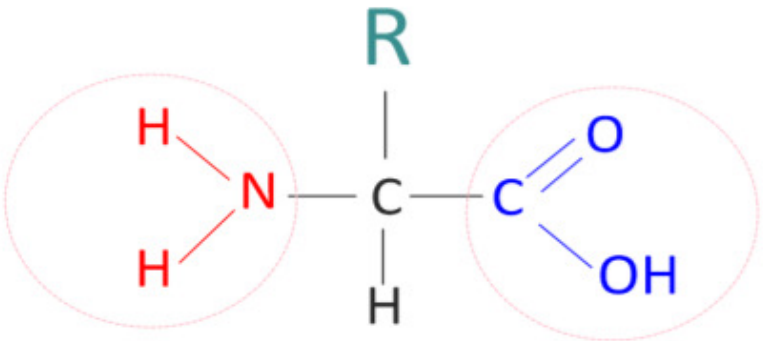
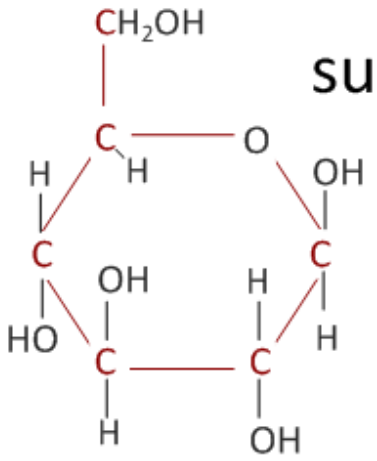


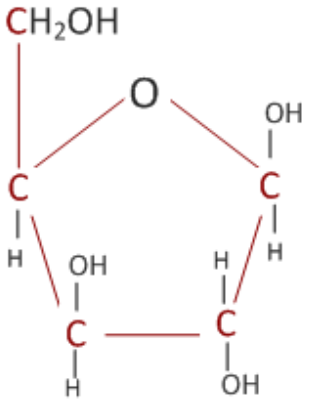
Carbohydrates, Lipids and Proteins

Organic compounds contain carbon and are found in living organisms.

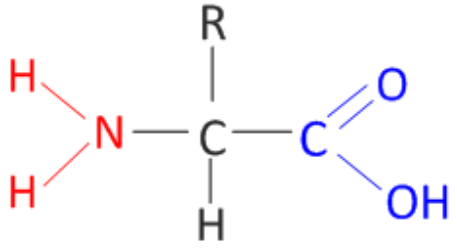
sugars



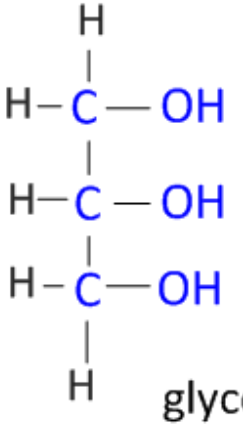
glucose



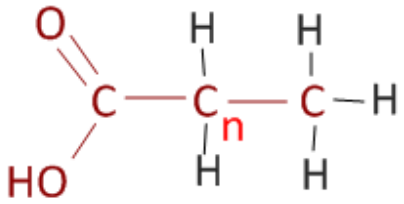
ribose

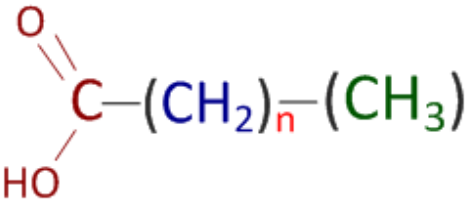


amino acids



glycerol





fatty acids

Some carbon-containing compounds are inorganic.

CO CO_2

oxides of carbon

HCO_3^- Na_2HCO_3

hydrogen carbonates

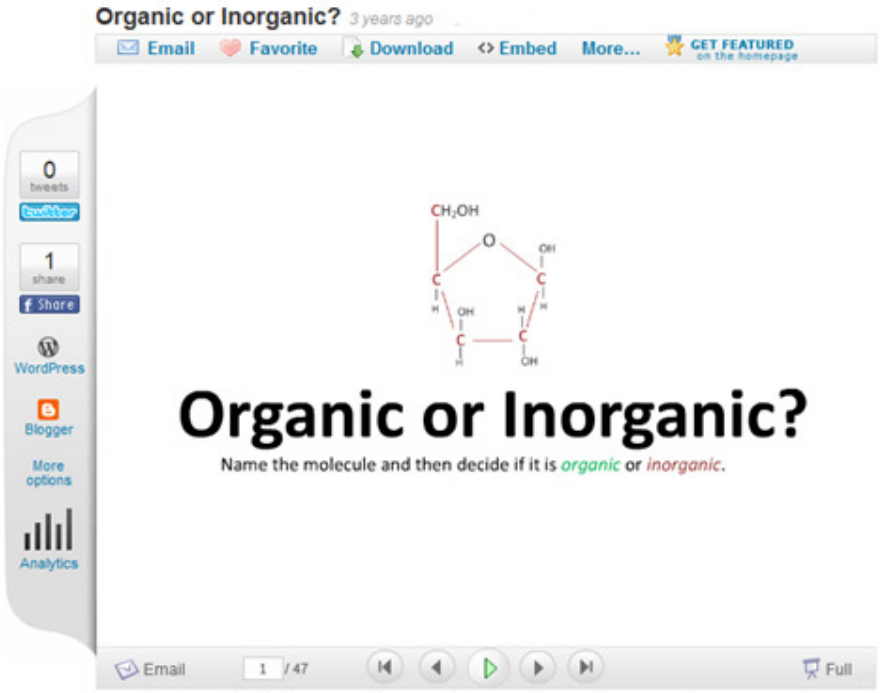
CO_3^{2-}

$CaCO_3$

Na_2CO_3

carbonates

Test yourself:



http://www.slideshare.net/gurustip/organic-or-inorganic-presentation

Four Major Organic Macromolecules

- Carbohydrates
- Lipids
- Proteins
- Nucleic Acids

Monomers, Dimers, Polymers

- Monomer: The repeating chemical unit that serves as the building block of larger molecules

- Dimer: A chain of 2 monomer subunits

- Polymer: A long molecule consisting of identical or similar building blocks linked by covalent bonds

...

How are polymers made?

- Monomers are linked together to become polymers by a condensation or dehydration reaction

- Origen of name: a molecule of water is lost when monomers are chemically linked

- Most of the macromolecules in your body are polymers

How are polymers disassembled?

- When polymers break down to monomers they undergo a reaction called hydrolysis.

- Hydrolysis is essentially the reverse of dehydration (bonds between monomers are broken by water)

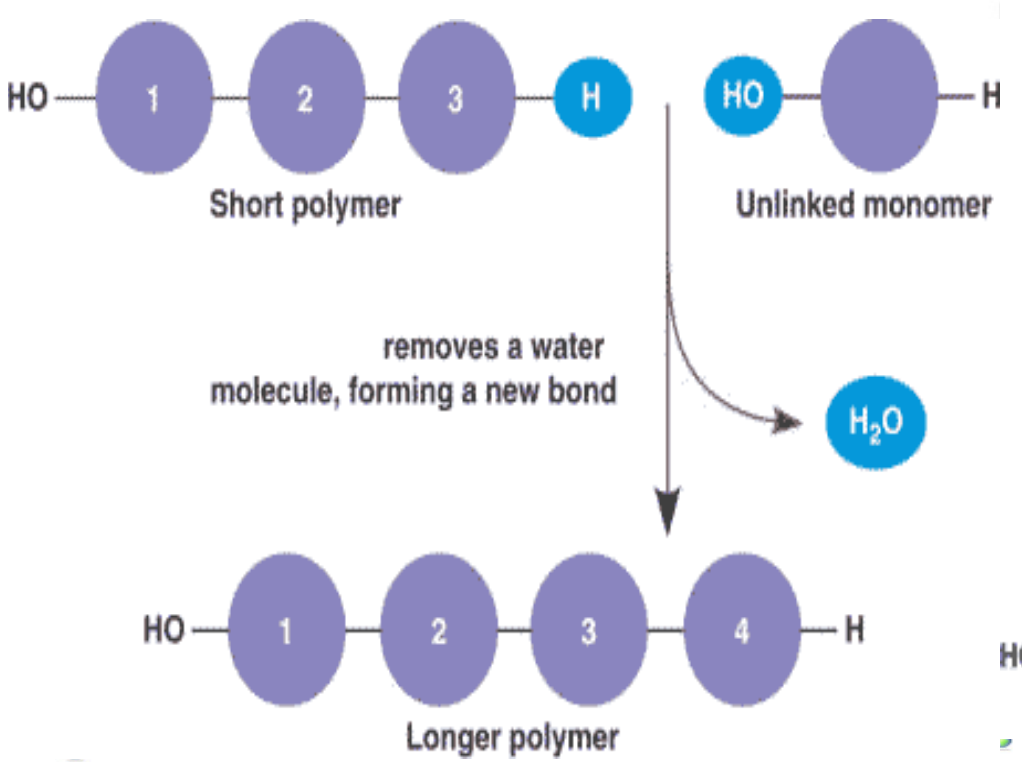
Condensation makes bonds,
water releasing

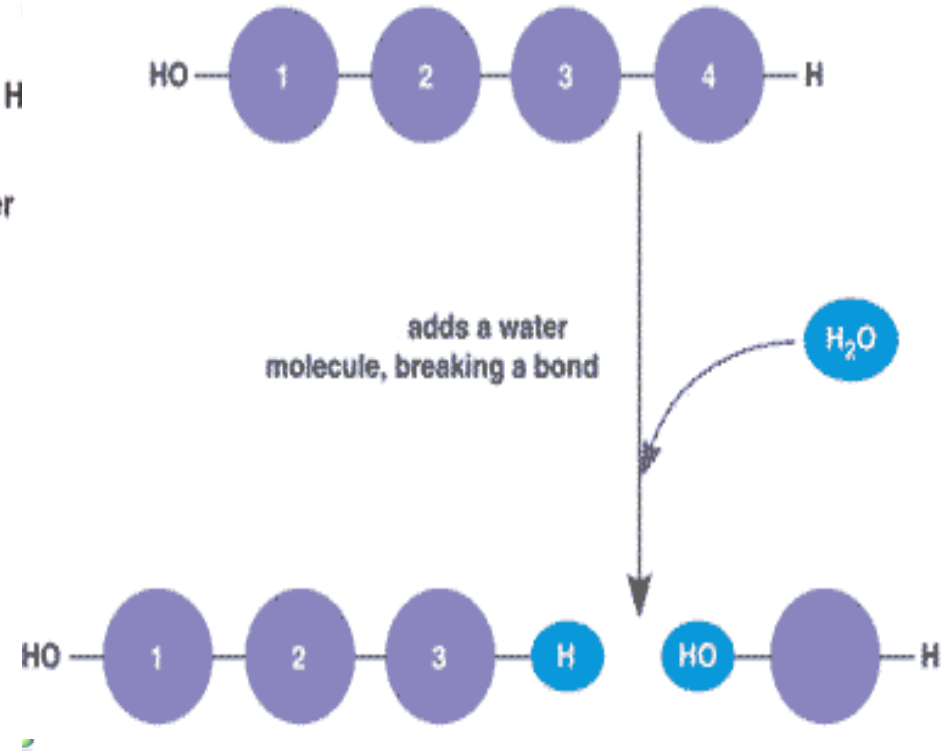
ANABOLIC reactions are those which build molecules (e.g. *protein synthesis*)

Hydrolysis breaks bonds:
water splitting

CATABOLIC reactions are those which break down molecules (e.g. *digestion*)

All of these reactions require enzymes - biological catalysts.





	Monomer	Dimer	Polymer
Carbohydrate	Monosaccharide		
Lipid			
Protein	Amino acid		
Nucleic Acid	Nucleotide		

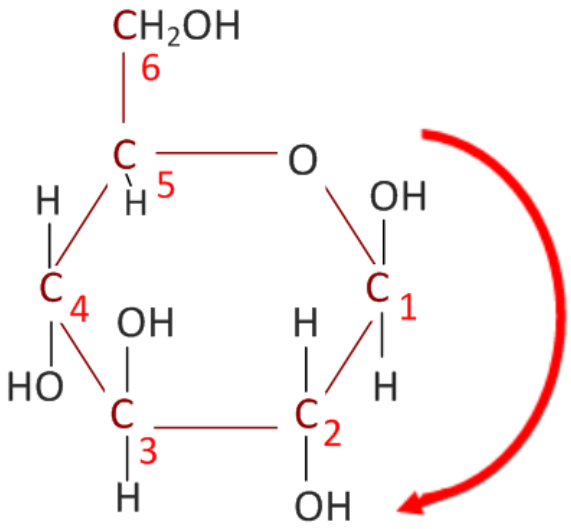
	Monomer	Dimer	Polymer
Carbohydrate	Monosaccharide	Disaccharide	polysaccharide
Lipid	Glycerol & fatty acid	X	Trigylceride, phospholipid etc.
Protein	Amino acid	Dipeptide	Polypeptide (Protein)
Nucleic Acid	Nucleotide	Dinucleotide (ex: Nicotinamide adenine *dinucleotide = NAD+*)	Polynucleotide

Carbohydrates

Monosaccharides have ring structures in water:

(sugars)

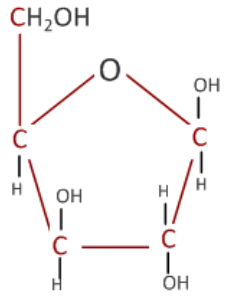
glucose:



start at oxygen and count the carbons clockwise

*hex*ose sugar: six carbons

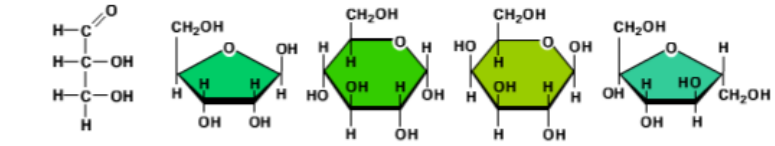
ribose:



