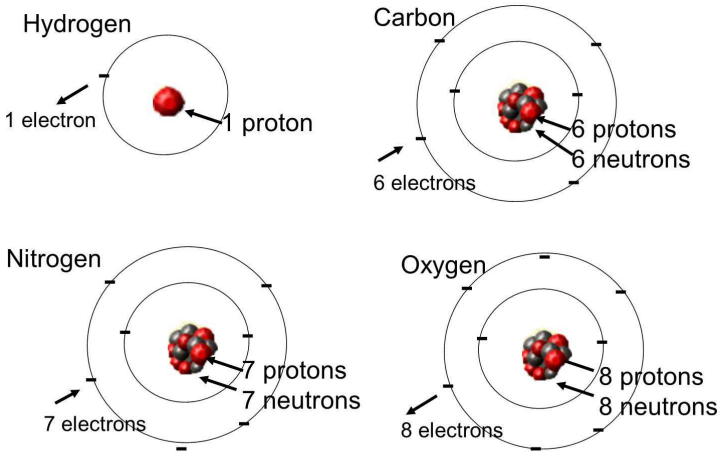
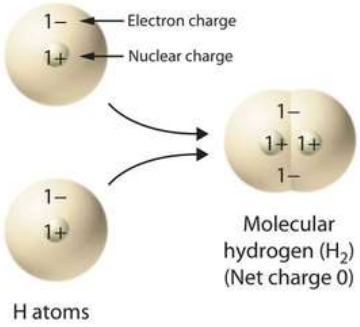
Atoms are comprised of protons, neutrons and electrons



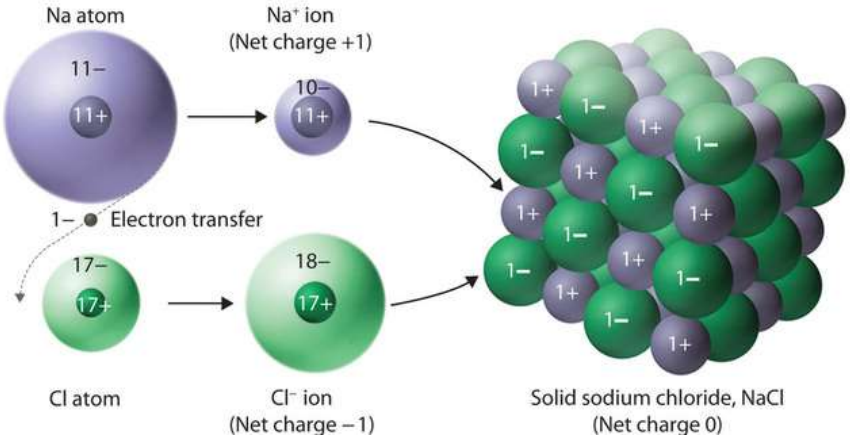
The atoms of each **Element** differ by the number of protons.

Atoms can be joined through **covalent bonds** to form **Molecules.**



Covalent bonds form when atoms share electrons

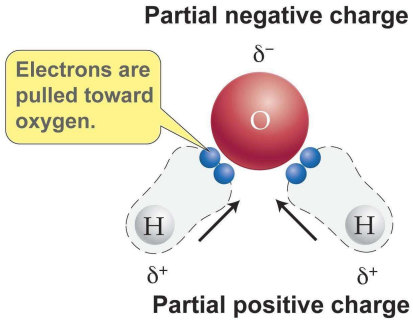
Ions are formed when atoms loss or gain electrons.

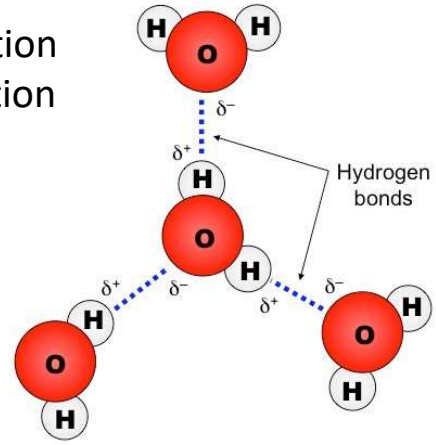


Ionic bond is a kind of chemical bond that forms from the electrostatic attraction force between oppositely charged ions.

