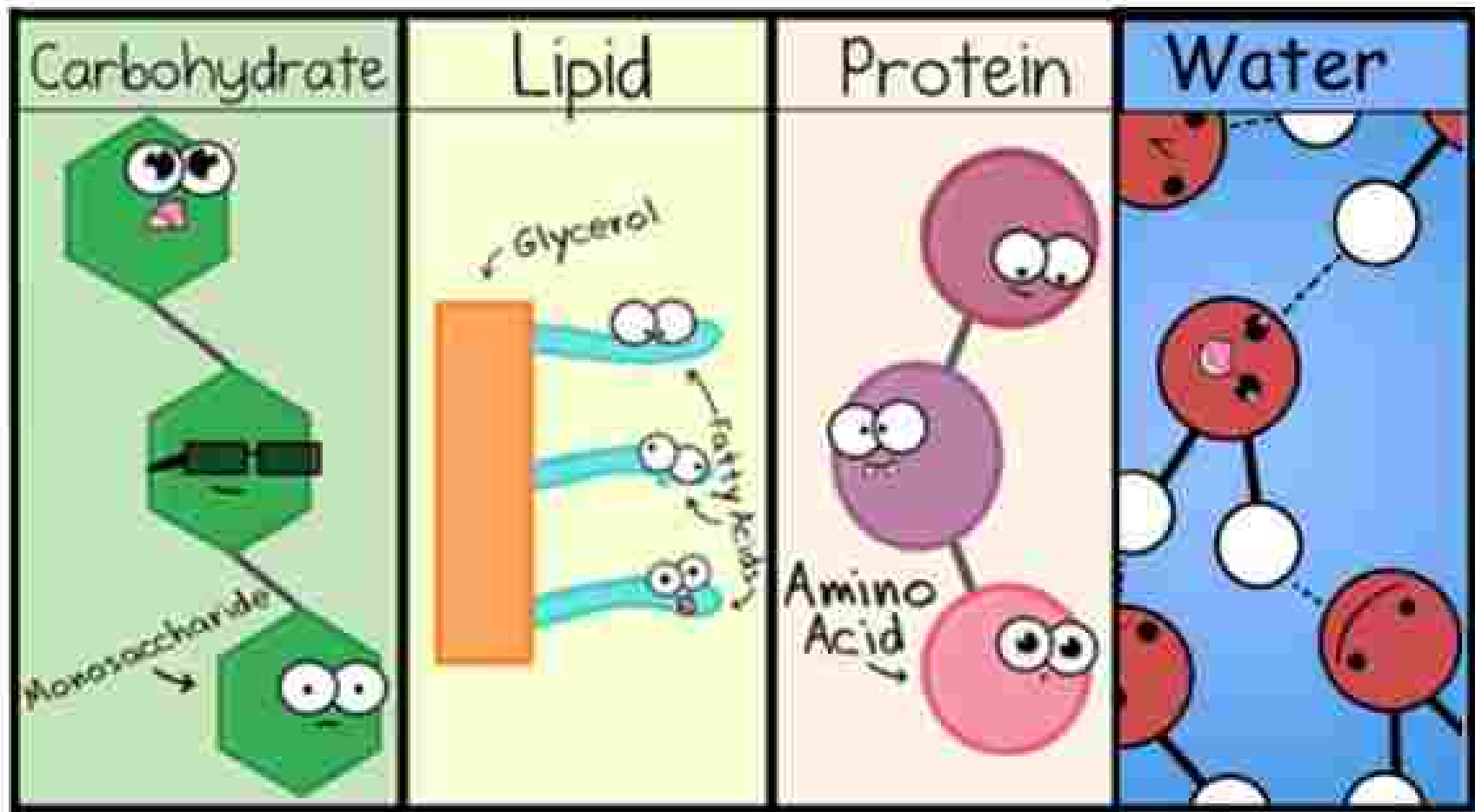




# Biological Molecules



# Chapter Outline

Monomer to Polymer  
Hydrolysis and Condensation

## Carbohydrates

- Monosaccharide, disaccharide and polysaccharide
- Glycosidic bond
- Starch (amylose and amylopectin)
- Glycogen
- Cellulose
- Benedict's Test / Iodine Test

## Lipids

- Glycerol + 3 Fatty acids
- Ester bond
- Triglycerides
- Phospholipids
- Emulsion Test

## Protein

- Amino acids
- Peptide bond
- Primary to quaternary structure
- Globular vs Fibrous proteins
- Haemoglobin
- Collagen
- Biuret Test

## Water

- Hydrogen bond

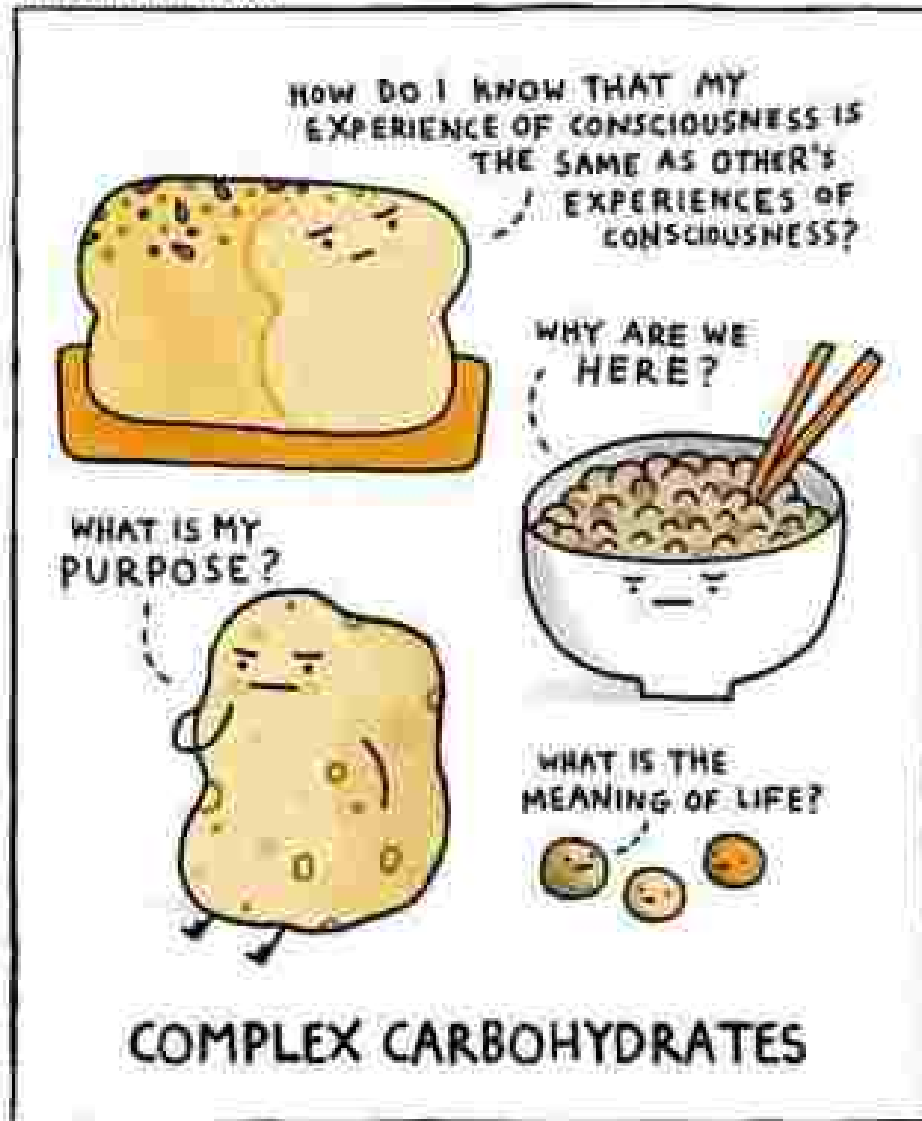


**YOU  
ARE  
WHAT  
YOU  
EAT**

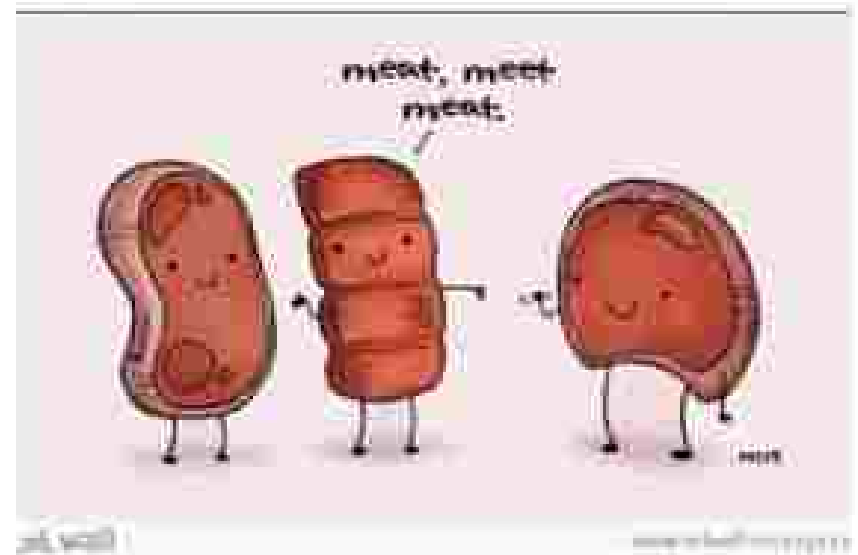
# Carbohydrates

## MONDAY PUNDAY

BY GEMMA CORRELL  
WWW.GEMMAIDRELL.COM



# Proteins



# Lipids



# The Building Blocks of Life

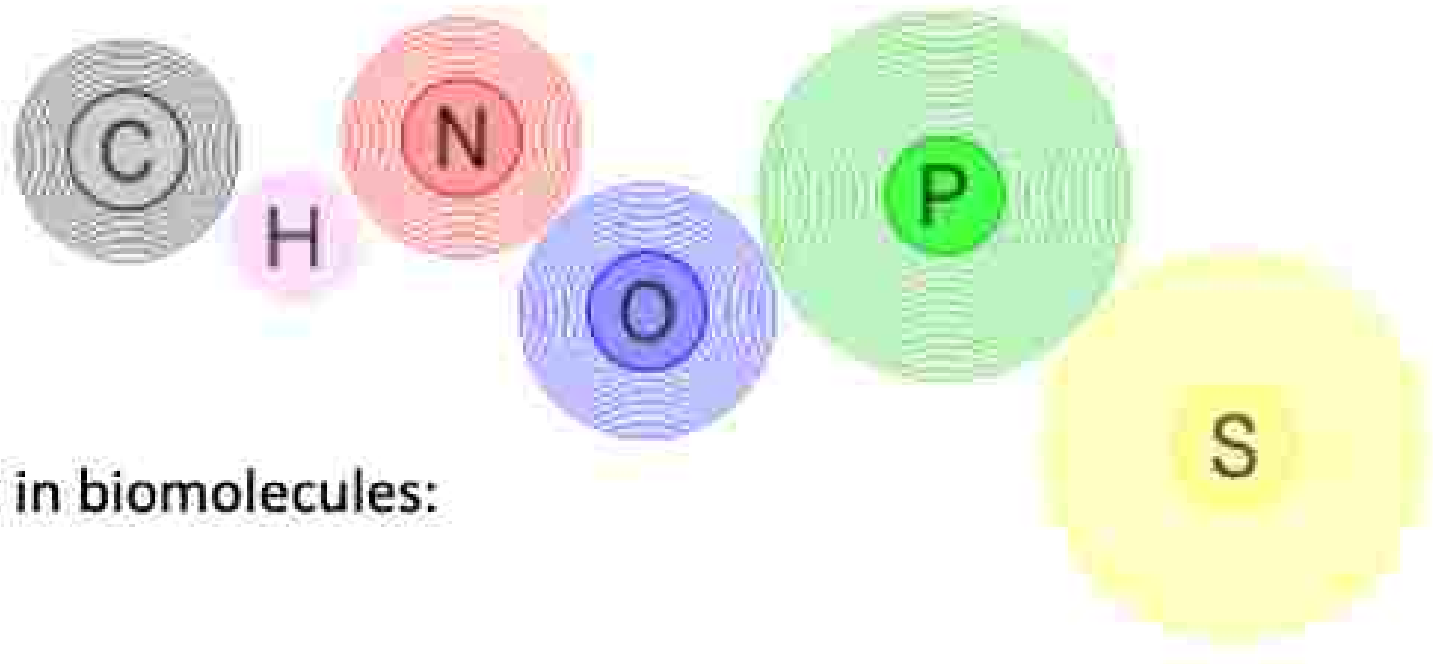
4 most common elements in living organisms:

**C**arbon

**H**ydrogen

**O**xygen

**N**itrogen



Also common in biomolecules:

**P**hosphorus

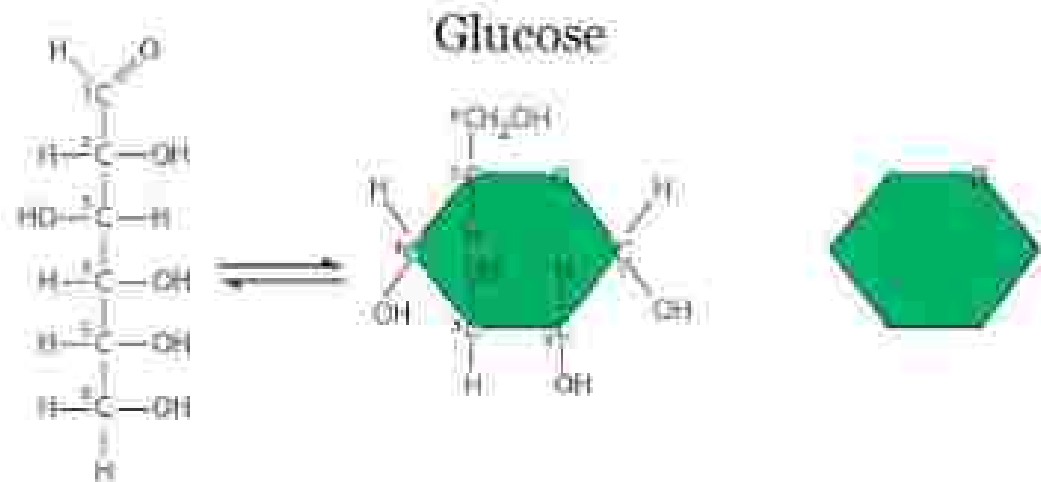
**S**ulphur

# Monomers

- Elements make up **monomers**
- **Simplest repeating unit of a polymer**

E.g. of monomers:

- Monosaccharides  
(carbohydrate monomers)
- Amino acids
- Nucleotides
- Fatty acids, Glycerol



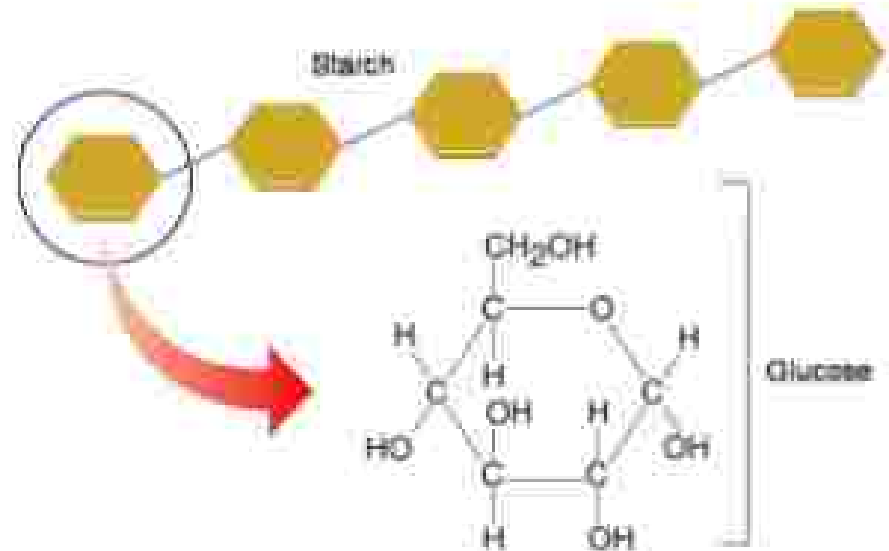
# Polymers

- Polymers are made of

1) **Repeating monomers**

2) Joined **end to end**

→ In a process called **polymerisation**



E.g. of polymers:

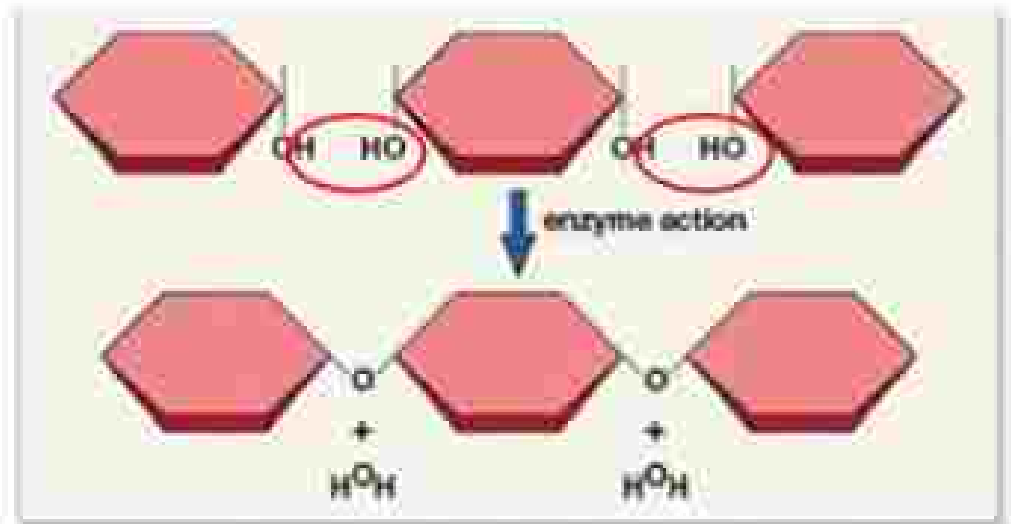
- Polysaccharides – carbohydrates
- Polypeptides – protein
- Polynucleotides – nucleic acids

- Polymers can become so large in size → **macromolecule**
- Giant molecule**

# Condensation and Hydrolysis

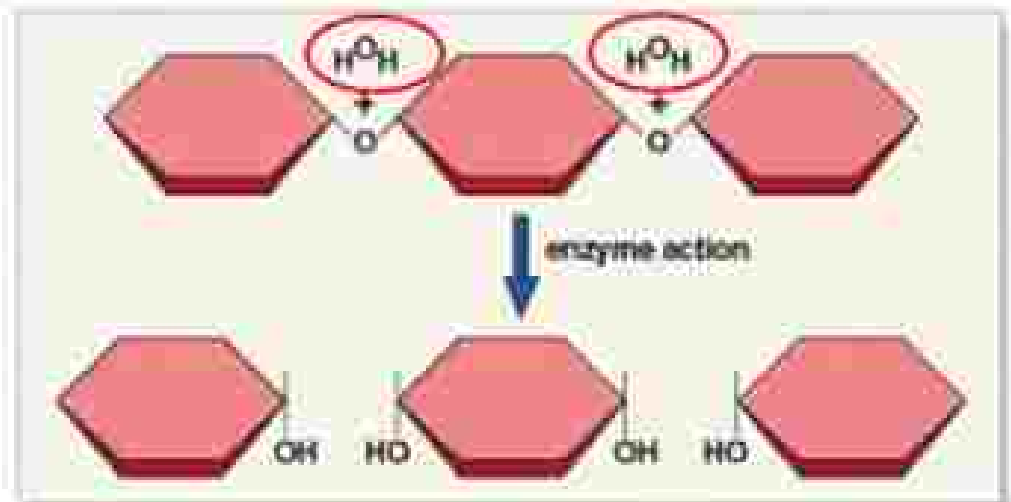
## Condensation:

- Two molecules combine
- Removal of water



## Hydrolysis:

- Molecule breaks down
- Addition of water





# CARBOHYDRATES

---





# Carbohydrates

- Made of **C, H, O**
- General formula:  $C_x(H_2O)_y$

3 groups:

1) Monosaccharides



2) Disaccharides



3) Polysaccharides



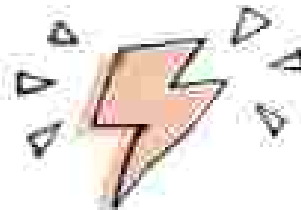
# Carbohydrates

## Roles of Carbohydrates in Living Organisms

### 1) Source of energy in respiration

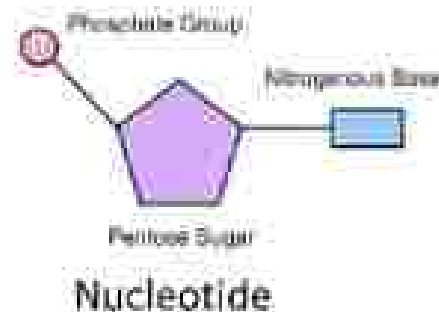
Eg: Starch, glycogen

High C-H bonds  $\rightarrow$  energy  $\rightarrow$  ATP



### 2) Building blocks for larger molecules

Eg: RNA, DNA, ATP, glycoproteins and glycolipids in plasma membranes



### 3) Structural support

Eg: Cellulose



# Carbohydrates

## Monosaccharides

- Single sugar molecule
- **Soluble, sweet**
- Molecular formula:  $C_nH_{2n}O_n$

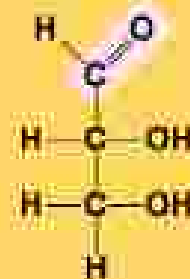


Classified according to the number of carbon atoms:

- 3C – triose ( $C_3H_6O_3$ )
- 5C – pentose ( $C_5H_{10}O_5$ )
- 6C – hexose ( $C_6H_{12}O_6$ )

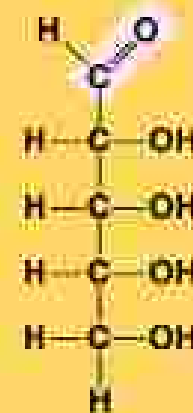
### Structural formula

**Triose sugars**  
( $C_3H_6O_3$ )



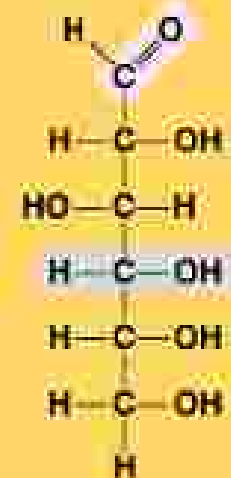
Glyceraldehyde

**Pentose sugars**  
( $C_5H_{10}O_5$ )



Ribose

**Hexose sugars**  
( $C_6H_{12}O_6$ )

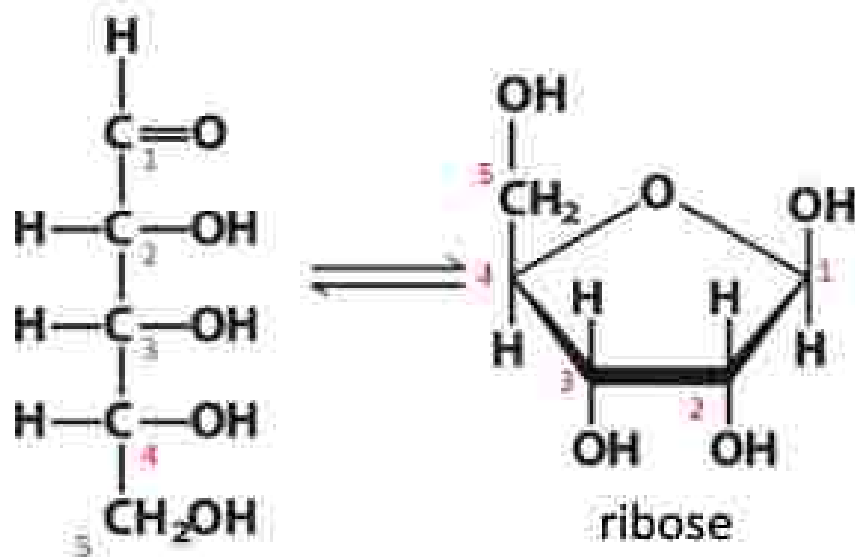


Glucose

# Carbohydrates

## Linear Structures vs Ring Structures

- In pentose and hexose sugars (5C and 6C)
  - Chain of carbon atoms are long enough to close up on itself
  - **Ring structure**
  - **More stable**, more common

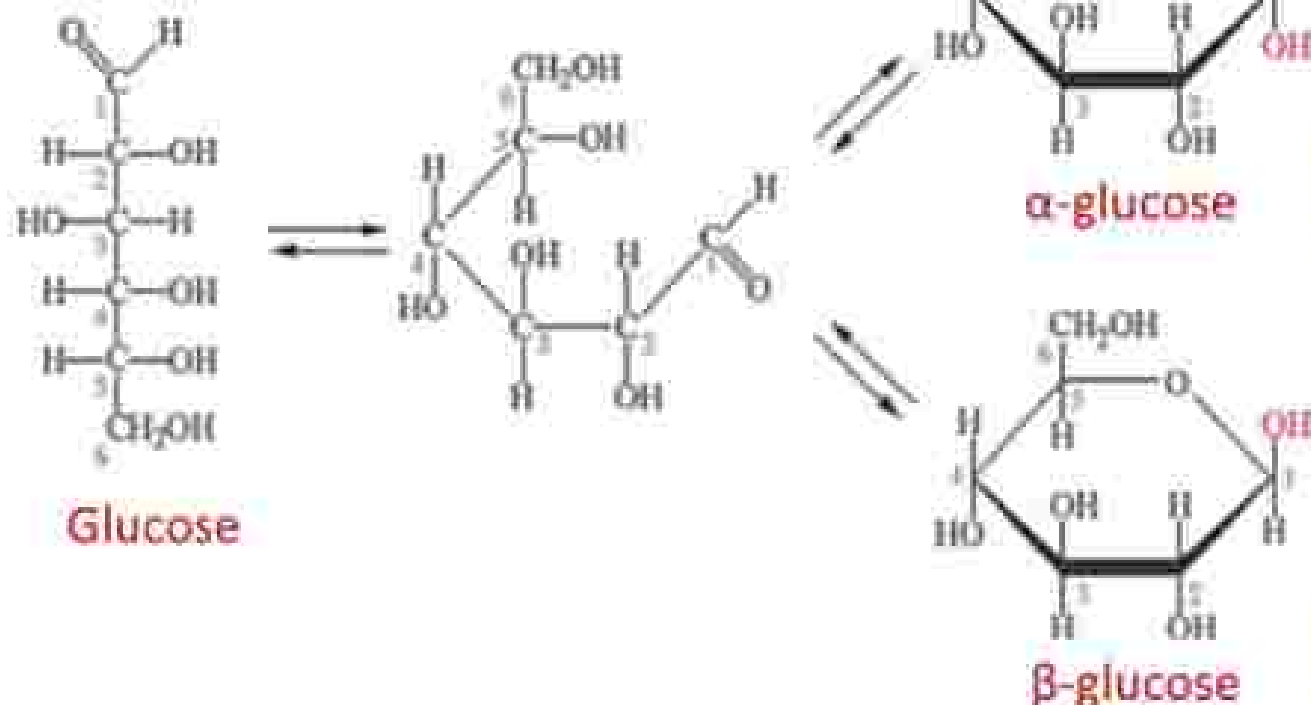


# Carbohydrates

## Ring Structures of Glucose

- Close up at C1 and C5
- Has 2 isomers:  **$\alpha$ -glucose** and  **$\beta$ -glucose**
- Same molecular formula ( **$C_6H_{12}O_6$** ), same chemical substance, different form

You need to remember how to draw the ring structure of  **$\alpha$ -glucose** and  **$\beta$ -glucose**!

