



UNIT 4 CHEMISTRY – AREA OF STUDY 2
SUMMARY NOTES FOR THE VCAA EXAMS
WRITTEN BY A STUDENT WHO OBTAINED A
NEAR PERFECT STUDY SCORE

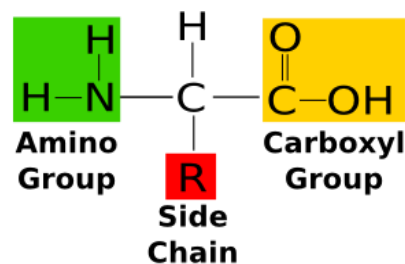
AREA FOOD CHEMISTRY

AMINO ACIDS

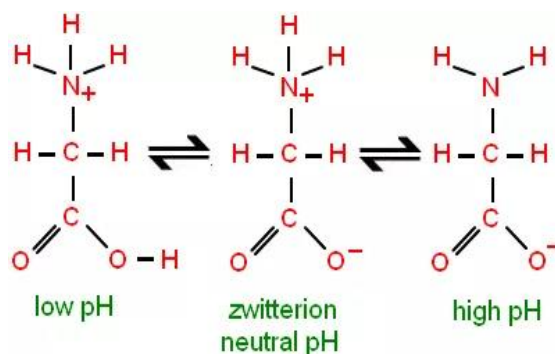
- the monomers that make up proteins (enzymes, hormones, keratin, antibodies)
- plants can manufacture all their amino acids, animals obtain these from food
- difunctional—contain both a weakly acidic carboxyl group COOH and a weakly basic amino group NH₂
- both functional groups are attached to a central alpha carbon *distinguishing difference is the R group
- 20 amino acids
- some are essential (cannot be synthesised by the body) others are non essential (can be synthesised)
- both functional groups are polar, making amino acids soluble (extensive H bonding with water)
- all (except glycine) are chiral

STRUCTURE:

- carbons are numbered from right to left (carboxyl group is one)
- R-Groups can be:
 - non-polar (CH₃)
 - polar (CH₂COOH)
 - proton donors (CH₂COOH)
 - proton acceptors (CH₂NH₂)



AMPHIPROTIC ACTIONS:

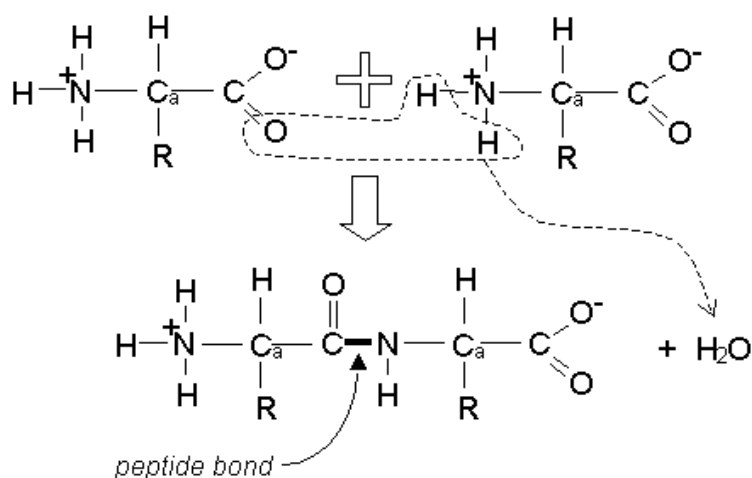


- amino acids are amphiprotic (can act as acid or base) depending on pH of solution *as an equilibrium reaction, one form will be most dominant
- **zwitterion (pH 5-7):** electrically neutral form of an amino acid which contains both a positive and a negative charge (**isoelectric point**)
- **Acid solutions:** positive charge when COO⁻ group gains a H⁺ *acts as a base*
- **Basic solutions:** negative charge when NH₃ group loses a proton *acts as an acid*

Effect of R Group: some amino acids have basic or acidic R groups due to presence of NH₂ or COOH which can influence charges e.g Asn @ pH 3 will have 2+ charge

PROTEIN FORMATION

- formed via condensation polymerisation
- peptide links **AMIDE BONDS** -CO-NH- are formed to form a polypeptide (proteins have more than 50 amino acids in the polypeptide chain)
- can be dipeptides=two amino acids, trippedide= three amino acids
- during digestion, proteins are hydrolysed to produce the individual amino acids (requires water and enzymes)