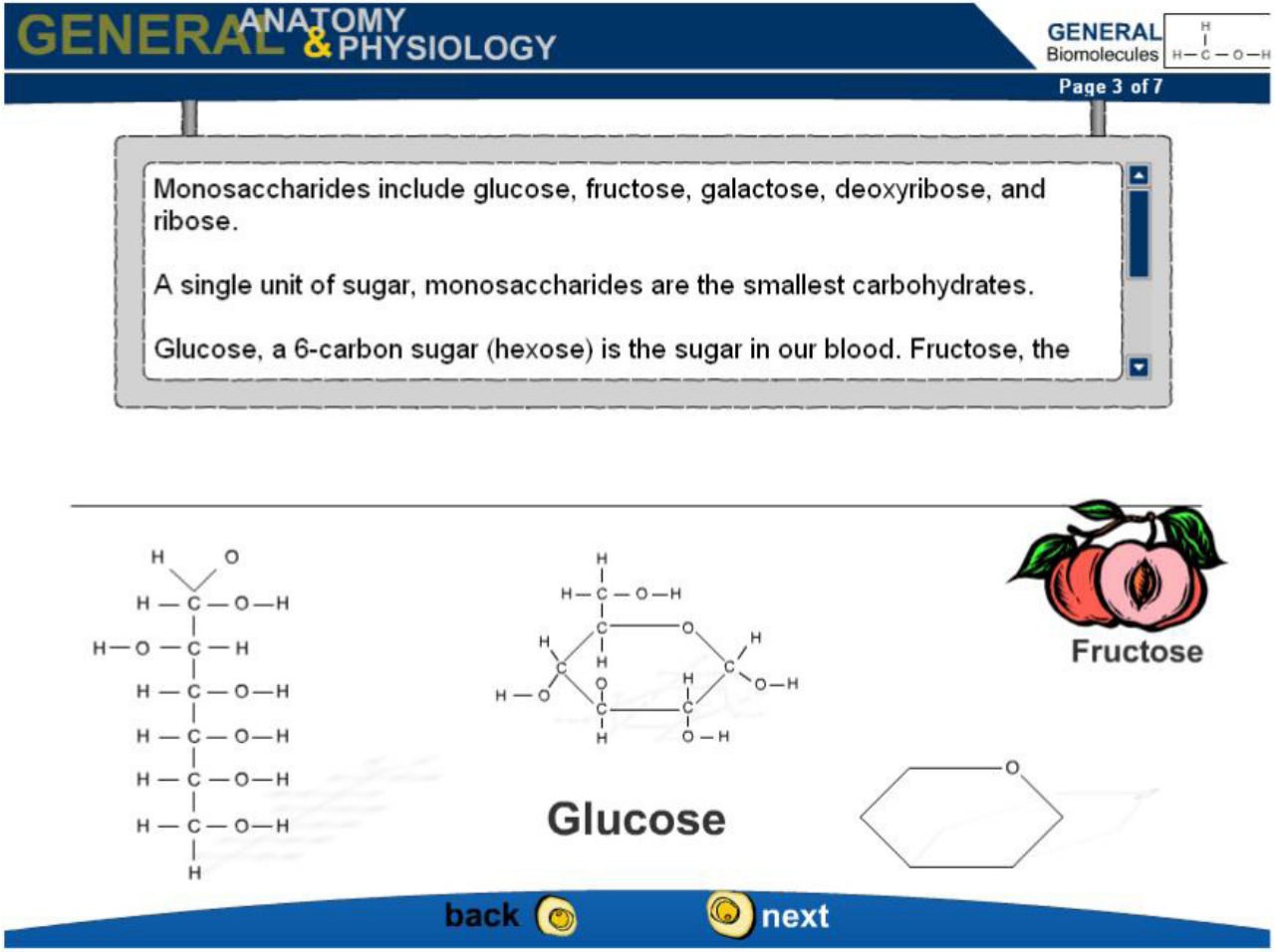
*pent*ose sugar

From Campbell Biology:

Monosaccharides



Carbohydrates:

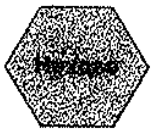


- http://www.wisc-online.com/objects/ViewObject.aspx?ID=AP13104

Examples of Monosaccharides:

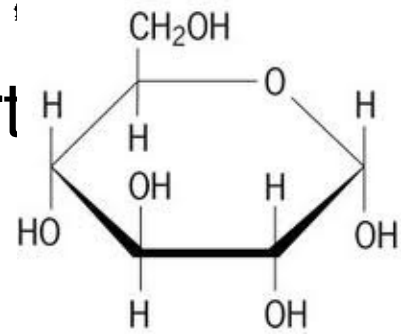
- Pentose Sugars vs. Hexose Su

e.g., ribose, deoxyribose

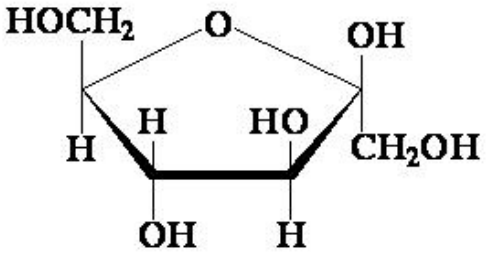


e.g., glucose,

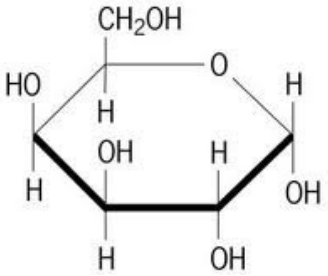
- Glucose: carried by the blood to transport "energy" to cells throughout the body



- Fructose: "Fruit sugar" - a simple monosaccharide found in many plants.

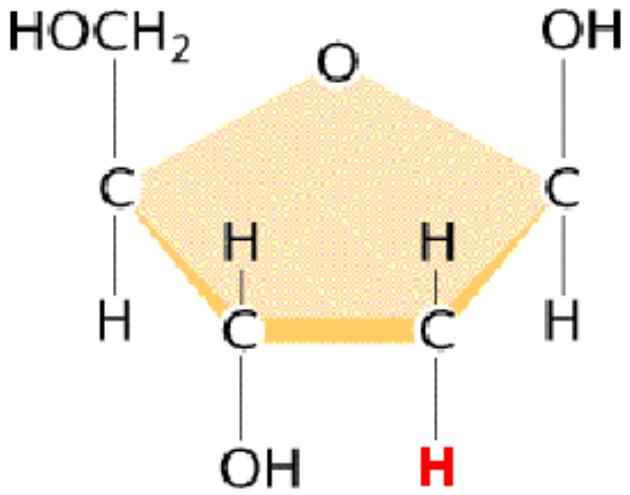


- Galactose: (from Greek "milk") is a type of sugar that is less sweet than glucose.

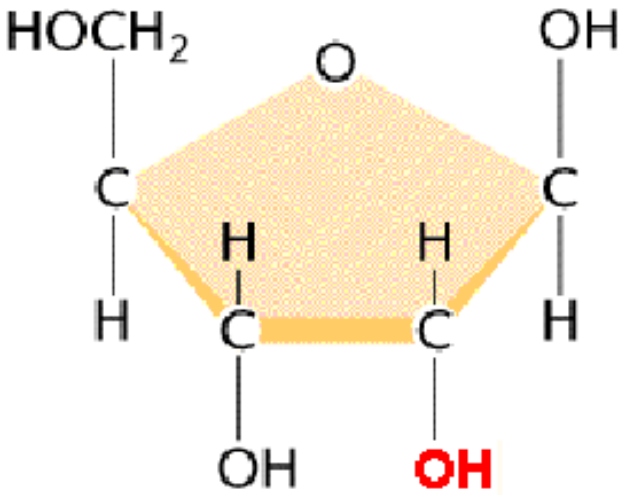


Examples of Monosaccharides Cont'd:

- Ribose: Sugar making up part of the 'backbone' of RNA
- Deoxyribose: Sugar making up part of the 'backbone' of DNA



2-Deoxyribose

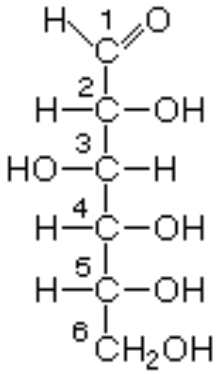


Ribose

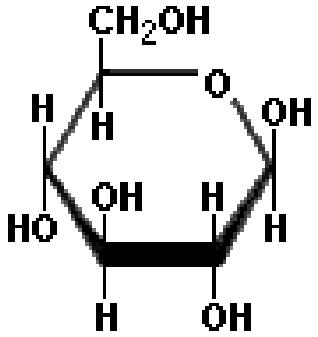
Chain and Ring Forms

- Many saccharide structures differ only in the orientation of the hydroxyl groups (**-OH**).
- This slight structural difference makes a big difference in the biochemical properties, taste, and in the physical properties such as melting point and Specific Rotation (how polarized light is distorted).
- Many simple sugars can exist in a chain form or a ring form. The ring form is favored in aqueous solutions,
- The **glucose** ring form is created when the oxygen on carbon number 5 links with the carbon comprising the carbonyl group (carbon number 1) and transfers its hydrogen to the oxygen to create a hydroxyl group.
- The rearrangement produces *alpha* glucose when the hydroxyl group is on the opposite side of the **-CH2OH** group, or *beta* glucose when the hydroxyl group is on the same side as the **-CH2OH** group.
- Isomers, such as these, differ only in their configuration about their carbonyl carbon atom.
- Glucose is sometimes illustrated as a "chair form" because it is a more accurate representation of the bond angles of the molecule. The "boat" form of glucose is unstable.

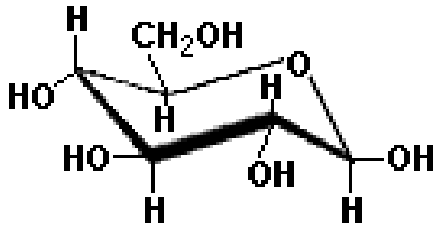
β-D-Glucose



β-D-Glucose



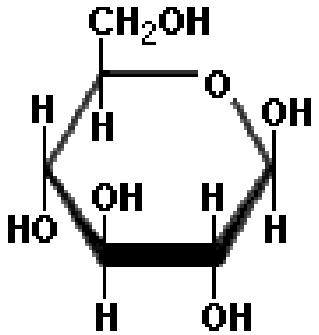
β-D-Glucose
(chair form)



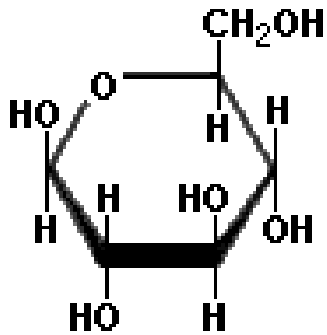
Stereochemistry

- Saccharides with identical functional groups but with different spatial configurations have different chemical and biological properties.
- Stereochemisty is the study of the arrangement of atoms in three-dimensional space.
- Stereoisomers are compounds in which the atoms are linked in the same order but differ in their spatial arrangement.

β-D-Glucose

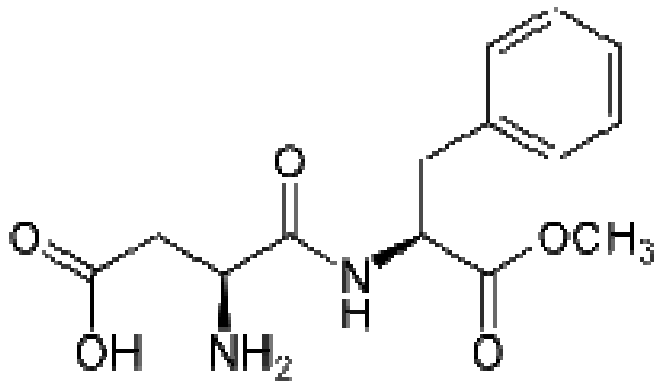


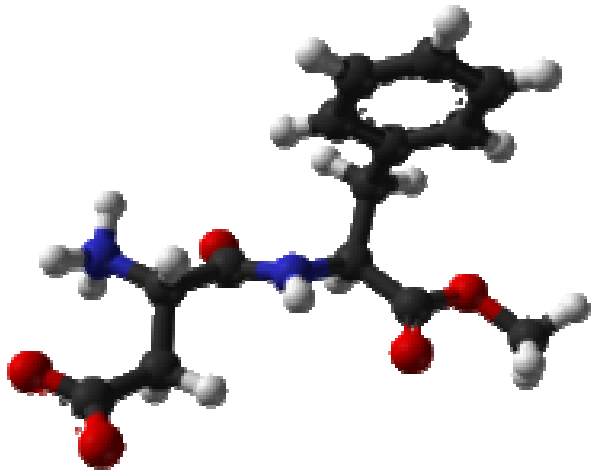
β-L-Glucose



Artificial Sweeteners? NOT Carbohydrates!

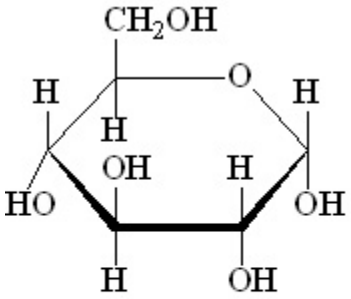
- Ex: Aspartame



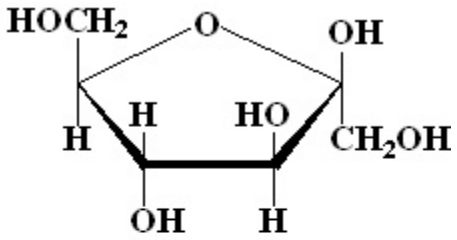


- Aspartame, an artificial sweetener, is approx.200 times sweeter than sucrose (table sugar). Thus, even though aspartame produces four kilocalories of energy per gram when metabolized, the quantity of aspartame needed to produce a sweet taste is so small that its caloric contribution is negligible
- Its breakdown products include phenylalanine, thus aspartame must be avoided by people with the genetic condition phenylketonuria (PKU).