Molecules interact through

- Hydrogen bonds
- *Van der waals* attraction
- Hydrophobic interaction

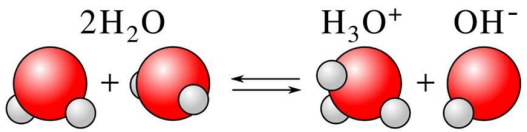


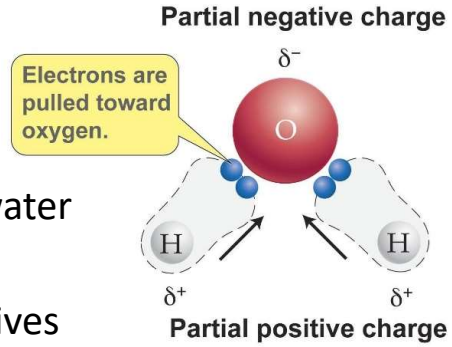


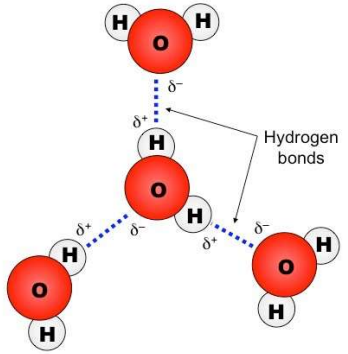
Water is the solvent in the body!

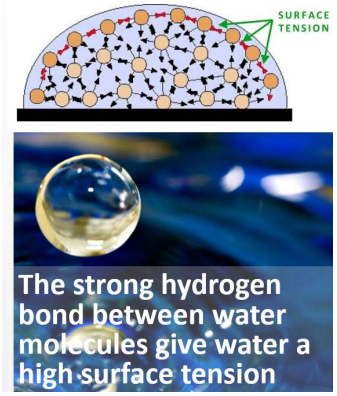
Properties of water:

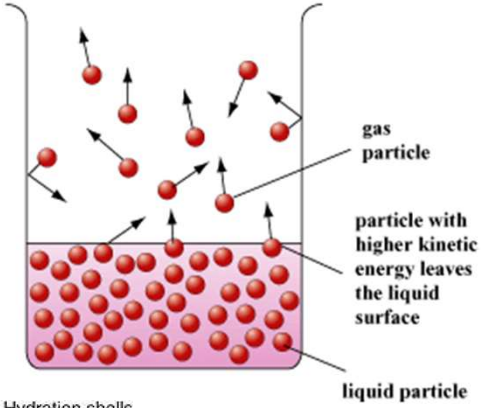
1. Water is a **polar molecule** (i.e. charge is not evenly distributed over a water molecule, the O atom is slightly -ve while the H atoms are slightly +ve)
2. Water molecules are held together tightly by ***hydrogen bonds***, which gives water unique properties:
   - **strong surface tension**
   - **high specific heat** – a lot of energy is need to heat water
   - **high boiling point**
   - **high heat of vaporization** – a lot of energy is need for breaking hydrogen bonds to free individual water molecules
   - **a near universal solvent** – the polar water molecules dissociate ionic compound into ions or other polar molecules by surrounding them.
   - **hydrophobic effect** – tendency of non-polar molecules (e.g. lipids) in aqueous solution to avoid contact with water
3. Water undergoes autoionization to form hydrogen ion (H^+) and hydroxide ion (OH^-). In pure water, their concentrations are the same.