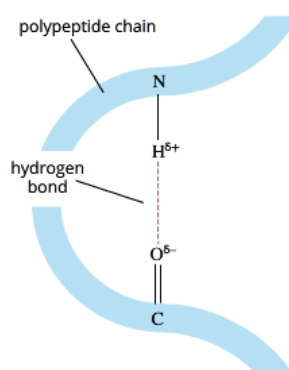
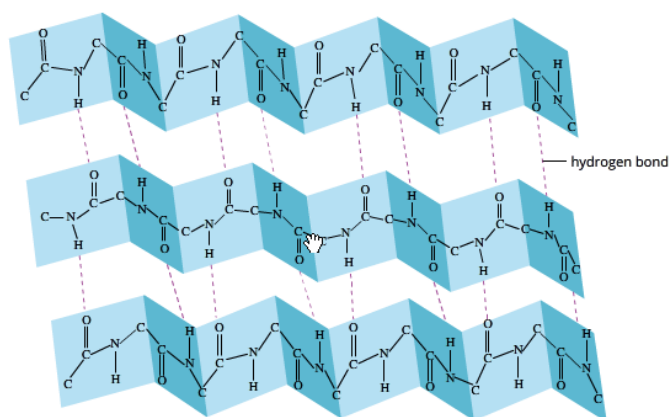
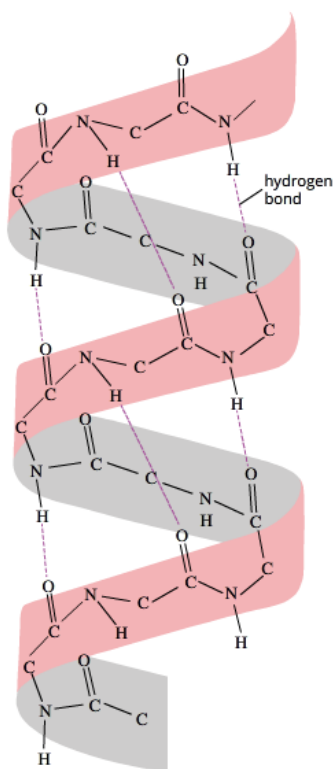


*always two isomers of the dipeptide depending on which way they condense (orientation)

- N terminal: NH₃ end
- C terminal: COOH end

PROTEIN STRUTURES

- **primary structure:** the number, type and sequence of the amino acid residues in the protein—joined by strong covalent bonds **the length is determined by the gene that codes for the protein**
- **secondary structure:** three-dimensional structure, due to Hydrogen bonding between neighbouring amide groups
- hydrogen bonding between non-bonding electron pairs on an oxygen atom (C=O) and a hydrogen atom (NH₂) from the same amino acid*results in an **alpha helix**
- interchain hydrogen bonding between polypeptides resulting in **beta pleated sheets**



- **tertiary structure:** bending and folding of the protein

overall 3D structure

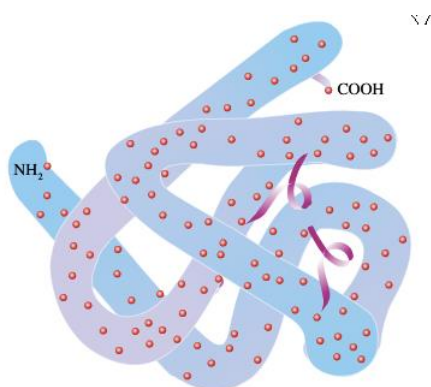
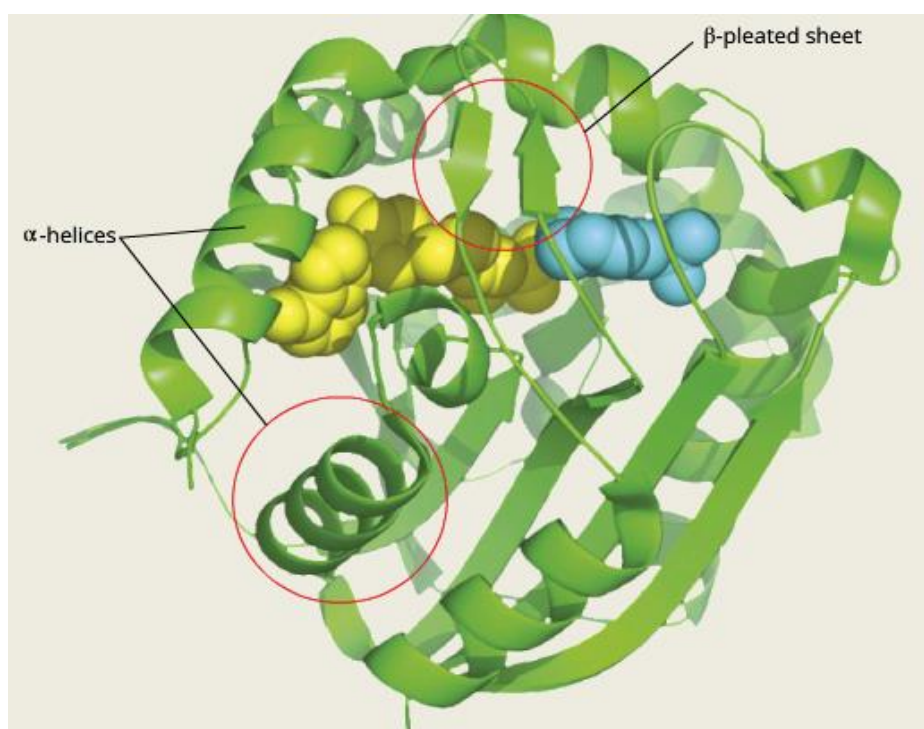
hydrophobic R groups fold inwards (away from water)