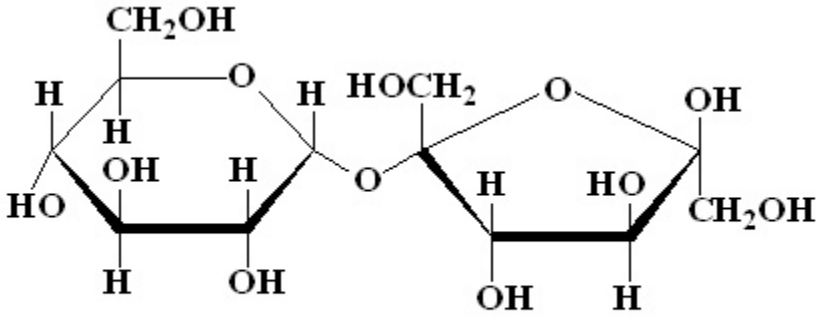
Two Monosaccharides Bonded→ Disaccharide



glucose



fructose

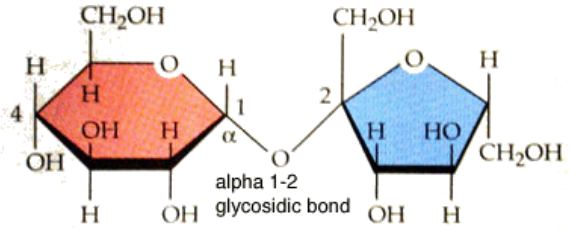


sucrose

Disaccharides

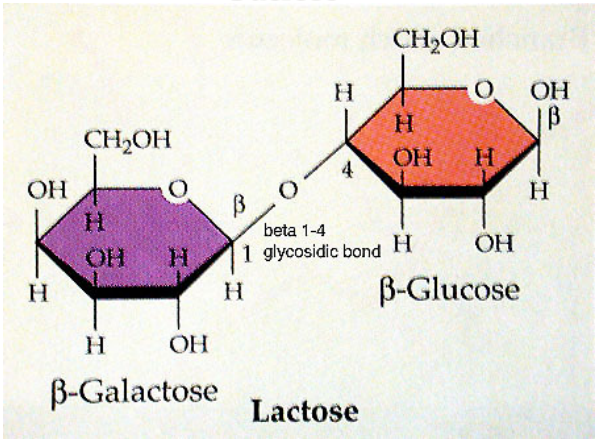
- Sucrose: Glucose & Fructose
  - Table Sugar

Sucrose has the molecular formula $C_{12}H_{22}O_{11}$



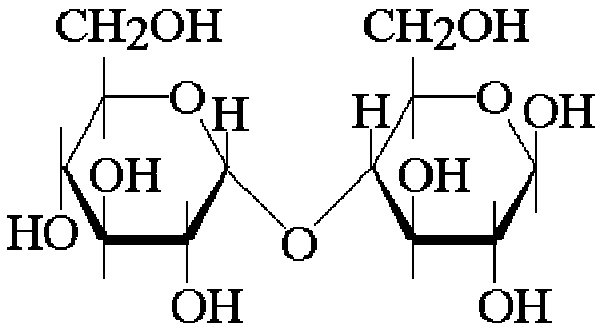
Sucrose

- Lactose: Glucose & Galactose
  - Milk Sugar (Lactose makes up around 2~8% of milk (by weight).



Lactose

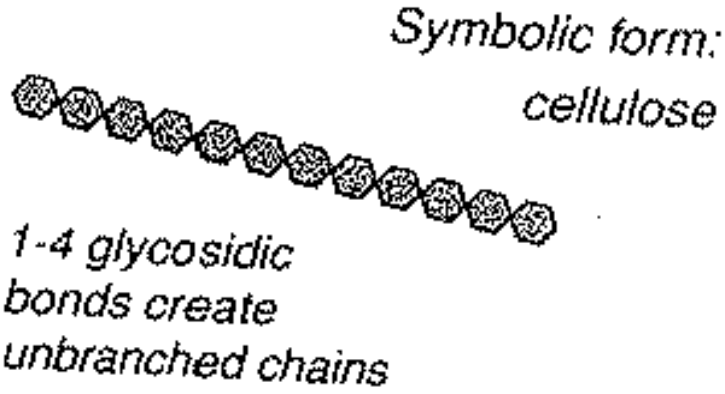
- Maltose: Glucose & Glucose
  - Malt Sugar (Maltose is the disaccharide produced when amylase breaks down starch. It is found in germinating seeds such as barley as they break down their starch stores to use for food. It is also produced when glucose is caramelized.)



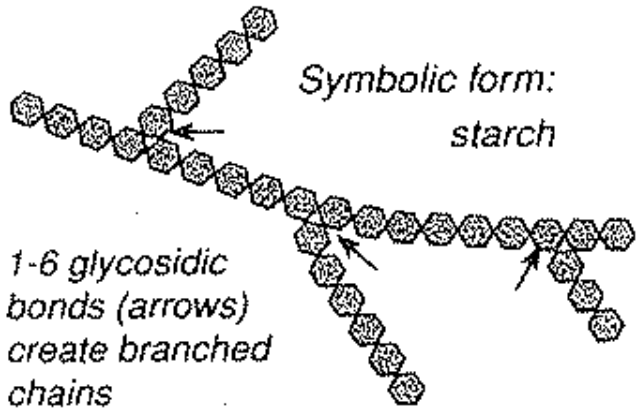
Maltose

Polysaccharides

- Cellulose: Structural material in plant cell walls

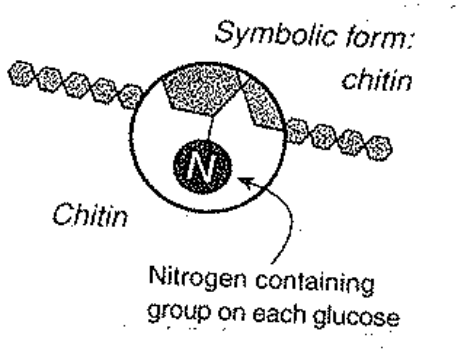


- Starch: Energy storage molecule in plant cells

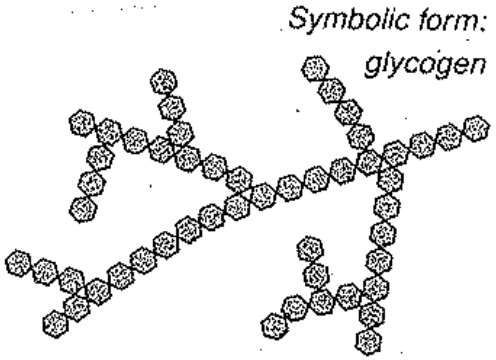


Polysaccharides Continued…

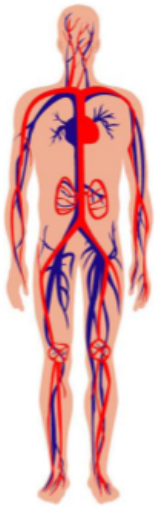
- Chitin: Tough/hard polymer found in the exoskeleton of insects and arthropods



- Glycogen: Storage compound in animal tissues (liver and muscle)



Some examples of *mono-*, *di-* and *poly-saccharides*:



animals

mono-	glucose galactose	monosaccharides are small, easily absorbed sugars - fast releases for repiration
di-	lactose maltose	disaccharides are quickly digested into their monosaccharides. lactose is found in milk - ideal for nursing young
poly-	glycogen	insoluble storage molecule: excess sugars converted by insulin for storage in the liver

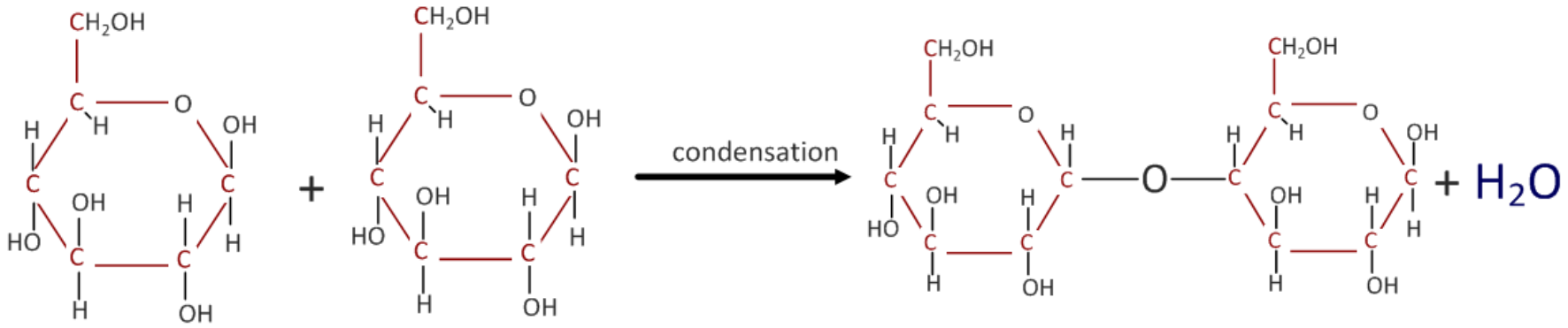
plants

mono-	fructose	monosaccharides are small, easily absorbed sugars - fast releases for repiration
di-	sucrose	soluble but unreactive, so can be transported around the plant in the phloem.
poly-	cellulose starch	large and insoluble - makes the plant cell wall Starch: insoluble plant energy storage molecule

Monosaccharides are the monomers of polysaccharides:

(sugars) (carbohydrates)

glucose + glucose → (condensation) maltose (disaccharide) + water



water is removed

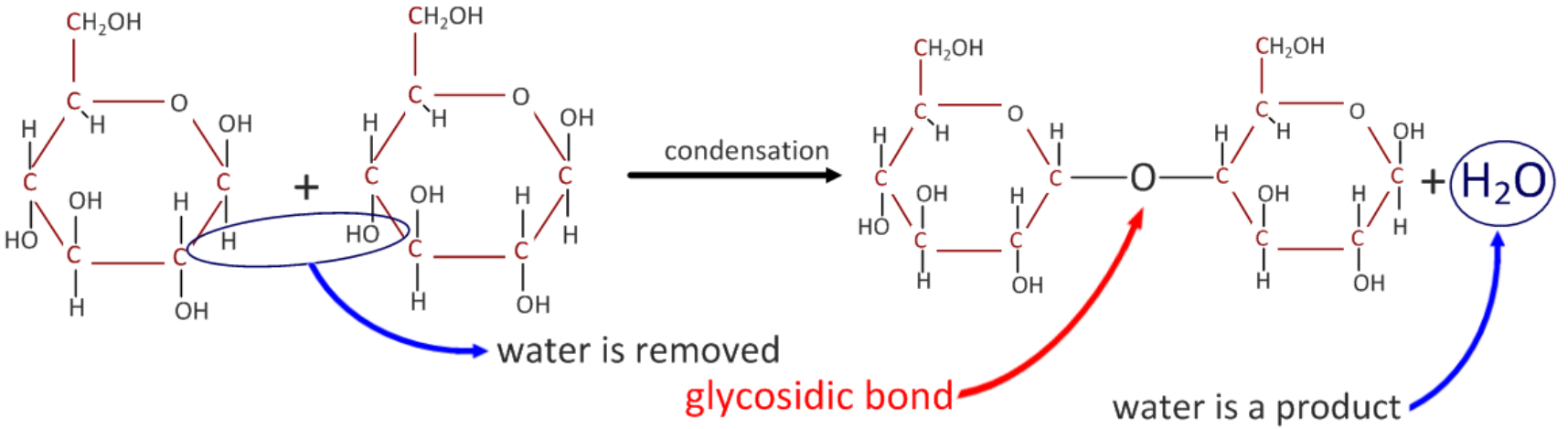
glycosidic bond

water is a product

Monosaccharides are the monomers of polysaccharides:

(sugars) (carbohydrates)

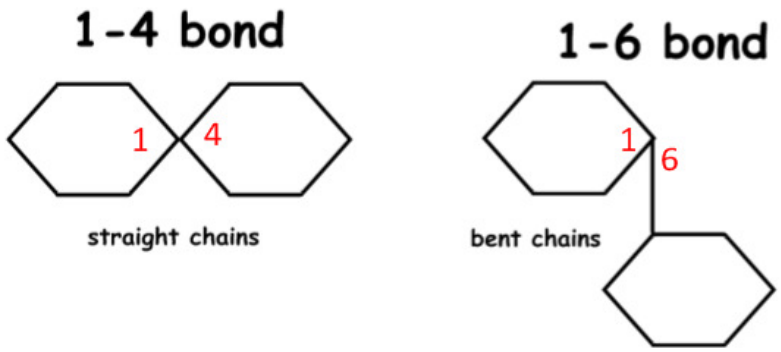
glucose + glucose $\xrightarrow{\text{condensation}}$ maltose (disaccharide) + water



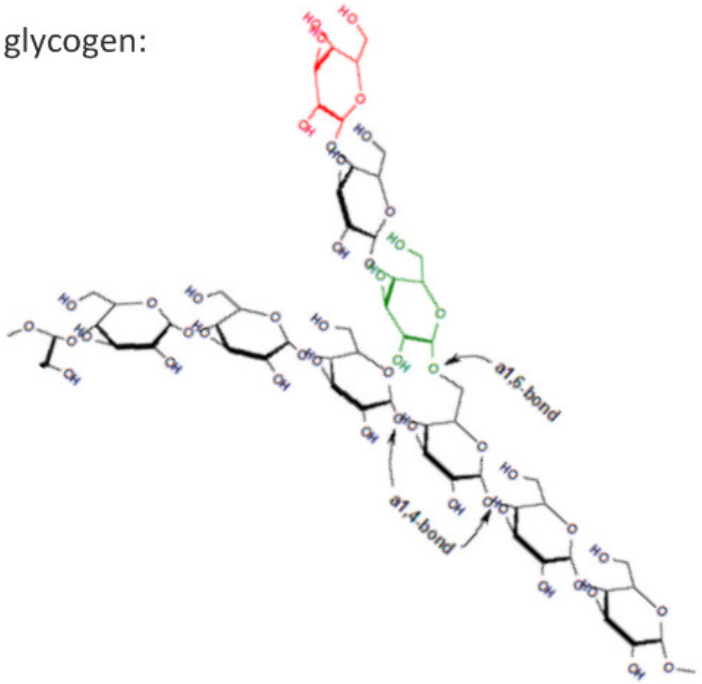
Polysaccharides (such as glycogen) are polymers more than two molecules.