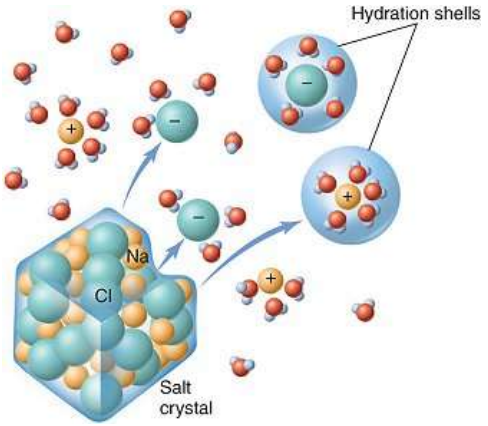










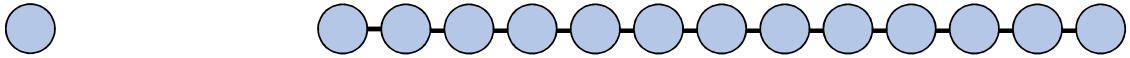


Elements that make up the body

Element (Symbol)	Occurrence (of all atoms in body)	Comments
Hydrogen (H)	63%	In H_2O (~60% body weight) and all macromolecules that make up the body
Oxygen (O)	26%	In H_2O and all macromolecules, required for cellular respiration (production of ATP)
Carbon (C)	9%	In all macromolecules
Nitrogen (N)	1%	In proteins and nucleic acids (DNA & RNA)
Sulphur (S)		In proteins
Sodium (Na)		Most abundant cation (+ve charged ion) in extracellular fluid (ECF), amount regulated by kidney to control ECF volume and blood pressure
Chlorine (Cl)		Major anion in ECF
Potassium (K)		Most abundant cation in intracellular fluid, amount regulated by kidney, amount in ECF affects resting membrane potential and therefore nerve and muscle function
Calcium (Ca)		Mainly in bone and teeth, low ICF concentration, increase intracellular Ca^{2+} triggers changes in cell function (e.g. induce exocytosis of neurotransmitters)
Phosphorus (P)		In nucleic acids, plasma membrane (phospholipids), ATP, bone and teeth
Iron (Fe)		Part of hemoglobin in red blood cell, responsible for binding oxygen
Iodine (I)		Synthesis of thyroid hormone

Macromolecules

Macromolecules are large molecules formed by joining many units of small molecule, known as monomer, together (by covalent bonds) to form a polymer. The resulting polymer is very big and is therefore called a macromolecule.

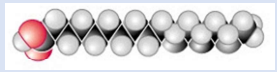
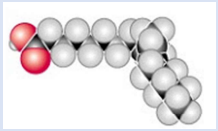
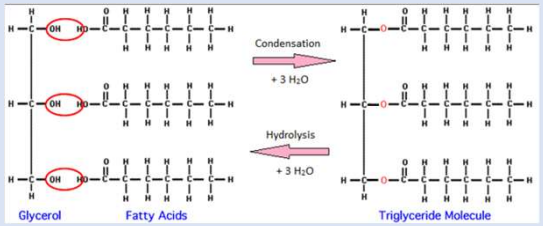
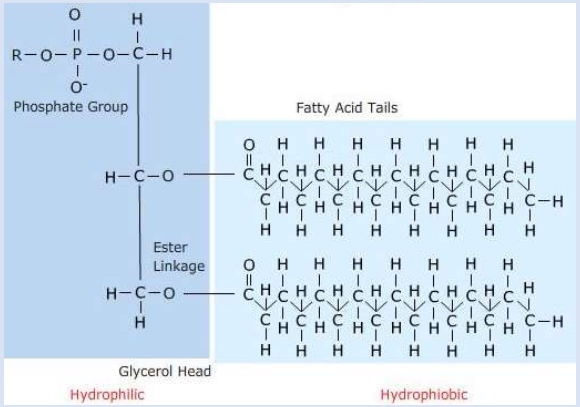
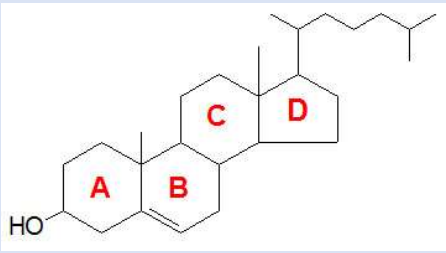
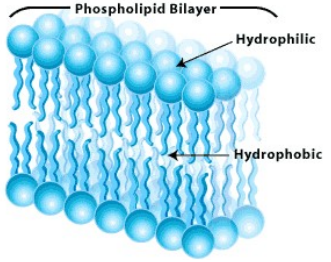


monomer **polymer (a macromolecule)**

	Nucleic acids	**Proteins**	**Carbohydrates**	**Lipids***
Monomer	Nucleotides	Amino acids (20 different types)	Monosaccharides (glucose is the monomer for all polysaccharides – cellulose, starch and glycogen)	• Triacylglycerol - Fatty acids and glycerol • Phospholipids - Fatty acids, glycerol, phosphate and an alcohol

* *Although lipids are not polymer, they are considered as macromolecules*

Lipids are defined based on physical property (i.e. they do not dissolve in water)