long and narrow—fibrous proteins responsible for structural functions

tightly folded alpha helix chains—globular proteins such as enzymes

arise due to bonding between R groups such as ion-ion interactions ($\text{NH}_3^+/\text{COO}^-$), hydrogen bonding ($\text{C=O}/\text{OH}$), dipole-dipole interactions, dispersion forces

disulphide bridges: due to cysteine which bonds to another cysteine to form very strong S-S covalent bonds



- **denaturation:** results in a loss of function due to...

pH change

heat

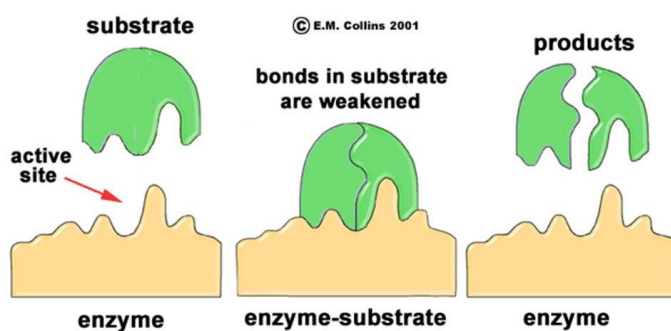
presence of salts

involves uncoiling and unfolding of the helices (does not break peptide links)

primary structure left intact

ENZYMES

Enzyme Action



- * biological catalysts that speed up the rate of reaction by providing an alternate reaction pathway with a lower E_a
- * differ from inorganic catalysts as they are—much more efficient, much more selective, easily denatured
- * lock and key model: substrate and active site have exact complementary shapes
- * enzyme-substrate complex achieved through either dispersion forces, dipole-dipole interactions or hydrogen bonds *causes bonds within substrate to weaken and break

CONDITIONS AFFECTING ACTIVITY:

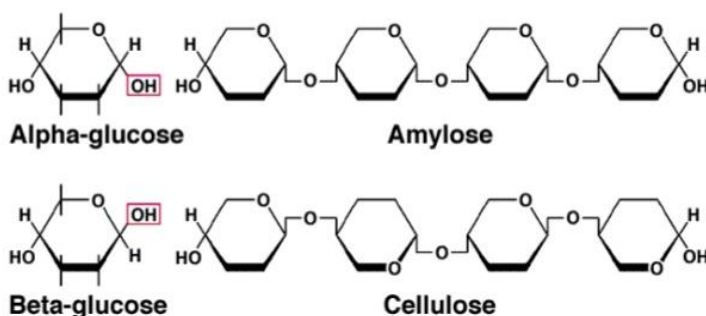
temperature: as temperature increases, rate of reaction increases due to higher KE of particles and higher proportion of collisions, enzymes will DENATURE past their optimal point as intermolecular bonds break

pH: each enzyme has an optimal pH based on acidic or basic nature of R group

CARBOHYDRATES

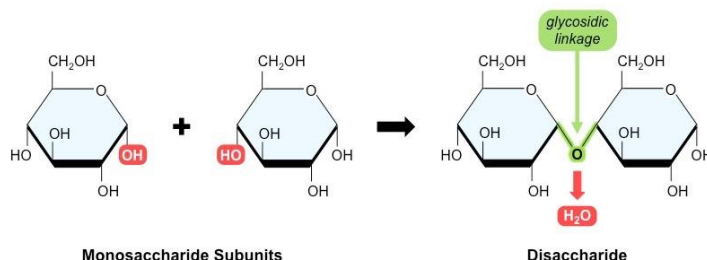
- * most widely distributed and abundant organic compounds in the biosphere
- * general formula is $C_x(H_2O)_y$
- * monosaccharides are the most simple— $C_6H_{12}O_6$
 - isomers are glucose, fructose, galactose
 - properties: crystalline solid, soluble (polar molecules), sweet tasting
 - role: cellular respiration to yield ATP
- * structure: energy and structural factors favour a more stable ring structure
 - rings produced through interactions within straight chain structure therefore have two geometric forms *differ in spatial arrangement of the hydroxyl and hydrogen groups on one carbon atom

Alpha-glucose and Beta-glucose, Plus Primary Structures of Amylose and Cellulose



- * disaccharides: formed by condensation reaction involving two monosaccharides e.g...

