Carbohydrates

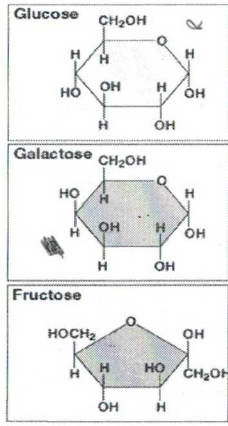
Characteristics of Carbohydrates:

- Contain carbon, hydrogen and oxygen in a 1:2:1 ratio.
- Contain a high number of hydroxyl functional groups, making them polar and soluble in water.
- Functions: Energy storage & Structure

Monosaccharides:

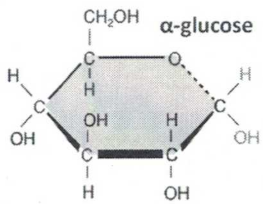
- Mono = one, Saccharide = sugar
- Examples include: glucose, galactose, and fructose.
- They are all **isomers** of each other, meaning they have the same chemical formula but different arrangments.

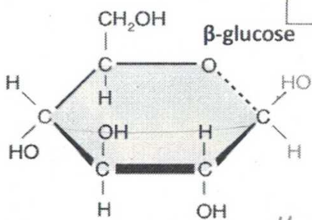
- Compounds with the same chemical formula can have different arrangement of atoms. These molecules are called **isomers**
- **Isomers** have the atoms linked in a different sequence from one another.
  - Despite the relatively small differences, structural isomerism can have important consequences for the polymers that result. For example:



$C_6H_{12}O_6$

Flip C_4



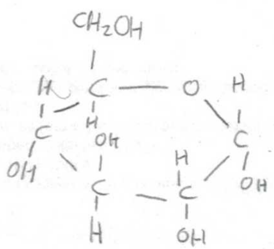


A-glucose polymers form starch

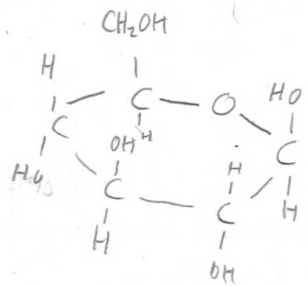
β-glucose polymers form cellulose

Structural isomers of glucose:

- The **#4 carbon** determines whether it is glucose or galactose
  - Glucose – hydroxyl group on bottom
  - Galactose – hydroxyl group on top
- The **#1 carbon** determines whether it is alpha or beta
  - α – hydroxyl group on bottom
  - β – hydroxyl group on top



α DDUD

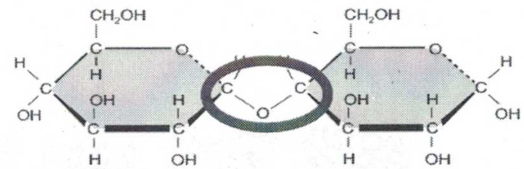


HO-OH H
OH-HO

β↑↓↑↓

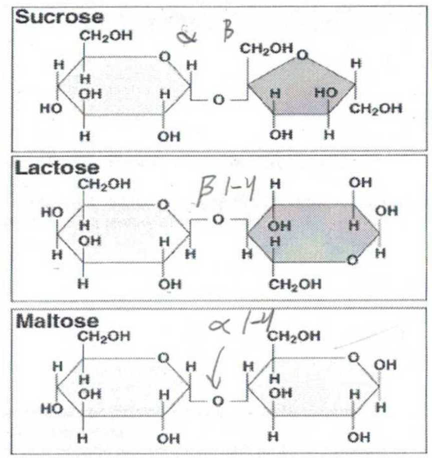
Disaccharides:

- Disaccharides are double-sugar molecules joined through a glycosidic linkage (a type of condensation rxn between two hydroxyl groups)
- Used as energy sources and as building blocks for larger molecules.
- Provide a convenient way to transport glucose.
- The type of disaccharide formed depends on the monomers (single units) involved and whether they are in their α- or β- form.



Above shows the glycosidic linkage between two alpha glucose molecules

- Two monosaccharides joined by a covalent bond
- A covalent bond between monosaccharides is called: glycosidic.
- Glucose + Fructose → Sucrose
- Glucose + Galactose → Lactose
- Glucose + Glucose → Maltose