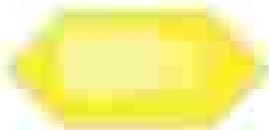


# Carbohydrates

## Disaccharides

### MONOSACCHARIDES

GALACTOSE



FRUCTOSE



GLUCOSE



### DISACCHARIDES



LACTOSE



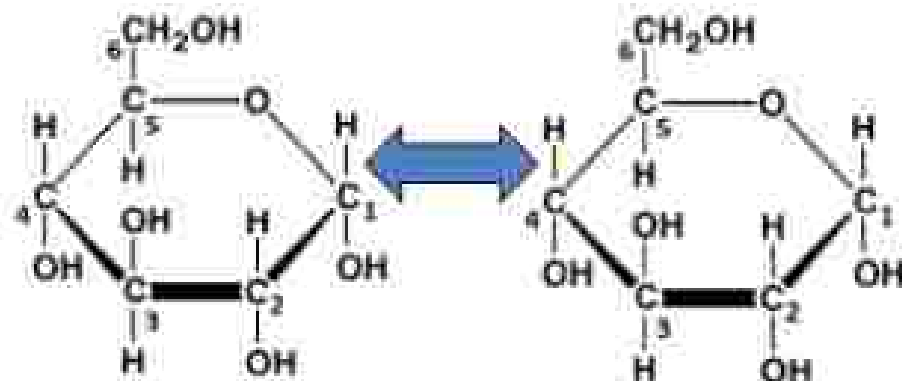
MALTOSE



SUCROSE

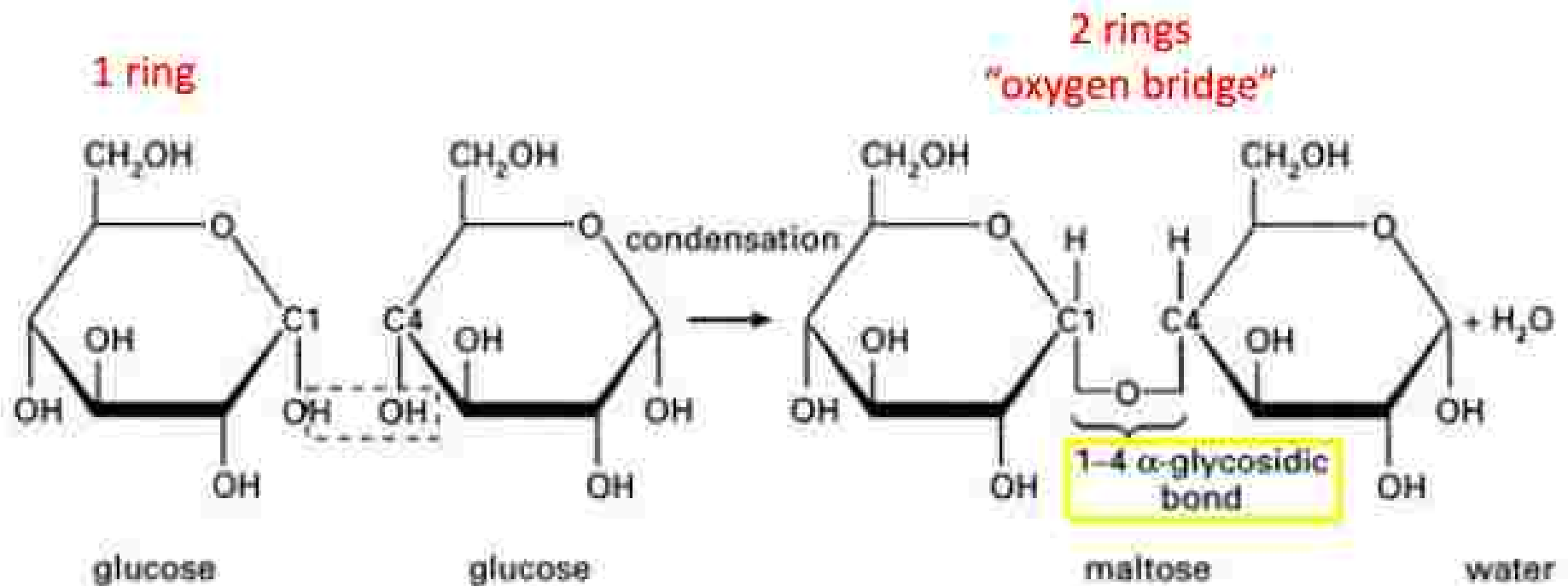
# Carbohydrates

## Disaccharides



- Soluble, sweet
- Formed from 2 monosaccharides
- Through a process called **condensation**
- 1 hydroxyl group (-OH) + hydrogen atom (H)  
→ **Produce 1 water molecule (H<sub>2</sub>O)**
- **Glycosidic bond** formed – this is a covalent bond
- Break down of disaccharides to monosaccharides  
→ **Hydrolysis**  
→ **Require addition of water**
- Both reactions controlled by enzymes

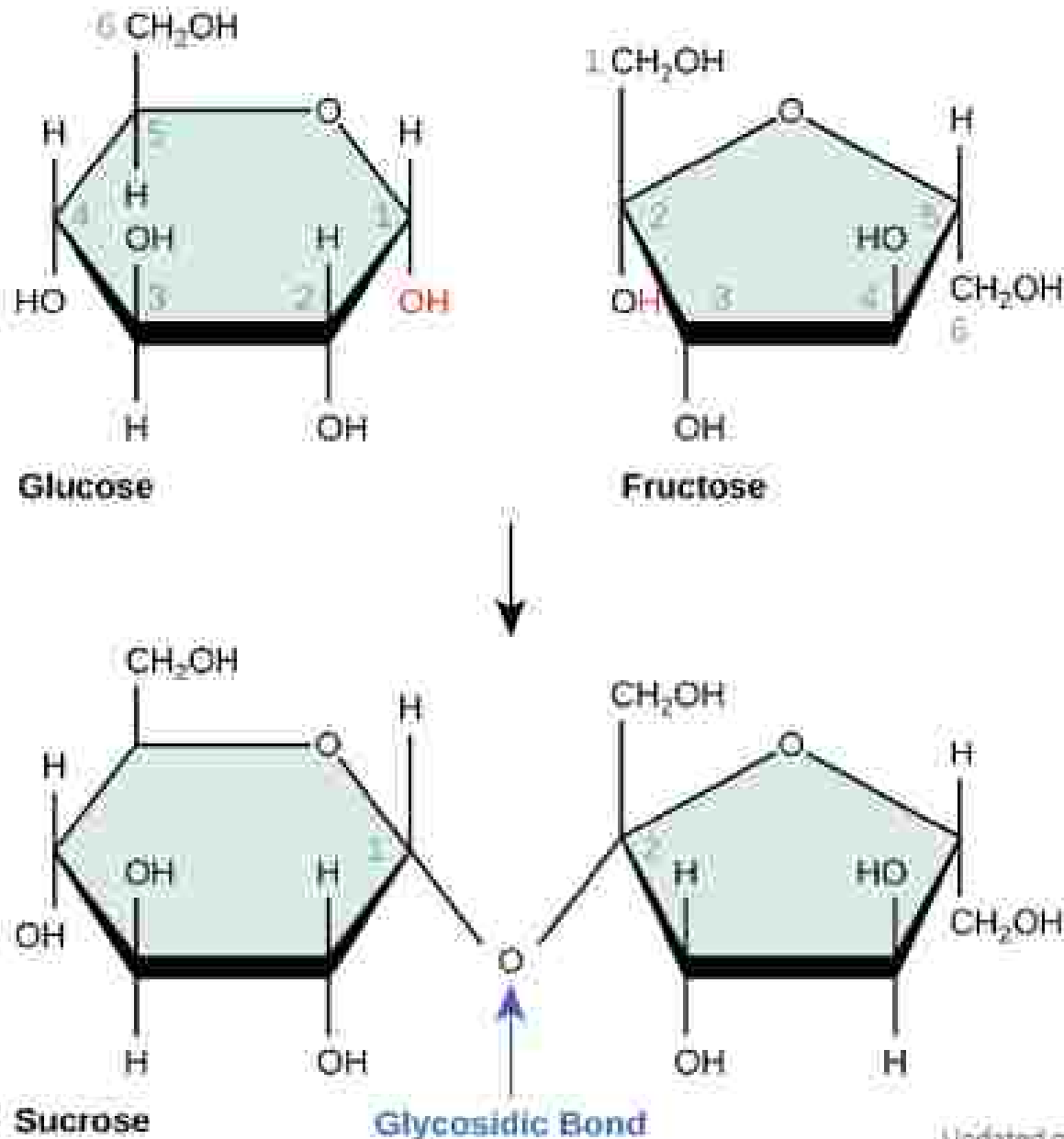
# Formation of Disaccharide - Maltose



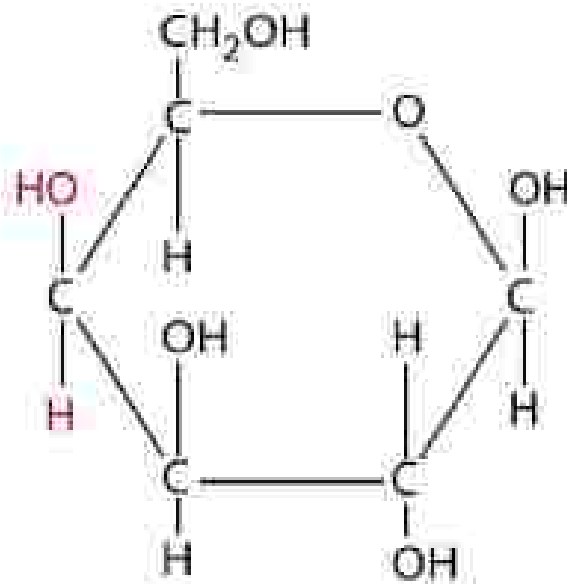
You need to know how to draw products of condensation / hydrolysis reactions!



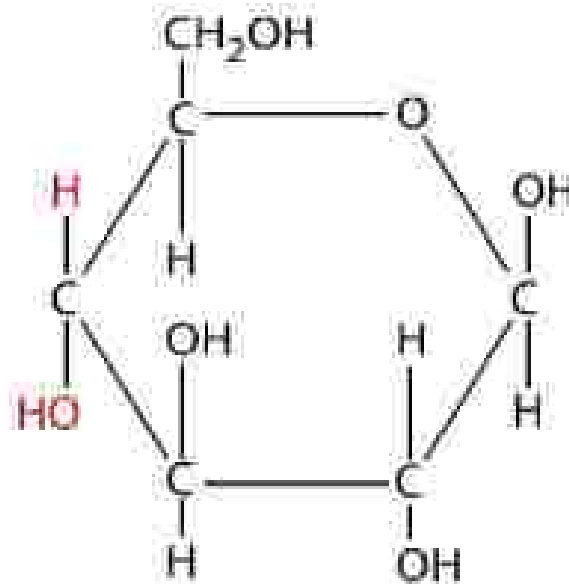
# Formation of Disaccharide - Sucrose



# Formation of Disaccharide - Lactose



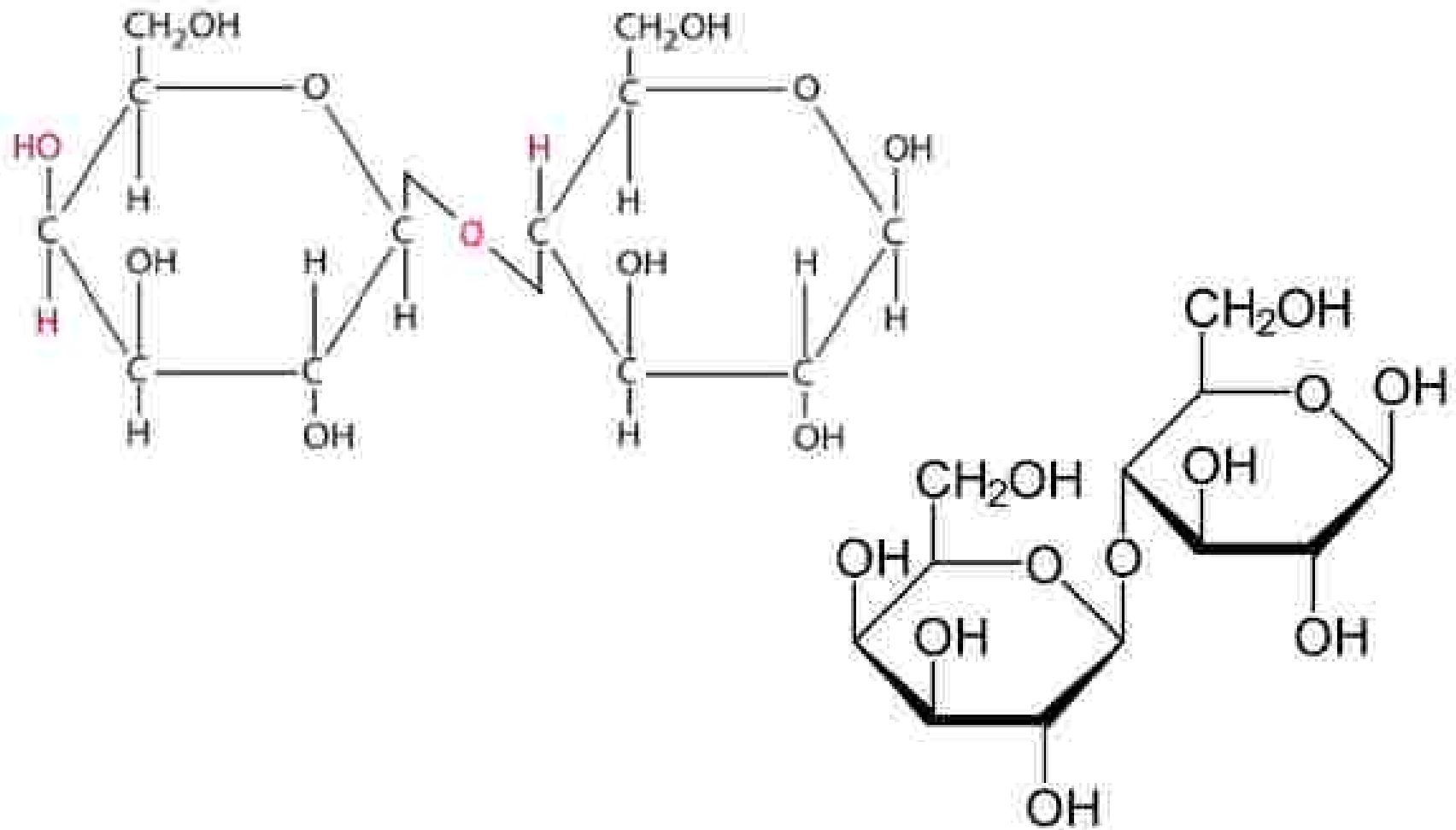
Galactose



Glucose

- Draw the structural formula of lactose.

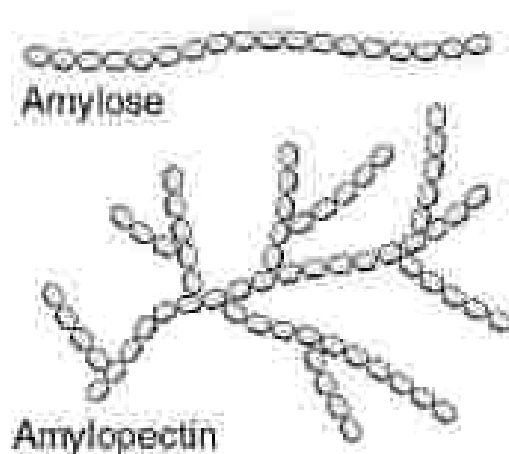
# Formation of Disaccharide - Lactose



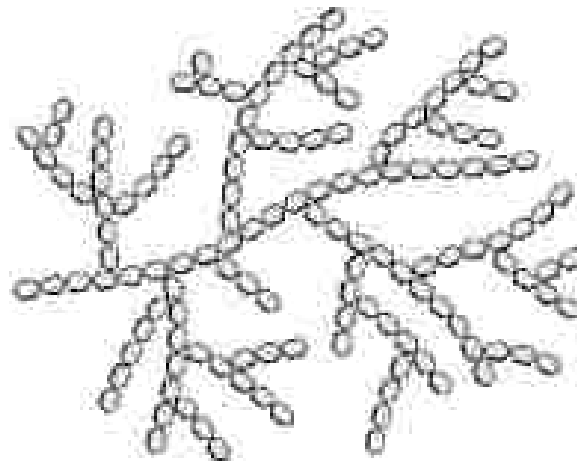
# Carbohydrates

## Polysaccharides

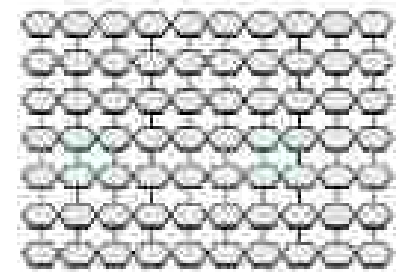
- Polymers / macromolecules
- Made via **condensation**
- **Glycosidic bonds**
- Not sugars → **not sweet, insoluble**
- E.g. **Starch, glycogen, cellulose**



Starch



Glycogen



Cellulose (fiber)

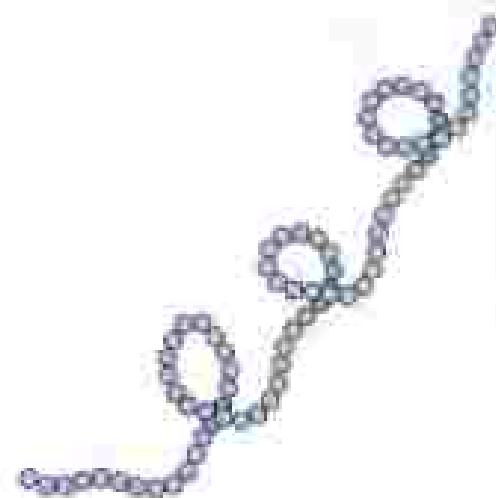
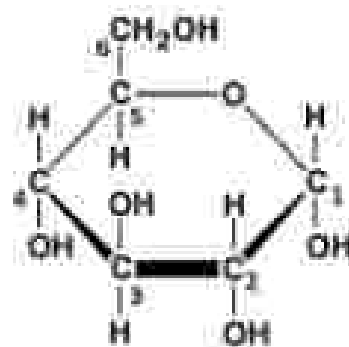
# Carbohydrates

## Polysaccharides - Starch

- **Storage molecule in plants**
- Food reserve
- Amylose + amylopectin

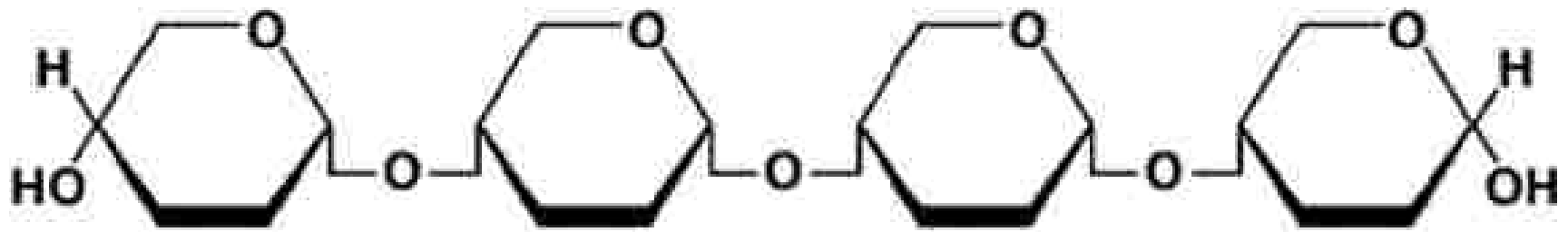
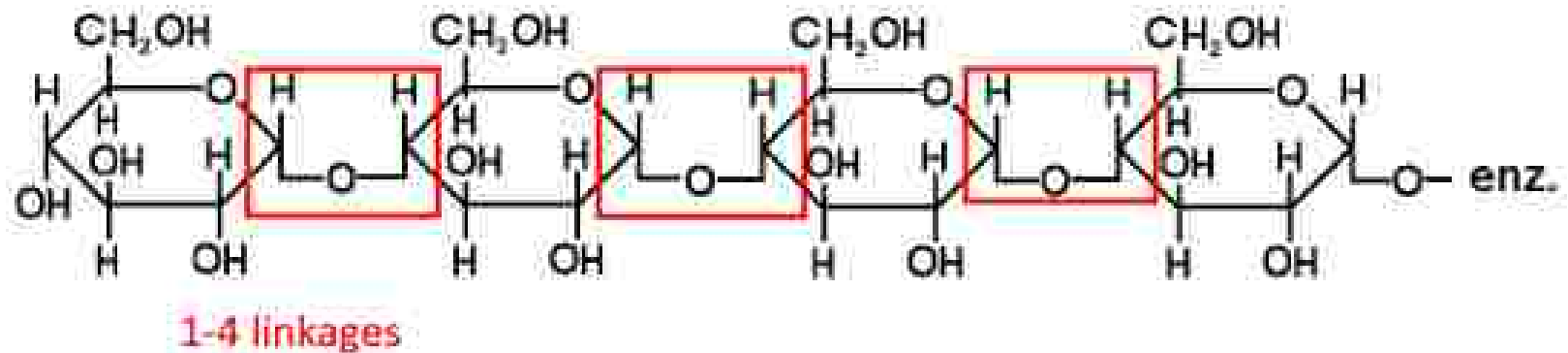
### 1) Amylose

- Made from  **$\alpha$ -glucose** molecules
- Linked by 1-4 glycosidic bonds
- Long, **helical**
- **Unbranched**, linear chain