	Fatty acid	Triacylglycerol	Phospholipids	Steroids
Structure	Long (hydrophobic) hydrocarbon chain with a (hydrophilic) carboxyl group -COOH) at the end • Saturated fatty acids have no double bond  • Non-saturated fatty acids have ≥ 1 double bonds (oil) 	3 fatty acids joined to a glycerol molecule 	2 fatty acids, glycerol molecule, phosphate group and an alcohol  A hydrophilic head and two hydrophobic tails	All steroids are derived from **cholesterol** and contain the characteristic cholesterol ring 
Function	Free fatty acids, released from hydrolysis of triacylglycerol, circulate in the blood and are taken up by cells to be metabolized to release energy to form **ATP**	Storage form of energy in adipose tissue (i.e. fat cells)	Two layers of phospholipids form biological membranes like the plasma membrane 	Diverse functions, e.g. • ***hormones*** – sex hormones, aldosterone, cortisol • ***vitamin D*** for intestinal absorption of Ca^{2+} • ***bile salts*** aid digestion of lipids in intestine

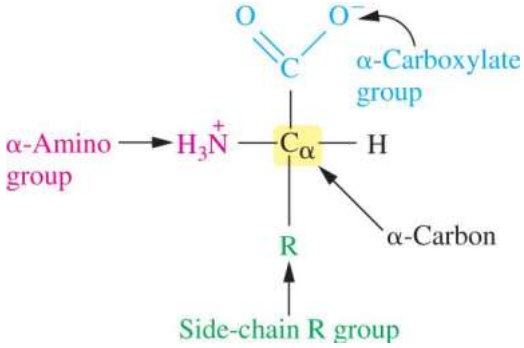
Carbohydrates

The suffix "-ose" is used for naming sugars
The suffix "ase" is used for naming enzymes

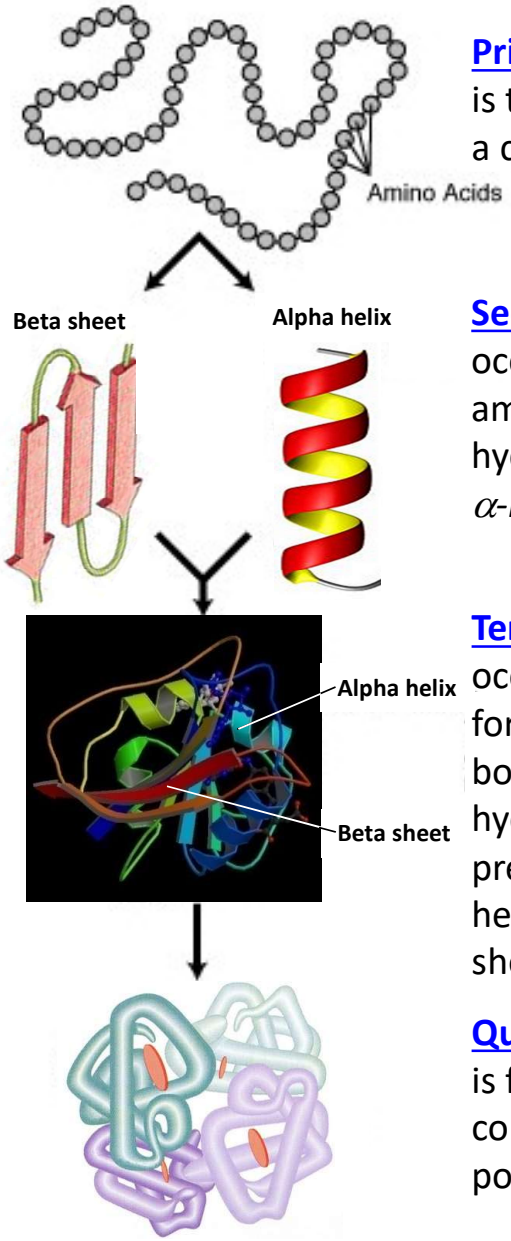
	Monosaccharides	Disaccharides	Polysaccharides		
			Glycogen	**Starch**	**Cellulose**
Notes	• The simplest carbohydrates that cannot be further hydrolyzed • ***Glucose*** **is the preferred energy source for most cells**	Two monosaccharides joined together through **glycosidic bond** • Lactose (glucose + galactose) • Maltose (glucose + glucose) • Sucrose (glucose + fructose)	• Made and stored in liver and skeletal muscles • Hydrolyzed into glucose for use	• Amylose + amylopectin • Storage form of carbohydrates in plant	• Plant cell wall
Enzyme for digestion	No need	Disaccharides cannot be absorbed • Lact**ase – some people lack this enzyme →** ***lactose intolerance*** • Malt**ase** • Sucr**ase**		• Salivary amylase • Pancreatic amylase	Human don't have the enzyme for digestion of cellulose

Protein

An **amino acid** contains an amino group ($-NH_2$), a carboxyl group (-COOH) , a hydrogen atom (-H) and a side group (-R) joined to a carbon atom. There are 20 different side groups so that there are 20 different amino acids.