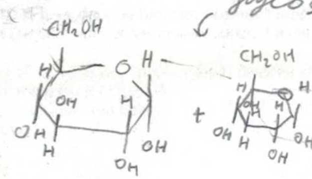


glucose & fructose

glucose & galactose

glucose & glucose

glycosidic



Maltose

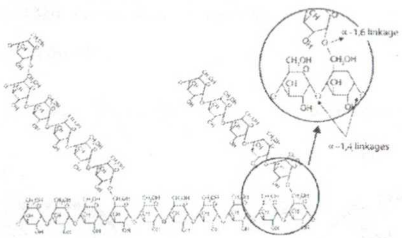
Polysaccharides

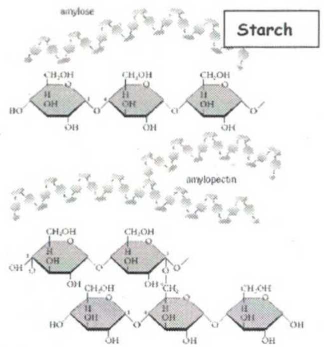
- Poly = 'many'
- Complex carbohydrates composed of long chains of monosaccharides
  - Many subunits – 100s-1000s
  - E.g. starch, glycogen, cellulose, chitin
    - (these are all formed with glucose monomer units)
- Polysaccharides are used for:
  - **energy storage** (starch - plant and glycogen - animal)
  - **structural support** (cellulose and chitin)

STARCH

Carbon 1 Carbon 4

- Energy storage for plants
- Composed of **amylose** (α1-4 links) and **amylopectin** (α1-4 links but α1-6 links where it branches)
- The angles of the glycosidic linkages cause the polymer to twist/coil in a way that makes them insoluble in water

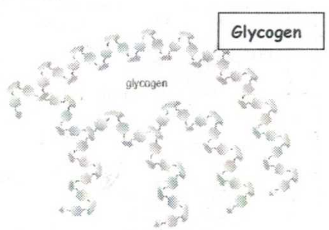




GLYCOGEN

- Animal energy storage
  - Humans store glycogen in their livers
- Composed of α1-4 links but α1-6 links where it branches
- ***More branched than starch***
  - What is the significance of this????

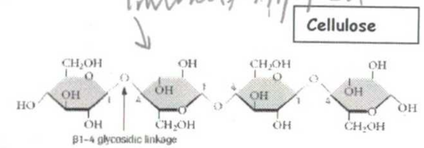
↳

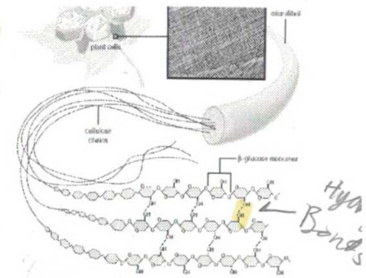


CELLULOSE

Inverted/flipped

- Composed of β1-4 links
- Every other glucose subunit becomes inverted to accommodate this link
- Not coiled or branched
- Used in plant cell walls
- Tough physical properties:
  - Used in wood for lumber and paper
  - Used in cotton and linen for clothing
- Humans are able to break down starch, but not the β-glucose linkages in cellulose
  - Some animals (Ruminants– cows, sheep, rabbits) have microorganisms in their gut that produce enzymes that can break down these linkages
- Even though we cannot digest it, cellulose is an important part of digestive health:
  - Fibres, called roughage, gently scrape walls of lg. intestine
  - Intestinal cells secrete mucus, lubricating feces and helping in elimination of solid waste
  - Keeps feces moist by binding water in the large intestines

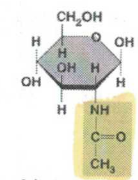




CHITIN

Kite–Ten

- Cellulose-like polymer of N-acetylglucosamine
- Monomer is a glucose molecule with a nitrogen containing group attached at second C position
- Used in insects and crustaceans to form hard exoskeleton



(a) The structure of the chitin monomer.

	Cellulose	Starch: Amylose	Starch: Amylopectin	Glycogen
Source	Plant	Plant	Plant	Animal
Subunit	β-glucose	α-glucose	α-glucose	α-glucose
Bonds	1-4	1-4	1-4 *and* 1-6	1-4 *and* 1-6
Branches	No	No	Yes (~per 20 subunits)	Yes (~per 10 subunits)
Diagram				
Shape				

MACROMOLECULES - CARBOHYDRATES

Using notes or text pages, answer the following.