They are often very long and may be branched.

Glycosidic bonds can be 1-4 or 1-6 (carbon links)



glycogen:



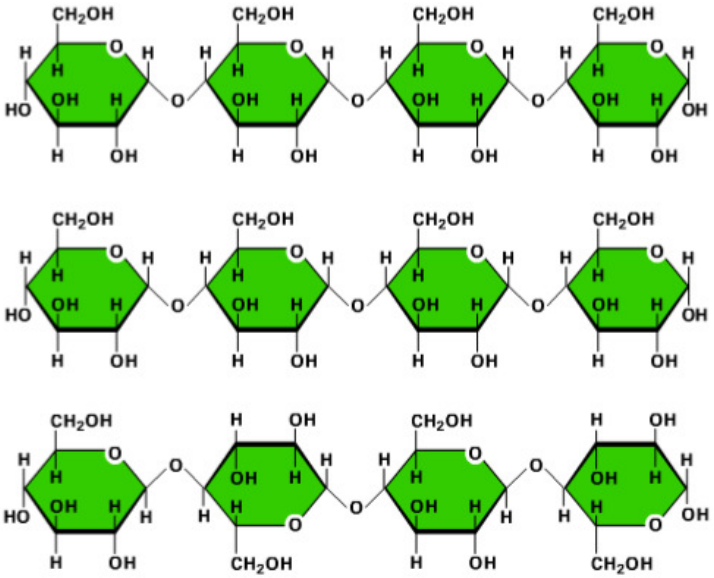
http://upload.wikimedia.org/wikipedia/commons/thumb/0/0d/Glycogen.png/468px-Glycogen.png

From Campbell Biology:

Starch

Glycogen

Cellulose



Question:

1 2 3

Condensation makes bonds, water releasing

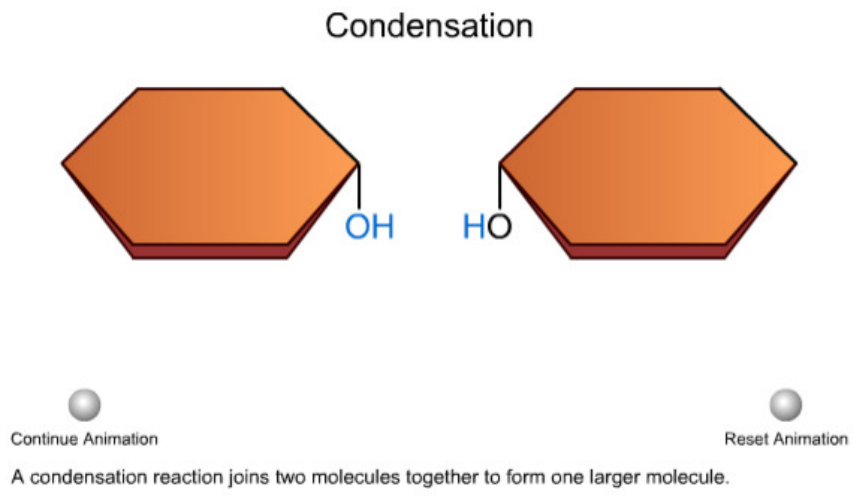
ANABOLIC reactions are those which build molecules (e.g. *protein synthesis*)

Hydrolysis breaks bonds:

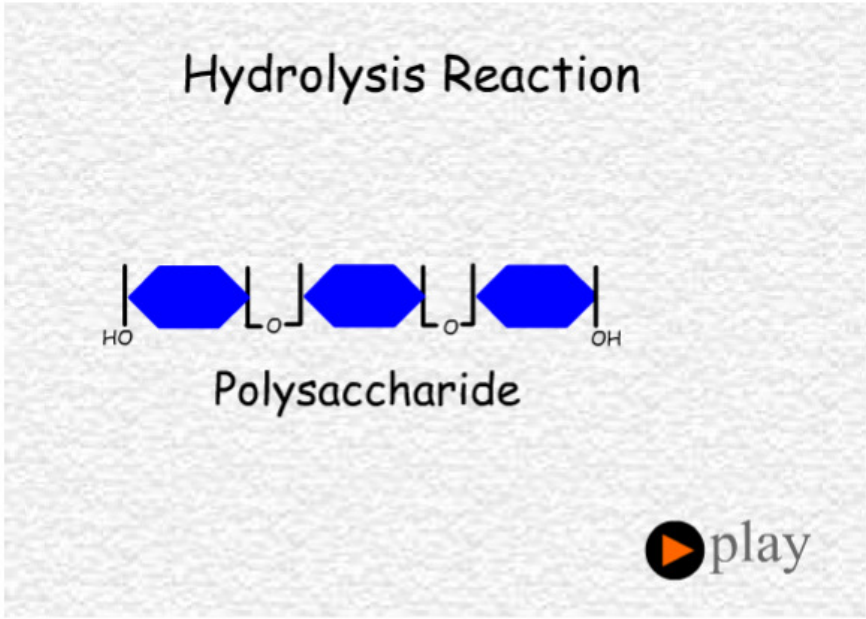
water splitting

CATABOLIC reactions are those which break down molecules (e.g. *digestion*)

All of these reactions require enzymes - biological catalysts.

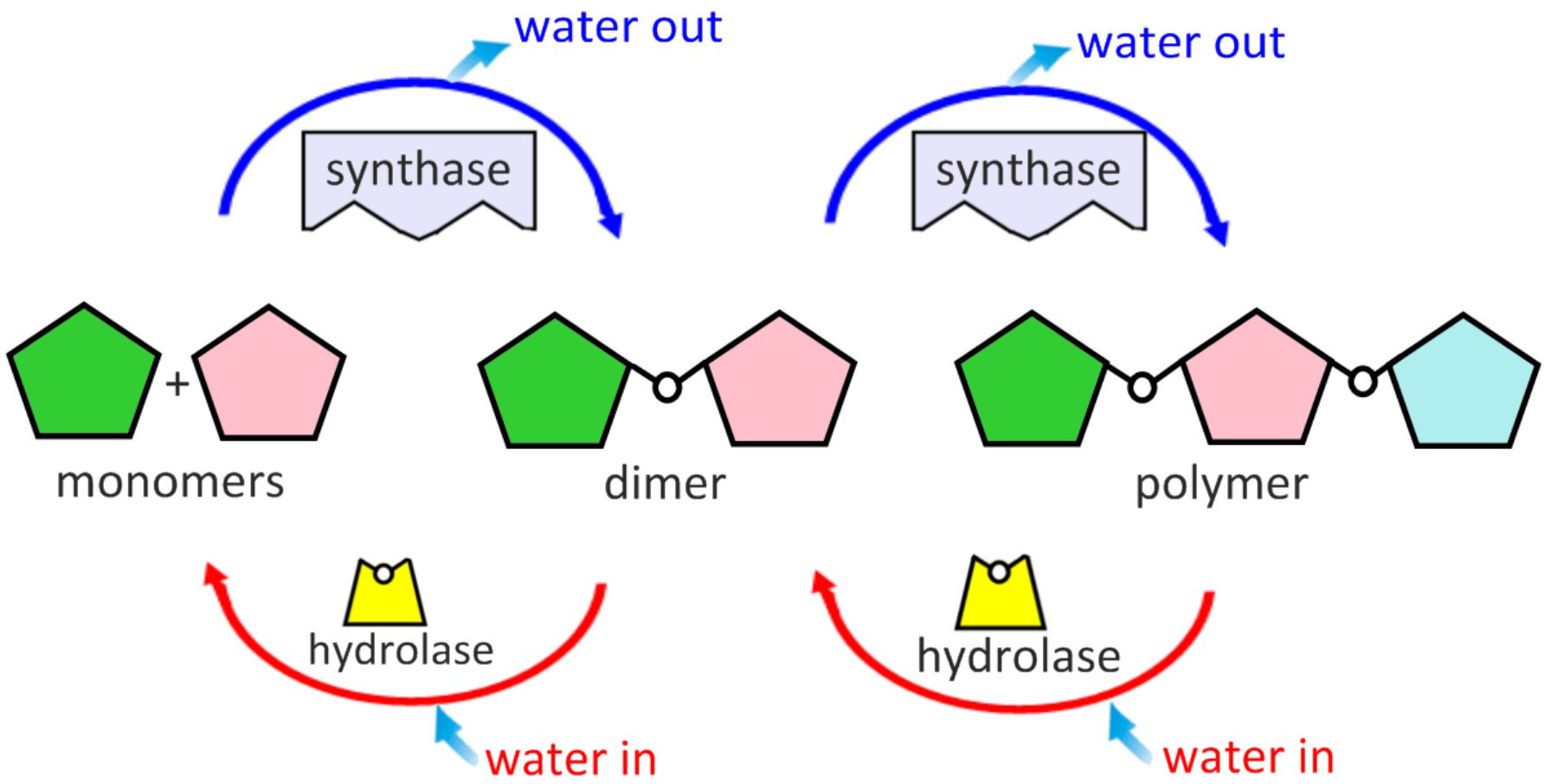


http://trc.ucdavis.edu/biosci10v/bis10v/media/ch02/reaction_types.html



http://www.tvdsb.on.ca/Westmin/science/sbioac/biochem/condense.htm

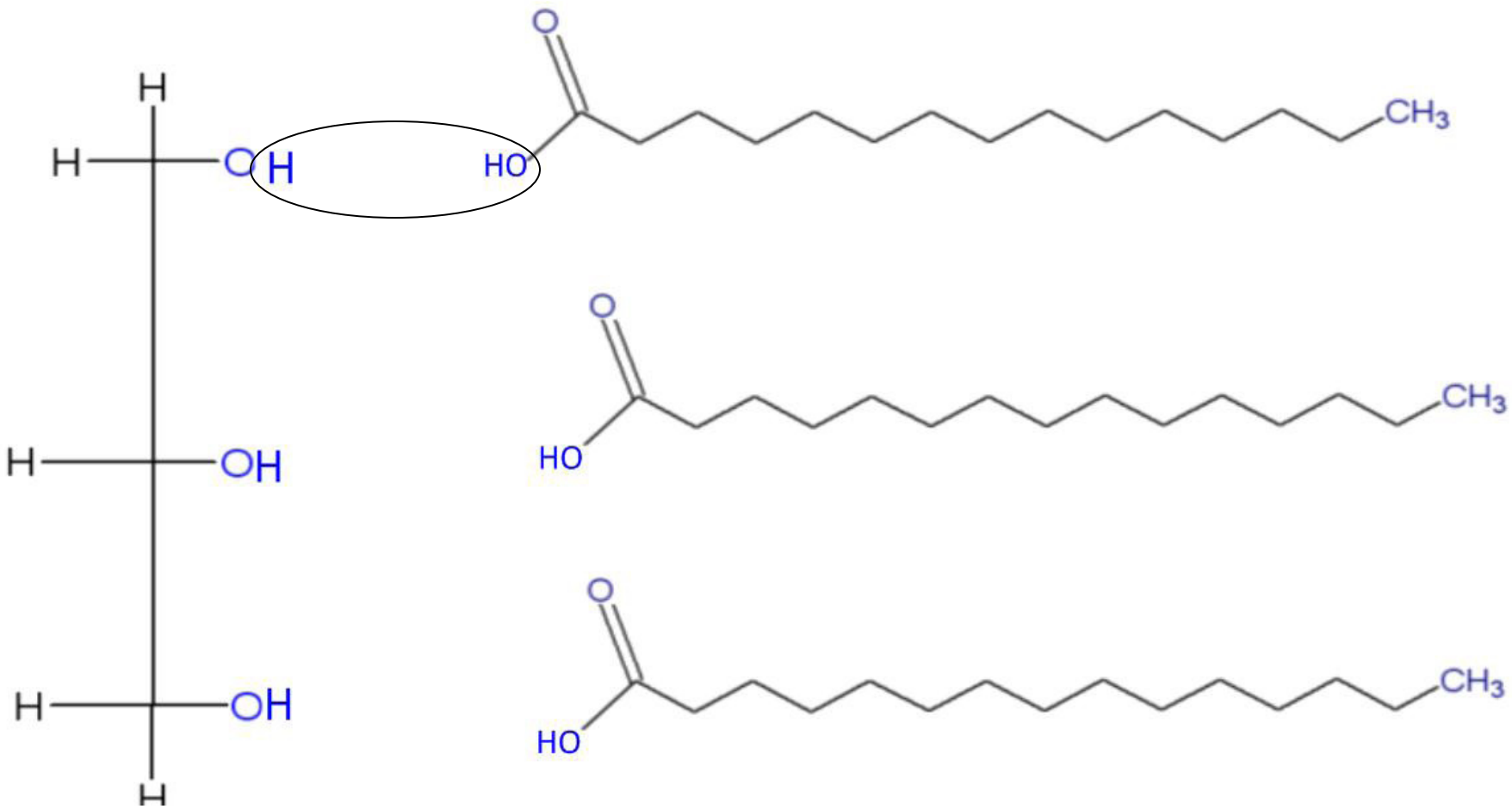
Condensation



Hydrolysis

Lipids

Condensation in triglycerides:



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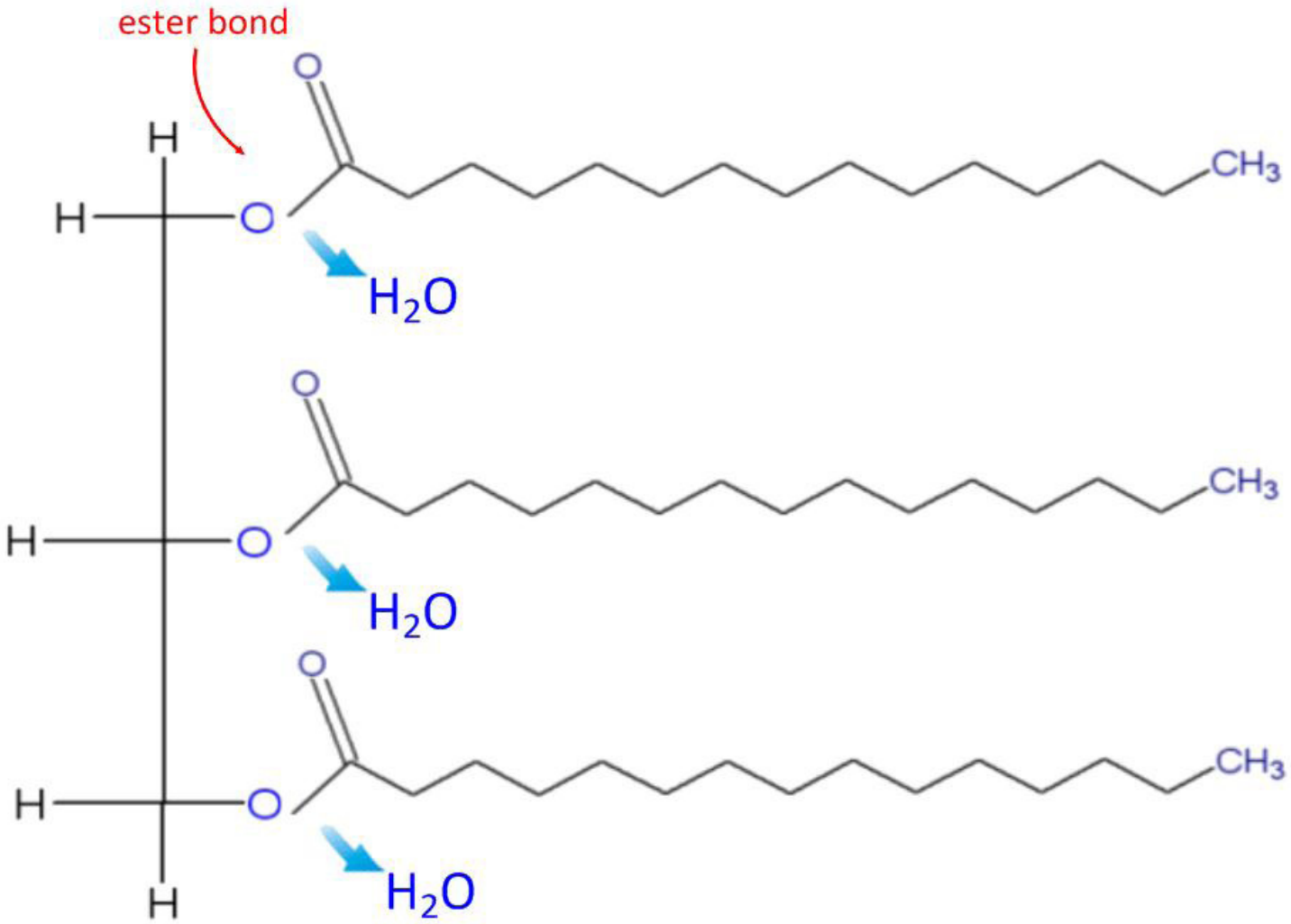
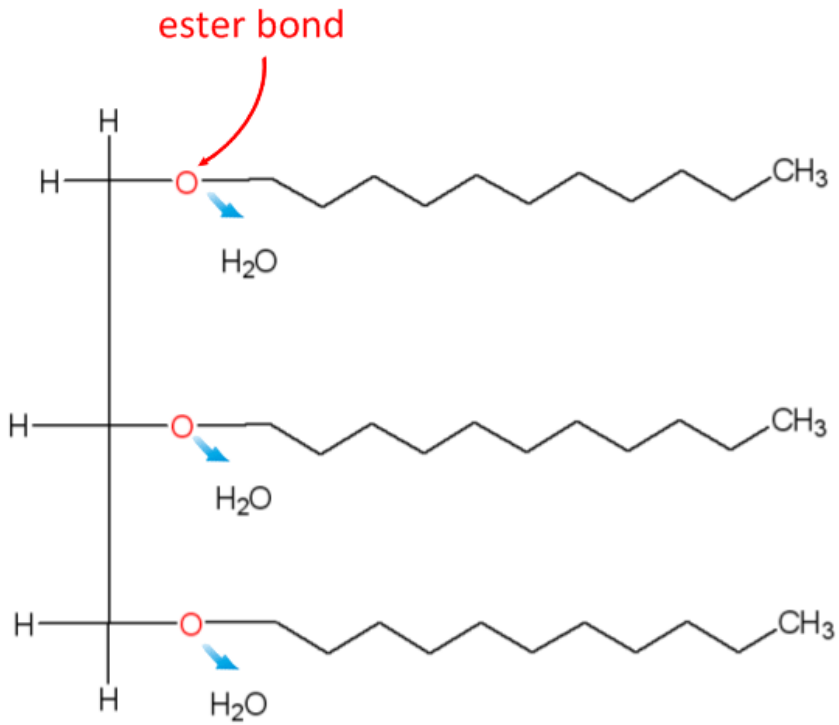
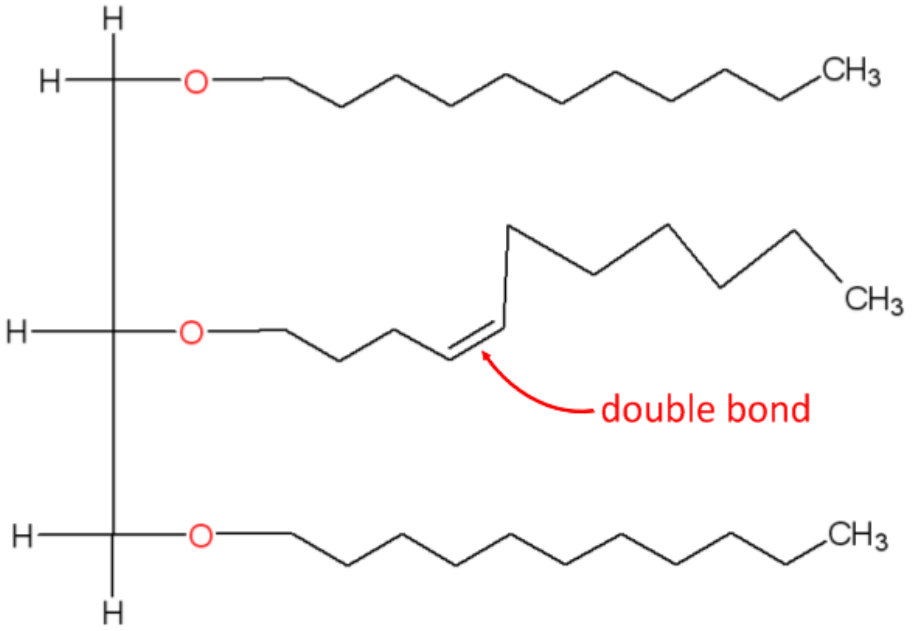


Single bonds = saturated fats



These animal fats are solid at room temperature

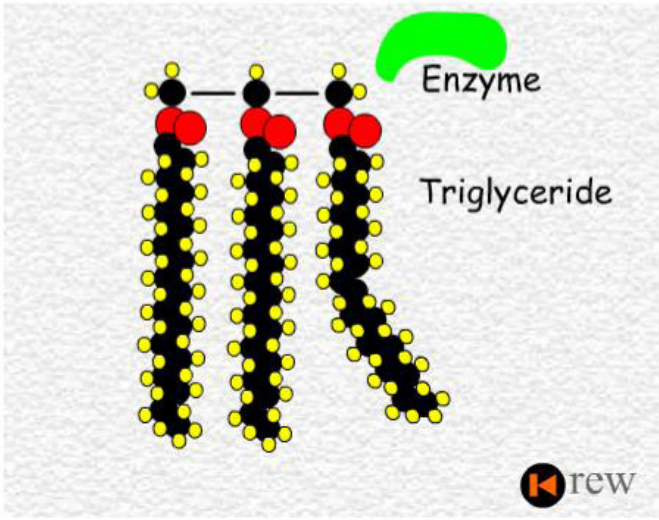
Double bonds = unsaturated fats



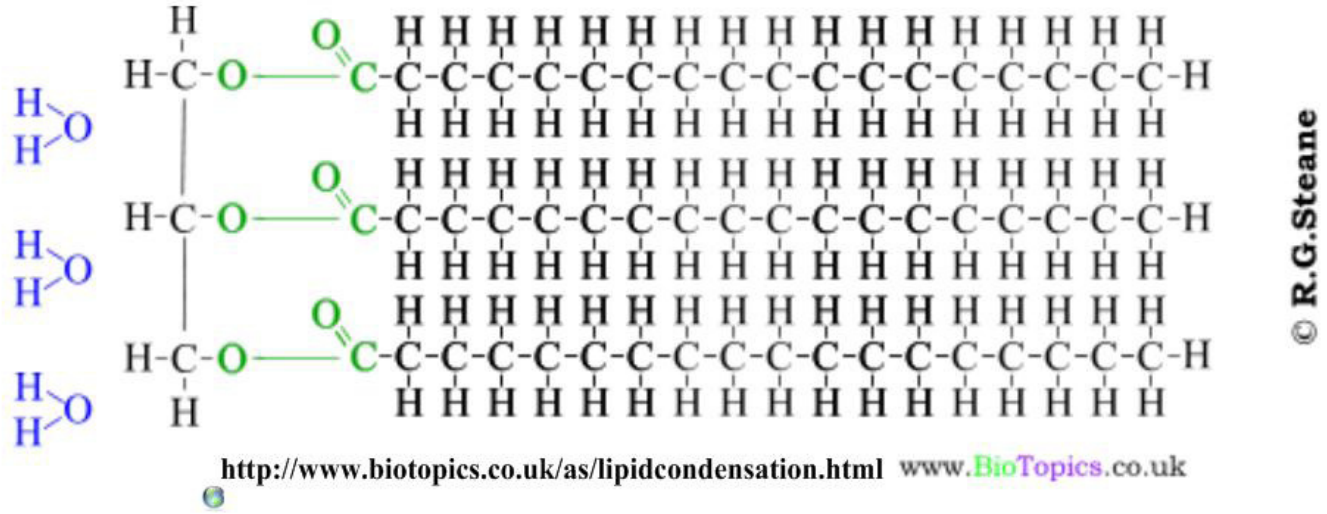
These plant oils are liquid at room temperature

Can you deduce the meanings of *mono-unsaturated* and *poly-unsaturated*?

Some more animations on triglycerides:



http://www.tvdsb.on.ca/westmin/Science/sbioac/biochem/triglyc.htm



http://www.biotopics.co.uk/as/lipidcondensation.html www.BioTopics.co.uk

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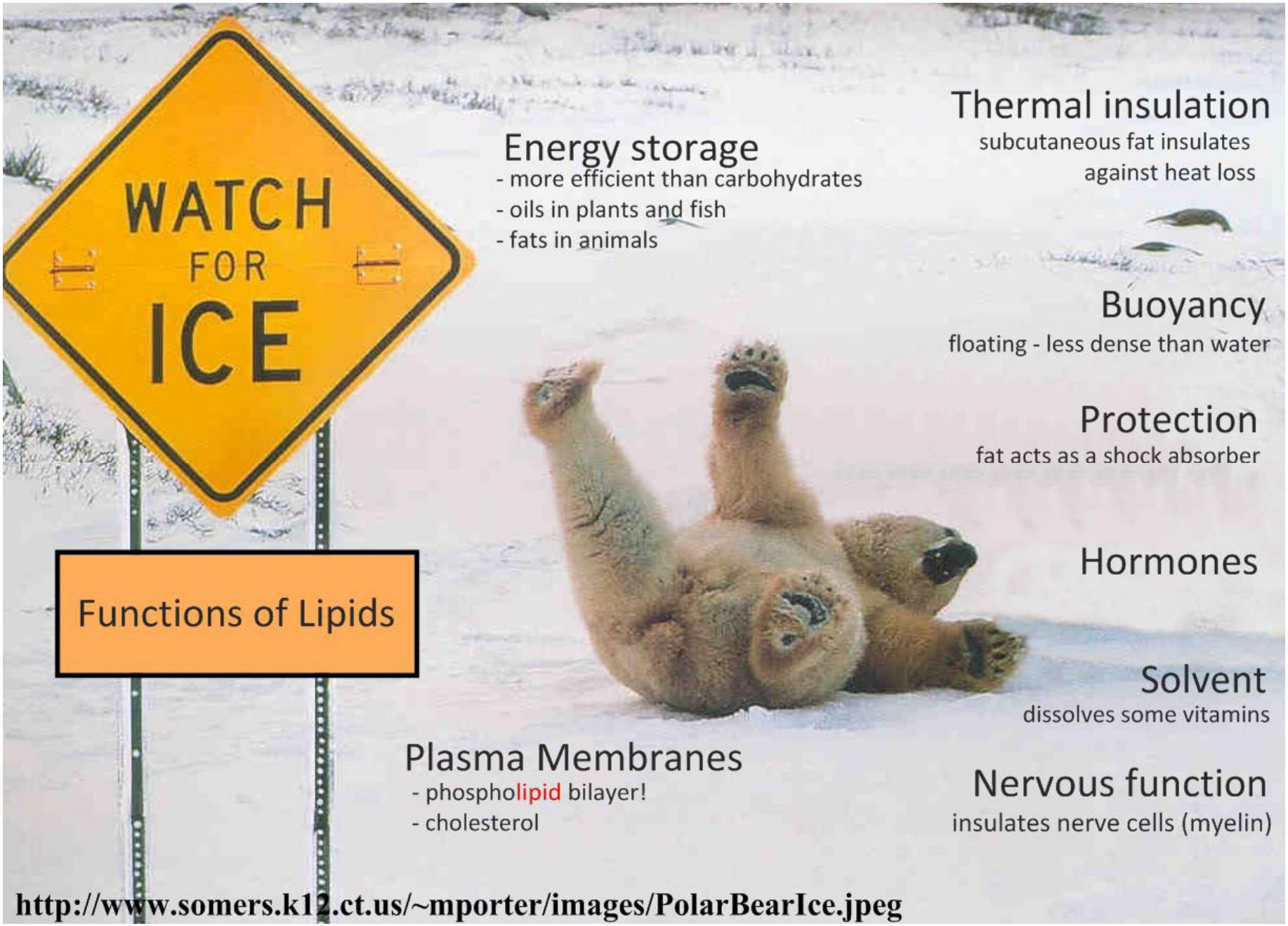