Proteins are formed by joining amino acids through **peptide bonds**. A long chain of amino acids is called a **polypeptide**. Proteins have many function and their **function are determined by their 3D structures**, which are determined by the arrangement of amino acid sequences. Therefore, the amino acid sequence is the **primary structure** of a protein. The **secondary structure** of a protein is the formation of ***α-helix*** and ***β-pleated sheet*** due to attraction force between atoms in the polypeptide, mainly the **hydrogen bonds**. The **tertiary structure** is the folding, twisting and/or bending of the amino acid chain and the secondary structure into a 3 dimensional shape. **Quaternary structure** is only found in proteins that contain 2 or more polypeptide chains. Each polypeptide is called a ***subunit***. The interaction between the subunits to form the final shape of the protein is referred to as quaternary structure.



Primary protein structure is the specific sequence of a chain of amino acids linked by peptide bonds

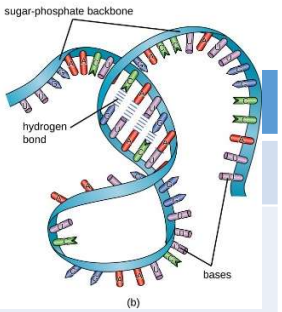
Secondary protein structure occurs when the atoms in the amino acids are linked by hydrogen bonds to form *α-helix* and *β-pleated sheet*

Tertiary protein structure occurs when certain attraction forces (hydrogen bonds, ionic bonds, van der Waals force, hydrophobic interaction) are present between the α-helices and the β-pleated sheets

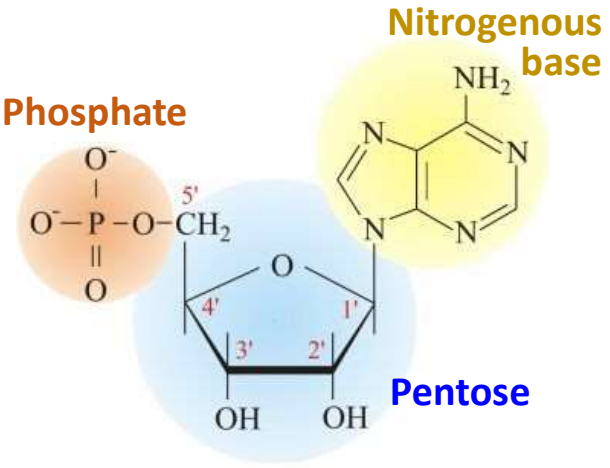
Quaternary protein structure is found only in a protein consisting of more than one polypeptide chain

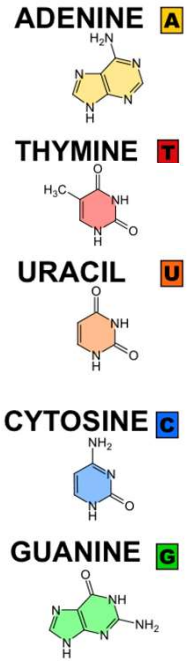
Nucleic acids are formed by joining nucleotides.