# Carbohydrates

## Polysaccharides - Starch



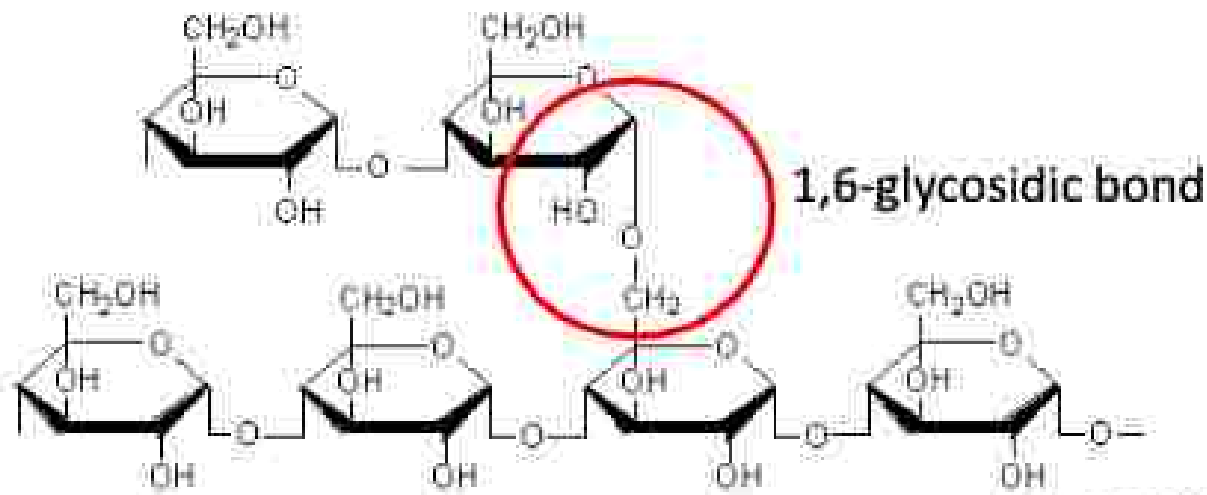
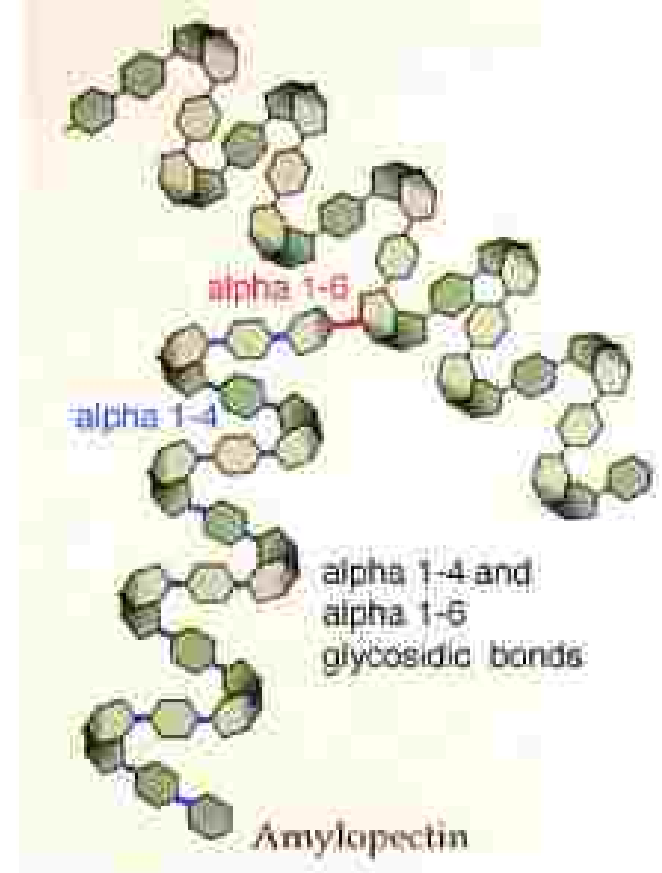
**Amylose**

# Carbohydrates

## Polysaccharides - Starch

### 2) Amylopectin

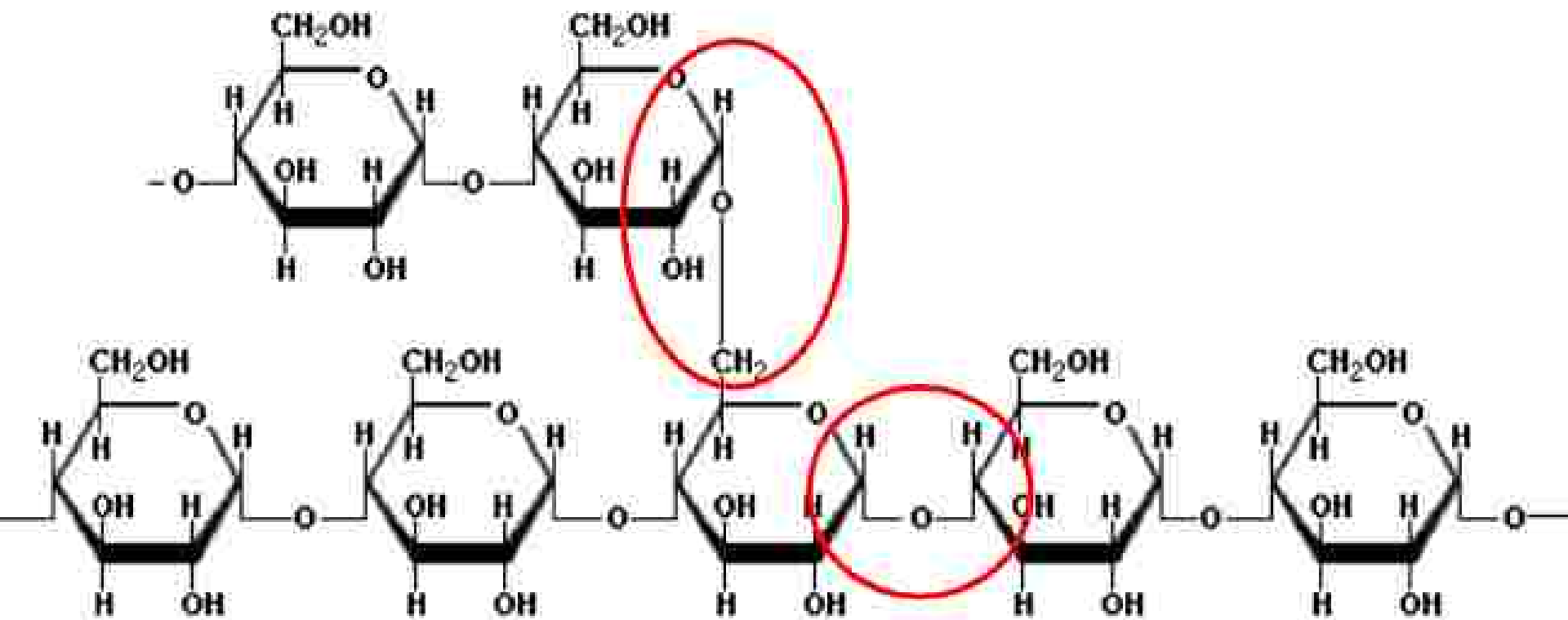
- **Branched** molecule
- Made of  $\alpha$ -glucose molecules
- **1-4 and 1-6 glycosidic bonds**
- **Branches are at 1-6 linkages**
- Shorter chains



# Carbohydrates

## Polysaccharides - Starch

Amylopectin





# Testing the Presence of Starch

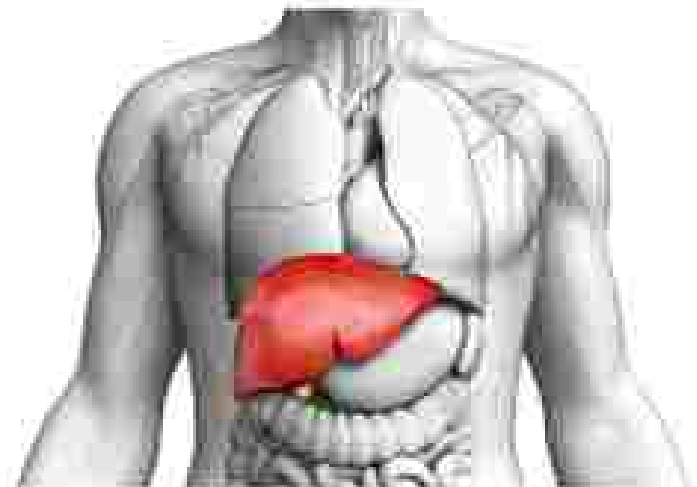
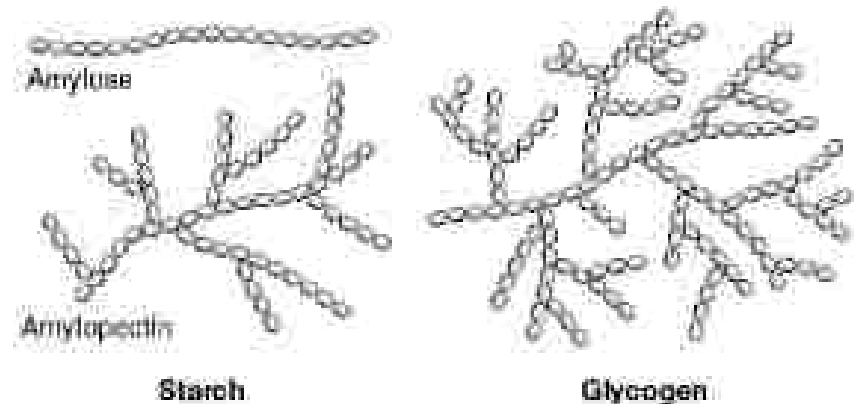
- **Iodine solution**
- Iodine in potassium iodide solution
- Reacts with amylose in starch
- Form a starch-iodine complex
- Orange / brown → Dark blue



# Carbohydrates

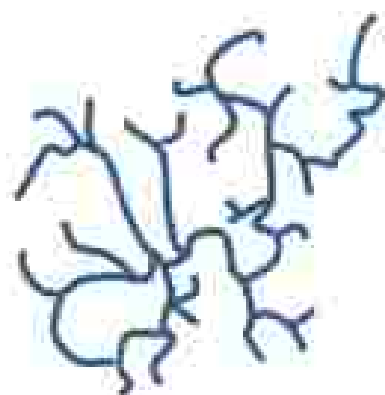
## Polysaccharides - Glycogen

- Storage of carbohydrates in **animals**
- Structure similar to amylopectin
- $\alpha$ -glucose
- **1-4 and 1-6 glycosidic bonds**
- **More branched** than amylopectin
- Clumped together  $\rightarrow$  forms **granules**
- Abundant in **liver and muscle cells**

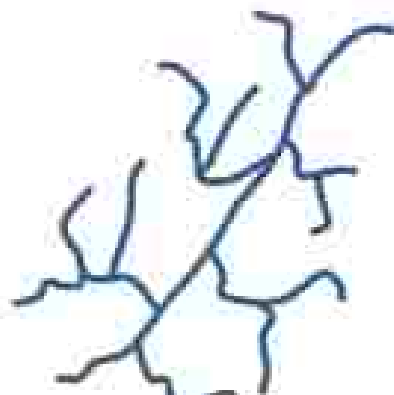


# Carbohydrates

## Polysaccharides - Glycogen

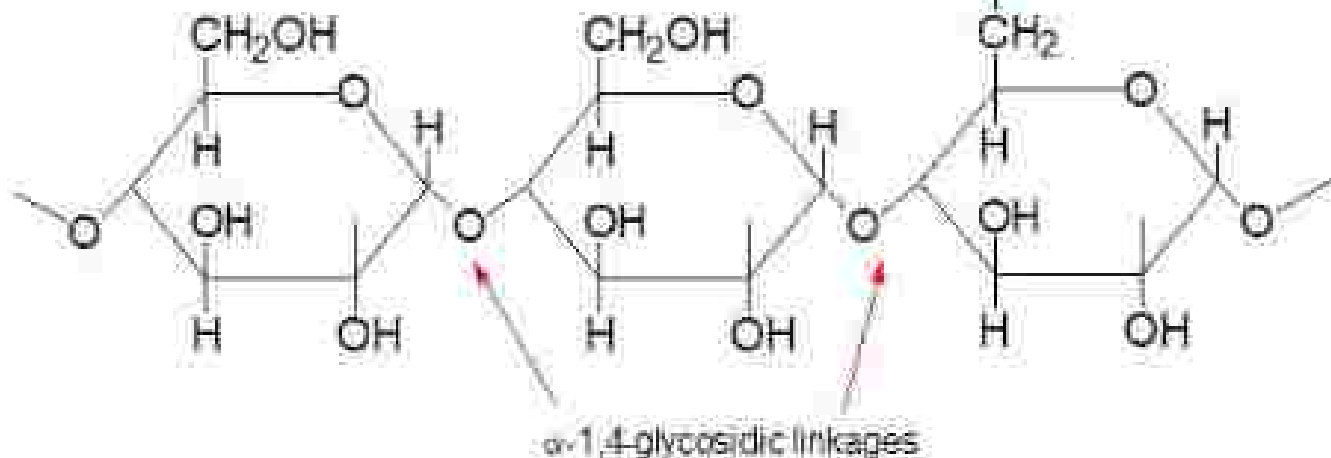
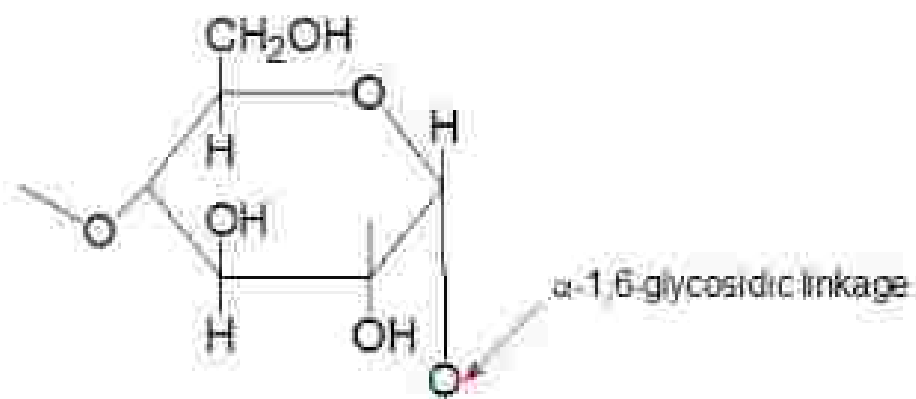


glycogen



amylopectin

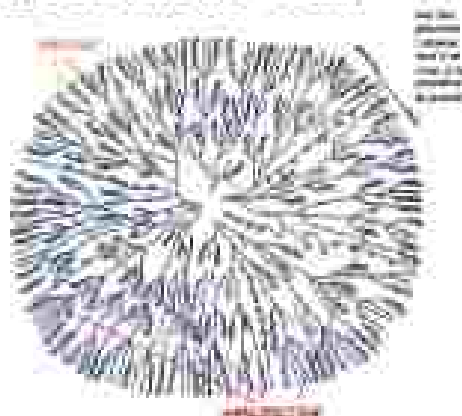
**More branched than amylopectin**



# Q: Why does excess glucose need to be stored as starch and glycogen?

## Glucose is:

- **Soluble** – increase concentration / decrease water potential of cell  
→ water would enter  
→ **cell volume increase**, animal cells may burst
- **Reactive** – interferes with **other** reactions in cell



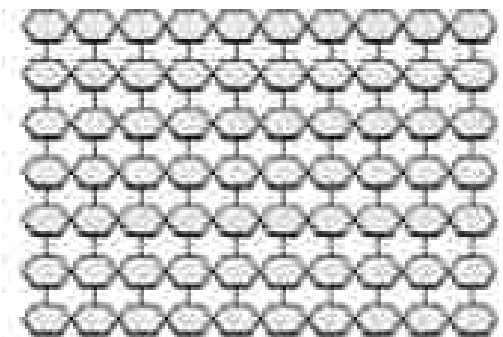
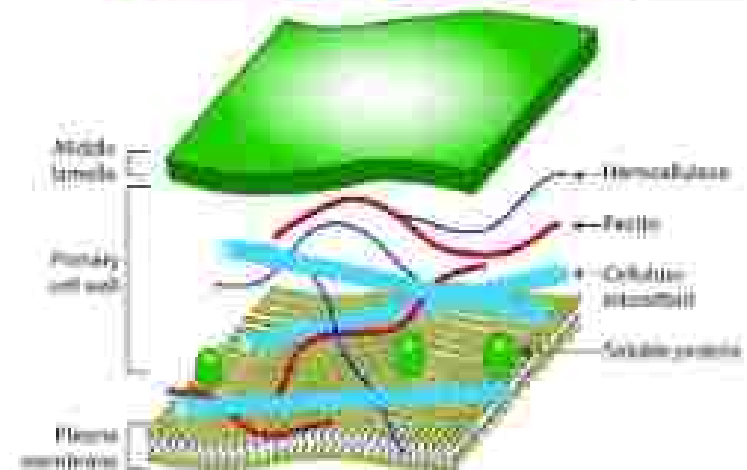
## Starch and glycogen is:

- **Inert** – non reactive
- **Insoluble** – no osmotic effect on cell, does not easily diffuse out of cell
- **Compact** – large quantity of energy released when hydrolysed
- **Glucose can be stored / mobilised quickly** – many ends for attachment/removal of glucose

# Carbohydrates

## Polysaccharides - Cellulose

- Structural role in **plant cell walls**
  - **High tensile strength**
  - Prevent cell bursting
  - **Helps cell withstand turgor pressure**
  - Fully permeable



# Carbohydrates

## Polysaccharides - Cellulose

Structure:

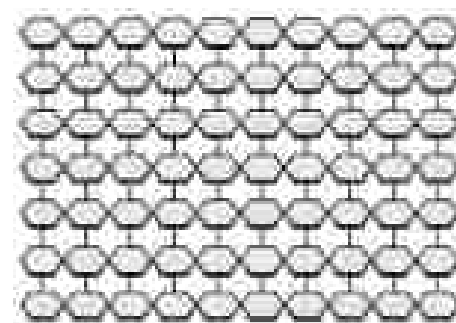
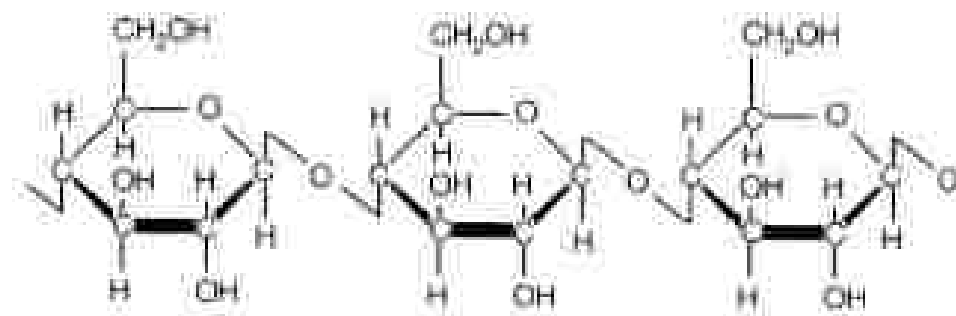
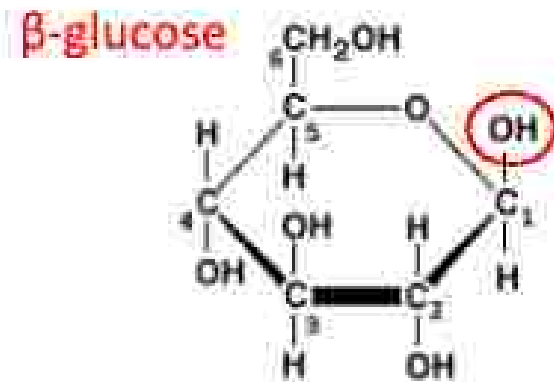
- **$\beta$ -glucose**

→ Molecules of  $\beta$ -glucose are **rotated at  $180^\circ$**  to each another

→ **1-4 glycosidic bonds**

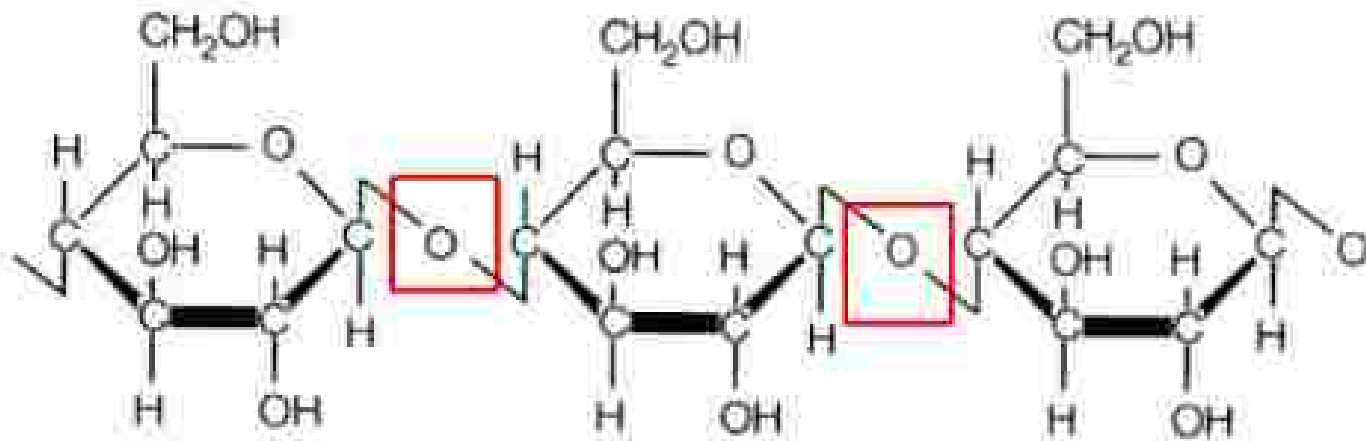
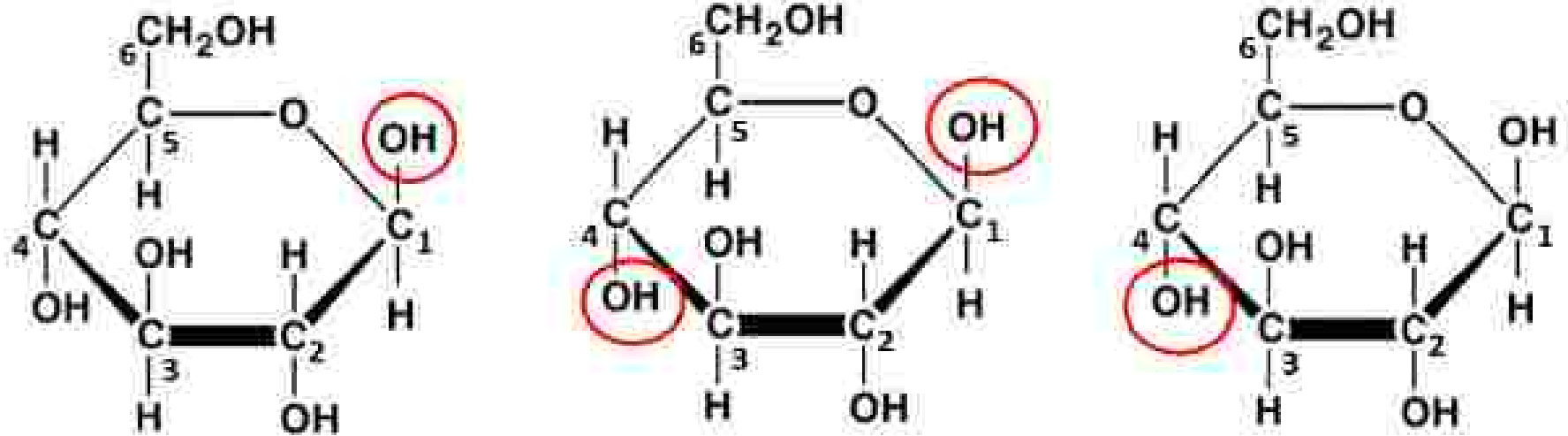
- **Unbranched**, straight chain, linear

