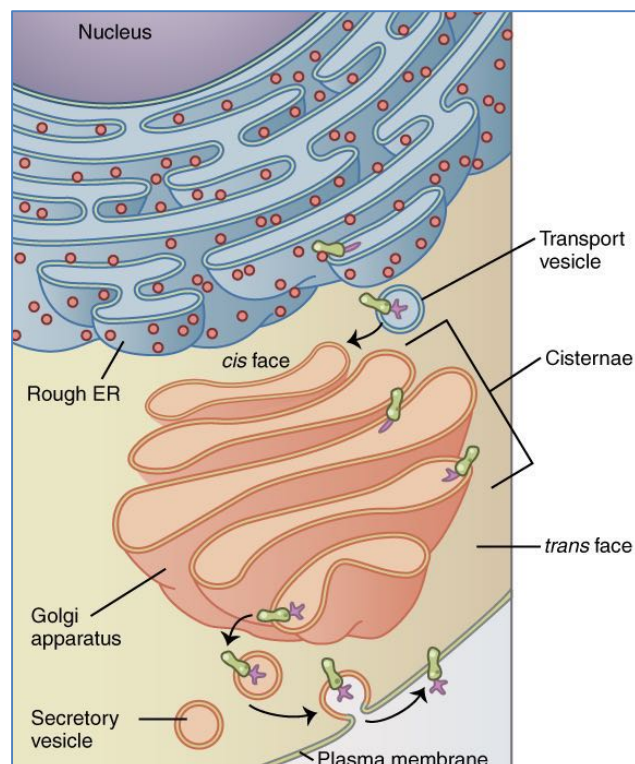
- Not covered with ribosomes (hence smooth)
- Doesn't synthesise proteins
- Metabolises lipids
- Synthesises steroid-based hormones (testosterone/oestrogen)
- Detox of drugs/xenobiotic chemicals
- Storage site of calcium ions in skeletal/cardiac muscle



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▪ **Golgi apparatus**

- The cellular courier
- Modifies, Concentrates and packages proteins and membrane synthesised in the Rough ER for intracellular transport or excretion
- Packaged proteins/membranes are released from the 'shipping face' in a transport vesicle for either excretion or cellular functions



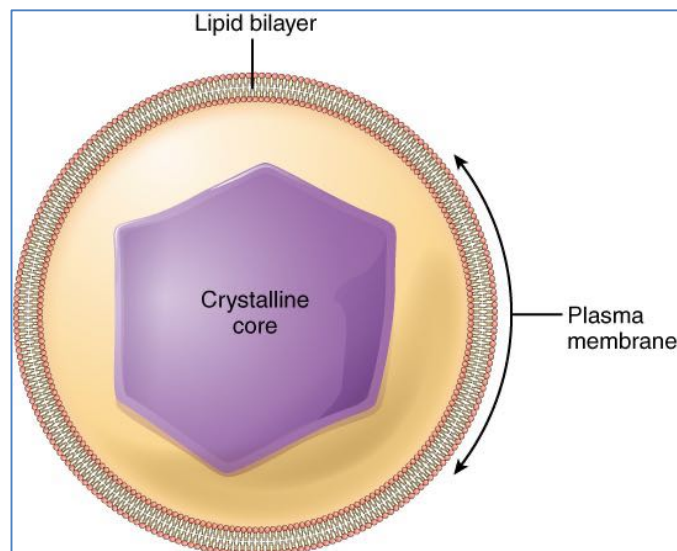
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▪ **Lysosomes:**

- Membranous sacs **created by the Golgi**
- Contain concentrated enzymes
- Inside is acidic for max enzyme function
- Destroy 'old' cellular material
- Destroy bacteria/viruses engulfed by white blood cell

▪ **Peroxisomes**

- Membranous sacs
- Contain enzymes
- Detoxify harmful xenobiotic substances (alcohol)
- Neutralises highly reactive free radicals (by-products of biochemical processes)



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○ **Non-Membranous Organelles**

▪ **Cytoskeleton**

- Elaborate network of large filamentous rod-like proteins
- Provide structural support
- Provide the central mechanism for movement
- Ensures the distribution of organelles throughout cell

