UNIT 4 CHEMISTRY – AREA OF STUDY 2

SUMMARY NOTES FOR THE VCAA EXAMS

WRITTEN BY A STUDENT WHO OBTAINED A NEAR PERFECT STUDY SCORE

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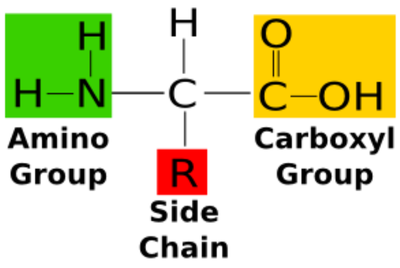
AREA FOOD CHEMISTRY

AMINO ACIDS

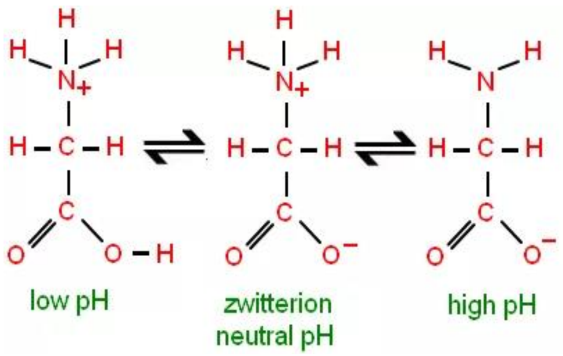
- the monomers that make up proteins (enzymes, hormones, keratin, antibodies)
- plants can manufacture all their amino acids, animals obtain these from food
- difunctional—contain both a weakly acidic carboxyl group COOH and a weakly basic amino group NH2
- both functional groups are attached to a central 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:

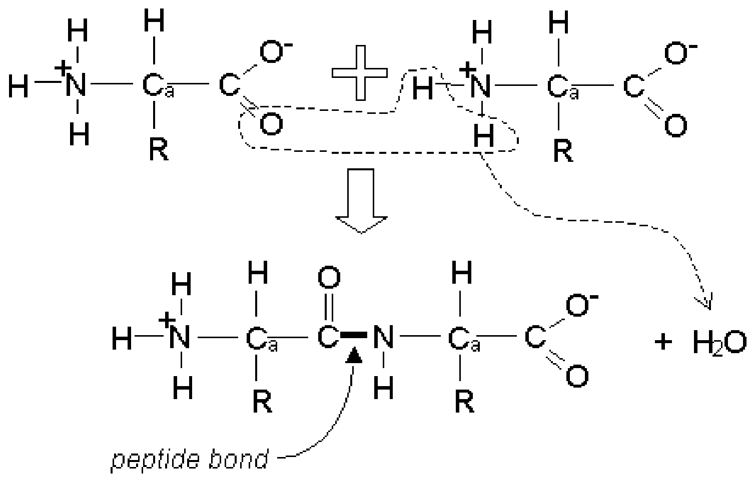


- amino acids are amphiprotic (can act as acid or base) depending on pH of solution *as an equilibrium reaction, one form will be most dominant
- ***zwitterion (pH 5-7):*** electrically neutral form of an amino acid which contains both a positive and a negative charge **(isoelectric point)**
- **Acid 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