WATCH
FOR
ICE
Functions of Lipids
Energy storage
- more efficient than carbohydrates
- oils in plants and fish
- fats in animals
Thermal insulation
subcutaneous fat insulates
against heat loss
Buoyancy
floating - less dense than water
Protection
fat acts as a shock absorber
Hormones
Solvent
dissolves some vitamins
Plasma Membranes
- phospholipid bilayer!
- cholesterol
Nervous function
insulates nerve cells (myelin)
http://www.somers.k12.ct.us/~mporter/images/PolarBearIce.jpeg

Uses of lipids: buoyancy

http://www.youtube.com/watch?v=c_l-5lndoqw

Uses of lipids: thermal insulation

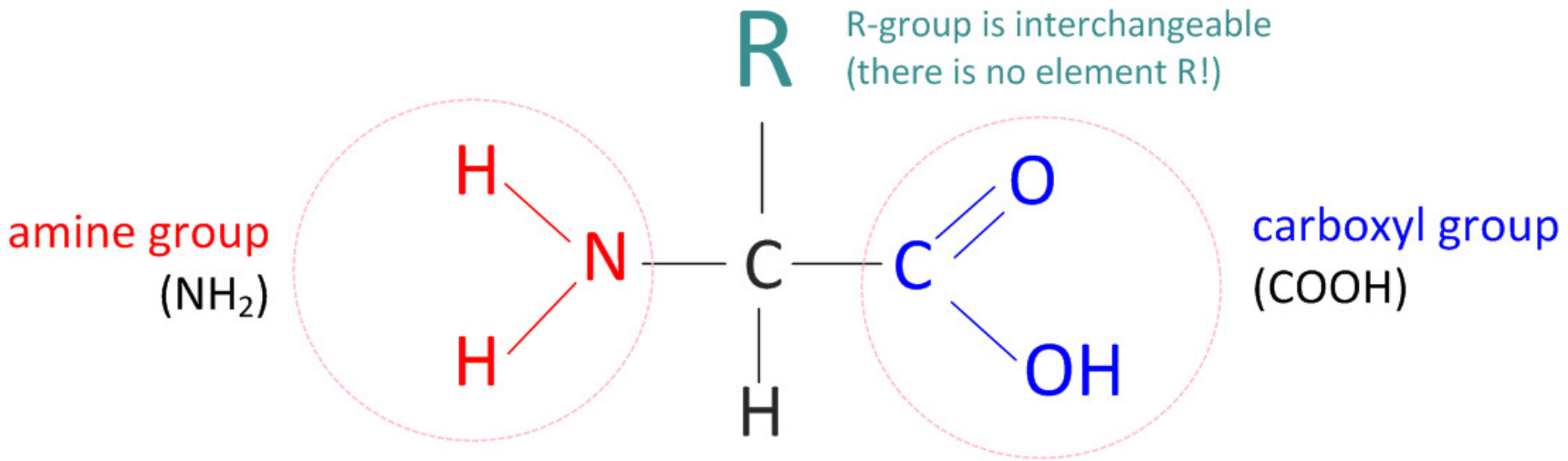
How and why are these investigations carried out under different experimental conditions?

http://www.youtube.com/watch?v=vccnaNSwUs4

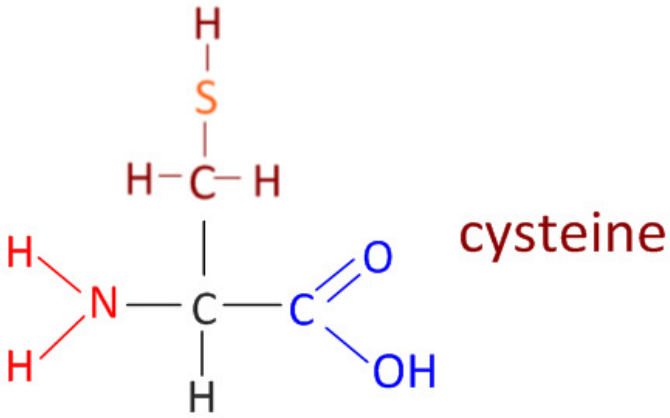
http://www.youtube.com/watch?v=R-aG4WdqiDU

Proteins
(Intro)

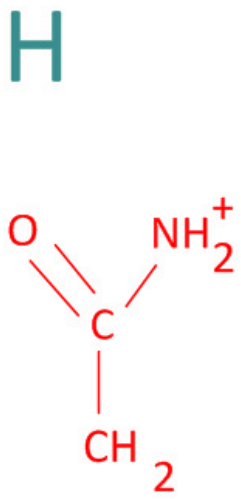
Amino acids are the *monomer* of proteins (polypeptides)



The R group is interchangeable - giving 20 different amino acids:



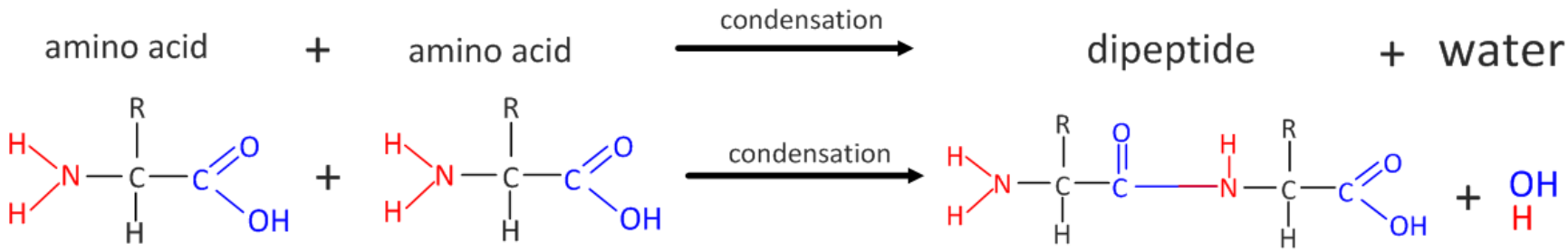
cysteine

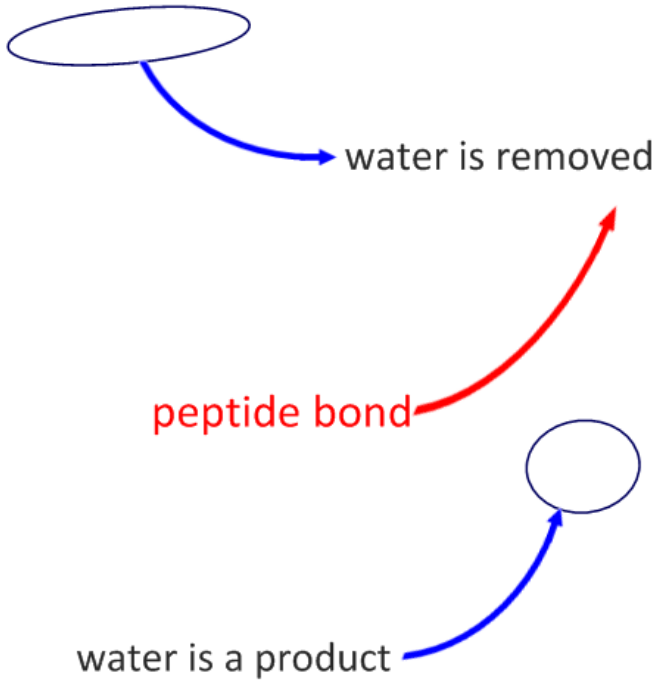


glycine

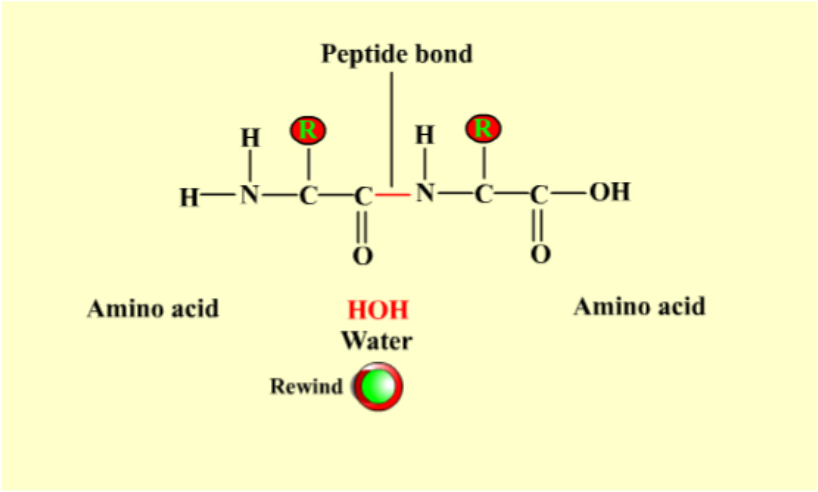
asparagine

Amino acids are the *monomer* of proteins (polypeptides)





Condensation forms a peptide bond:



http://www2.nl.edu/jste/proteins.htm

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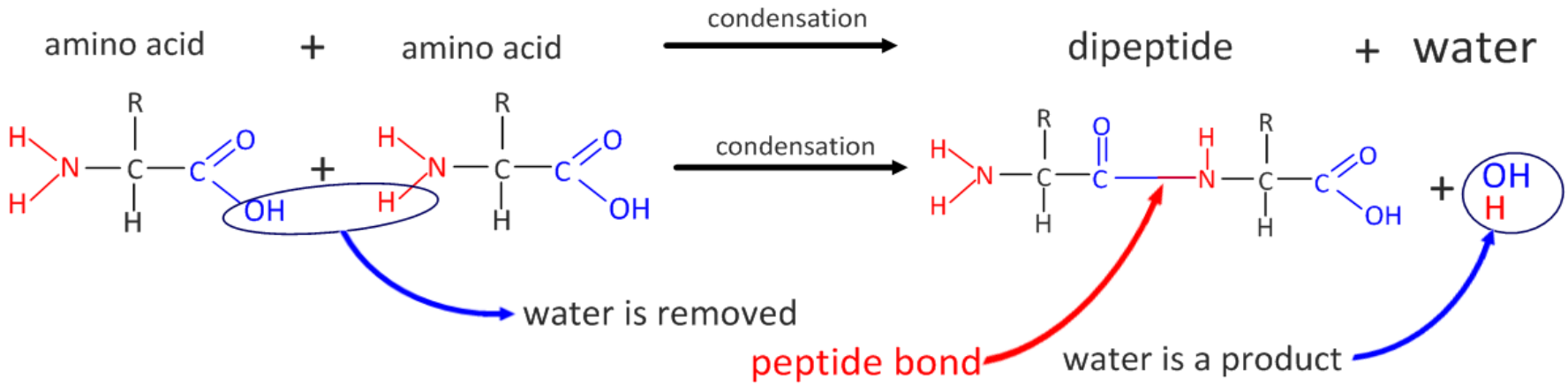

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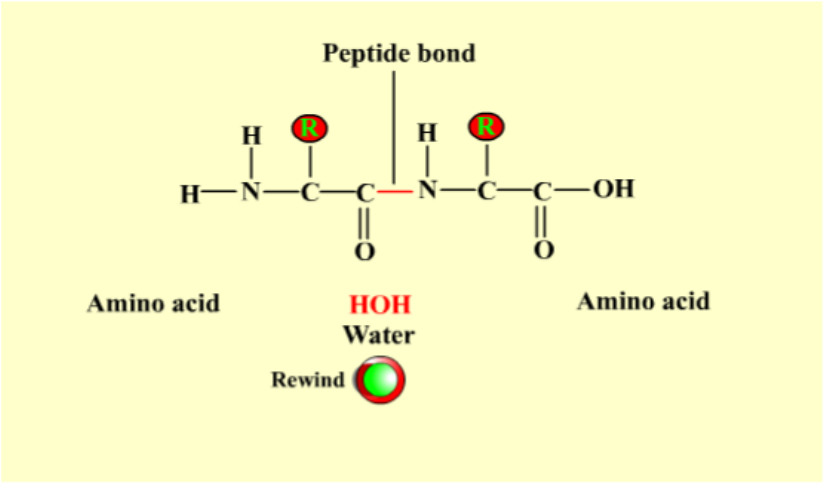
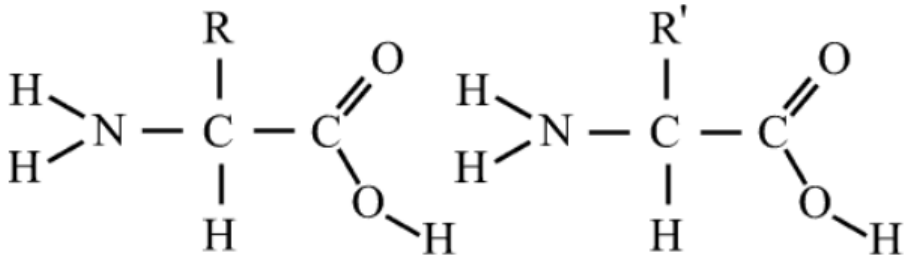