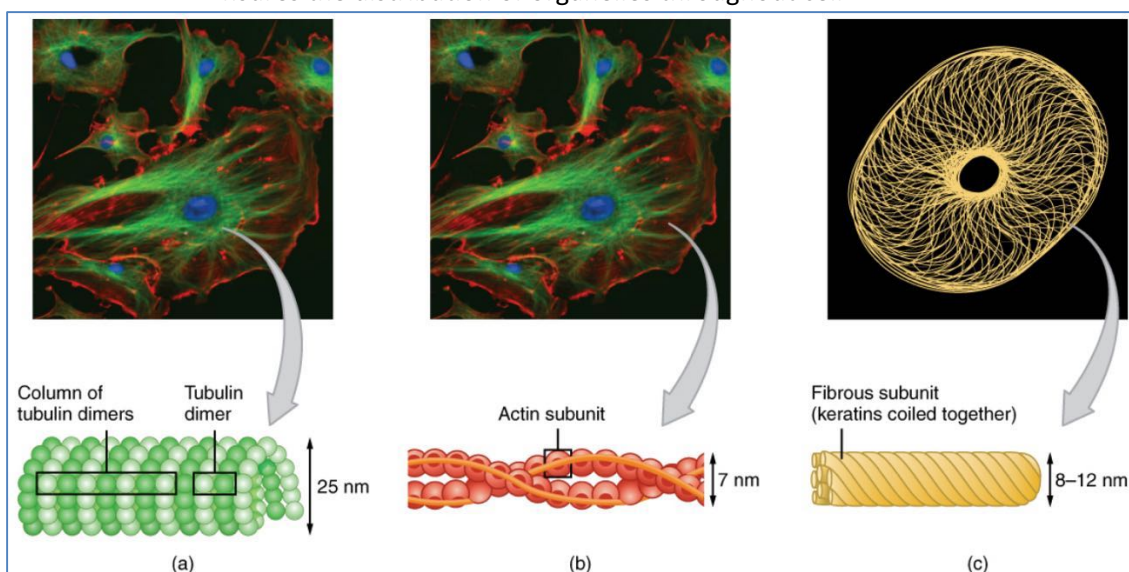
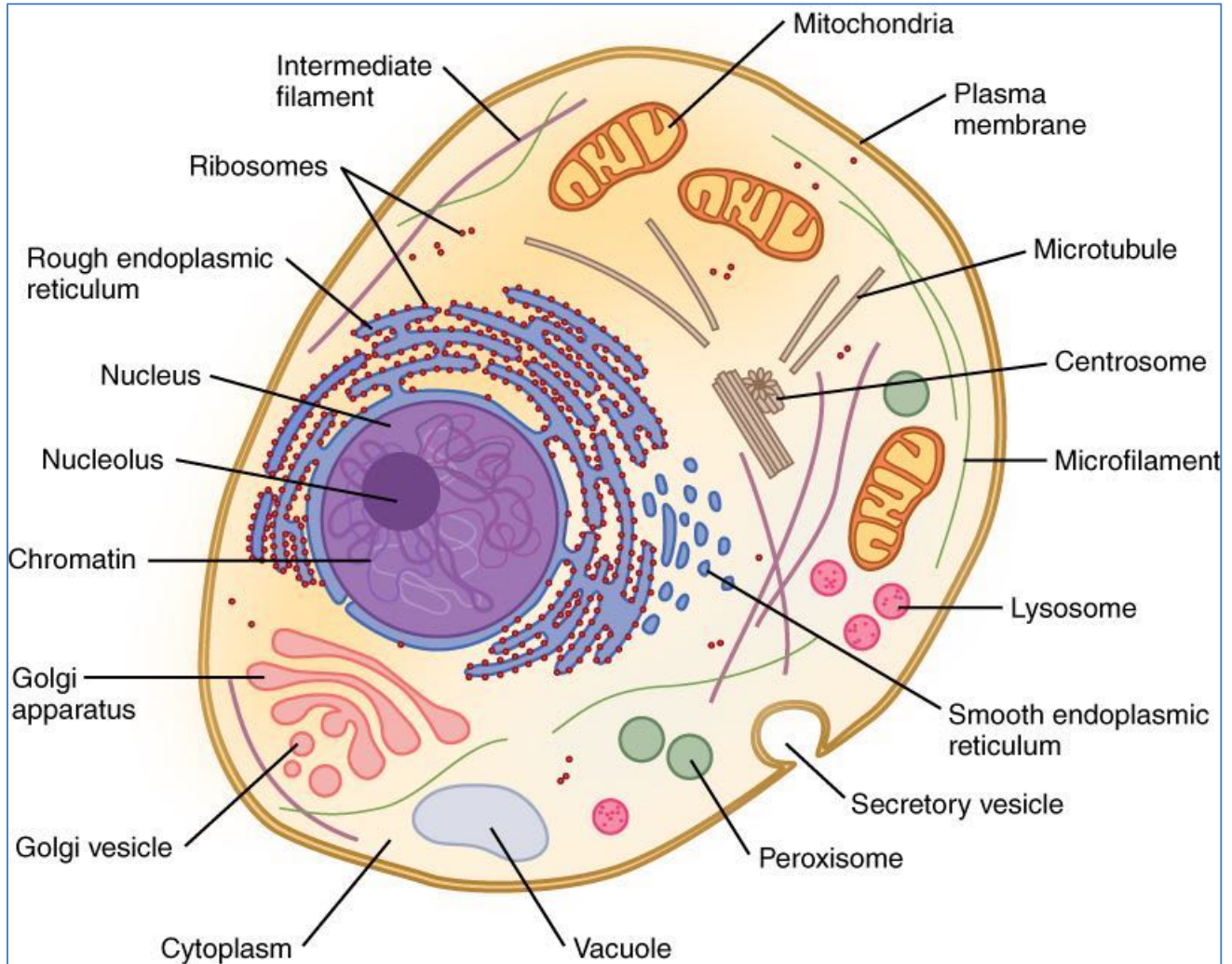


Figure 3.18 The Three Components of the Cytoskeleton The cytoskeleton consists of (a) microtubules, (b) microfilaments, and (c) intermediate filaments. The cytoskeleton plays an important role in maintaining cell shape and structure, promoting cellular movement, and aiding cell division.

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- Centrioles
- Ribosomes
 - Composed of protein & ribosomal RNA (rRNA)
 - Are the site of **protein synthesis**
 - Found either on the Endoplasmic Reticulum or free in the cytosol
 - **ERs with ribosomes** are called '**Rough**' ER



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