- glucose + glucose → maltose
- glucose + fructose → sucrose
- glucose + galactose → lactose



bond between monosaccharides is a glycosidic or ether bond (c-o-c)

- * polysaccharides: complex, high Mr carbohydrates made from 10-10,000 monosaccharides e.g starch, cellulose, glycogen

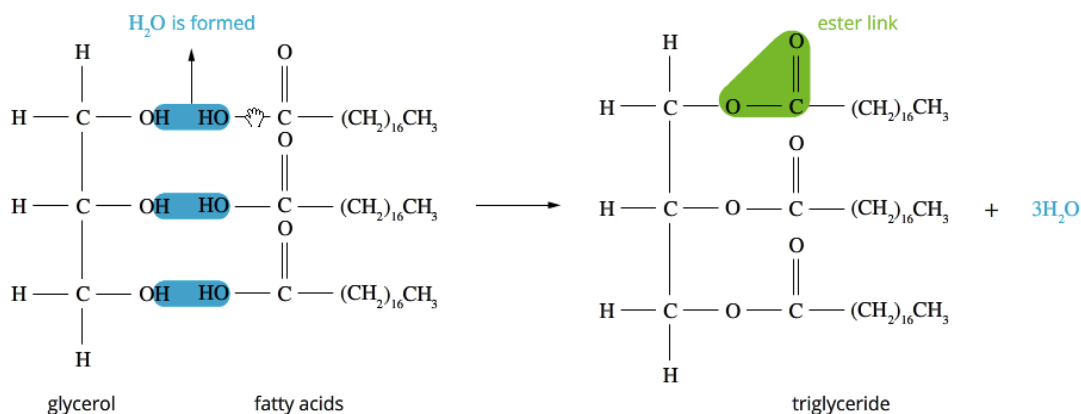
LIPIDS

- a class of compounds including fats and oils—primary function is a source of energy
- complex esters called glycerides formed via a condensation reactions between the alcohol **glycerol** $C_3H_8O_3$ and fatty (carboxylic) acid molecules
- triglycerides are formed when three fatty acids are involved

Type	R group	No of C=C	Example
saturated	C_nH_{2n+1}	0	$C_{27}H_{56}COOH$
monounsaturated	C_nH_{2n-1}	1	$C_{17}H_{33}COOH$
polyunsaturated	C_nH_{2n-x}	more than 1	$C_{17}H_{31}COOH$

- lipids are mixtures of all three types
 - animal fats are mainly saturated (solid at room temp) *due to stronger dispersion forces
 - vegetable oils are mainly unsaturated (liquid at room temp)

SYNTHESIS:



condensation reaction involving carboxyl group of a fatty acid and hydroxyl group of glycerol

DIGESTION:

- lipids are large, non-polar and insoluble
- bile (in intestine) converts lipids to a soluble form
- emulsified lipids then undergo hydrolysis to produce fatty acids and glycerol

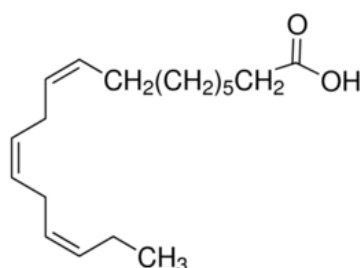
SATURATED FATS:

made from only saturated fatty acids, generally unreactive and exist as waxy solids at room temp e.g cheese

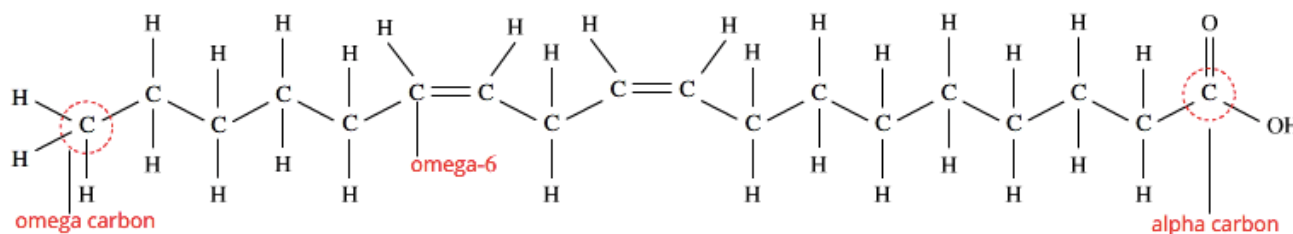
UNSATURATED FATS:

- classified according to the position of the first double bond from the end of the hydrocarbon chain
- omega carbon is the carbon atom in the methyl group at the end of the hydrocarbon chain

e.g Linolenic Acid $C_{17}H_{31}COOH$ is an **omega 3** fatty acid and has 3 $C=C$ and the first is on the third carbon from the omega carbon



- Linoleic acid $C_{17}H_{31}COOH$ is an **omega 6 fatty acid**, has 2 $C=C$ and the first is on the sixth carbon atom from the omega carbon



MELTING POINTS:

fatty acids

- * as chain length increases, strength of intermolecular (dispersion) forces increases, therefore melting point increases
- * the presence of C=C in the R group means weaker dispersion forces (chains can't pack as closely together due to repulsions between electron dense double bond) + configuration of alkyl groups on the double bond in the cis arrangement
- * melting point of saturated fatty acids is higher

lipids

- * mixtures of saturated, mono and poly unsaturated triglycerides
- * greater the percentage of saturated fatty acid residues, the stronger the dispersion forces therefore higher melting point *usually derived from animals fats and solid at room temp
- * those predominately unsaturated have lower melting points, liquid at room temp and derived from plants

ESSENTIAL/NON-ESSENTIAL:

- most fats are non essential as they can be converted into other fatty acids
 - all polyunsaturated fats are fatty acids such as linolenic and linleic acid
-

MACRONUTRIENTS + MICRONUTRIENTS

- Macronutrients: includes protein, carbohydrates and fats, minerals and water needed in high amounts for body functions
- Micronutrients: needed in the diet in very small amounts, are essential as cofactors for enzymes (such as digestive enzymes) e.g Fluorine, Zinc
- Vitamins: chemicals which cannot be synthesised by the body but are vital for metabolism, often cofactors for enzymes e.g Vitamin D needed for calcium absorption

SOLUBILITY OF VITAMINS:

➤ water soluble vitamins:

have more hydroxyl groups (form H bonds with water) allowing them to dissolve in blood

secreted by the body if not used

removed from foods if cooked in water e.g Vitamin B and C

➤ fat soluble vitamins:

have few hydroxyl groups therefore fewer H bonds with water

build up on the fatty tissues of the body

can dissolve in non-polar environments due to dispersion forces between long non-polar chains e.g Vitamin D,E,A,K

METABOLISM OF FOOD

Nutrients:

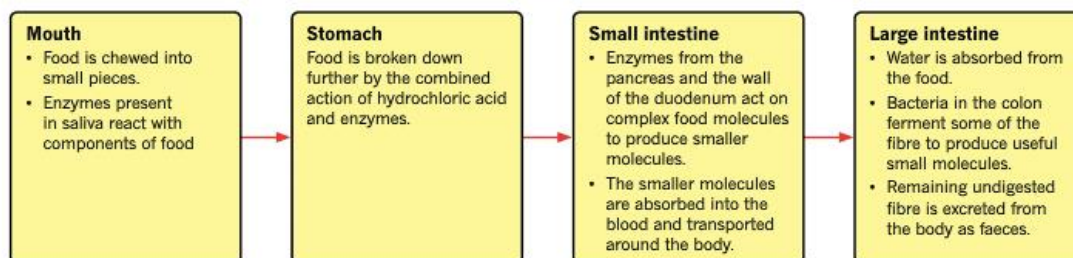
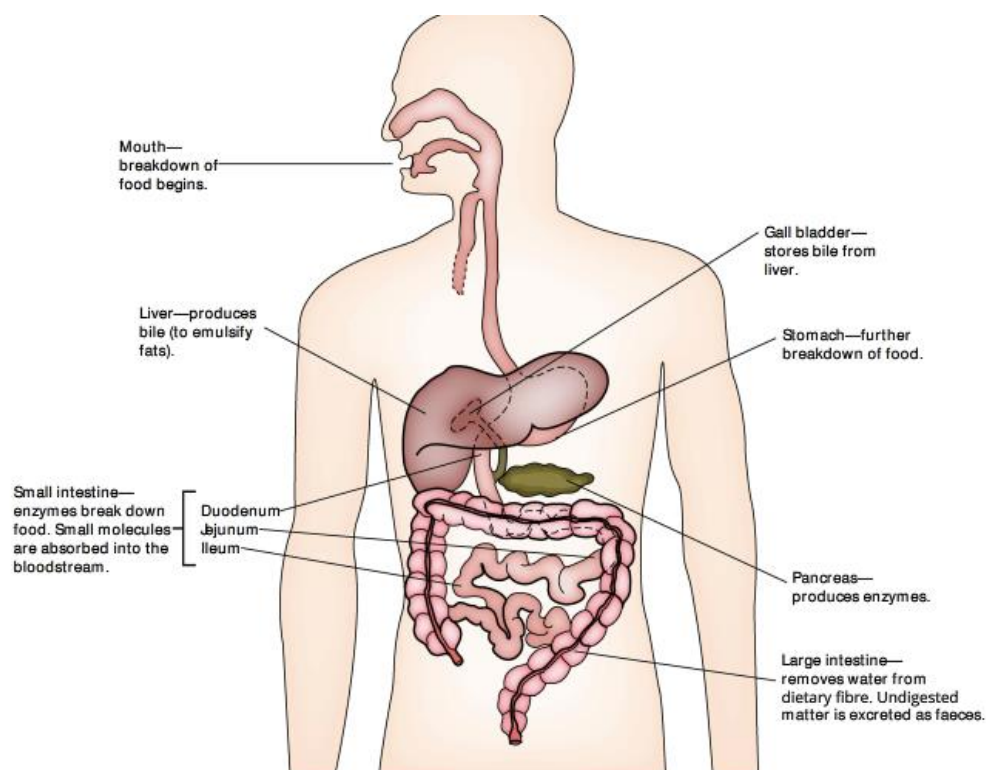
- provide energy
- regulate growth and repair
- provide specialised roles eg disease prevention, cellular process