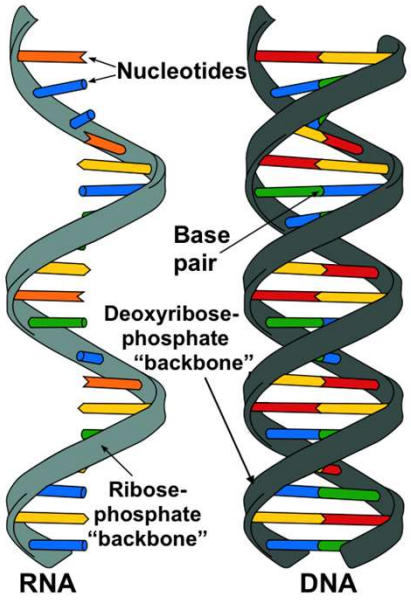
	Deoxyribonucleic acid	Ribonucleic acid
Pentose	Deoxyribose	Ribose
Bases	Adenine (A), **Thymine (T)**, Guanine (G), Cytosine (C)	Adenine (A), **Uracil (U)**, Guanine (G), Cytosine (C)
Structure	**Double helix** - 2 strands are joined by hydrogen bonds through ***complementary base pairing*** (i.e. A always pairs with T on the other strand, C always pairs with G)	**Single stranded** but bases within an RNA molecule can form hydrogen bonds to give secondary structure (i.e. hairpin loops)
Location	The nucleus	The cytoplasm associated with ribosome
Function	• Hereditary material • Contain the (genetic) codes for production of proteins and instructions for forming an organism	Role in protein synthesis (***translation***) • rRNA – structural component of ribosome • mRNA – carry the codes for protein synthesis from nucleus to the ribosome • tRNA – carry amino acids to ribosome
Synthesis	***Replication*** before cell division	Made from DNA through ***transcription***



Nucleotides consist of 3 components





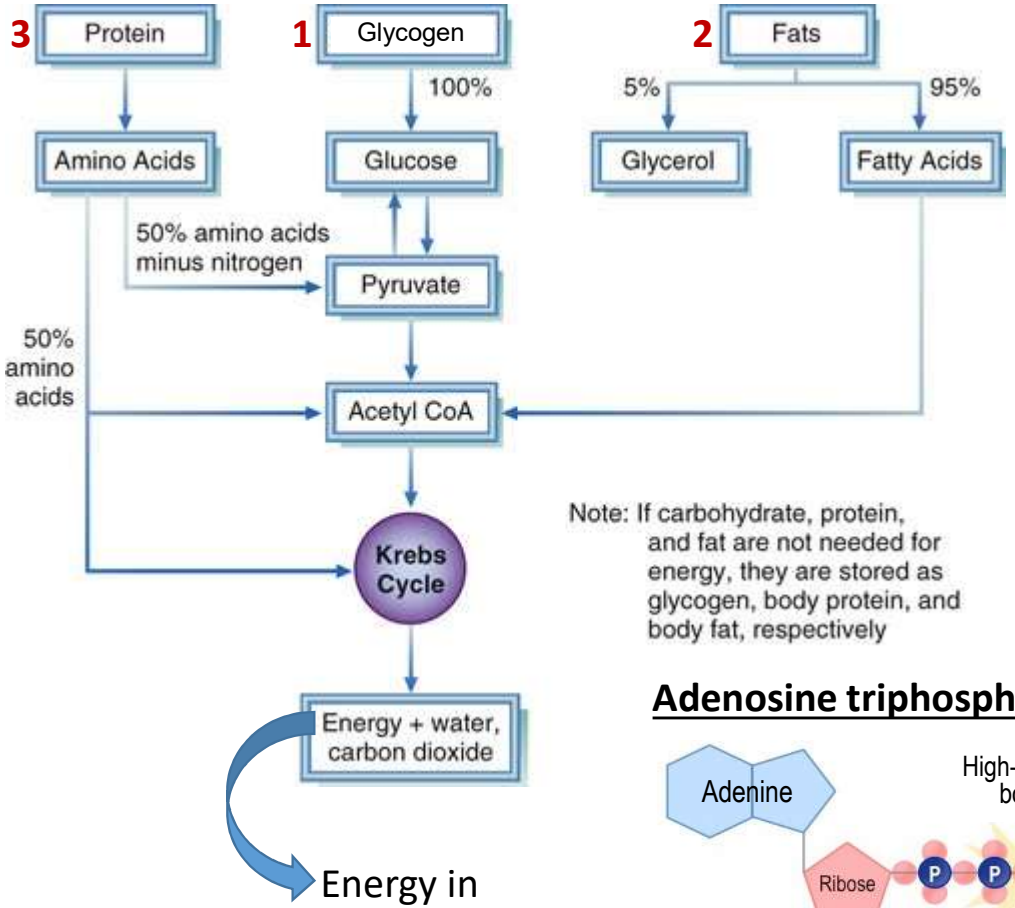


Macromolecule	Elements	Structure	Covalent bond between monomers	Function/Remark
Carbohydrates * end in *"–ose"*	C - carbon H - hydrogen O - oxygen	• Monosaccharides (e.g. glucose, fructose, galactose) • Diasccharides (e.g. maltose, sucrose, lactose) • Polysaccharides (glycogen in animals, starch & cellulose in plants)	Glycosidic bond	• Glucose as primary energy source for body. • Glycogen as temporary energy storage (in liver and skeletal muscles).