http://www2.nl.edu/jste/proteins.htm

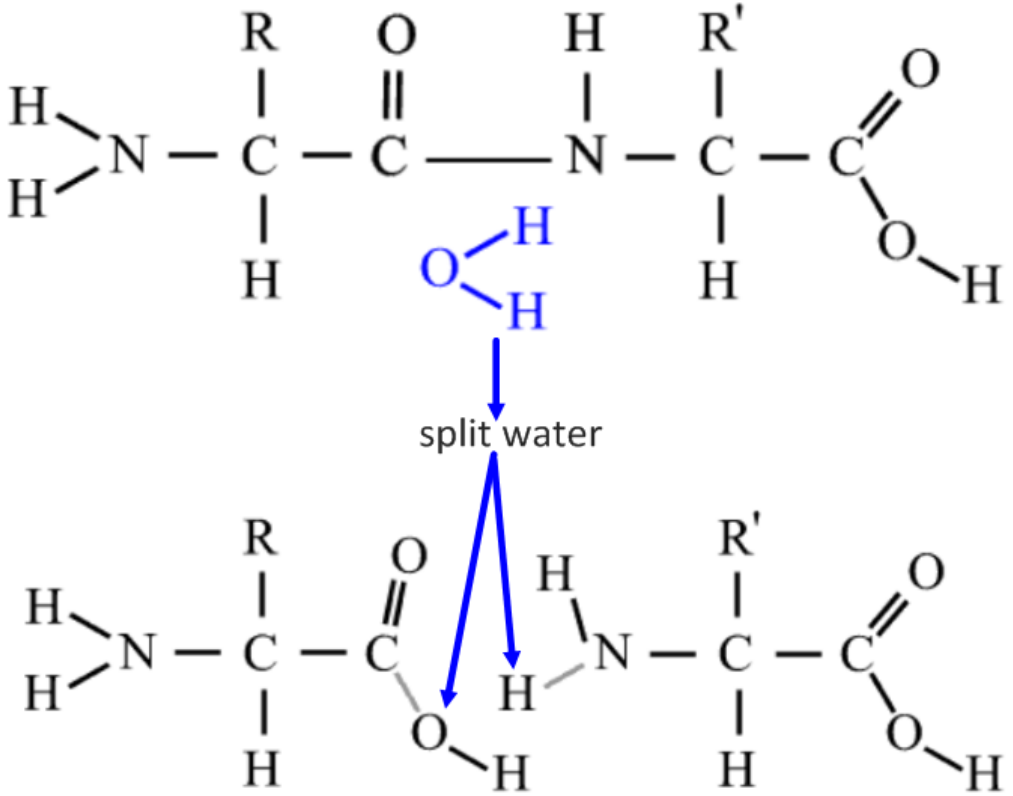
- http://www2.nl.edu/jste/proteins.htm

Hydrolysis is the reverse of condensation.

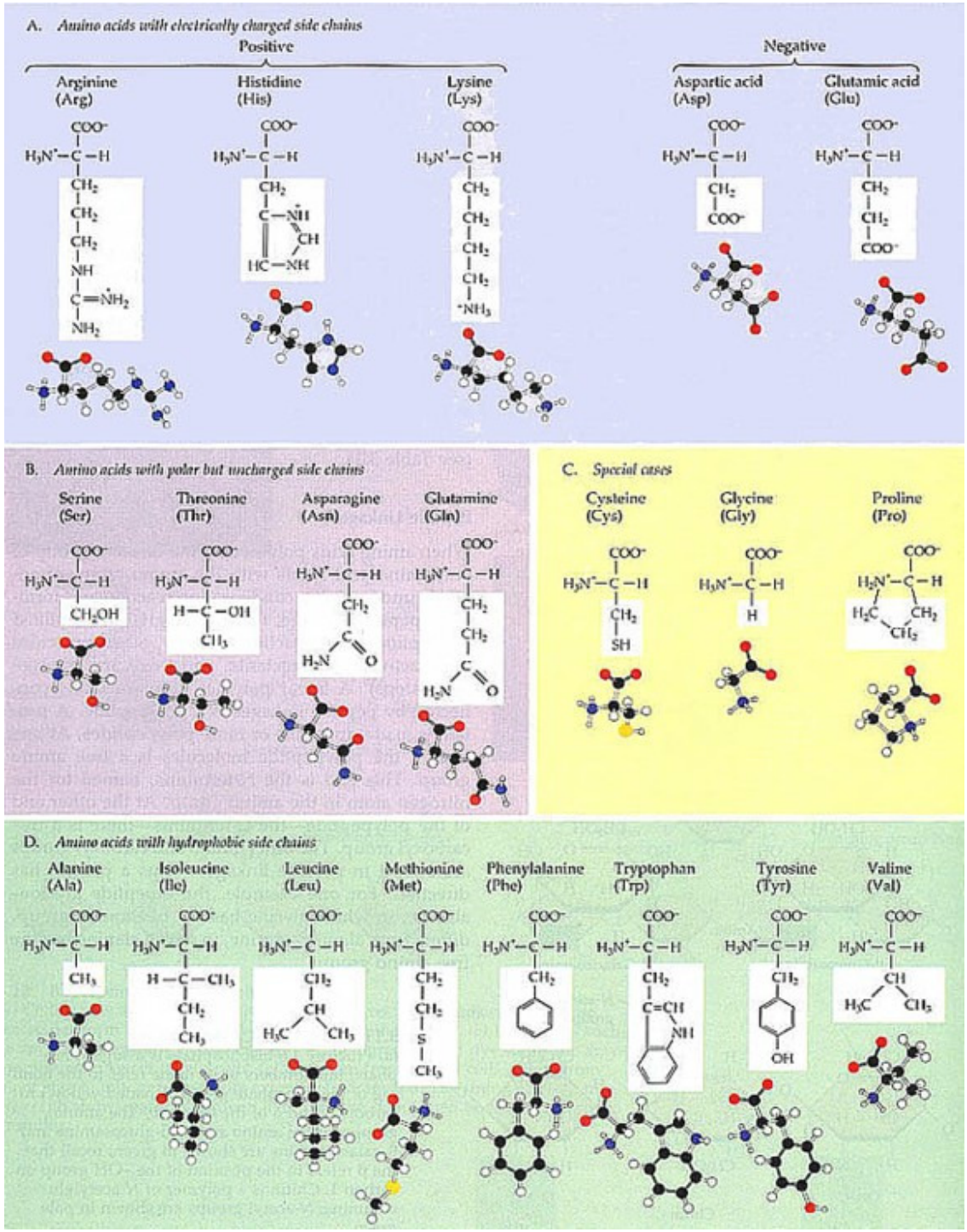
Water is split to break bonds apart.



Hydrolysis of dipeptides:



http://www.biotopics.co.uk/as/aminocon.html


A. Amino acids with electrically charged side chains
Positive
Negative
Arginine (Arg)
Histidine (His)
Lysine (Lys)
Aspartic acid (Asp)
Glutamic acid (Glu)
B. Amino acids with polar but uncharged side chains
Serine (Ser)
Threonine (Thr)
Asparagine (Asn)
Glutamine (Gln)
C. Special cases
Cysteine (Cys)
Glycine (Gly)
Proline (Pro)
D. Amino acids with hydrophobic side chains
Alanine (Ala)
Isoleucine (Ile)
Leucine (Leu)
Methionine (Met)
Phenylalanine (Phe)
Tryptophan (Trp)
Tyrosine (Tyr)
Valine (Val)

Essential Amino Acids?

- The amino acids regarded as essential for humans are phenylalanine, valine, threonine, tryptophan, isoleucine, methionine, leucine, lysine, and histidine.

- Additionally, cysteine (or sulphur-containing amino acids), tyrosine (or aromatic amino acids), and arginine are required by infants and growing children.

- Essential amino acids are "essential" not because they are more important to life than the others, but because the body does not synthesize them, making it essential to include them in one's diet in order to obtain them.

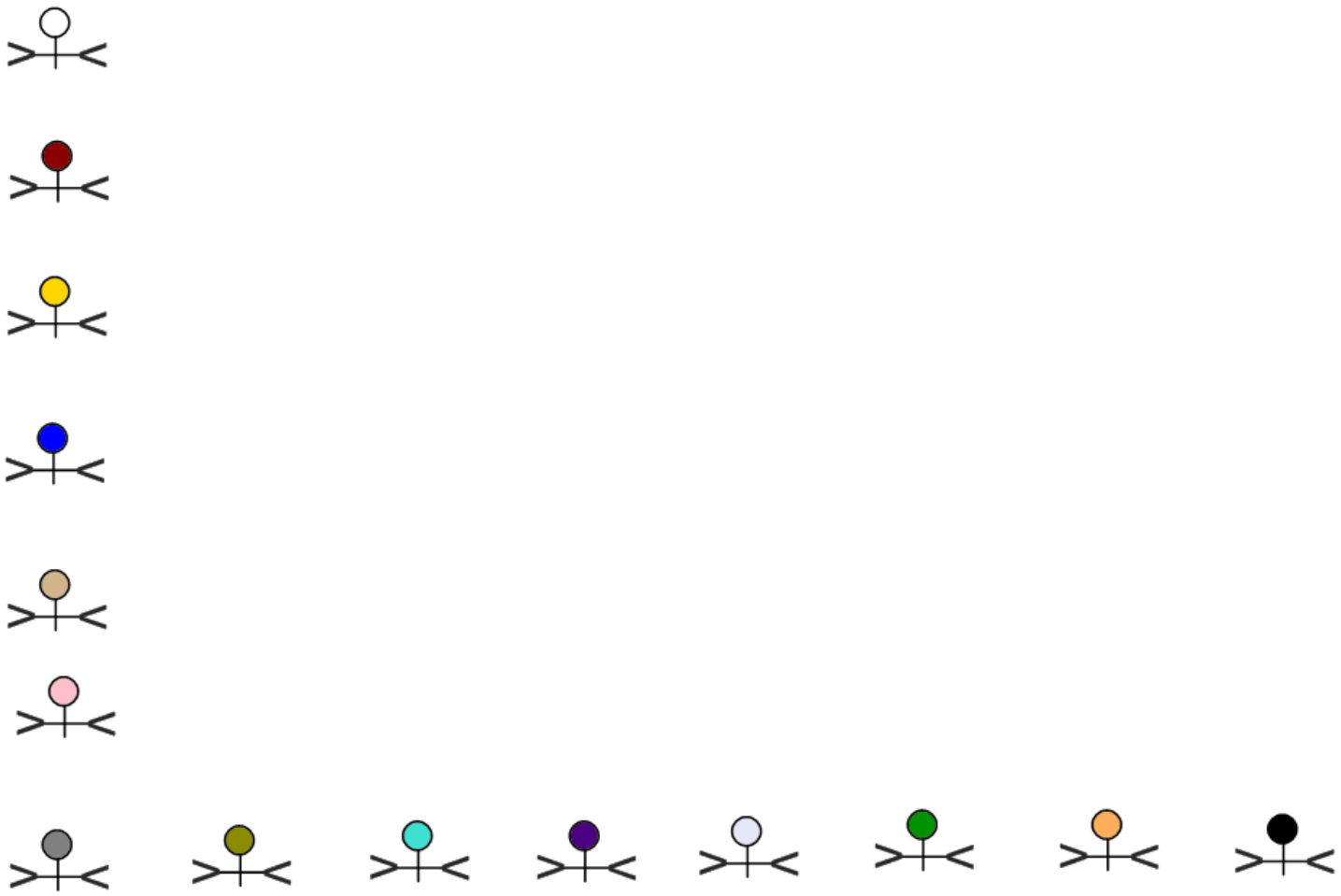
- In addition, the amino acids arginine, cysteine, glycine, glutamine, histidine, proline, serine and tyrosine are considered **conditionally essential**, meaning they are not normally required in the diet, but must be supplied to specific populations that do not synthesize it in adequate amounts.

PKU

- An example would be with the disease phenylketonuria (PKU). Individuals living with PKU must keep their intake of phenylalanine extremely low to prevent mental retardation and other metabolic complications. However, they cannot synthesize tyrosine from phenylalanine, so tyrosine becomes essential in the diet of PKU patients.

Why are there infinite possibilities of polypeptides?