Metabolism:

- the chemical processes which occur within an organism that are necessary for the maintenance of life
- involves the breakdown of substances (nutrients from food) to yield energy for vital processes
- synthesis of larger molecules necessary for building structural tissue such as bone or muscle

DIGESTION:

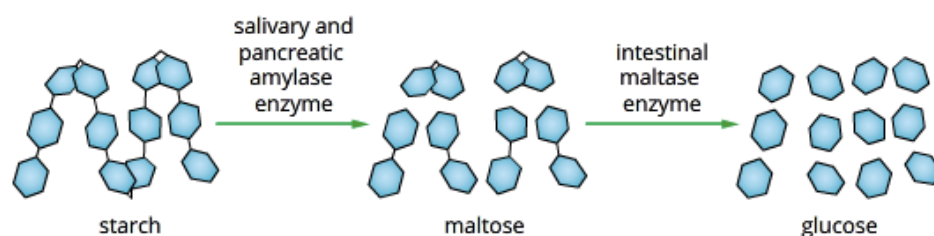
breakdown of large molecules in food into smaller molecules—a complex process involving separate and specific enzymes for each chemical reaction



CARBOHYDRATES: HYDROLYSIS

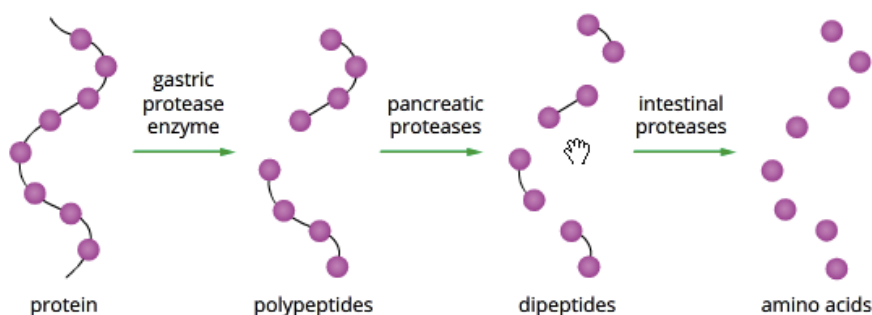
Polysaccharides e.g starch $\rightarrow$ Disaccharides e.g maltose $\rightarrow$ Glucose

- glucose produces glycogen (condensation polymerisation) to be an energy store for cell resp



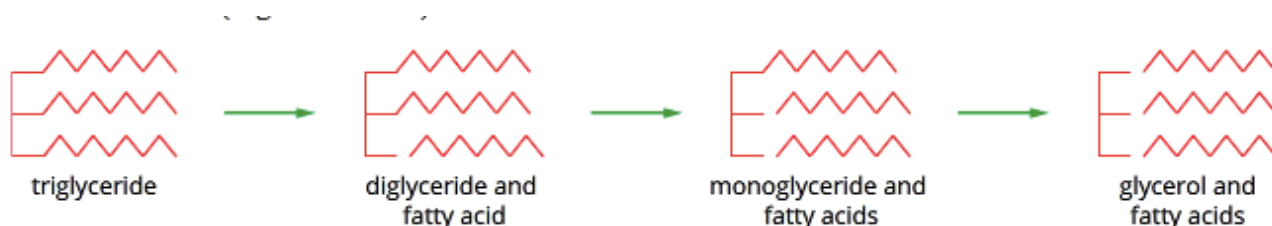
PROTEIN: HYDROLYSIS

- produces individual amino acids used to synthesise other proteins
- initially broken down by pepsin in stomach—produces smaller peptide chains which move to duodenum



TRIGLYCERIDES: FATS AND OIL

- catalysed by lipase—found in duodenum in small intestine and hydrolyses the ester links producing glycerol and fatty acids