Protein	C - carbon
	H - hydrogen
	O - oxygen
	N - nitrogen
	S - sulphur
		• Amino acids
		• Peptides (shorter chains)
		• Polypeptides/protein
		  • Globular protein (most proteins are globular in shape)
		  • Fibrous protein (e.g. collagen)
			Peptide bond	• Diverse function in the body (e.g. enzymes to catalyze reaction, structural support like collagen, transport proteins, antibodies for immunity…).
				
				* *Protein function determined by its 3D confirmation, which is in turn determined by its primary, secondary, tertiary and quaternary structures.*

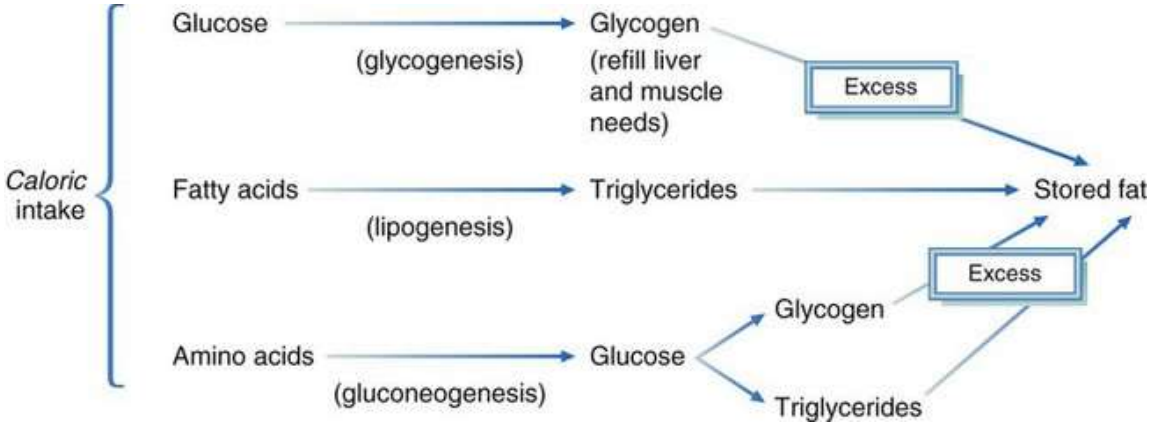
Lipids	C - carbon H - hydrogen O - oxygen ** P - phosphorus in phospholipids*	• Fatty acid (FA) • Triglycerides (aka triacylglycerols) (3 FA + 1 glycerol) • Phospholipid (2 FA + 1 glycerol + 1 phosphate gp linked to an alcohol gp) • Steroids	Ester bond + phosphodiester bond in phospholipid	• Fatty acid as alternative energy source. • Triglycerides as long term energy storage (in adipose tissue). • Phospholipids form cell membrane. • Cholesterol is the precursor for steroid hormones (e.g. estrogens, testosterone), vitamin D_3 and bile acids.
Nucleic	C H O N P	• Nucleotides • Ribonucleic acid (RNA) (bases = AUCG) • Deoxyribonucleic acid (DNA) (bases = ATCG)	Phosphodiester bond	• RNA play roles in protein synthesis. • DNA as genetic material that is inherited to offspring, contains codes for RNA & proteins synthesis.

Catabolism is the breakdown of molecules.

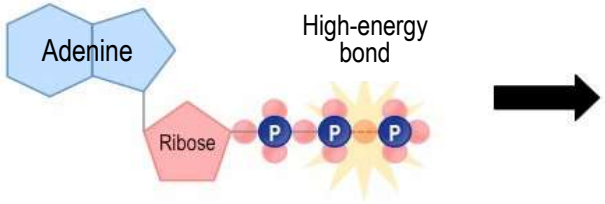


Note: If carbohydrate, protein, and fat are not needed for energy, they are stored as glycogen, body protein, and body fat, respectively

Anabolism is the synthesis of larger molecules.
Energy is needed for these reactions.



Adenosine triphosphate –



Adenosine diphosphate –