→ Form **fibres**



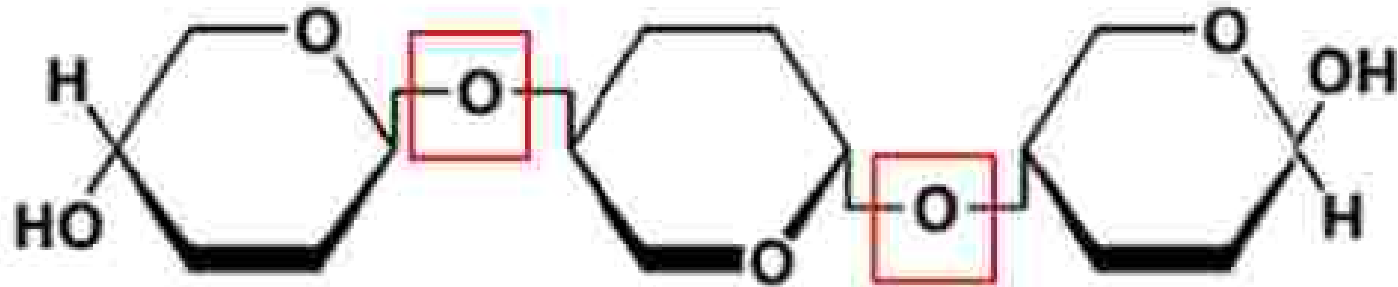
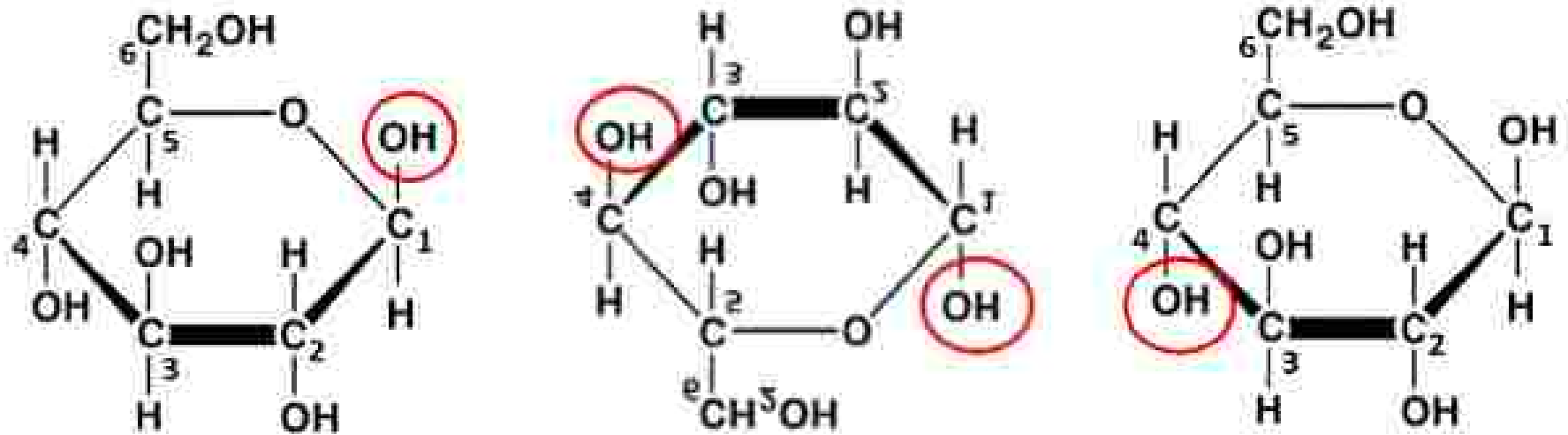
**Cellulose (fiber)**

# Condensation of $\beta$ -glucose into cellulose



$\beta$ , 1-4 glycosidic bonds

# Condensation of $\beta$ -glucose into cellulose



$\beta$ , 1-4 glycosidic bonds



# Carbohydrates

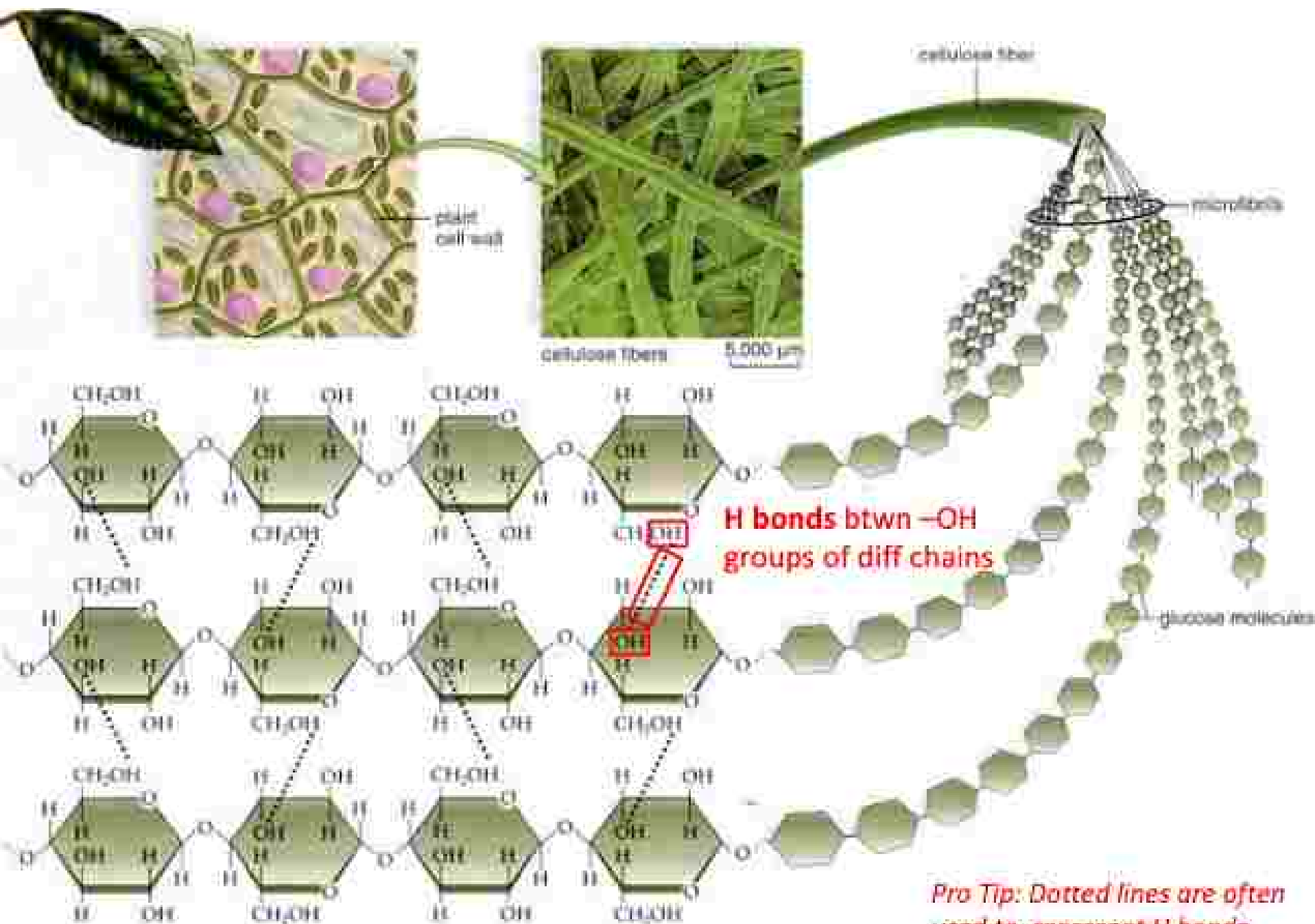
## Polysaccharides - Cellulose

From molecules → fibres with high tensile strength:



- 1) Cellulose are straight chains, can **lie parallel** to each other
- 2) **Hydrogens bonds** formed **between** cellulose molecules  
→ **many** -OH groups in cellulose
- 3) **Forms microfibrils and fibres**
- 4) Fibres are arranged in a **criss-cross manner**  
→ many **gaps** between fibres  
→ cell wall is permeable to water, ions etc.





*Pro Tip: Dotted lines are often used to represent H bonds*

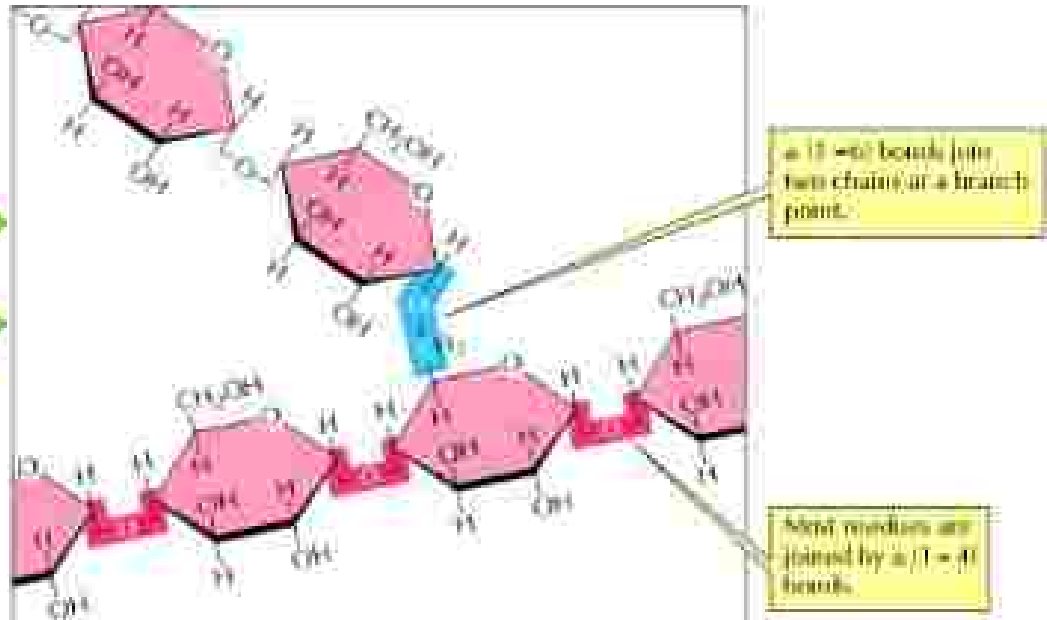
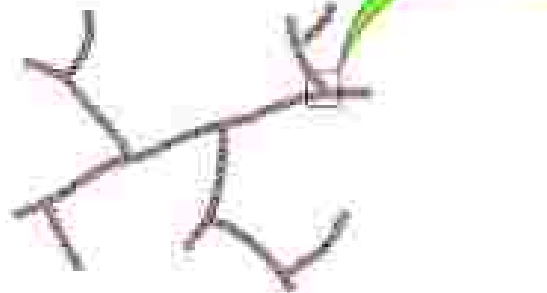
# Carbohydrates

## Polysaccharides

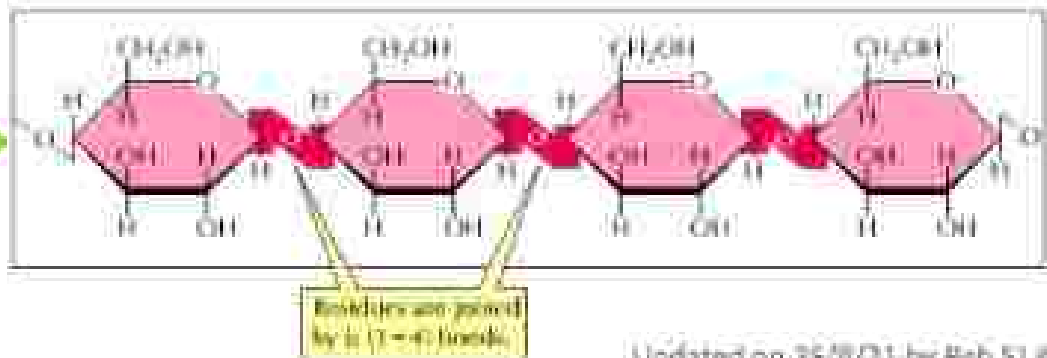
Amylopectin (starch)



Glycogen



Cellulose



# Carbohydrates

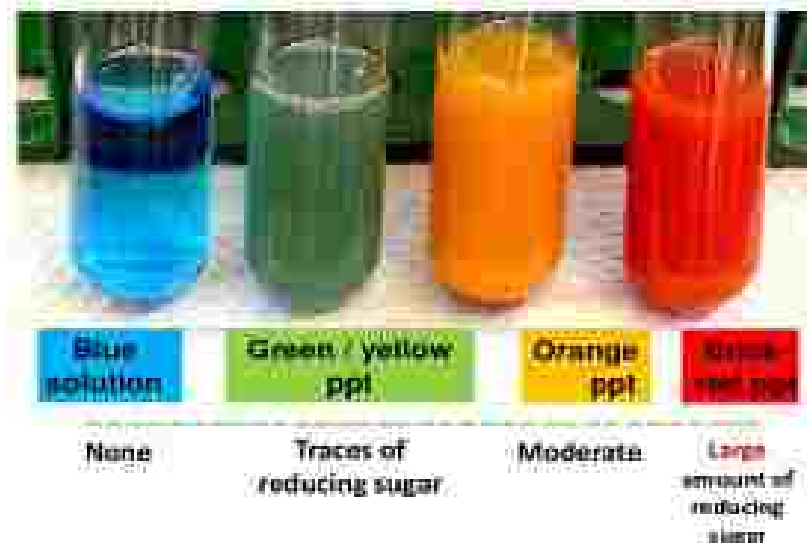
## Testing the Presence of...

Reducing Sugars	Non-Reducing Sugars
Galactose Glucose Fructose Maltose	Sucrose – the only one you really need to know!

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# Testing the Presence of Reducing Sugars

- Reducing sugar: All monosaccharides, disaccharides
- **Except sucrose**
- Add 2cm<sup>3</sup> of **Benedict's solution** to 2cm<sup>3</sup> of reducing sugar
- Copper (II) sulphate in alkaline solution
- Blue colour
- Reaction requires heating at 90°C
- If reducing sugar is present:  
 $\text{Cu}^{2+} \rightarrow \text{Cu}^+$  (in Benedict's sol)  
Blue, soluble  $\rightarrow$  Red, insoluble
- Forms a **brick-red precipitate**  
(if high conc. of reducing sugar present)



# Testing the Presence of Non-reducing Sugars (e.g. Sucrose)

1. Add  $2\text{cm}^3$  of sample to  $2\text{cm}^3$  of **acid** to hydrolyse glycosidic bonds  $\rightarrow$  monosaccharides
2. Heat at  $90^\circ\text{C}$
3. **Neutralize** using  $2\text{cm}^3$  of NaOH
4. Add  $2\text{cm}^3$  of **Benedict's solution** to  $2\text{cm}^3$  of the mixture
5. Heat at  $90^\circ\text{C}$



## Results:

- **Brick red precipitate** = Non-reducing sugar
  - Even after hydrolysis, remains **blue colour**
- = Not a SUGAR



# LIPIDS

---



# Lipids

**Made of:** C, H, O (sometimes, P)

**Important for:**

1. Energy storage  
(lipids have many C-H bonds, can generate more E than carbs)
2. Structural component of membranes
3. Other specific biological functions (e.g. hormones)

**Monomers:**

- Glycerol
- Fatty Acids

**Polymers:**

- Triglycerides (Fats and oils)
- Phospholipids



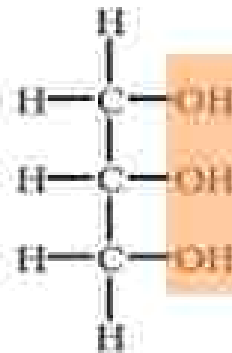


# Lipids

## Monomers – Glycerol and Fatty Acids

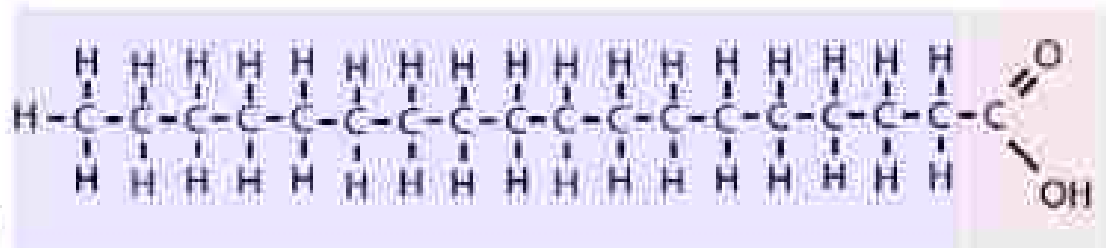
### Glycerol

- Has **3 carbons**
- 3 -OH groups
- functional gp



### Fatty Acid

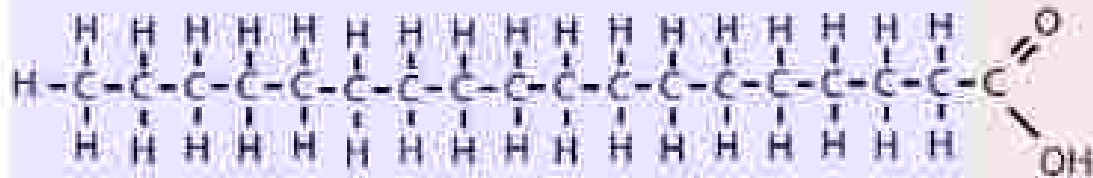
- Has an acid “head” (**-COOH** group)
- + a long **hydrocarbon chain**
- many C-H bonds
- hydrocarbon chain is hydrophobic and non-polar



long hydrocarbon chain

carboxylic  
acid group

# Fatty Acids in Simplified Diagrams



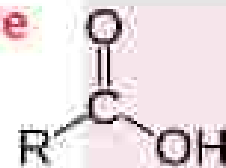
long hydrocarbon chain

carboxylic  
acid group

skeletal structure



simplified, general structure

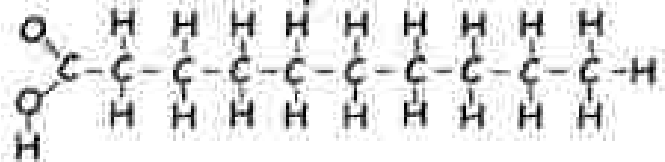


# Types of Fatty Acids

## 1) Saturated fatty acids

- No double bonds

Saturated fatty acid



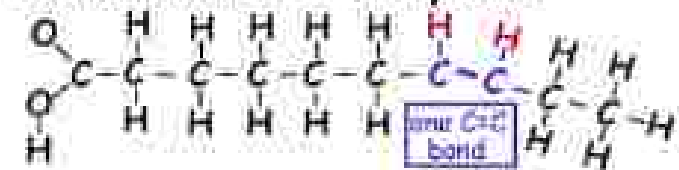
## 2) Unsaturated fatty acids

- Has double bonds

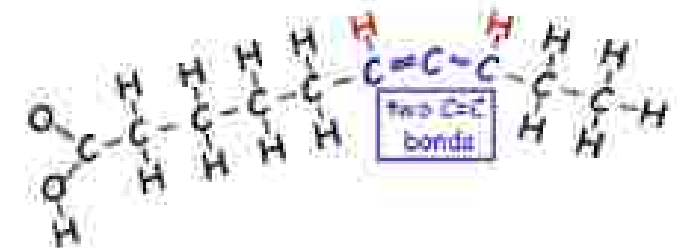
**Mono**unsaturated FA = 1 double bond

**Poly**unsaturated FA > 1 double bond

Monounsaturated fatty acid



Polyunsaturated fatty acid

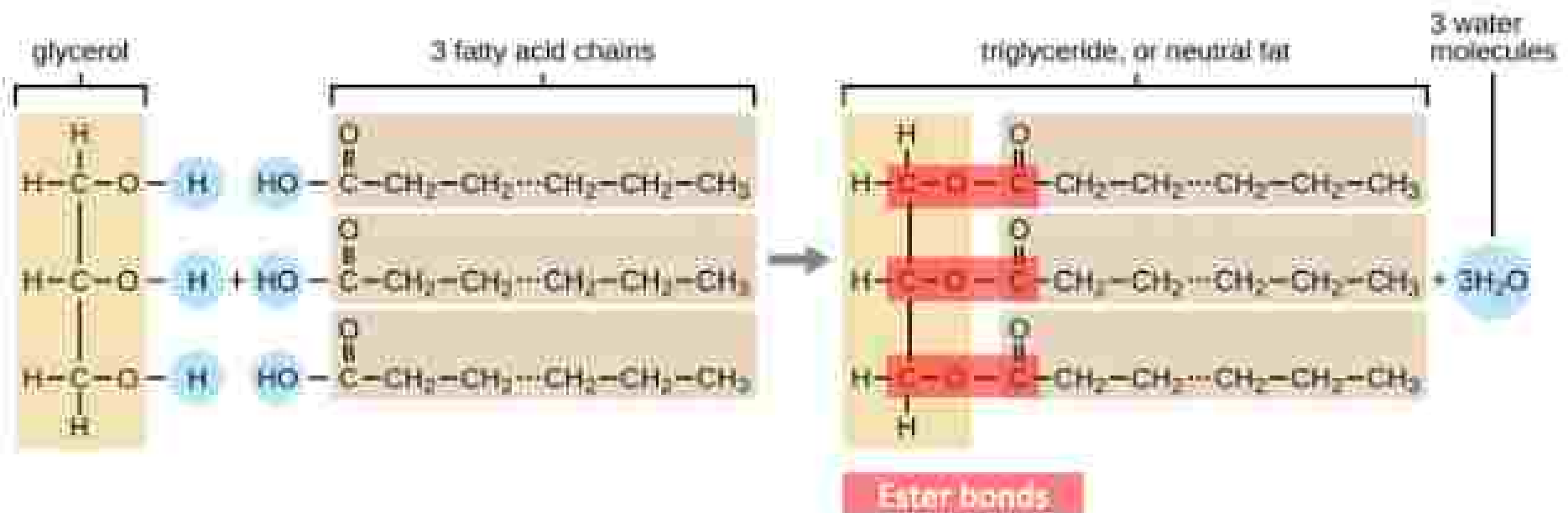


- Results in **kink** in hydrocarbon tail
- Lesser C-H bonds
- Lower melting point – liquid at room temp.

# Lipids

## Polymers – Triglycerides

- 3 fatty acids + 1 glycerol
- Linked by ester bonds
- Formed via condensation reactions
- FAs can be unsat. or sat.



# Lipids

## Polymers – Triglycerides

### Properties:

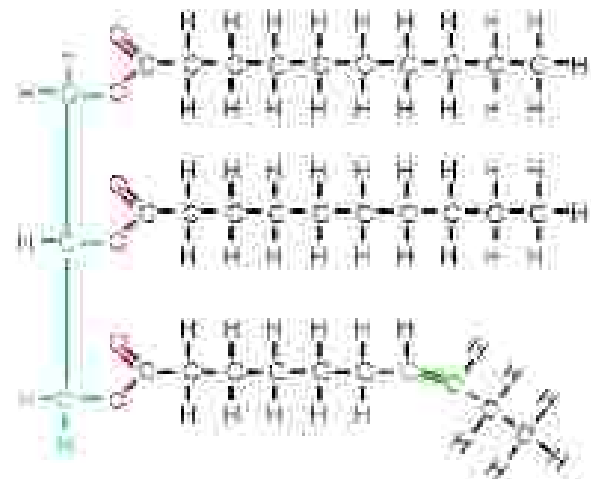
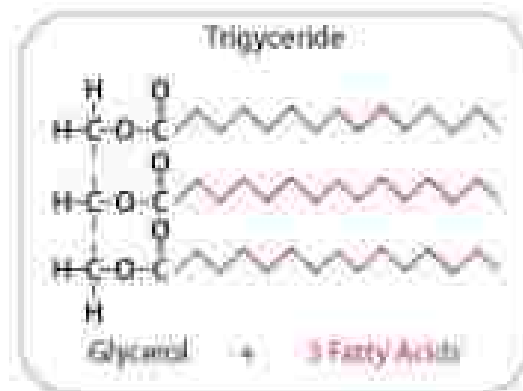
- **Insoluble in water**

→ Bcs of the long hydrocarbon tails of the fatty acids

→ Non-polar, hydrophobic

- **Soluble in organic solvents**

E.g. ether, chloroform, ethanol



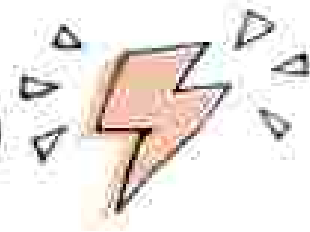
# Lipids

## Polymers – Triglycerides

### Roles of Triglycerides:

#### 1) **Source of energy**

- Many **C-H bonds** (more than carbohydrates)
- Higher proportion of hydrogen
- Insoluble, compact
- **More energy can be produced per unit mass**



#### 2) Metabolic source of **water**

- High ratio of H to O atoms
- Release water during fat oxidation
- especially for desert animals