*digestion reactions are hydrolysis requiring water and enzymes and is exothermic

- lipids are insoluble in water—need to be converted into a soluble form before hydrolysis
- Bile emulsifies the fats—the hydrophobic tails of the bile are adsorbed at the surface of the fat, the hydrophilic head is then exposed to the aqueous solution
- **lipase** (water soluble) is involved in hydrolysis of fat to produce glycerol and fatty acids *only enzyme in this pathway
- glycerol and fatty acids then pass into bloodstream where they reform into triglycerides (stored in adipose tissue as an energy reserve)

RANCIDITY:

- fats deteriorate over time
- unsaturated fats are especially susceptible to rancidity—the C=C are reactive and undergo chemical reaction which may contain other functional groups (aldehydes and ketones)

hydrocarbon chain may break apart forming smaller molecules *characterised by a change in smell or taste called **oxidative rancidity** (often forms aldehydes or ketones)

ANTIOXIDANTS:

- to decrease rate of deterioration food can be refrigerated, preservatives can be added or ANTIOXIDANTS can be used
- antioxidants—substances which slow the rate of oxidation of another substance by preventing the propagation
- act by intercepting the lipid peroxy radical by donating a hydrogen
- able to slow down formation of free radicals (formed during autoxidation)
e.g Vitamin C and E

AUTO-OXIDATION:

involves a free radical chain reaction—free radicals are highly reactive atoms or molecules with unpaired valence electrons

1) INITIATION:

- cleavage of C-H bond in the fatty acid
- requires energy due to strength of C-H bond
- $RH \rightarrow R + H$

2) PROPAGATION:

- free radical chain reaction in which free radicals react with O₂ to form other free radicals
- $R + O_2 \rightarrow RCOO \rightarrow RCOOH$ (hydroperoxide) + R
- $ROOH \rightarrow R'CHO$ (aldehyde) + R'' + OH

3) TERMINATION:

- process is completed when two radicals combine
- $R + ROO + ROOR + R_2 + O_2$

ENZYMES

- proteins and the biological catalysts for many chemical reactions in organisms
- not chemically altered in reaction
- more sensitive to changes in environment than inorganic catalysts
- highly specific—often can only catalyse one specific biochemical reaction

RELEVANCE OF OPTICAL ISOMERISM:

- * amino acids are chiral molecules (except glycine where the R group is H)
- * one of the two enantiomers of each amino acid is utilised in protein synthesis
- * many substrate molecules have chiral centres, only one enantiomer will 'fit' into the active site, this is the biologically active isomer

MODELS OF ENZYME ACTION:

- * Lock and key model (summarised early)
- * Induced fit model: enzymes have a flexible 3-D shapes which can be slightly modified to fit the shape of the substrate, after reaction the enzymes shape is regained

COENZYMES:

- Cofactors (must be present for reaction to be catalysed) can be metal ions or non protein organic components called coenzymes which are required for enzyme activity e.g Mg^{2+} are cofactors in DNA replication to balance out negative charge of DNA
- interact with enzymes during catalysis and act as electron carriers or carriers of specific groups of atoms e.g acetyl CoA carries $COCH_3$ or NADH
- this alters surface properties of the enzyme and enhance the binding properties of the enzyme, activating it
- may be chemically changes as a result of its involvement with an enzyme

GLYCAEMIC INDEX

- carbohydrate containing foods are rated on the glycemic index
- GI scale ranks foods according to their effect of blood sugar after two hours of consumption (100 is the standard, an equivalent amount of pure glucose)
- GI effect depends on:
 - type of starch
 - whether starch polymers are entrapped within food
 - fat and protein (and other substances) content of food
- useful to understand how the body breaks down carbohydrates, taking into account only available carbohydrates (total minus fibre)
- Low GI=values of 55 or less—release glucose more slowly and steadily due to slower digestion
- High GI =values greater than 70 release glucose very quickly
- linear polymer starch molecules (amylose) *pack together more tightly* and are *less soluble* than the branched polymer (amylopectin) —less access of enzymes to hydrolyse the ether links therefore amylopectin will digest MORE rapidly than amylose

ENERGY CONTENT

ENERGY FROM GLUCOSE:

- a monosaccharides which is the bodies most preferred energy source
- starch (polysaccharide is hydrolysed to produce glucose)
- energy is obtained from glucose via CELLULAR RESPIRATION

Aerobic— $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + 38 \text{ ATP}$ $\Delta = -2860\text{kg/mol}$

Anaerobic— $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{CH}_3\text{CH}(\text{OH})\text{COO}^- + 2\text{H}^+$ (lactic acid) -120kg/mol
or $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2$ (fermentation) -69kg/mol

ENERGY VALUES:

Nutrient	Energy content (kJ/g)	Energy value (available energy) kJ/g
Carbohydrates	17	17
Fats/Oil	39	37
Protein	24	17

- high energy content of fats is due to a high degree of oxidation
- carbohydrates have more oxygen atoms than fats therefore have a higher degree of oxidation—fats have greater potential for oxidation therefore release more energy on combustion
- represented in kJ/g as they are mixtures (no Mr) however glucose (pure substance) can have kJ/mol

Energy available to the body:

- * energy released when food is burned is often higher than that after it has been digested due to...
 - incomplete absorption of nutrient by the body after digestion of food
 - incomplete oxidation of nutrients
 - heat loss—oxidation may result in energy being used up in heat loss

Working out energy content in foods:

e.g Find energy content of cashews that are 29% carbohydrates, 18% protein and 46% fats

$29 \times 17 = 493 \text{ kJ of carbs}$

$18 \times 17 = 306 \text{ kJ of protein}$

$46 \times 37 = 1702 \text{ kJ of fat}$

$(1702 + 306 + 493) / 100 = 25 \text{ kJ/g}$

CALORIMETRY

- energy released during a combustion reaction is transferred into the water in the calorimeter
- calibration factor: required so that energy change for the entire system for each 1 degree celsius is known (units J/degrees celsius) once this is determined the calorimeter is CALIBRATED

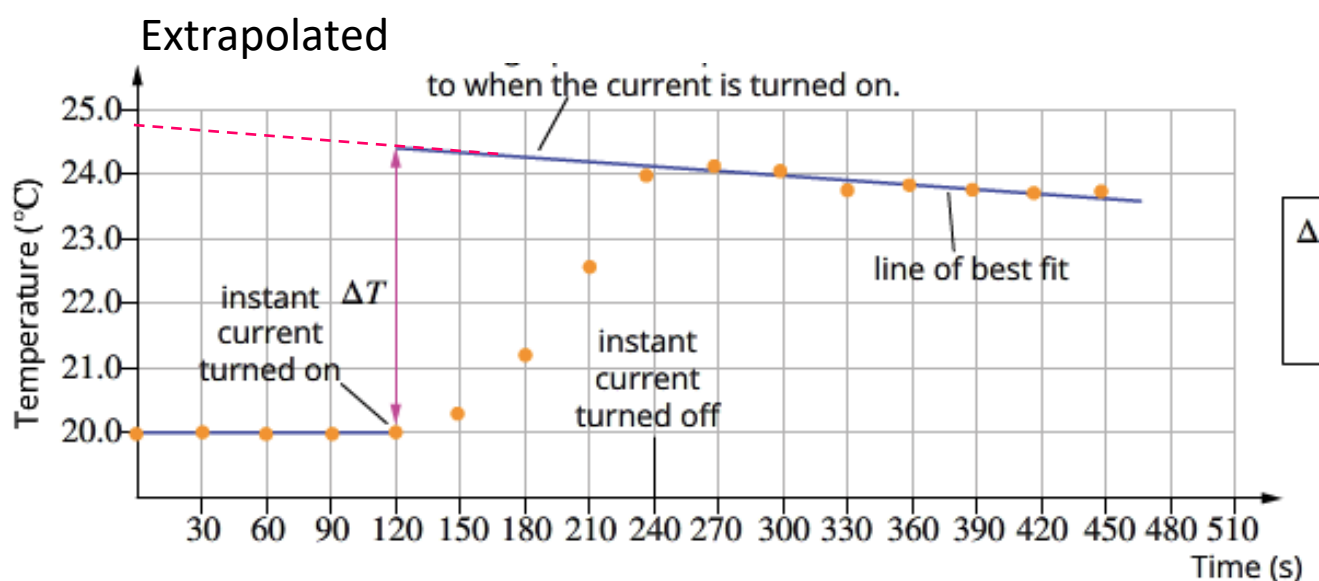
Electrical calibration:

- * calibrates by using an electric heater to release a known quantity of thermal energy and measuring the resultant rise in temperature
- * Energy = volts x current x time

$$CF = \frac{E}{\Delta T} = \frac{VIt}{\Delta T}$$

Temperature-time graphs:

- calorimeter is not perfectly insulated, it slowly loses heat during and after the heat is operating
- graphs at each time show accurately the change in temperature rather than finding delta T
- heat loss causes a decreasing gradient after heater is turned on—delta T is most accurately measure by extrapolating the line back to when heating commenced



Chemical calibration:

- * performing a chemical reaction in the calorimeter that release known quantity of thermal energy
- * often uses benzoic acid (C_6H_5COOH) enthalpy of combustion -3227kJ/mol

$$E = n \times \Delta H_c \quad CF = \frac{E}{\Delta T}$$