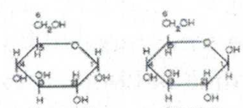
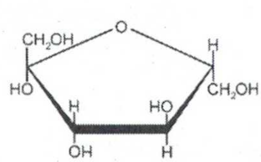
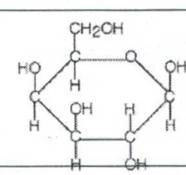
1. Define the following terms:
   a) Macromolecule A large molecule important to biological processes
   b) Monomer Subunit of a polymer
   c) Polymer A macromolecule made of
2. What are the four major groups of macromolecules that are important to biology? Carbohydrates Nucleic Acids Protein Lipids
3. Define carbohydrate in chemical terms.
   a) The general formula for a carbohydrate is CH_2O
   b) If a sugar has 11 oxygen atoms, how many hydrogen atoms does it contain? $C_{11}H_{22}O_{11}$
   c) Based on their molecular formula, which of the following are NOT carbohydrates?
      i. $C_3H_8O_3$
      ii. $C_{10}H_{18}O_9$
      iii. $C_{18}H_{32}O_{16}$
      iv. $C_4H_8O_2$
      v. $C_{16}H_{32}O_2$
      vi. $C_6H_{12}O_6$

THERE ARE THREE TYPES OF CARBOHYDRATES

A. **Monosaccharides** are the subunits of carbohydrates. They are the simple, sweet-tasting sugars.

4. Mono means: One. The most important simple sugar for humans is GLUCOSE. Glucose is represented by the chemical formula $C_6H_{12}O_6$

Important simple sugars:

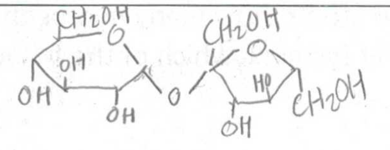
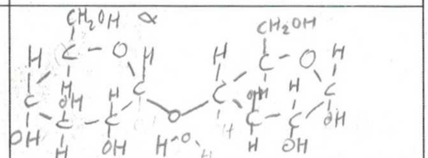
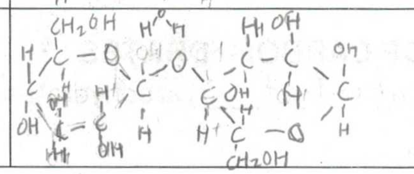
Name & Chemical Formula	Description/Use	Diagram	How are they similar	How are they different?
Glucose	Primary energy-storage unit used by polysacchandes (turned into starch or glycogen)		same chemical formula	different structures different properties can form different disaccharides
Fructose	Sugar found in fruit			
Galactose	Sugar found in milk			

5. Can two monosacch""araides have the same formula yet have different structures? Explain.
They can as seen between glucose & galactose

B. <u>Disaccharides</u> are sugars that consist of 2 monosaccharides.

6. Disaccharides are also known as double sugars. Therefore, di means: two

Important Disaccharides:

Name & Chemical Formula	Description/ Use	Monomer(s) Diagram	How are they similar	How are they different?
Sucrose Glucose + Fructose	Sugar			
Maltose Glucose + Glucose	Beer			
Lactose Glucose + galactose	Milk			

7. Look at Figure 1.7: **glucose + glucose -----------------> maltose**
   a) Name the functional group(s) in the glucose molecules. HO & HO
   b) Name the type of linkage formed between these monomers. Glycosidic
   c) Is this reaction an example of hydrolysis or dehydration synthesis? dehydration
   d) Why is maltose categorized as an **oligosaccharide**?
   Less than 20 monosaccharides
   Short chain of glucose

8. **glucose + fructose -------------------> sucrose**
   a) Name the functional group(s) in the glucose and fructose molecules. HO & HO
   b) Why are glucose and fructose considered to be isomers? Rearranged
   c) Name the type of linkage formed between these monomers. Glycosidic
   d) Is this reaction an example of hydrolysis or dehydration synthesis? Dehydration

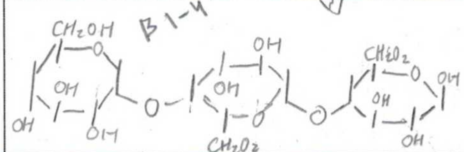
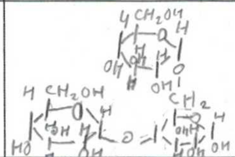
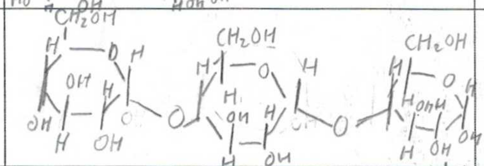
C. ***<u>Polysaccharides</u>*** also known as glycan
Homopolysaccharide → One type of monosaccharide
Heteropolysaccharide → Multiple types of monosaccharide

9. Define ***polysaccharide***
   a) What is a storage polysaccharide?
   - Plants store energy in the form of starch, examples of starchy plants are corn and Potatoes.
   - Animals store chemical energy as glycogen, which is found in the liver and __________ cells.

   b) What is a structural polysaccharide?
   Chitin & cellulose, used in cell walls

Starch – α 1-4 w/ α 1-6 when branched (amylopectin
Glycogen – More branches than starch
Chitin – β links with N