# Lipids

## Polymers – Triglycerides

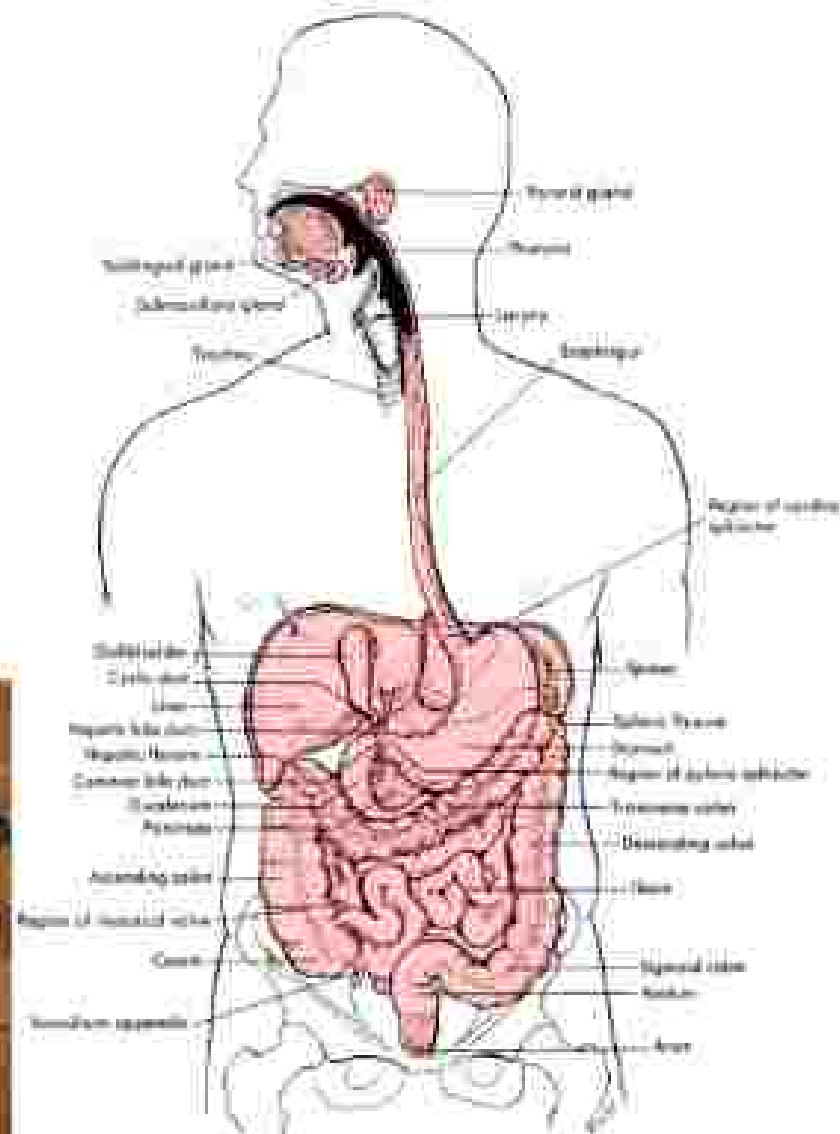
3) Insulator

→ below dermis

4) Protection of organs

5) Buoyancy

→ blubber



# Lipids

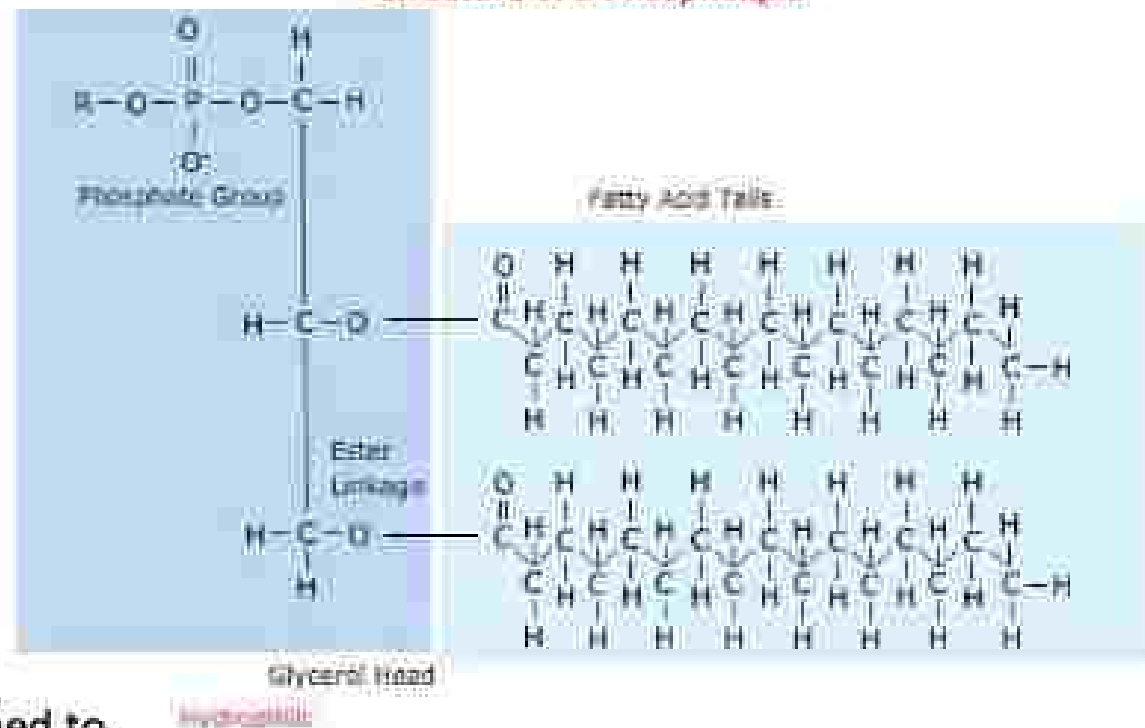
## Polymers – Phospholipids

- 1 fatty acid chain in triglyceride is replaced by a phosphate group

Composed of:

- **1 glycerol**
- **2 fatty acids**
- **1 phosphate gp**  
( $\text{PO}_4^-$ )

Structure of a Phospholipid



- May also have other gps attached to phosphate gp (represented by R)



# Lipids

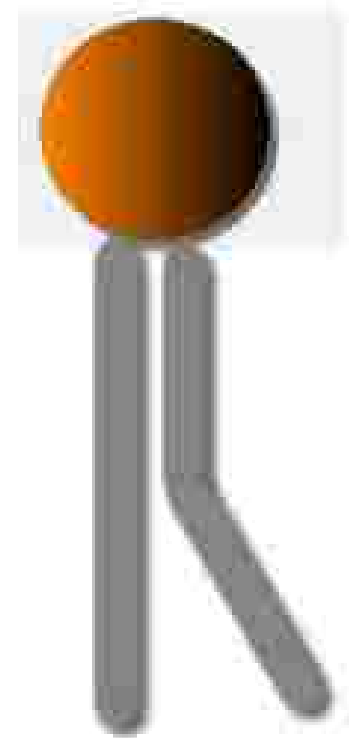
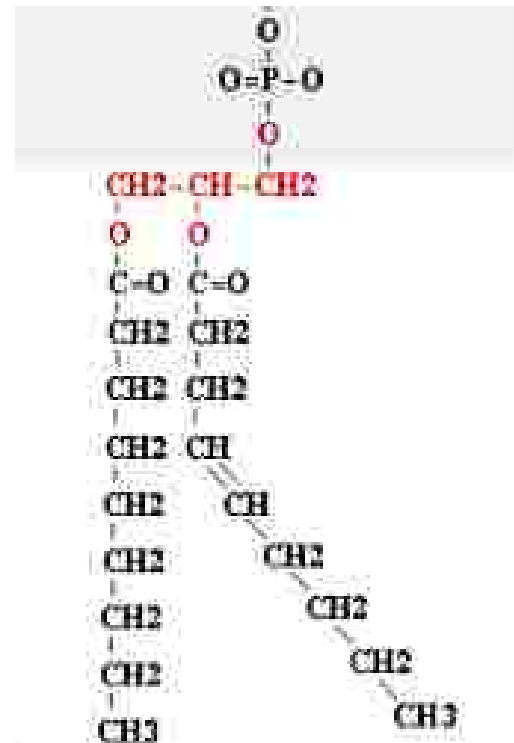
## Polymers – Phospholipids

### a) **Hydrophilic head**

- **Phosphate group**
- Charged, polar
- Forms H bonds with water

### b) **Hydrophobic tails**

- **Fatty acid residues**
- Hydrocarbon chains are insoluble and non-polar
- Repels water

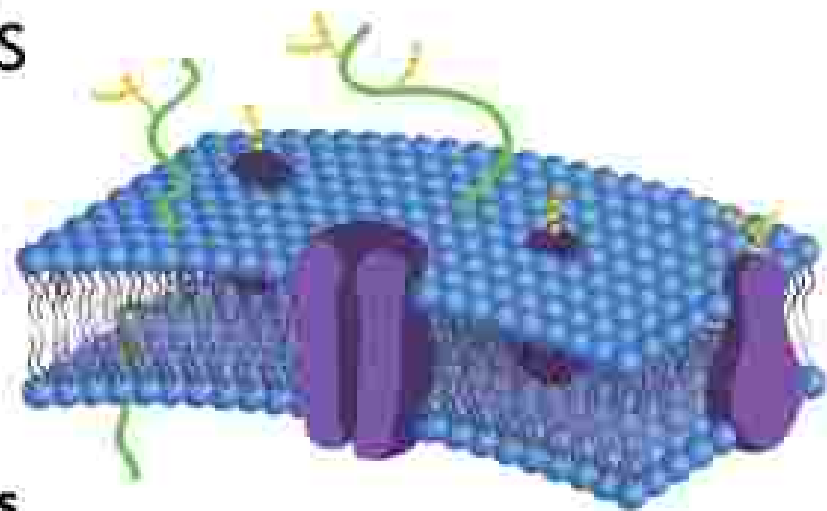


# Lipids

## Polymers – Phospholipids

### Roles of Phospholipids:

- 1) Forms a **phospholipid bilayer**
  - With **hydrophobic core**
  - **Barrier to water-soluble substances at membrane**
- 2) Allow regulation of **membrane fluidity**
  - Double bonds in unsat. fatty acid tails increases fluidity
  - Sat. FA decreases fluidity



# Lipids

## Polymers – Phospholipids

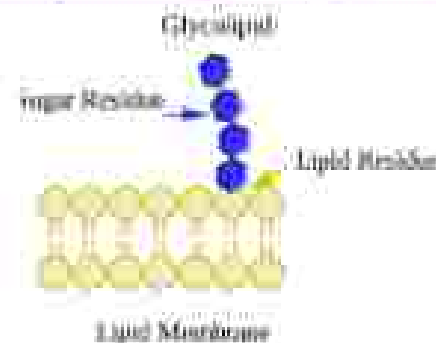
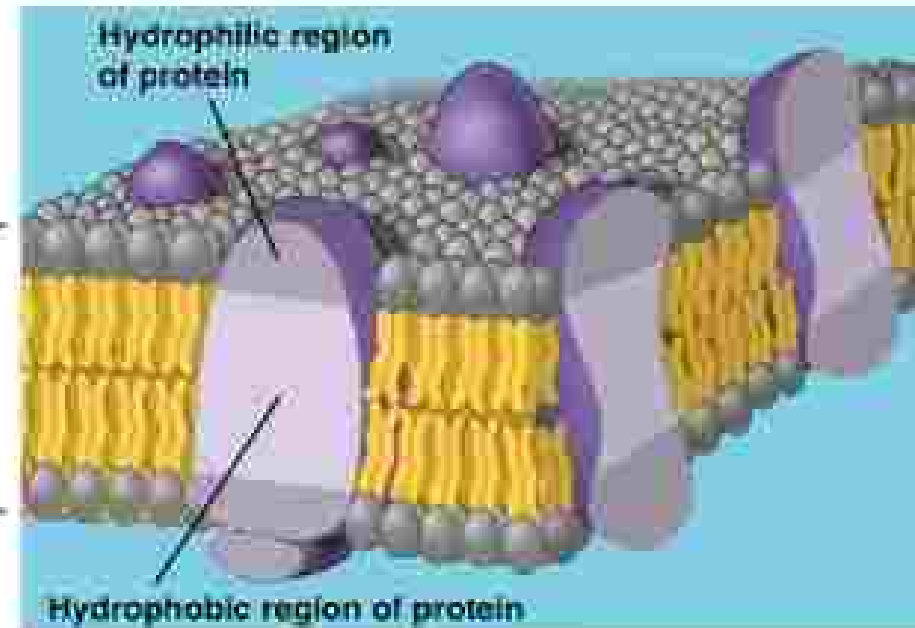
3) Help to hold membrane proteins in place

- Hydrophobic interaction with 'floating' membrane proteins

4) Can combine with carbohydrates to form glycolipids

- Important in cell recognition (more in Chap 4)

Phospholipid bilayer



# Emulsion Test for Lipids

- 1) Shake sample with ethanol
- 2) Pour mixture into a tube with water

## Results:

- **Transparent** – no lipids
- **White and cloudy** – lipids present

- Lipid molecules clump together
- Forming little groups dispersed throughout the liquid
- **Emulsion**





# PROTEINS

---



# Proteins

**Made of:** C, H, O, N (sometimes, S)

**Examples of structures made of protein:**

- **Haemoglobin**
- **Collagen**
- **Components of cell membranes**
- **Enzymes**
- **Antibodies**
- **Keratin**

**Monomer:** **Amino acids**

**Dimer:** **Dipeptide**

**Polymer:** **Polypeptide**

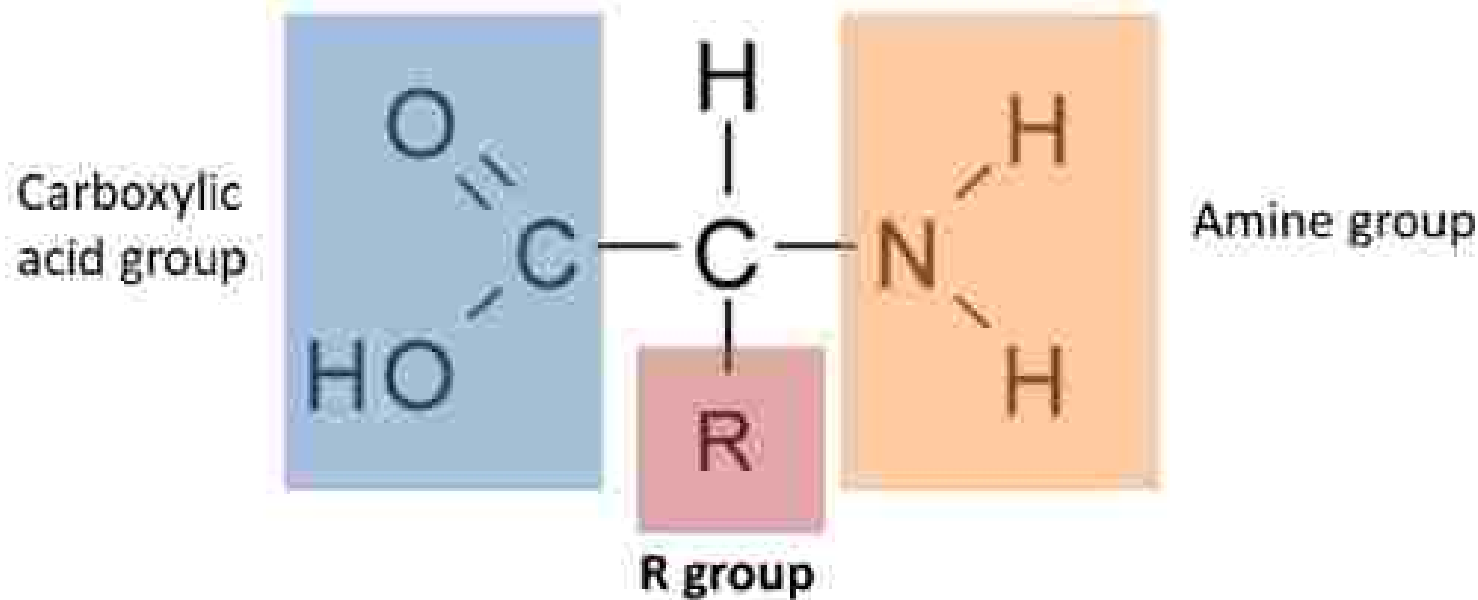


# Proteins

## Monomer – Amino acids

The general structure of amino acids:

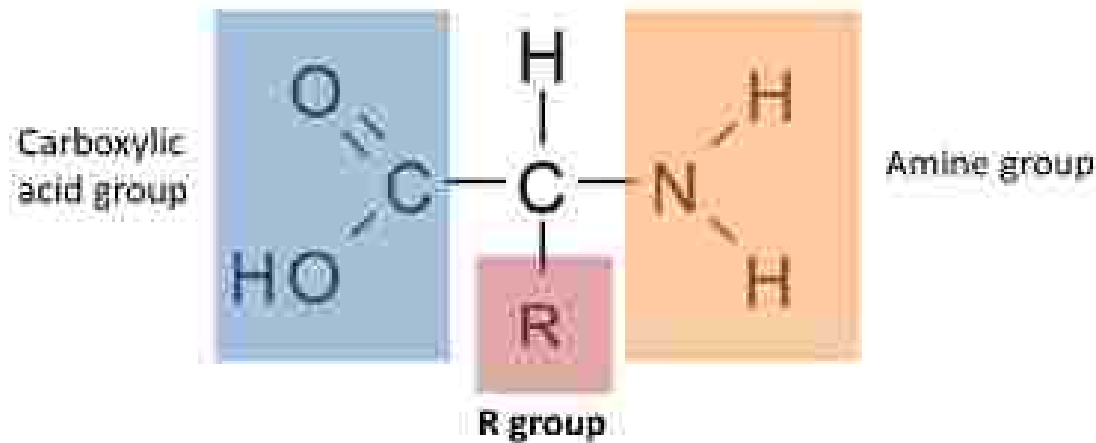
You need to know how to draw the general structure of amino acids!



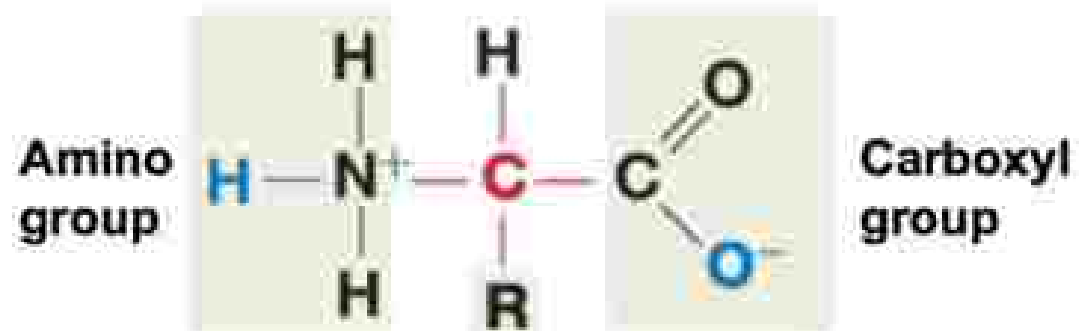
There are 20 types of R groups  
→ 20 different amino acids

# Proteins

## Monomer – Amino acids



skeletal structure



Side chain

a.a. are in an ionized state in water



# Proteins

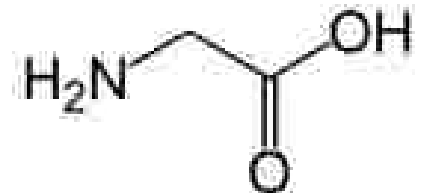
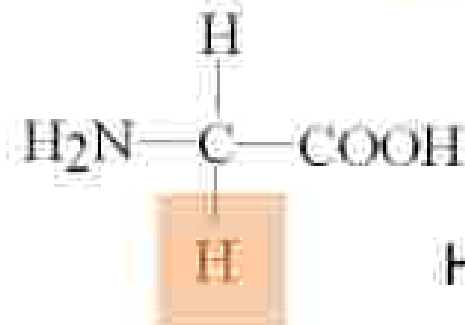
## Monomer – Amino acids

You need to know  
how to draw glycine!

E.g. types of amino acids

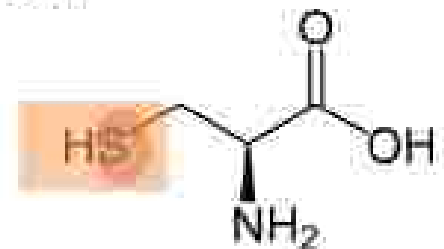
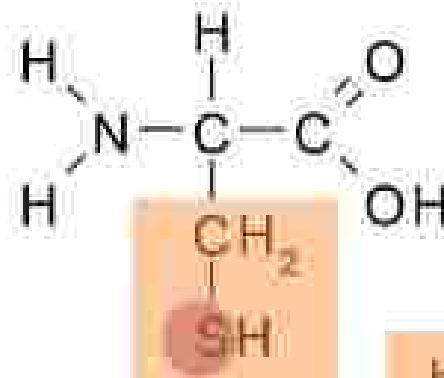
The simplest amino acid is **glycine**

R group = H



One more name to rmb is **cysteine**

R group = contains **sulphur**



## Twenty standard Amino Acids

## Nonpolar, aliphatic H groups

[illegible]

1000



**Language**



**Abstract**

### Argument II: groups



1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 2678, 2679, 2680, 26



### Termination



## Background

### Positively charged H<sub>2</sub> gel



**Letter**



## THE

\*Star, uncharged 10 grams



100

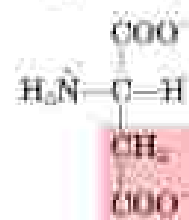


**Abstract**

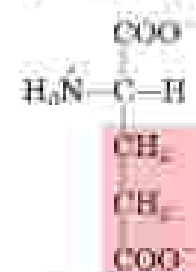


Age Group	Percentage of Respondents
18-24	15
25-34	25
35-44	35
45-54	45
55-64	55
65-74	65
75-84	75
85+	95

### Negatively charged R groups



## Appendix



## Discussion

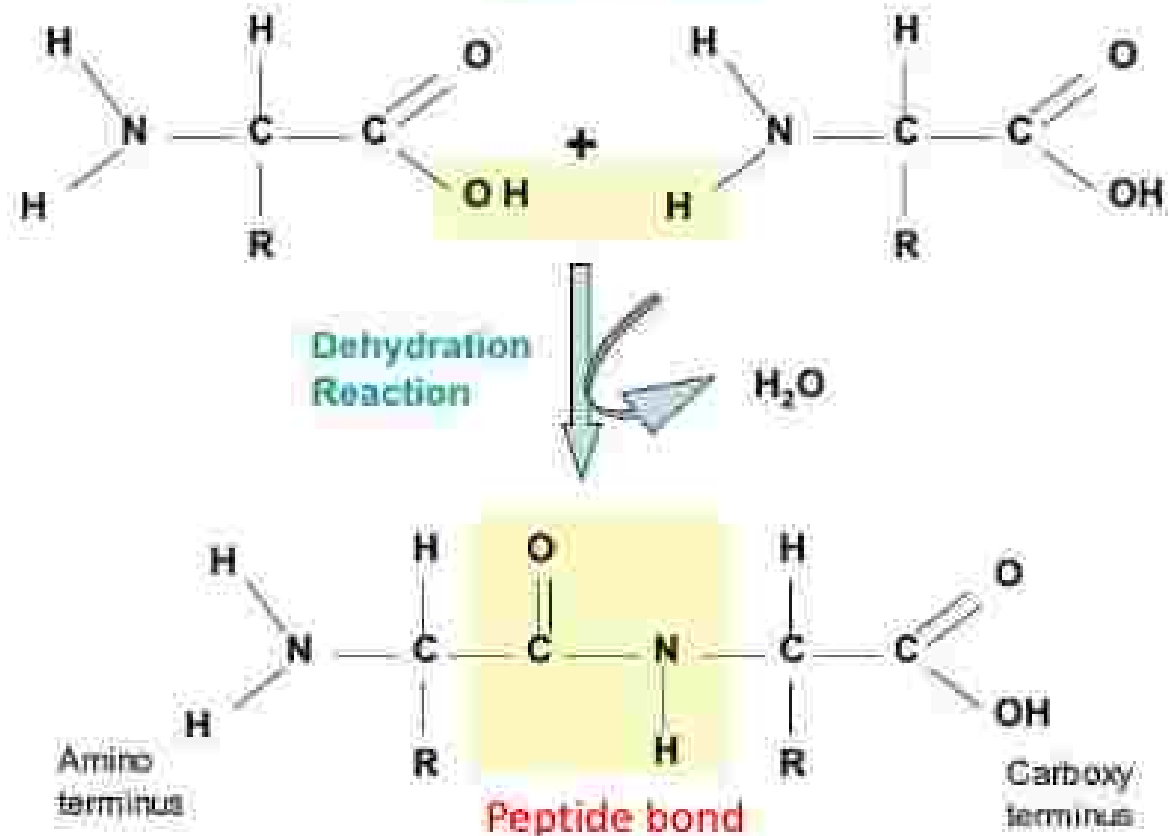
**You DO NOT need to memorise this!**

# Proteins

## Dipeptides

You need to know how to draw products of condensation / hydrolysis reactions!