- could be any length - 20 amino acids - amino acids in any order or combination



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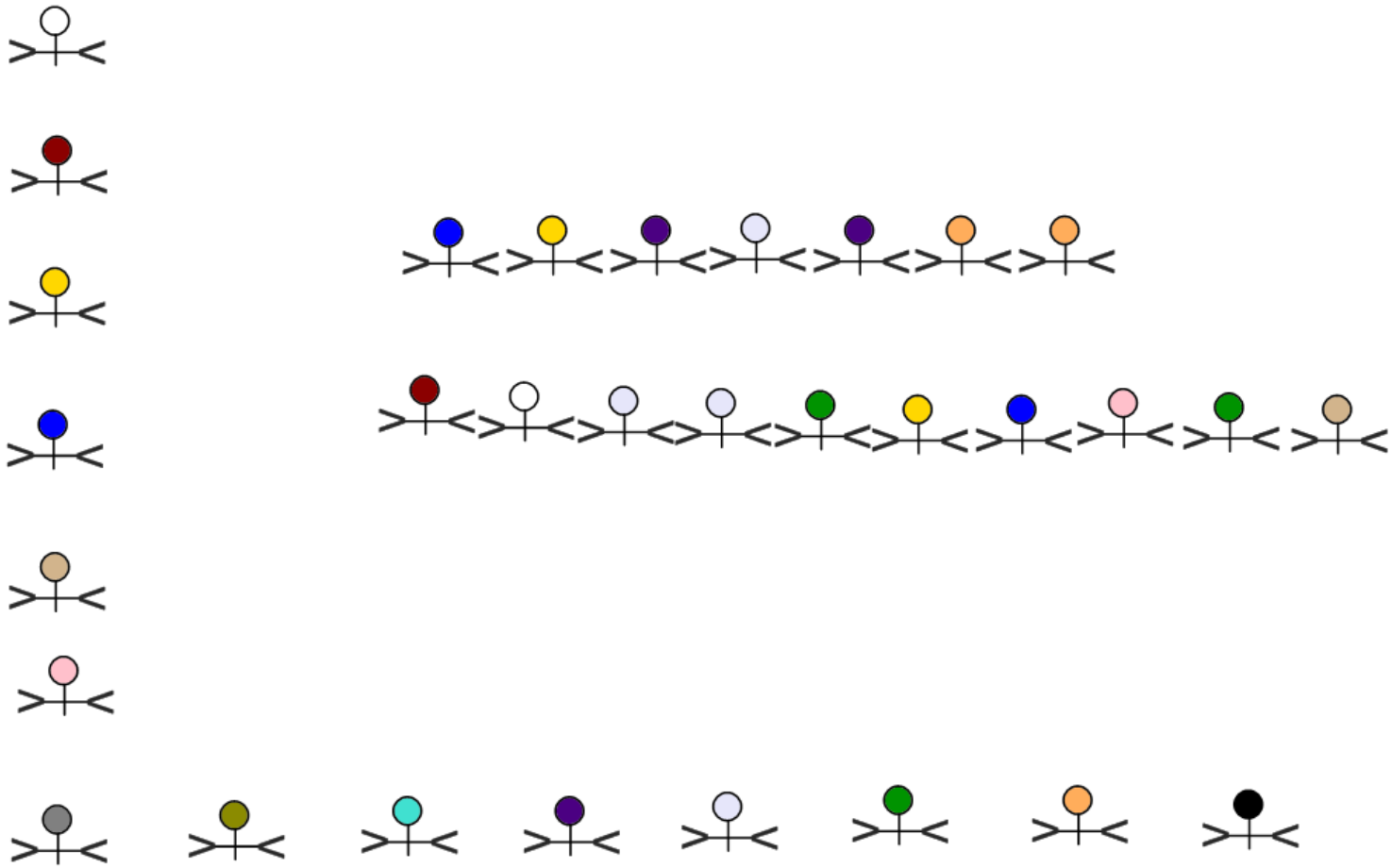
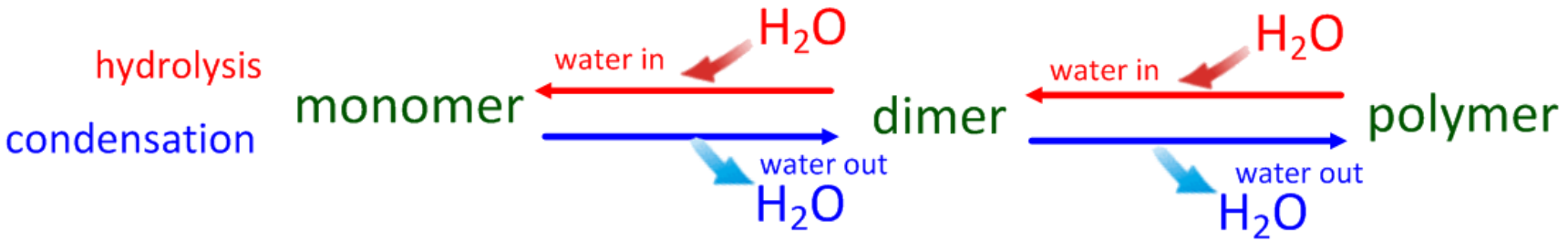


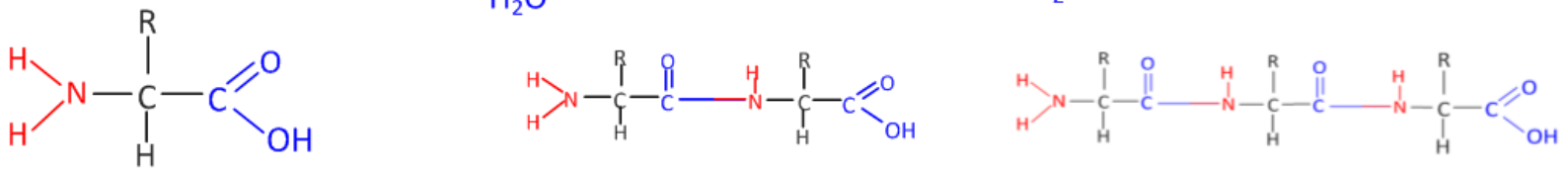
Summary of condensation and hydrolysis reactions:



proteins

amino acid $\rightleftharpoons$ dipeptide $\rightleftharpoons$ polypeptide

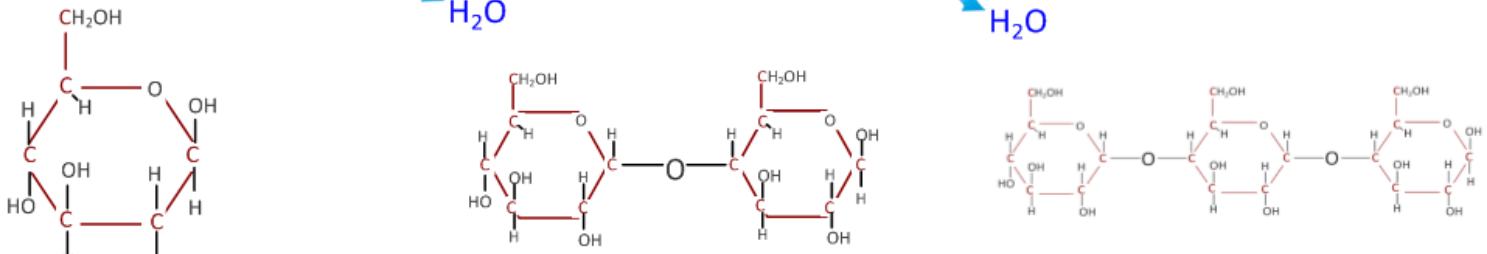
(H_2O in / H_2O out)



carbohydrates

monosaccharide $\rightleftharpoons$ disaccharide $\rightleftharpoons$ polysaccharide

(H_2O in / H_2O out)



How do carbohydrates, fats and proteins compare?

Carbohydrates	Fats	Proteins
17 kJ g^{-1}	38 kJ g^{-1}	13 kJ g^{-1}
quickly digested and used: excess stored as fat	used for storage (most efficient)	digested quickly used in muscle
fast release of energy	slow release of energy	muscles use energy! (mitochondria)
needs less oxygen to release energy (ideal for oxygen-debt, or high-impact exercise)	needs more oxygen to release energy	muscle is lost when calories are restricted

http://en.wikipedia.org/wiki/Food_energy

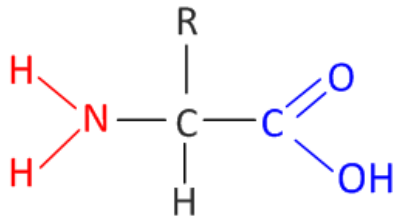
Review check

For each of carbohydrates, proteins and lipids can you...?

1. Identify, draw and name the monomers?
2. Outline the reactions to join molecules together?
3. Outline the reactions to break polymers down?
4. Outline their role in energy storage?
5. State their functions?

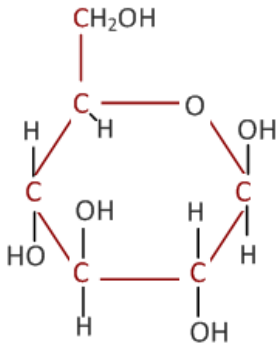
ChemSketching organic molecules:

Can you draw, 3D render and animate these molecules?



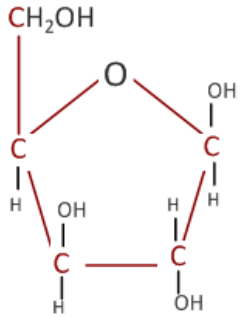
amino acids

(choose your own)



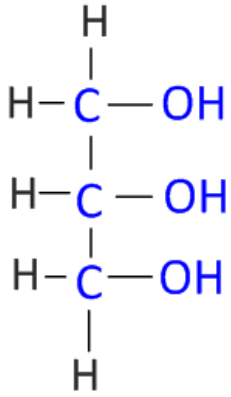
glucose

OR



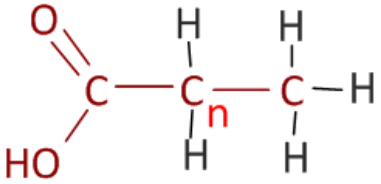
ribose

How about making a triglyceride?



glycerol

3 x



fatty acids

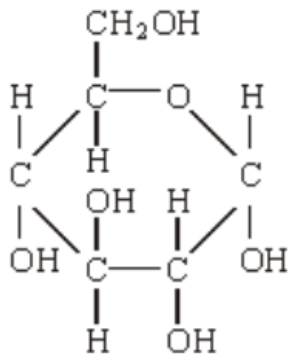
Get the sofware here:

http://www.acdlabs.com/download/

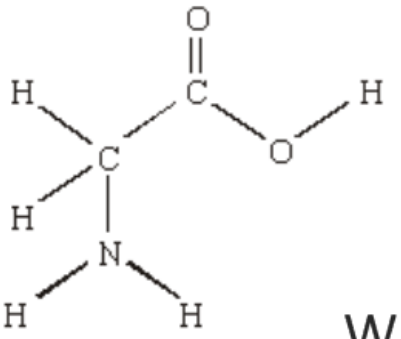
Which molecule represents ribose?

Past paper question

A.

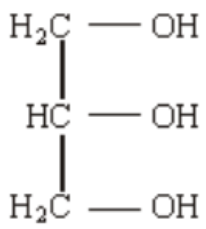


B.

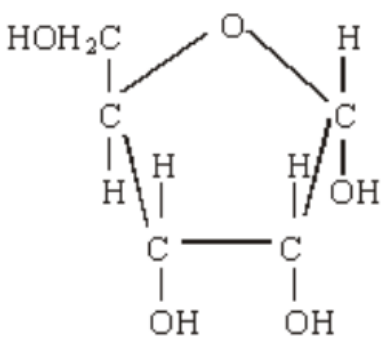


What is molecule B?

C.



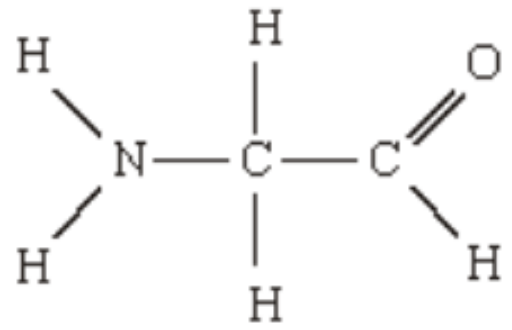
D.



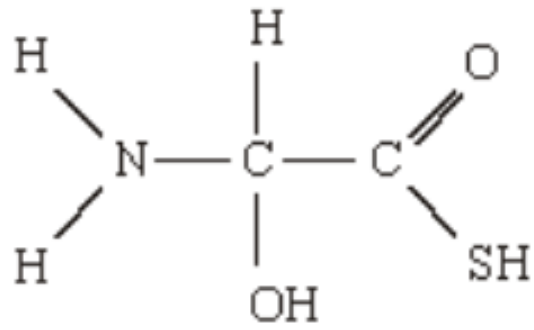
What is molecule C?

Which structure represents an amino acid?

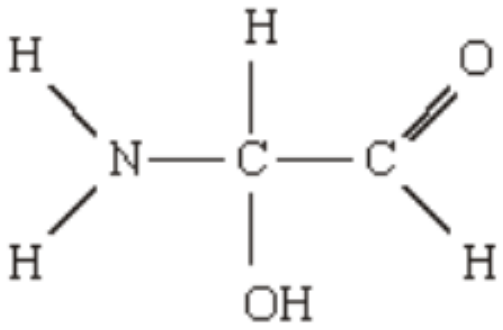
A.



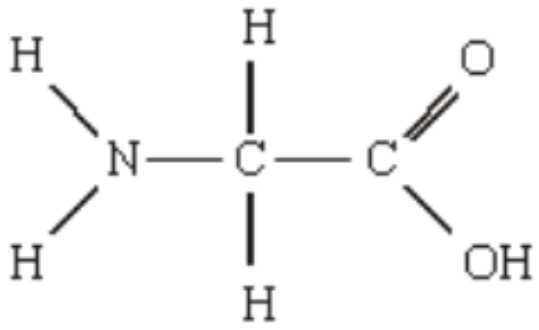
B.



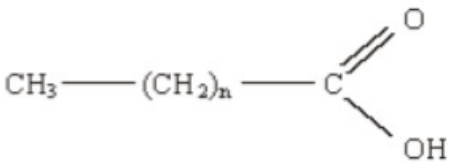
C.



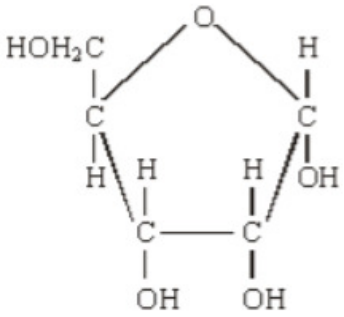
D.



I.



II.



Past paper question

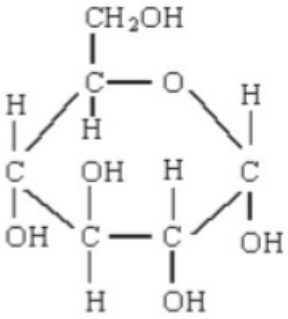
Which molecule is:

i. ribose

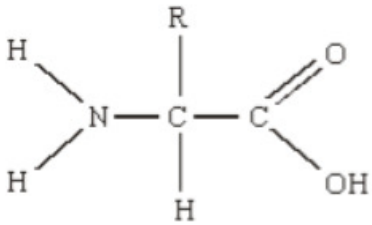
ii. generalised fatty acid

iii. generalised amino acid

III.



IV.



Discuss which two molecules are most similar in structure.