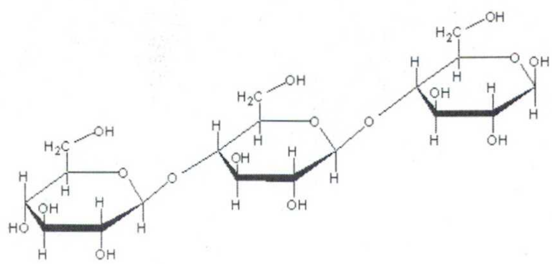
10. ***Important Polysaccharides:***

Name & Chemical Formula	Diagram	Organisms it is found in	Function
Cellulose β 1-4		Plants	Structure
Starch, Amylopectin		Plants	Store energy
Starch Amylose		Both	//

Chitin

11. Consider the polysaccharide to the right:
    a) What is the linkage between the sugar units? α 1-4
    b) How many water molecules would be produced in the synthesis of a polysaccharide consisting of 5 glucose monomers?

    4 water molecules



12. Why, even though starch is easily digested by animals, is cellulose not? As you answer this question, be sure to consider both the composition of these molecules and the arrangement of the monosaccharides of which they are composed.

Cellulose is made up of β 1-4 glucose bonds. These bonds are not able to be broken down hydrolyzed due to our lack of the enzymes required to do so. Furthermore, the structure of Cellulose allows for hydrogen bonds to form, making a stronger structure

13. How do the structures of carbohydrates affect their functions?

Different rxns & di/poly saccharides

Lipids

- Lipids are a group of organic compounds with an oily, greasy, or waxy consistency.
- Like carbohydrates, lipids contain carbon, hydrogen, and oxygen, but in lipids, the proportion of oxygen is much smaller.
- They are relatively insoluble in water and tend to be hydrophobic (water repellent).

Biological Roles of Lipids:

Role	Description
Source of Energy	Lipids are concentrated sources of **energy** and can be broken down to provide fuel for aerobic respiration
Waterproofing	Waxes and oils, when secreted on to surfaces provide **waterproofing** in plants and animals.
Structural Framework	Phospholipids form the **structural framework** of cellular membranes
Absorbing Shock	Fat **absorbs shocks**. Organs that are prone to bumps and shocks (e.g. kidneys) are cushioned with a relatively thick layer of fat.
Metabolic Water Source	Lipids are a source of **metabolic water**. During respiration, stored lipids are metabolized for energy, producing water and carbon dioxide.
Insulation	Stored lipids provide **insulation** in extreme environments. Increased body fat levels in winter reduce heat losses to the environment.

GLYCERIDE FATS

**All glyceride fats are attached to a glycerol backbone.
There are three categories of glyceride fats:

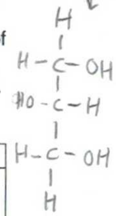
Monoglycerides have one fatty acid attached to a glycerol

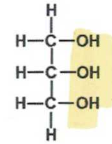
Diglycerides have two fatty acids attached to a glycerol

Triglycerides have three fatty acids attached to a glycerol

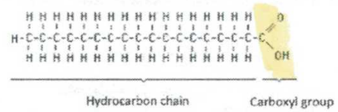
Monomer units in Glyceride Fats:

Can alternate





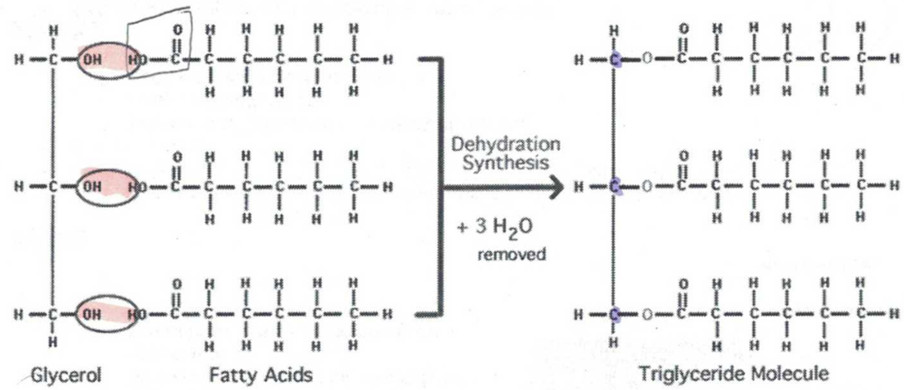
GLYCEROL
Contains 3 hydroxyl groups



FATTY ACID
Contains a carboxyl group
When Carboxyl & Hydroxyl bond, ester linkage

Triglyceride Structure:

- It is the result of an ester linkage (dehydration synthesis) between a glycerol and three fatty acids



ESTER VS GLYCOSIDIC LINKAGE
Compare and Contrast:

ester	glycosidic
- Between hydroxyl & carboxyl - Found in lipids	- Between 2 hydroxyls - Found in Carbs

- Both formed using dehydration
- Both intramolecular covalent

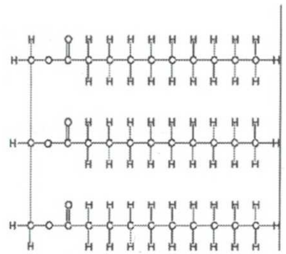
How many water molecules will be needed to hydrolyze 7 diglycerides and 3 triglycerides?