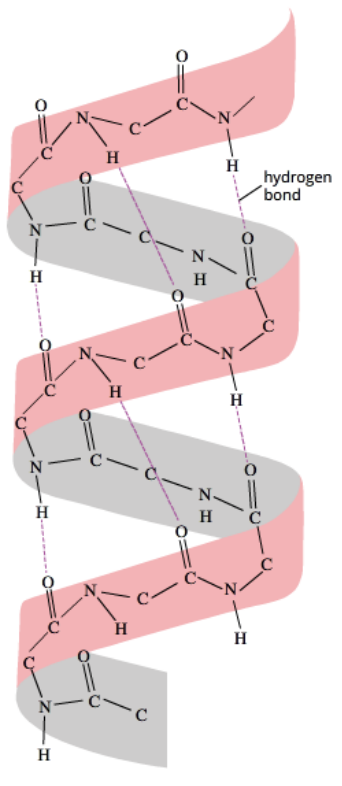
PROTEIN STRUTURES

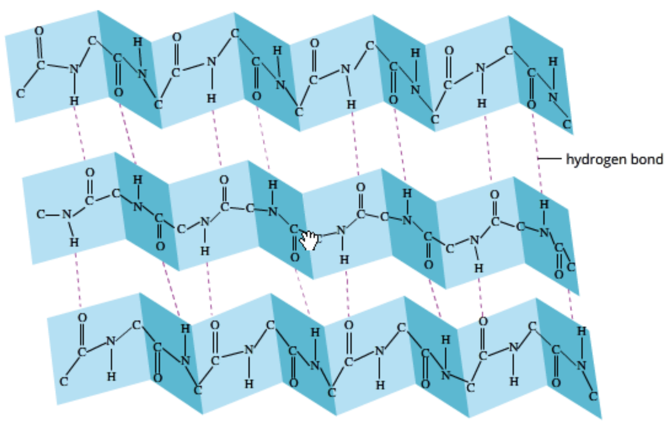
- ***primary structure:*** the number, type and sequence of the amino acid residues in the protein—joined by strong covalent bonds **the length is determined by the gene that codes for the protein**

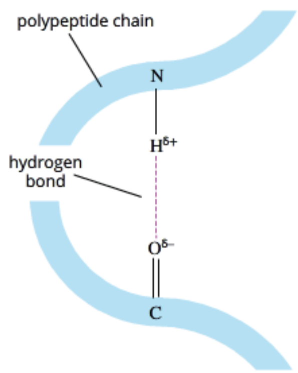
- ***secondary structure:*** three-dimensional structure, due to Hydrogen bonding between neighbouring amide groups

- 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

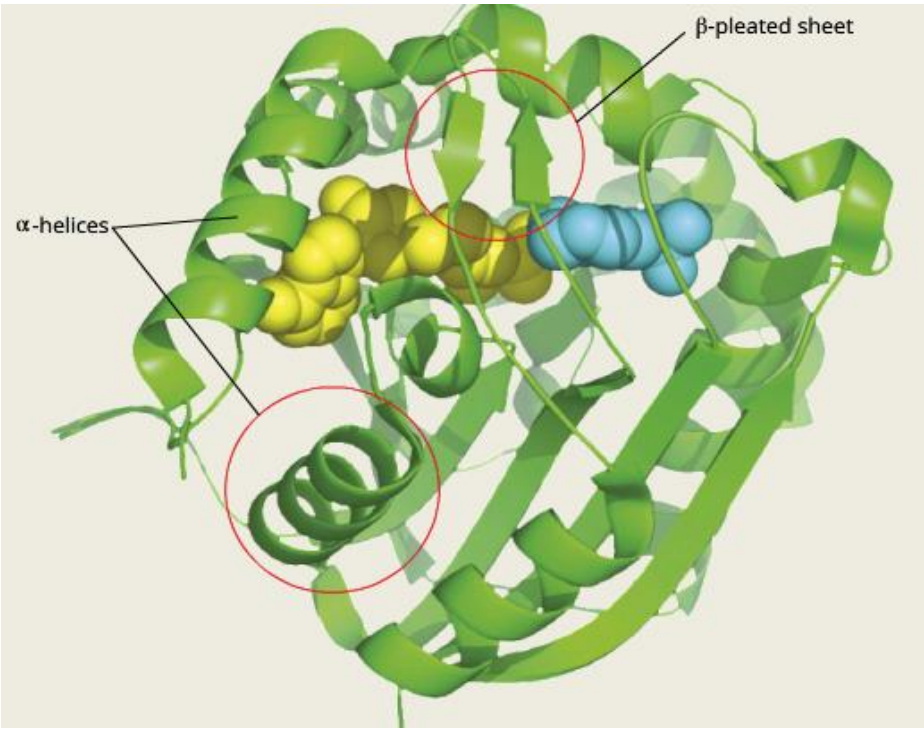
  hydrophobic R groups fold inwards (away from water)

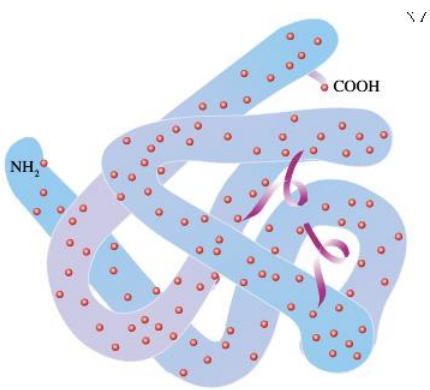
  long and narrow—fibrous proteins responsible for structural functions

  tightly folded alpha helix chains—globular proteins such as enzymes

  arise due to bonding between R groups such as ion-ion interactions (NH3+/COO-), hydrogen bonding (C=O/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