### Peptide Bond

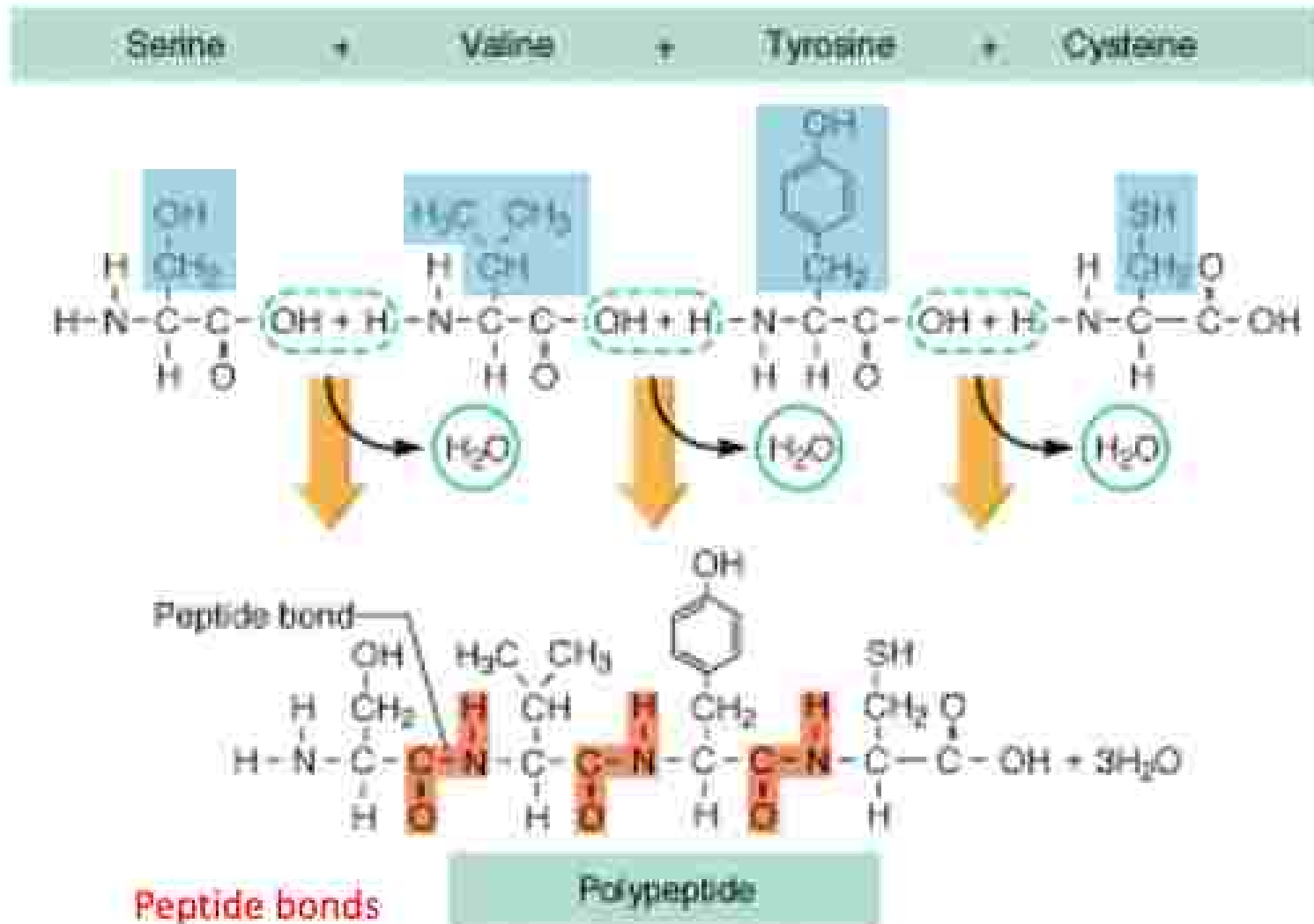


**Peptide bond** forms between C of  $-\text{COOH}$  and the N of  $-\text{NH}_2$

# Proteins

## Polypeptides

- Synthesised at the ribosome
- Condensation reaction

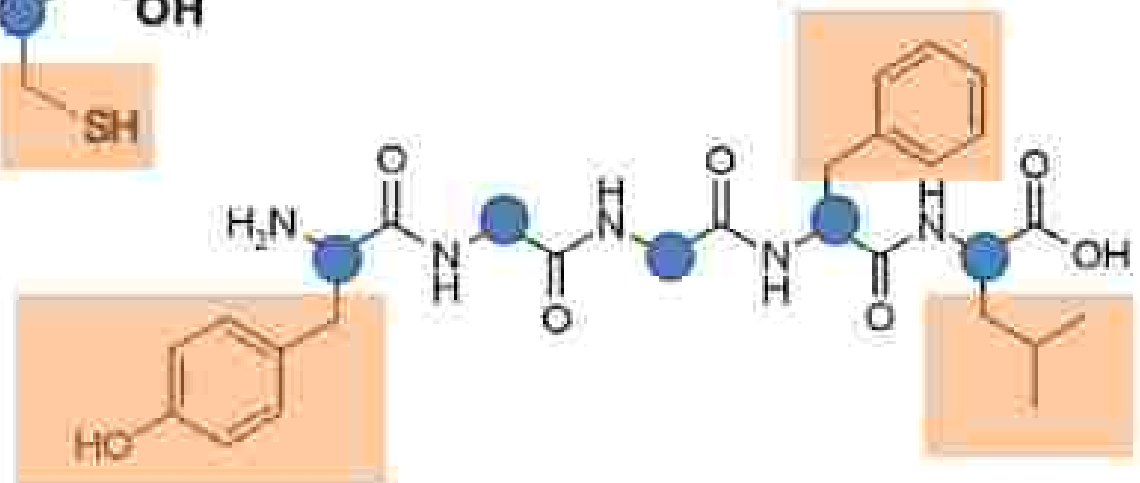
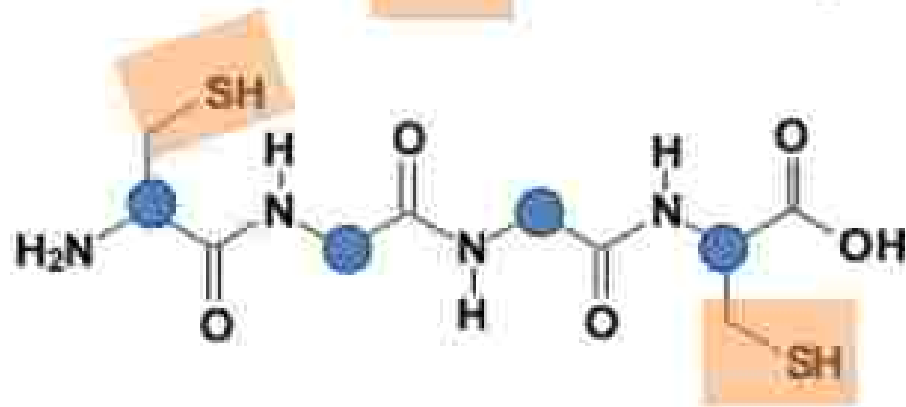
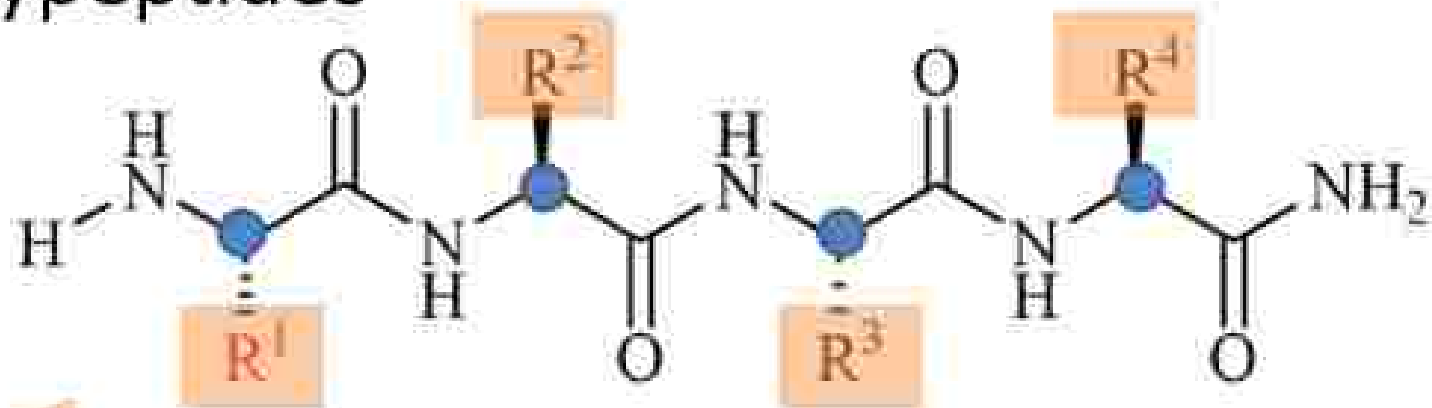


# Proteins

## Polypeptides

● = central carbon atom

■ = R group

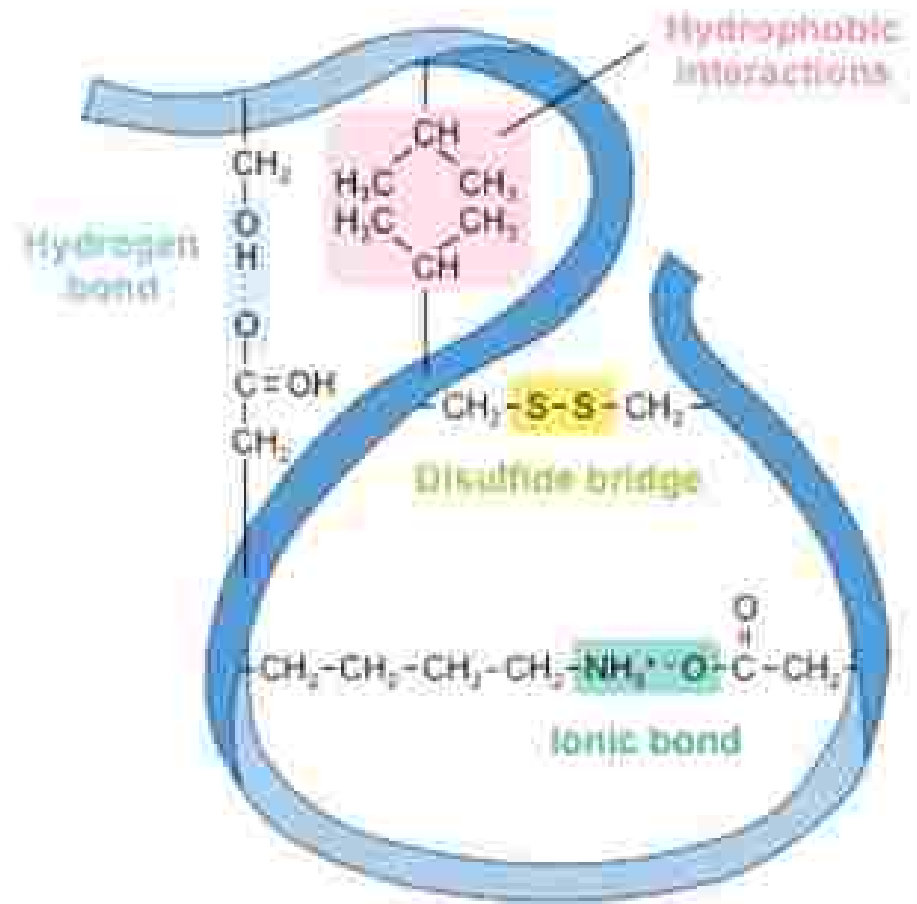


# Protein

## 4 types of bonds

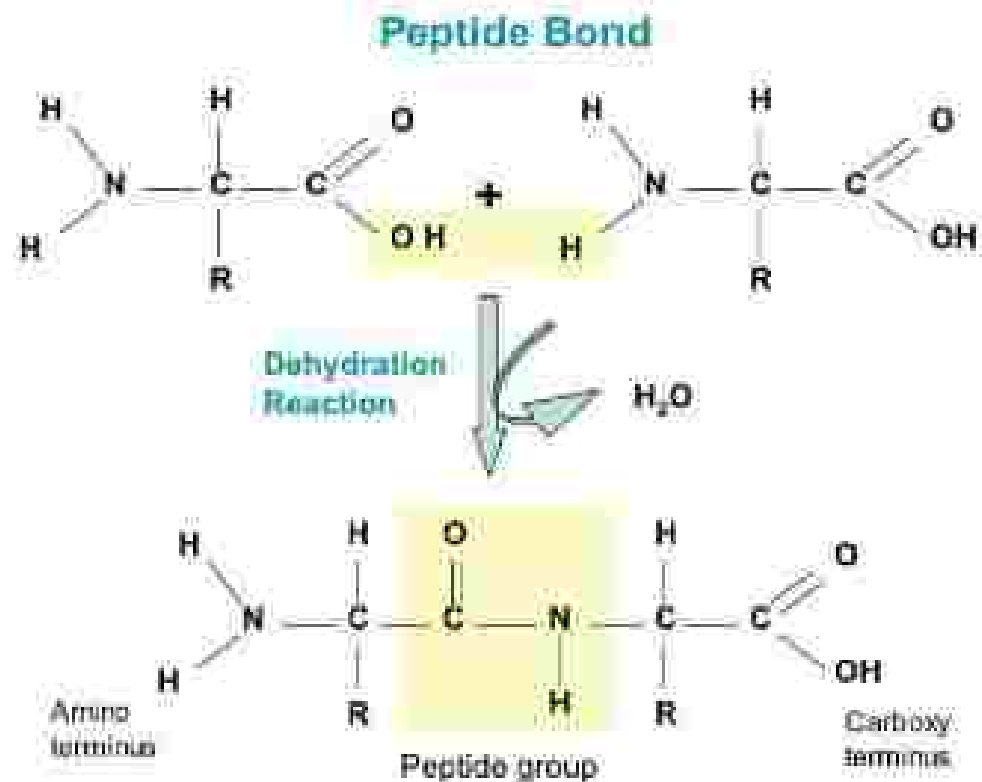
Peptide bonds  
(present in all polypeptides)

1. Hydrogen bonds
2. Disulfide bonds
3. Ionic bonds
4. Hydrophobic interactions



# Peptide bonds

- Very Strong
- **Covalent** bonds
- Between C of **-COOH** and the N of **-NH<sub>2</sub>**
- Result of condensation reaction
- Present in all polypeptides

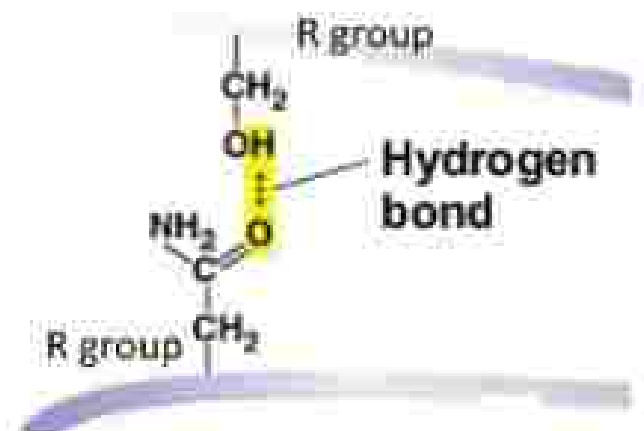
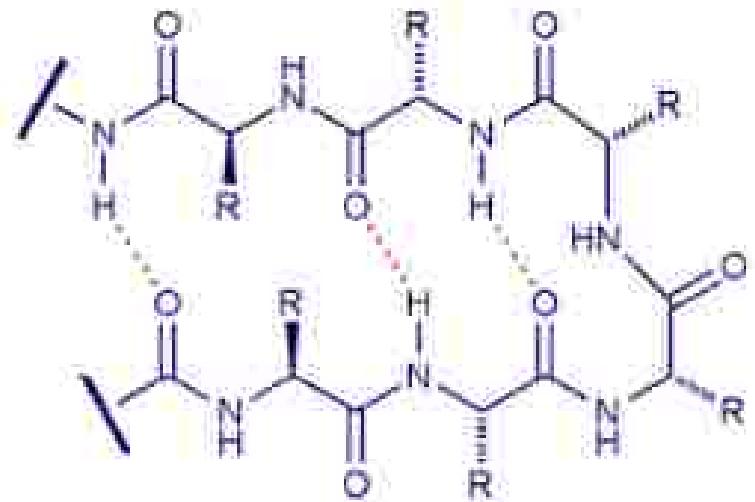


# 1. Hydrogen Bonds

- Individually weak
- But many H bonds  
→ cumulatively strong
- Between H of  $\text{-NH}$  /  $\text{-OH}$  group and O of  $\text{-CO}$  group
- OR between **R groups**

Easily broken by:

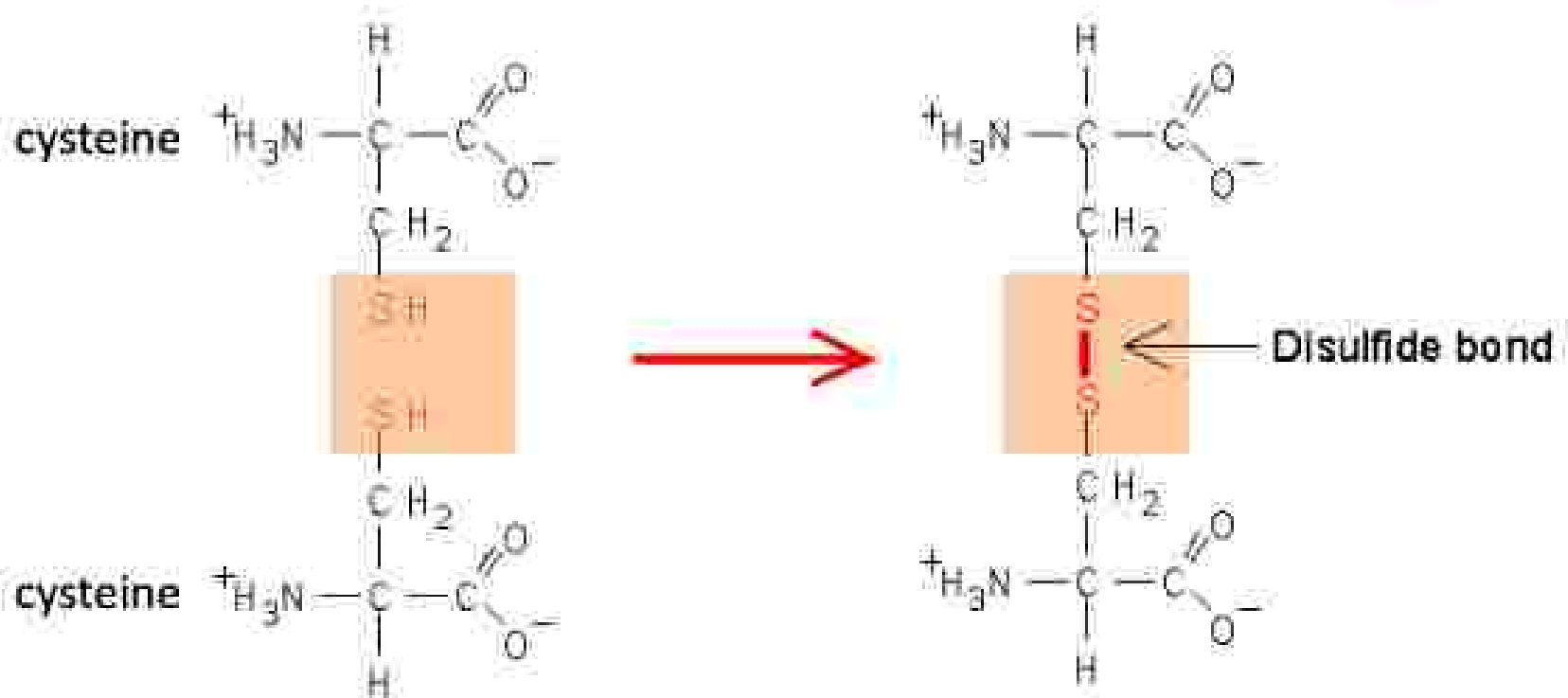
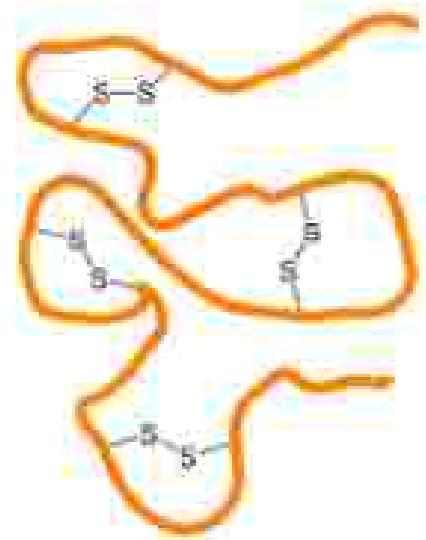
- **High temperatures**
- **pH changes**





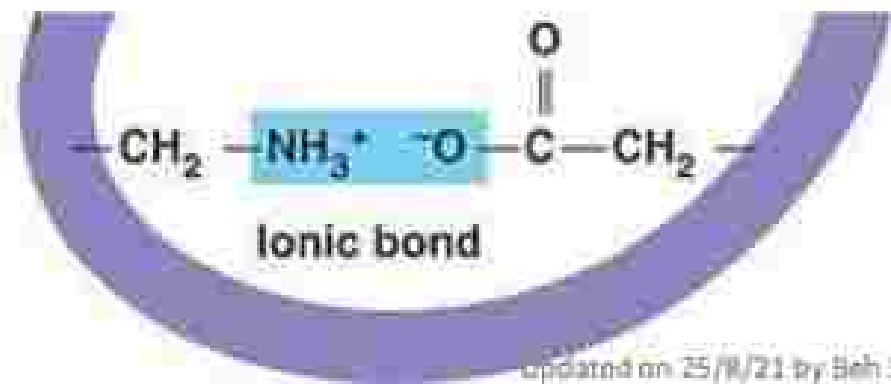
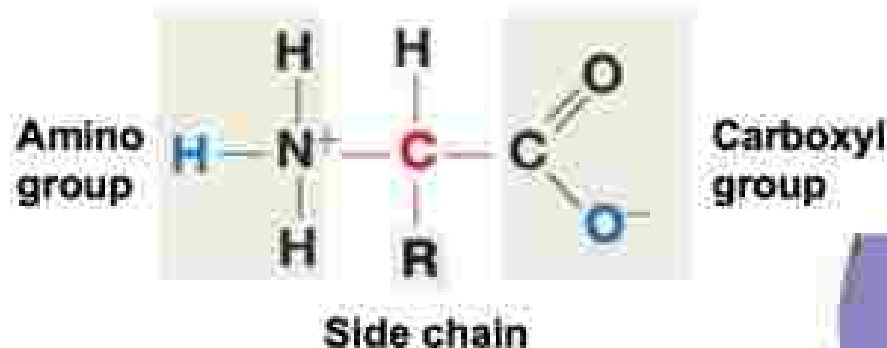
## 2. Disulfide Bonds

- Very strong **covalent** bonds
- Between **sulphur** atoms of **cysteine** amino acids



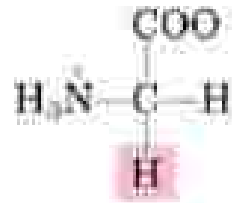
### 3. Ionic Bonds

- Between **ionized amine** and **carboxylic acid** groups  
→  $\text{NH}_3^+$  and  $\text{COO}^-$  groups  
→ that are not involved in peptide bonding
- OR** between **charged R groups**
- Weaker than disulphide bonds, but stronger than H bonds
- Easily broken down by **pH changes and high temp**

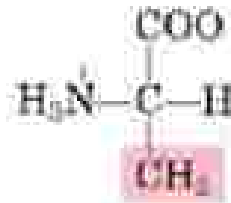


# 4. Hydrophobic Interactions

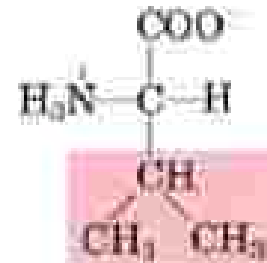
- Between **non-polar / hydrophobic R groups**
- Repel and move away from water
- Weakest