$7 \times 2 = 14$
$3 \times 3 = 9$
$+$
23

Fats and Oils

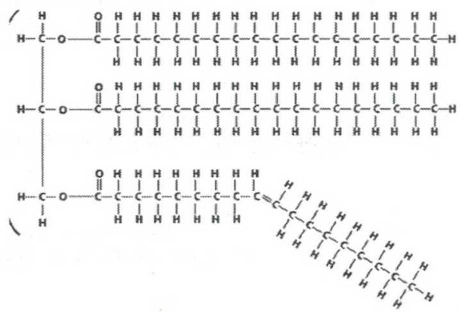
- The difference between fats and oils is their physical state at room temp.
  - Fats are solid
  - Oils are liquid
- These differences in the physical properties of fats and oils are a result of the type of fatty acid attached to the glycerol molecule.
  - Some are saturated fatty acids, with a maximum number of hydrogen atoms.
  - Some are unsaturated, with double bonds and fewer hydrogen atoms.

Saturated Fats:



- Solid at room temp.
- Only single bonds between C atoms (therefore 'saturated' with hydrogens)
  - Gives a straight shape to the fatty acids
  - Straight, hydrocarbon chains fit closely together, allowing many LDF forces to form
    - Hence – they are **SOLID**

Unsaturated Fats:



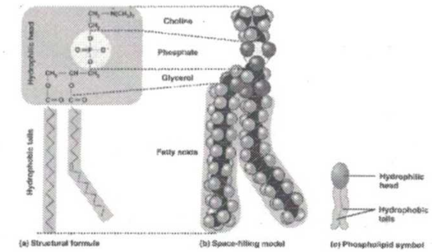
- Liquid at room temp.
- Have one or more C=C (double bonds)
  - Not using maximum # of hydrogen … therefore 'unsaturated'
  - Gives a bent/kinked shape to the fatty acids
- Bent hydrocarbon chains **do not** fit closely together, not allowing as many LDF forces to form
  - Hence – they are **LIQUID**

Hydrogenation:

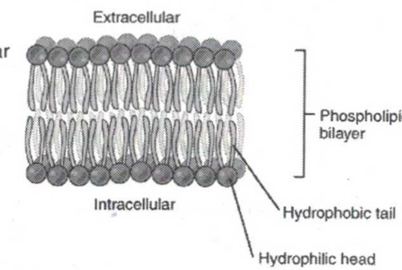
- An industrial process
- Hydrogen atoms are added to the double bonds in unsaturated triglyceride
  - Used to convert liquid fats (corn oil, canola oil) into a semisolid material (margarine, shortening)

Phospholipids

- If one of the fatty acid groups of a triglyceride is replaced by a phosphate group, the molecule is known as a phospholipid. It consists of:
  - a **glycerol** molecule
  - two **fatty acid chains**
  - a **phosphate** (PO_4^{3-}) group



- Phospholipids are a major component of cell membranes, forming the **phospholipid bilayer**
  - The phosphate end of the molecule is polar and attracted to water (**hydrophilic**) while the fatty acid end is non-polar and is repelled (**hydrophobic**).
  - As a result, phospholipids naturally form a bilayer with the hydrophobic ends orientated inwards.

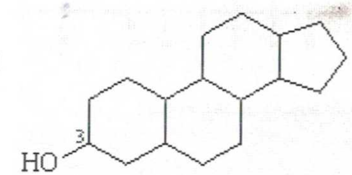


WAXES:

- Waxes consist of long chains of fatty acids linked to alcohol or carbon rings
- hydrophobic, firm and pliable
- Roles of Waxes:
  1. Waterproof coatings on various plants (cutin)
  2. Keep bird feathers dry
  3. Form honeycombs (beeswax)

STEROLS:

- A sterol is a compact hydrophobic molecule containing four fused hydrocarbon rings and several different functional groups
  - They do not contain fatty acids



- Examples of sterols are cholesterol, testosterone and estrogen

LIPID TEXTBOOK QUESTIONS:
Section 1.2, page 40 # 11-13, 15, 16

Text Pg. 35-40
Text Ref: 1.4

Macromolecules: LIPIDS

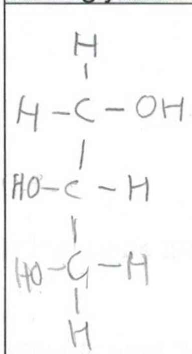
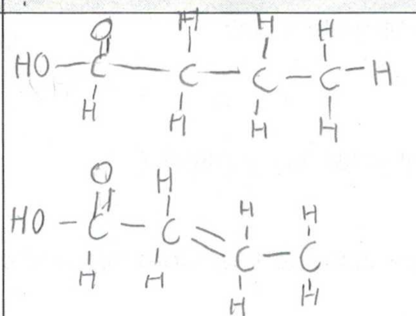
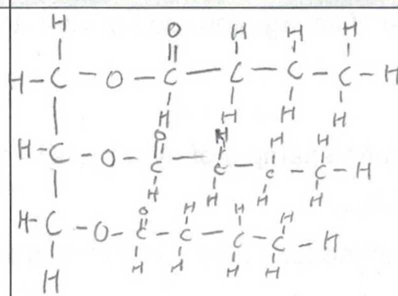
SBI 4U0

1. Define lipid
A group of organic compounds with an oily, greasy, or waxy consistency

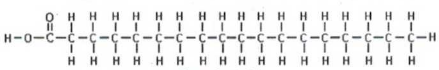
2. Using the atomic structure, explain why lipids do not dissolve in water. What is this called?
Lipids are non-polar & water is polar

FATS & OILS

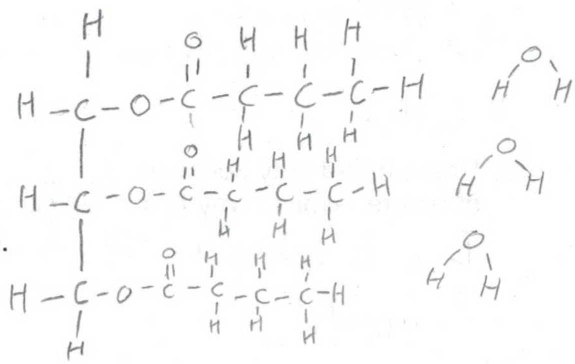
3. Complete the table below:

Outline the structure of glycerol	Outline the structure of a fatty acid chain	Draw a triglyceride using structural diagrams
		

4. Draw the following reaction: **Glycerol + 3 stearic acids ----------> glycerol tristearate + 3 water**
Stearic acid -



Stearic Acid



a. Name the functional group in the glycerol molecule.
Hydroxyl

b. Name the functional group in the stearic acid molecule.
Carboxyl

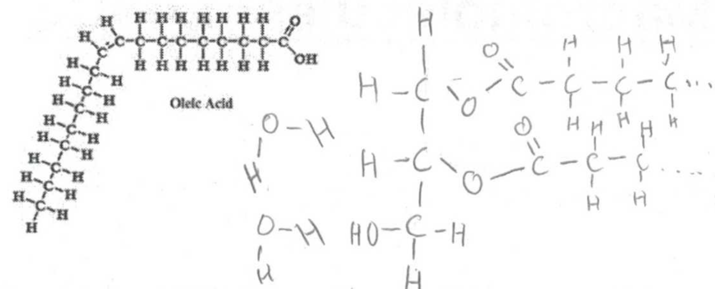
c. Why is stearic acid a saturated fatty acid?
No double bonds & max hydrogen atoms possible

d. Name the type of linkage formed between these molecules?
Ester Linkage

e. Is this reaction an example of hydrolysis or dehydration synthesis?

dehydration

5. Draw the following reaction: **glycerol + 2 oleic acid ----------> glycerol dioleate + 2 water**



a. Name the functional group in the glycerol molecule.

Hydroxyl

b. Name the functional group in oleic acid.

Carboxyl

c. What type of fatty acid is oleic acid?

Unsaturated

d. Name the type of linkage formed between these molecules?

Ester

e. Is this reaction an example of hydrolysis or dehydration synthesis?

Dehydration

6. a. The structure of the fatty acid chain determines its properties. Compare and contrast saturated and unsaturated fats.

b. Saturated fatty acids are solids at room temperature. Looking at their structure, explain why this is the case, and give two examples of saturated fats.

Saturated fats are structured in a linear & straight carbon chain which allows them to bond with other carbon chains through LDF forces due to their close proximity. These bonds allow it to be solid.

Butter

c. Unsaturated fatty acids are liquid at room temperature. Looking at their structure, explain why this is the case and give two examples of unsaturated fats.

Due to having a bent shape, it is unable to form strong LDF & are so liquid.

d. Unsaturated fats can be artificially saturated through chemical methods. Explain how it's done and why individuals would choose to do this process.