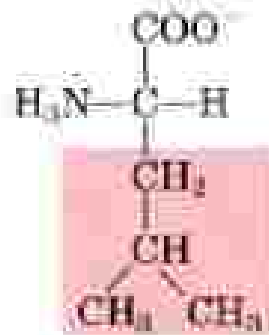
Glycine



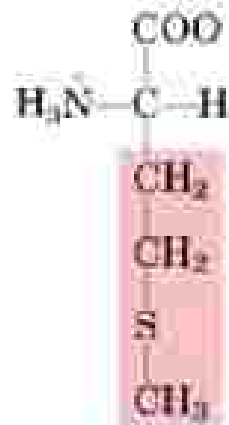
Alanine



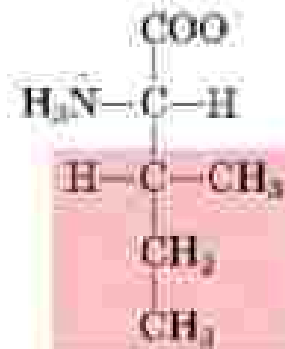
Valine



Leucine



Methionine



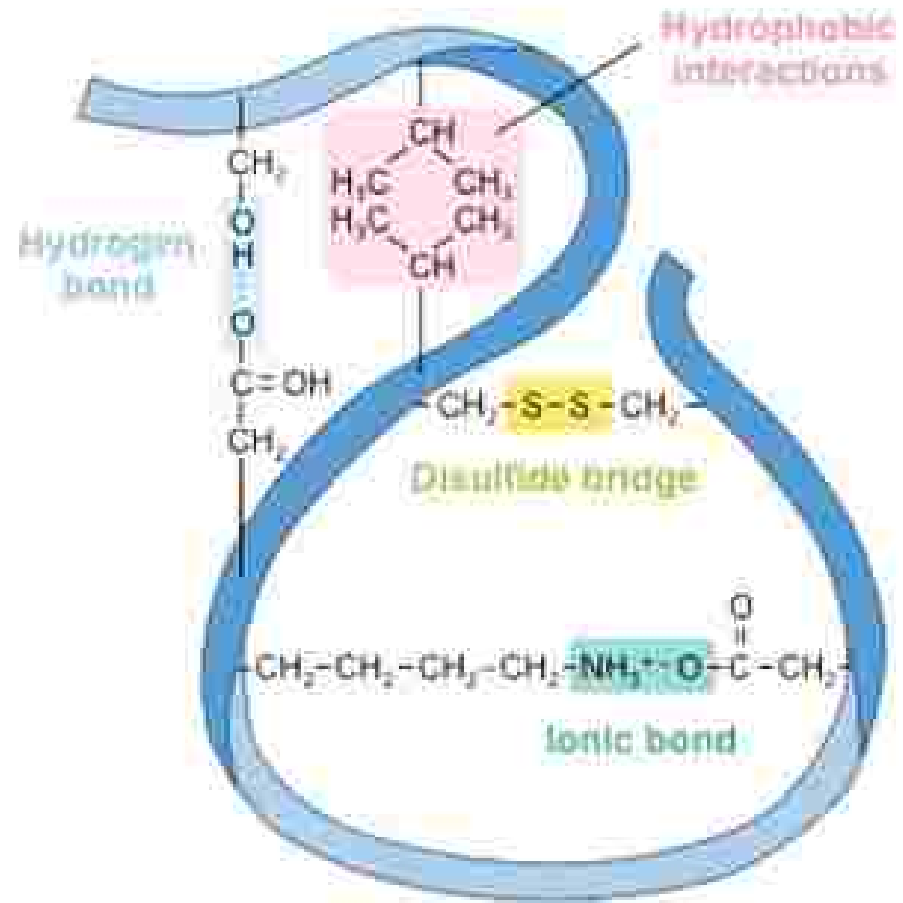
Isoleucine

# Protein

## 4 types of bonds

Weakest → Strongest

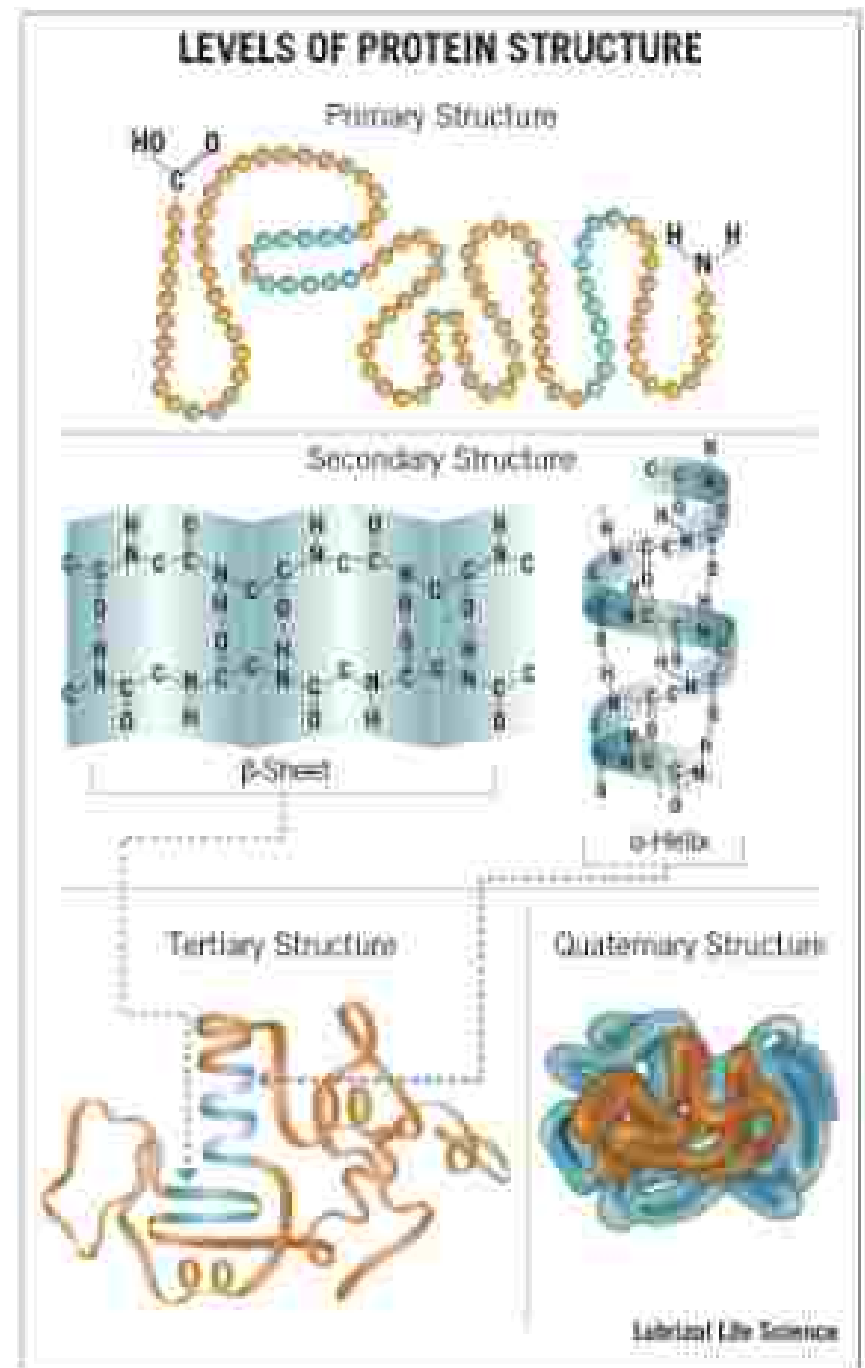
1. Hydrophobic interactions
2. H bonds
3. Ionic bonds
4. Covalent bonds  
i.e. disulphide bonds,  
peptide bonds



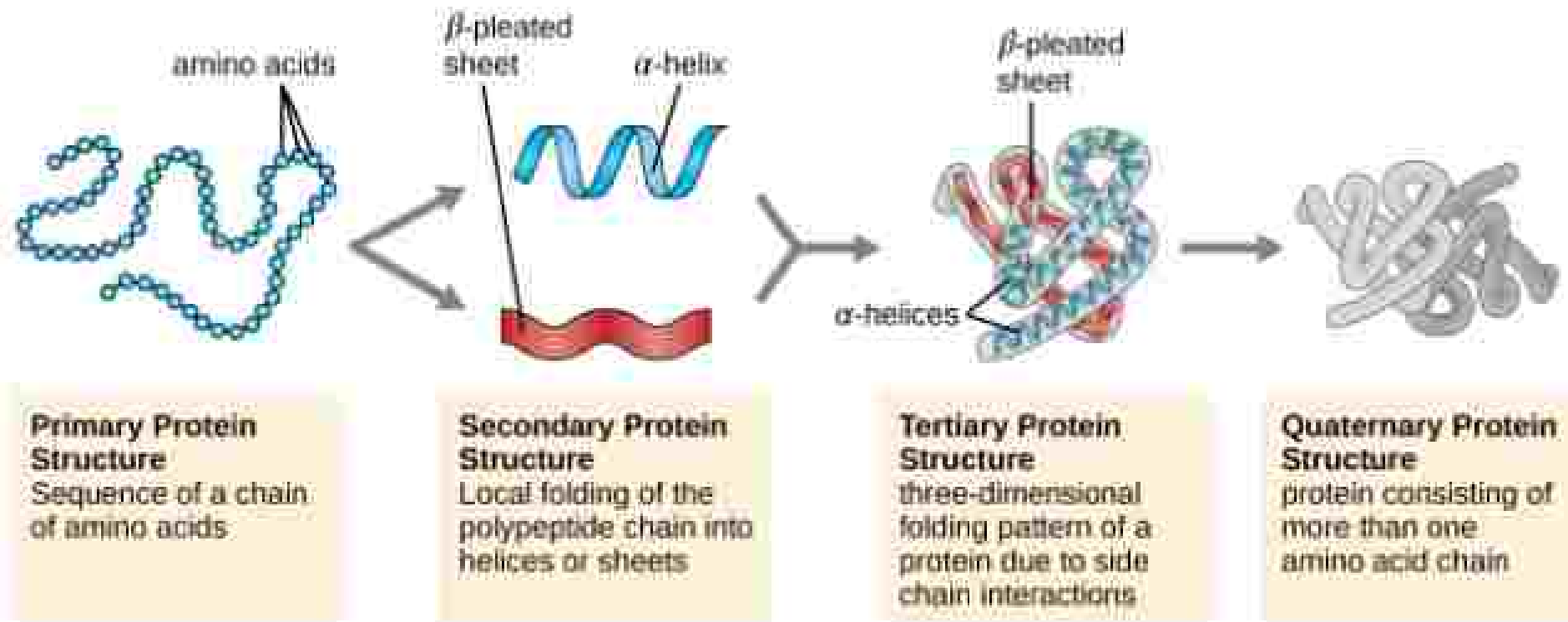
# Proteins

## 4 levels of protein structure

- Primary structure
- Secondary structure
- Tertiary structure
- Quaternary structure

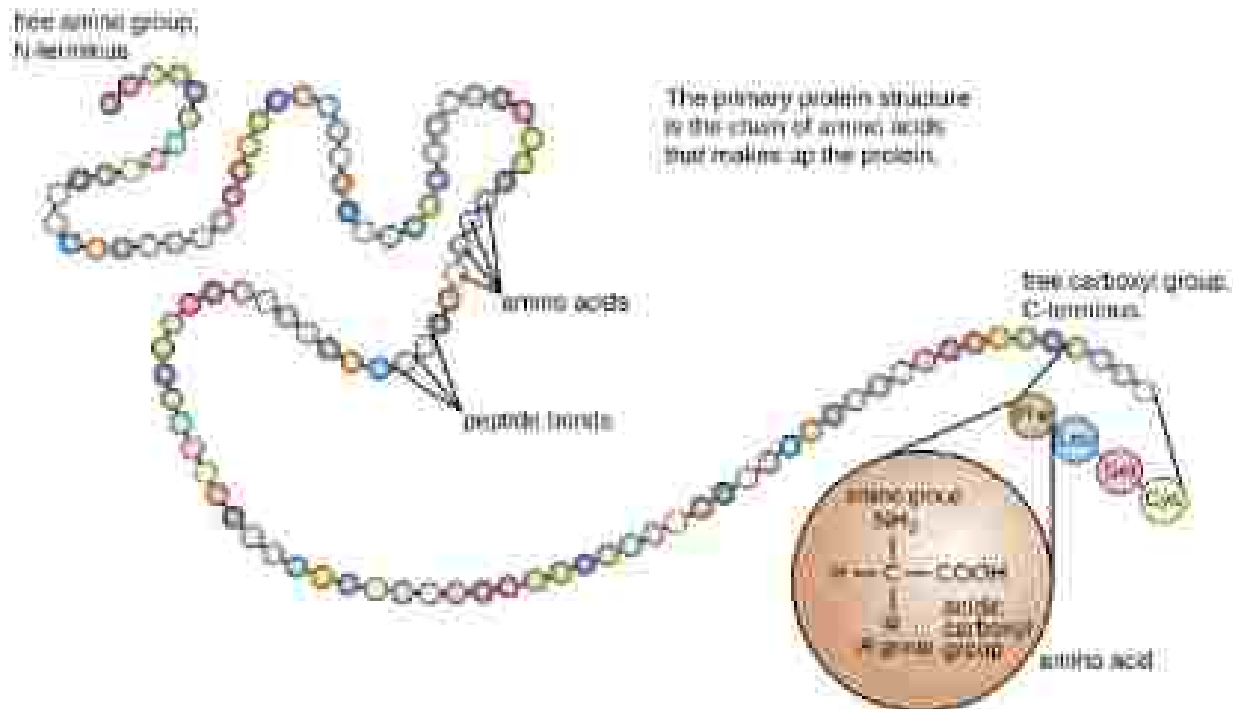


# 4 Levels of Protein Structure



# Primary Structure

- **Linear sequence of amino acids**
  - Held together by **peptide bonds**
  - Specific seq of amino acids
- each with diff properties of R groups
- Dictates folding of the polypeptide chain

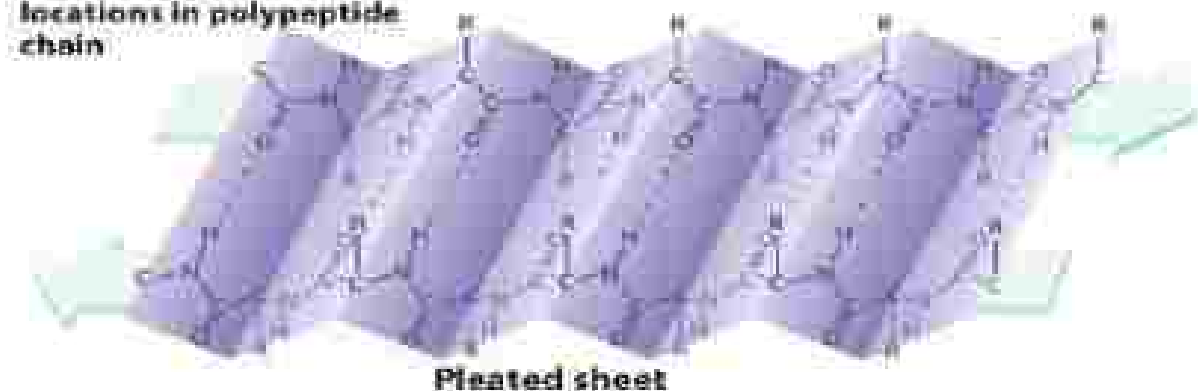
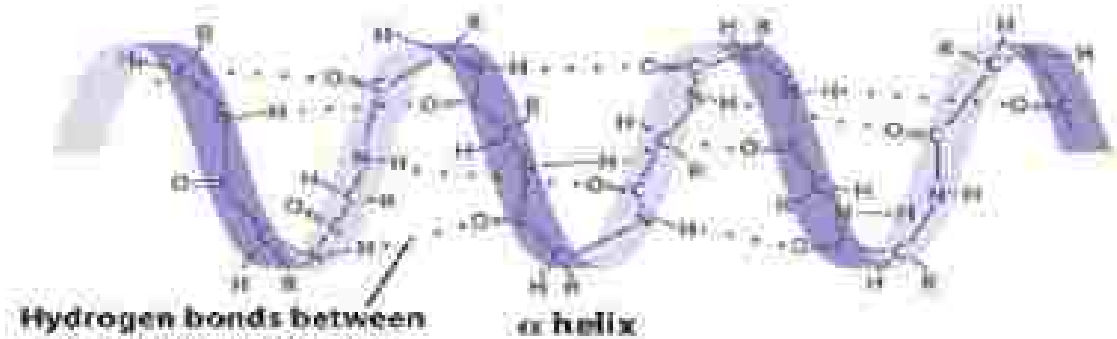


# Secondary Structure

- **H bonds** between amino acids
- Not located directly next to each other
- Of the same polypeptide chain

Two conformations:

- 1)  **$\alpha$  - helix**
- 2)  **$\beta$  - pleated**

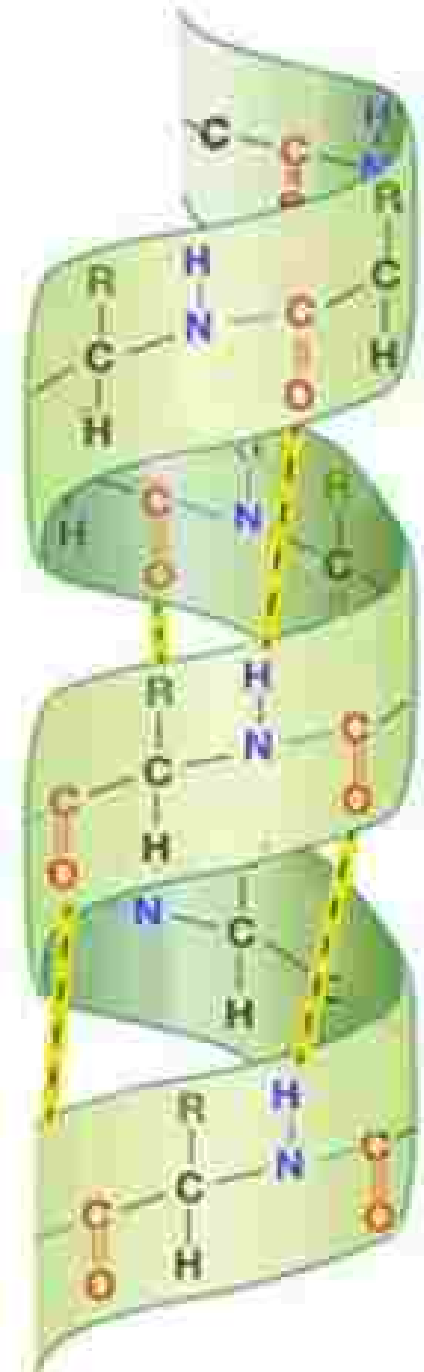




# Secondary Structure

## 1) $\alpha$ - helix

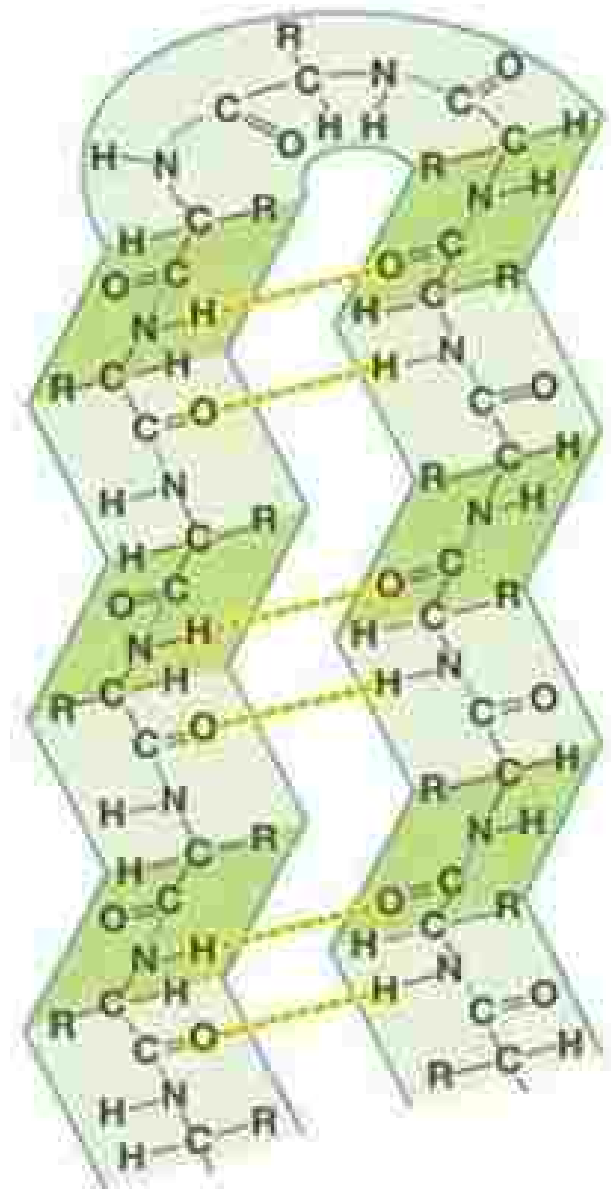
- **Hydrogen bonding**
- between H atom of the -NH group and O atom of the -CO group
- 4 places ahead
- Forms spring-like structures



# Secondary Structure

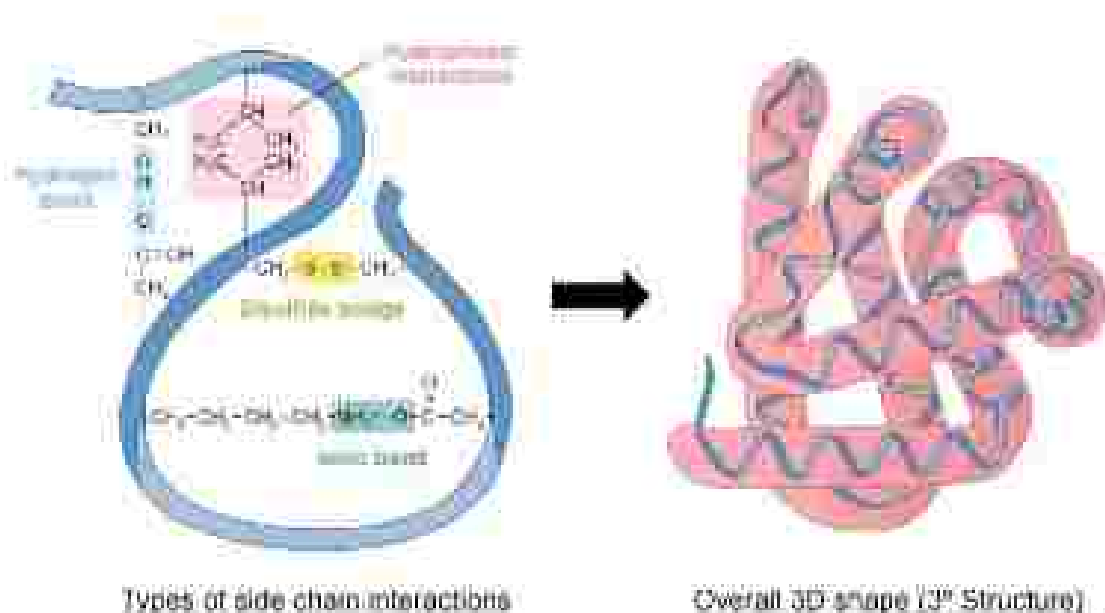
## 2) $\beta$ - pleated sheets

- **Hydrogen bonding**
- between H atom of the -NH group and O atom of the -CO group
- Straighter, looser form
- Parallel, flat sheets



# Tertiary Structure

- **Coiling and folding** of secondary structures
  - Into a precise **3D structure**
- Due to interactions between R groups
- One polypeptide chain only
- Could be held by **all 4 bonds** – H bonds, disulfide, bonds, ionic bonds, hydrophobic interactions

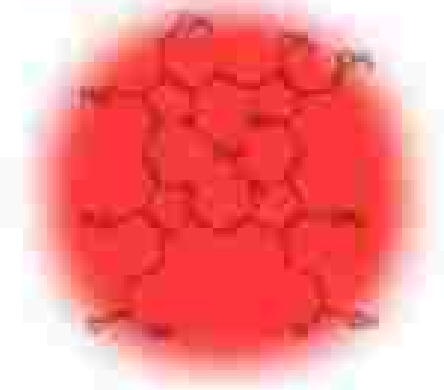


# Tertiary Structure

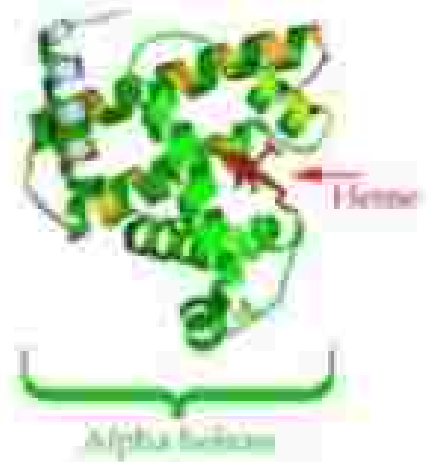
E.g. **myoglobin**

- Oxygen-carrying molecule
- Present in muscle cells
- gives it a red colour
- Made of 1 polypeptide chain
- Has a haem group = non-amino acid group
- That binds 1 molecule of oxygen