Through hydrogenation, Hydrogens are bonded to the double bonds of unsaturated triglycerides. This is the process used to make margerine

Proteins

Proteins are a group of macromolecules that are made up of amino acids monomers.
Proteins have a very close relationship with DNA:

- The genetic info found in our DNA codes for producing specific proteins
  - It is the proteins that then go on to accomplish all of life's processes

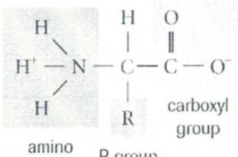
Functions of Proteins:

Function	Description
Enzymes	Biological catalysts that speed up chemical rxns in the body
Immunoglobulins	Protect against foreign microorganisms and cancerous cells (e.g. antibodies)
Protein Carriers	Transport materials through cell membranes and through the body (e.g. hemoglobin carries O_2 and CO_2 throughout mammalian bodies)
Structural	E.g. keratin found in hair and fingernails, fibrin helps blood clot, and collagen forms the protein portion of bones, skin, ligaments & tendons

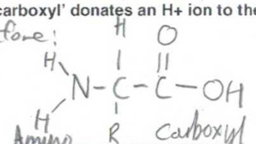
Amino Acids

Used in the human body

- Proteins are made up of a combination of amino acids folded into a 3D shape
  - **Shape determines its function**
  - The final shape is referred to as its conformation
- The ~~22~~ 20 amino acids differ only in the R groups they contain
  - 9 amino acids are ***essential***, meaning humans cannot make these amino acids & must obtain through diet.
- The R Groups determine the properties of the amino acid and the protein

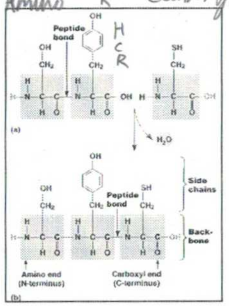


...when dissolved in water at a pH of 7, the 'carboxyl' donates an H+ ion to the



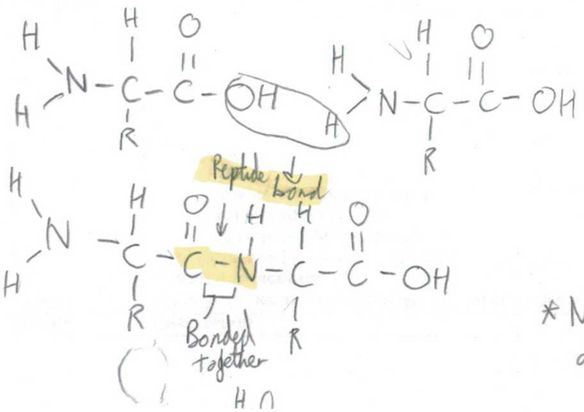
The R Groups on amino acids give the amino acids different properties:

- There are non-polar amino acids
- There are polar amino acids
- There are acidic amino acids (contain a carboxyl group on their R group)
- There are basic amino acids (contain an amino group on their R group)



Peptide Bonds

- The bonds that hold amino acids together are called **peptide bonds**
- Peptide bonds are formed by a dehydration synthesis reaction
  - Occurs between amino group of one aa and the carboxyl of an adjacent aa

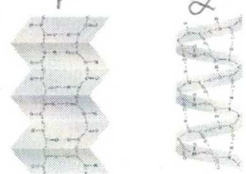


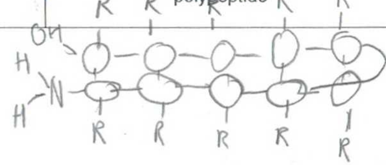
*Not a protein, just a dipeptide

Draw the structural diagram to represent the peptide bond that forms between serine and alanine:

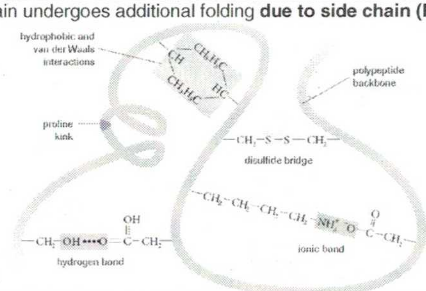
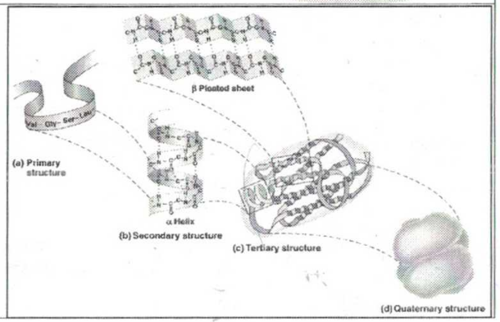
This structure is called a dipeptide. As more amino acids are added, it becomes a polypeptide.