Heme



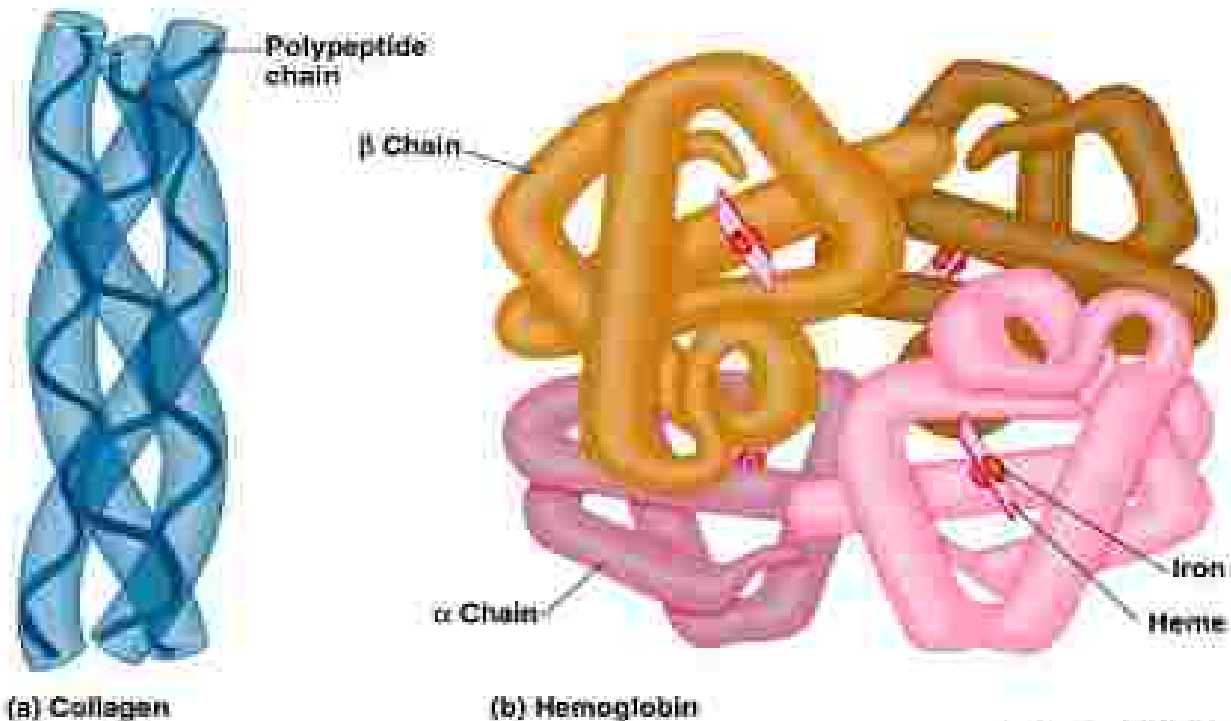
Myoglobin



# Quaternary Structure

- Combination of **two or more polypeptide chains**
- Held together by **all 4 bonds**

E.g. Haemoglobin, collagen



**Q: Which levels of protein structure are demonstrated by a haemoglobin molecule?**

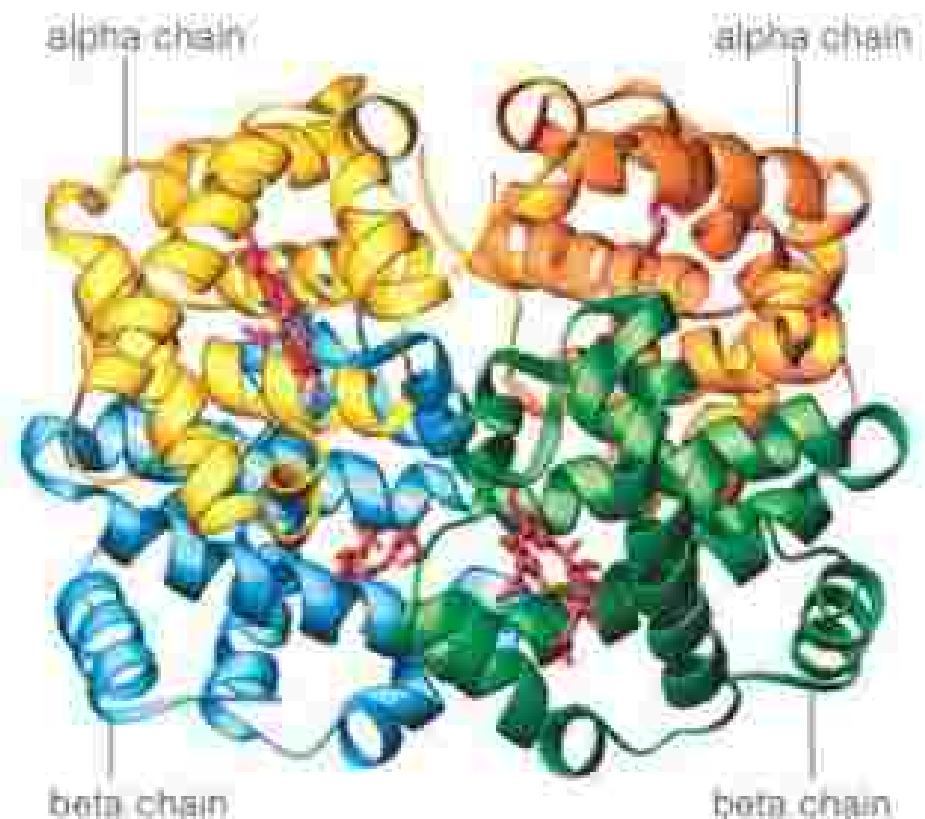
**A:**

primary

secondary

tertiary

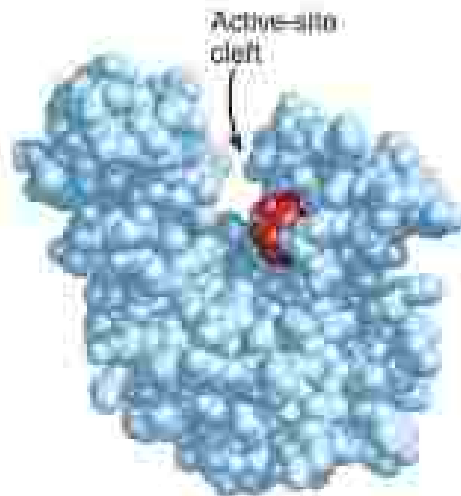
quaternary



# Proteins

## Globular vs Fibrous Proteins

Globular Proteins	Fibrous Proteins
<b>Spherical / ball shape</b>	<b>Long, parallel strands</b>
Mostly tertiary, sometimes quaternary structure	Mostly secondary structure and forms fibers
<b>Soluble</b> More functional roles	<b>Insoluble</b> More structural roles
E.g. All enzymes, antibodies, some hormones, myoglobin, haemoglobin	Eg: Collagen, keratin



**Enzyme**  
(tertiary/quaternary)



**Keratin**  
(secondary)

# Proteins

## Globular Proteins

**Q: What makes globular proteins soluble?**

**A:**

- Amino acids with non-polar / **hydrophobic R groups** are **inside**
- Amino acids with polar / **hydrophilic R groups** faces **outside**



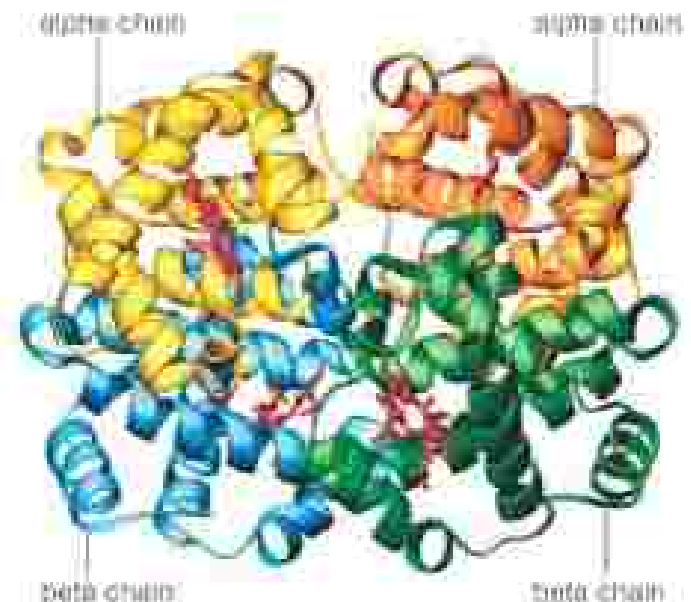
**Primary structure → Tertiary structure**



# Proteins

## Globular Protein – Haemoglobin

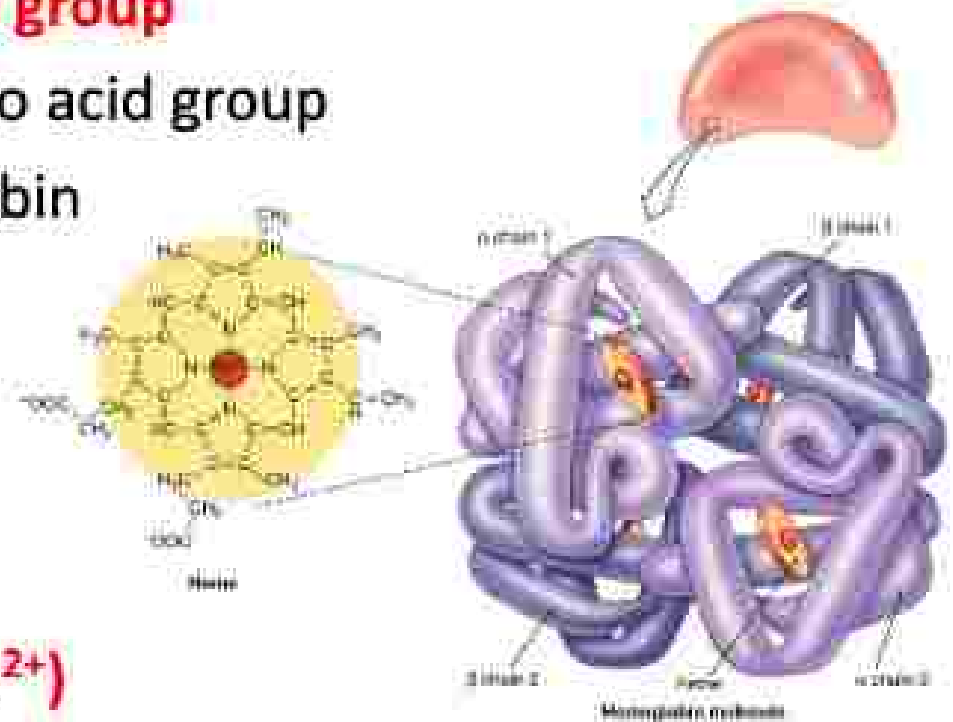
- Oxygen carrying pigment in RBC
- **Has quaternary structure**
- Made of 4 polypeptide chains
- 2  **$\alpha$ -globin** chains and 2  **$\beta$ -globin** chains
- **Globular**
- Amino acids with non-polar / **hydrophobic R groups** are **inside**
- Amino acids with polar / **hydrophilic R groups** faces **outside**



# Proteins

## Globular Protein – Haemoglobin

- Each polypeptide has a **haem group**
  - **Prosthetic group** = non-amino acid group
  - Permanent part of haemoglobin

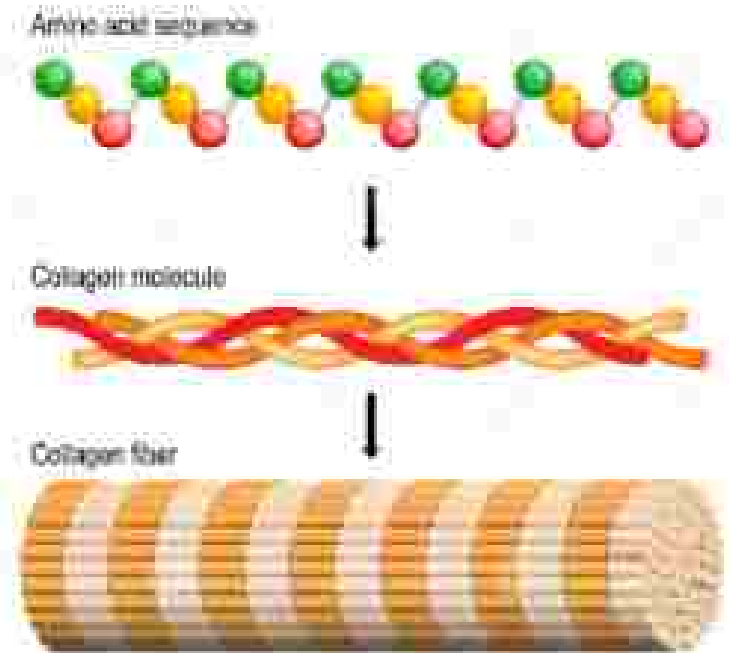


- Each haem has 1 **iron ion (Fe<sup>2+</sup>)**
  - Each Fe<sup>2+</sup> can bind 1 oxygen molecule
  - One haemoglobin can bind 4 molecules of O<sub>2</sub>

# Proteins

## Fibrous Protein – Collagen

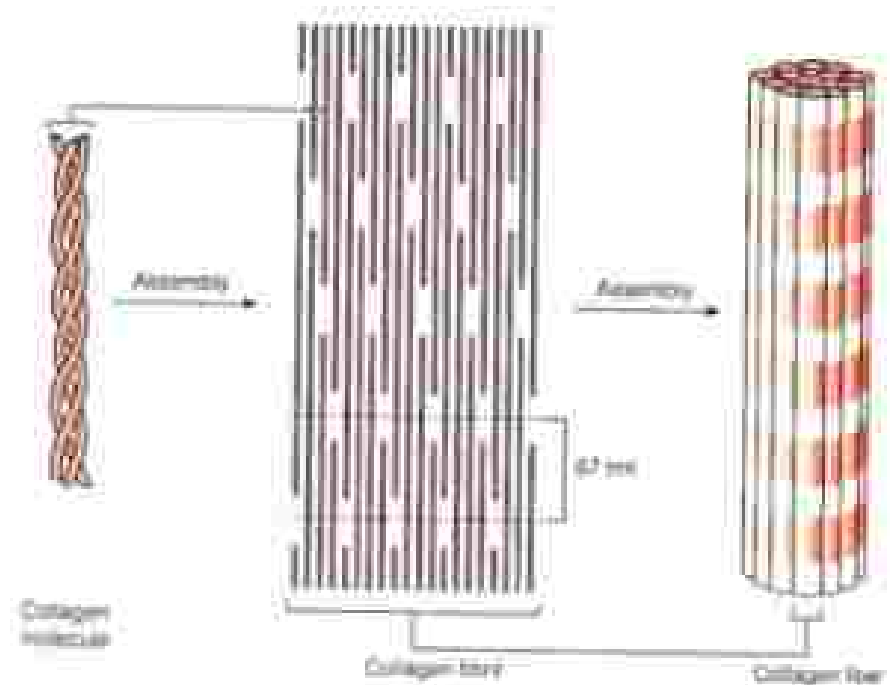
- Structural protein
- High tensile strength
- Every 3<sup>rd</sup> amino acid of each polypeptide is **glycine**
- Usually **proline-alanine-glycine** repeat
- Glycine has the smallest R group!  
→ so it can be tightly wound
- 3 polypeptide chains form **a triple helix collagen molecule**  
→ Held by **hydrogen bonds**  
→ **Quaternary structure**



# Proteins

## Fibrous Protein – Collagen

- **Collagen molecules** lie parallel
- And form **covalent cross-links**
- Between R groups of lysine a.a.
- **Staggered ends**  
→ so no weak spot
- Forms fibrils and **fibres**



# Proteins

## Fibrous Protein – Collagen

Polypeptide chain



Held together by:

**H Bonds**

Triple-stranded collagen molecule



**Covalent cross-linkages**



Collagen fibril



# Testing the Presence of Proteins

- **Biuret reagent**
- Copper (II) sulphate and dilute potassium hydroxide
- Add  $2\text{cm}^3$  of Biuret solution to  $2\text{cm}^3$  of sample
- **Purple** – protein present
- **Blue** – no protein
- $\text{NH}_2$  groups in amine react with copper ions  
→ purple





# WATER

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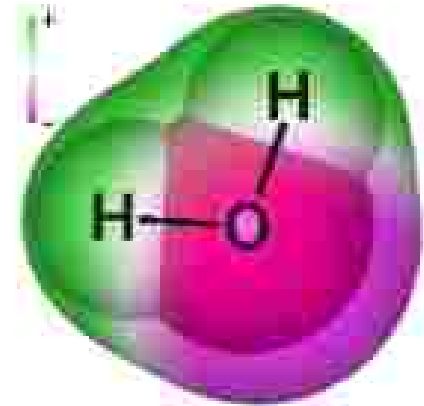


# Water

- **Dipole** in nature

→ O atom has slight negative charge

→ H atom has slight positive charge

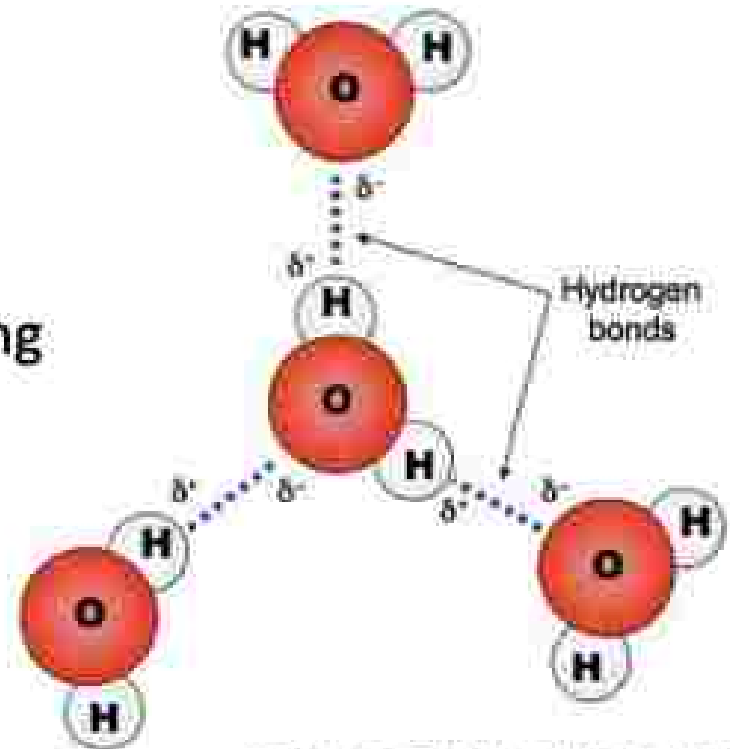


- **Hydrogen bonding**

→ between O and H atoms of  
diff water molecules

→ individually weak, cumulatively strong

→ result in many properties of water





# Water

## Properties of Water

- 1) High specific heat capacity
- 2) High latent heat of vaporisation
- 3) High latent heat of fusion
- 4) Water as a solvent
- 5) Cohesion, Adhesion and Surface Tension



# 1) High specific heat capacity



- **Specific heat capacity** = amount of heat required to raise the temperature of 1 kg of water by 1°C
- Large amount of energy needed to raise the temperature of water
  - Due to **H bonding** in water
  - Large energy needed to break H bonds
- **Provide stable temperature / environment**
  - Acts as buffer against sudden temperature change
  - Temperature of water does not change quickly



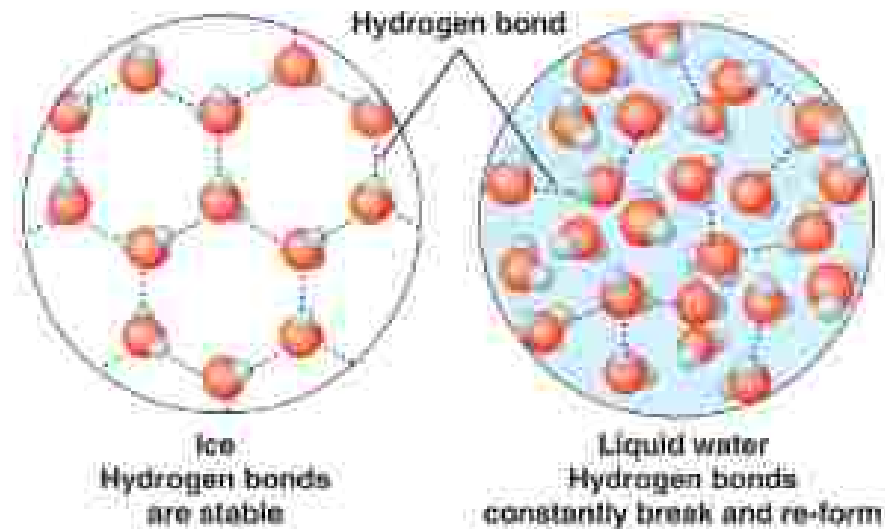
## 2) High latent heat of vapourisation

- **Latent heat of vapourisation** = amount of heat required to evaporate 1 g of water
- **Large amount of energy needed for water to evaporate**
  - Due to **H bonding** in water
- Able to **remove a large amount of heat** energy from surroundings
  - Important as a cooling mechanism



### 3) High latent heat of fusion

- Water also need **to lose a large amount of heat to freeze**
  - Due to H bonds
  - Provide stable habitats for aquatic organisms, less likely to freeze
- **Ice is less dense than water**
- Water is most dense at 4°C
- Floats → acts as **insulator** on surface of frozen lakes



# 4) Water as Solvent

- Water is **dipolar**
- **Dissolves** ions, **polar molecules**, **gases** (oxygen,  $\text{CO}_2$ ) and **waste products** (ammonia  $\text{NH}_3$  and urea)



Important for:

- **Transport**, removal of wastes, secretions, medium for enzymatic reactions

Not solvent for:

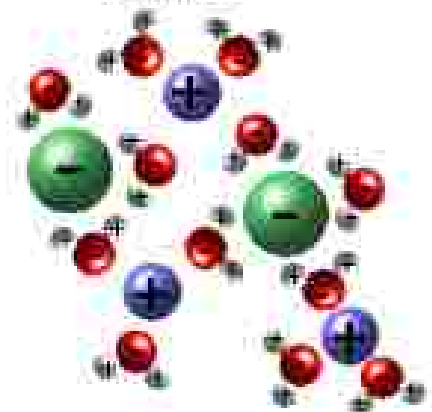
- Non-polar molecules (lipids)

NaCl crystal structure



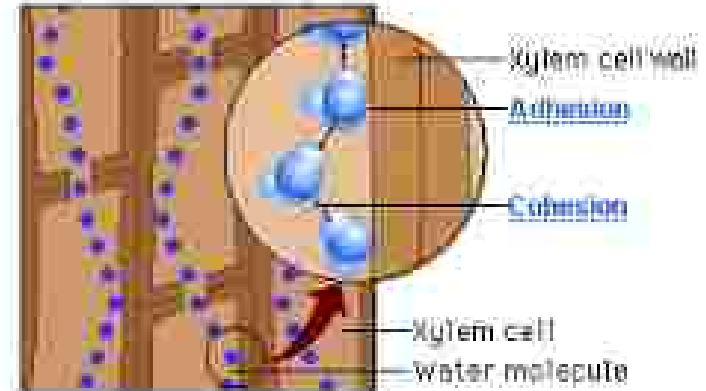
sodium (Na)  
chlorine (Cl)

NaCl in water



# 5) Cohesion, Adhesion and Surface Tension

- Tend to stick to each other – **cohesion**
- Tend to stick to surfaces – **adhesion**
- Because of H bonds



Useful for:

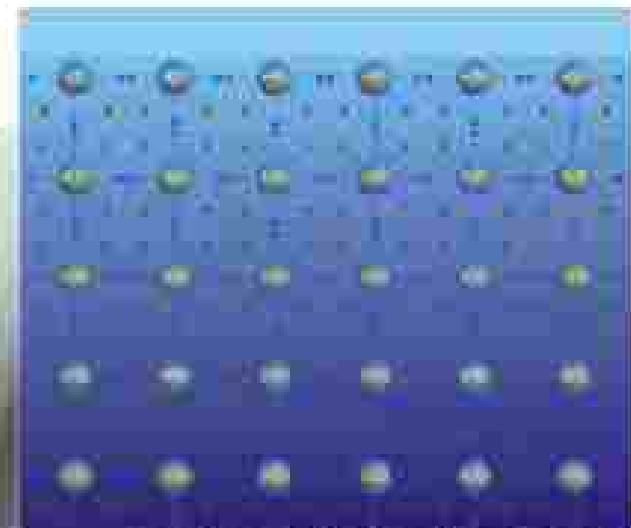
## 1) Transport of water in xylem tissue of plants

→ long, unbroken column of water

## 2) High surface tension

→ Surface dwellers' habitat

E.g. pond skater



**Q: Describe the importance of water as an environment for fish at the North Pole. [4]**

**A:**

- 1) Water is a solvent → provides (dissolved) oxygen and remove carbon dioxide / ammonia.
- 2) Water provides support / buoyancy
- 3) Water is liquid, so fish can move
- 4) Transparent, so fish can see
- 5) High specific heat capacity → so can provide stable temperature / environment
- 6) Ice less dense than water → ice floats and act as insulator, so can survive when water freezes
- 7) high latent heat of fusion, water does not freeze too easily
- 8) greatest density is at 4 °C → As a frozen lake warms after a cold winter, dissolved mineral nutrients are brought to the surface.

# Chapter Outline

Monomer to Polymer  
Hydrolysis and Condensation

## Carbohydrates

- Monosaccharide, disaccharide and polysaccharide
- Glycosidic bond
- Starch (amylose and amylopectin)
- Glycogen
- Cellulose
- Benedict's Test / Iodine Test

## Lipids

- Glycerol + 3 Fatty acids
- Ester bond
- Triglycerides
- Phospholipids
- Emulsion Test

## Protein

- Amino acids
- Peptide bond
- Primary to quaternary structure
- Globular vs Fibrous proteins
- Haemoglobin
- Collagen
- Biuret Test

## Water

- Hydrogen bond



**YOU  
ARE  
WHAT  
YOU  
EAT**



# Important Things to Remember

All tests

All bonds involved

Monomer and polymer names

Role of biomolecules

Examples of polymers – structure and function

P/S: Besides the **general structure of amino acids, glycine, alpha and beta glucose**, you don't need to know how to draw any chemical structures (from scratch anyway), but you need to be able to recognise them