Globular Protein Structure:
Divided into four levels of structure, also called its _______________:

Level	Description
Primary	• Chain of amino acids held together by peptide bonds • The unique sequence of amino acids in a polypeptide chain (The sequence of amino acids is determined by the nucleotide sequence of a particular gene) • In a protein with 'X' number of amino acids, number of possibilities is 20^x – Sequence is VERY specific – if off by one aa (amino acid), the final protein will not function properly 
Secondary	• As the primary structure grows, it starts to coil and fold → this is the secondary structure • The 2° Structure coils and folds as the polypeptide chain grows • Formed by hydrogen bonds between oxygen atoms of a carboxyl group (partially -) and hydrogen atoms of an amino group (partially +) • Two types ▪ **α helix** – tight coil produced by H-bonds that are repeated at the same distance in the aa chain ▪ **β pleated sheets** – H-bonds formed between parallel stretches of a polypeptide β α 



Polar & Non-Polar don't like eachother & the repulsion causes additional folding.
Attraction of "like likes like" can affect folding as well

Level	Description
Tertiary	In the 3° Structure, the polypeptide chain undergoes additional folding **due to side chain (R-group) interactions.** - Many different ways R groups can interact (some examples are highlighted in the PowerPoint note posted on D2L 
Quaternary	• Two or more polypeptide chains come together to form a functional protein, such as in collagen and haemoglobin. 

Protein Denaturation

- See animation (http://www.sumanasinc.com/webcontent/animations/content/proteinstructure.html)

Define **Denaturation**: ____

____

'Helpful' examples:	'Harmful' examples:

Review Proteins

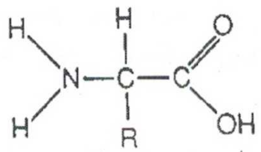
Section 1.2, Page 50 #19, 21-26

Text Ref: 1.4

Macromolecules: PROTEINS

SBI 4U0

1. Define **protein**: A group of macromolecules made of amino acids
2. Proteins are the most diverse and among the most important molecules in living organisms.
3. All proteins have the same basic structure, but they each have different functions.
4. *The monomer of a protein is called an* amino acid (pic below).



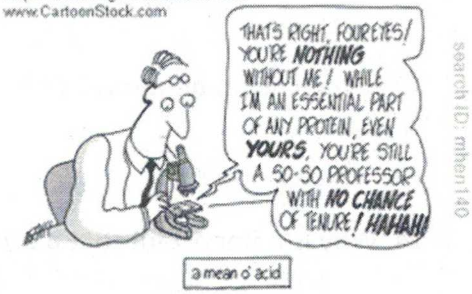
Amino NCR Carboxyl

Describe the general structure of an amino acid:
Carbon bonded to carboxyl & amino along with R group.

5. What is the significance of an " R " group?
Only varying component & decides f(x) & properties

6. There are 20 different amino acids, each with a different R group (this identifies which amino acid it is). Only 8 amino acids are ESSENTIAL – which means your body cannot produce them on its own & it must be absorbed externally (ie food)

7. The other 12 amino acids can be made by our bodies if we are not eating them in our diets.



a mean o' acid

8. Many amino acids join to form a polypeptide. This chain of amino acids then coils and folds together to create a functional protein. Amino acids are joined together by peptide bonds. These linkages are formed from a dehydration synthesis reaction.

9. Proteins perform many functions within the body, and a specific protein is needed for each function.

10. In chart form, describe the 4 levels of protein structure and indicate the relationship between structure and function in proteins.

Structure Level	Description (*brief*)
Primary	- Amino acids link together via peptide bonds into a polypeptide - Sequence is decoded by DNA
Secondary	- Polypeptide folds into β-pleated sheets & α helixes due to hydrogen bonds between non-adjacent amino acids & their subsequent pull.
Tertiary	- R group interactions fold the polypeptide chain into a unique 3D shape.
Quaternary	- Only for globular proteins - Multiple tertiary proteins form a final protein together - It's conformation determines its final function

11. What are disulfide bridges and in which level of protein structure do they occur?
- R group between cysteines, which contain sulphur in the R groups
- Forms a strong covalent bonds which stabilize tertiary structures.

12. Define **denaturation:**
A change in the 3D shape of a protein

13. What causes denaturation?
- pH
- temperature
- ionic concentration
- environmental factors

14. Why is it important that a protein maintains its shape?
It'll be unable to perform its function

15. Why do we cure meat with salt?
Denatures the enzymes in the bacteria which can spoil the food

16. How else do we use the denaturation of proteins in our lives?
- Blanching veggies
- Straightening / curling hair