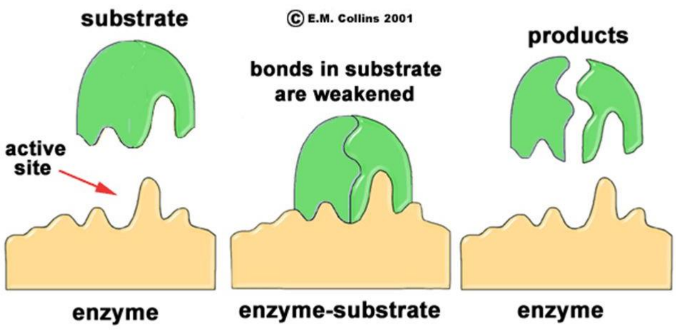
  heat

  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 bu providing an alternate reaction pathway with a lower Ea

- 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 complimentary shapes

- enzyme-substrate complex achieved through either dispersion forces, dipole-dipole interactions or hydrogen bonds *causes bonds within substrate to weaken and break

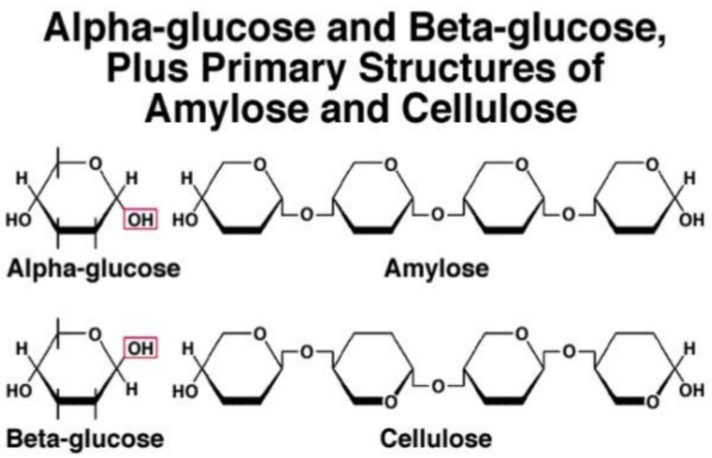
CONDITIONS AFFECTING ACTIVITY:

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

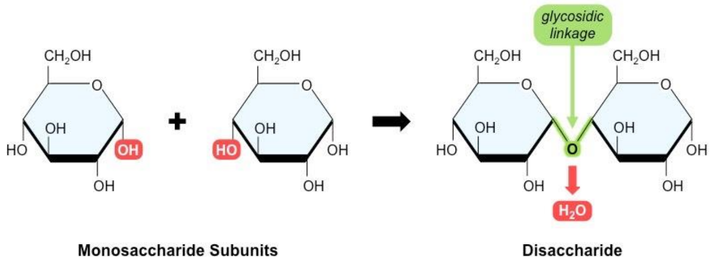
pH: each enzyme has an optimal pH based on acidic or basic nature of R group

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



- 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

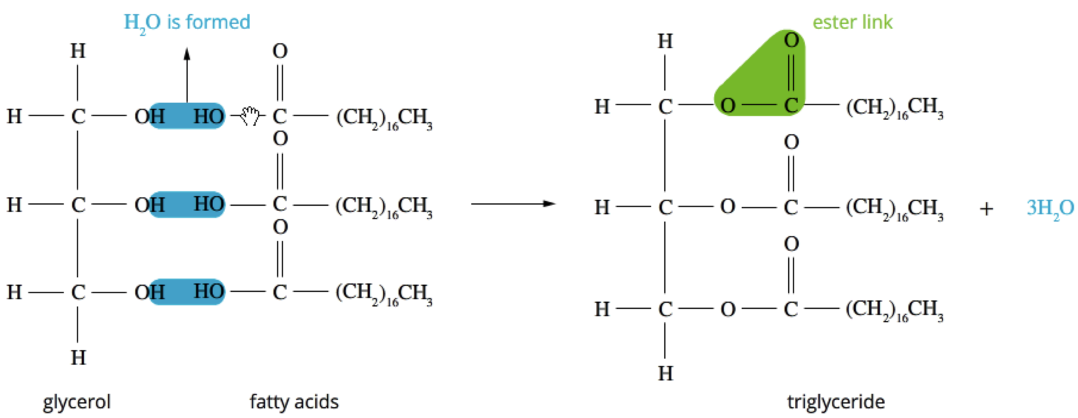
LIPIDS

- 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 C3H8O3*** and fatty (carboxylic) acid molecules
- triglycerides are formed when three fatty acids are involved

Type	R group	No of C=C	Example
saturated	CnH2n+1	0	C27H35COOH
monounsaturated	CnH2n-1	1	C17H33COOH
polyunsaturated	CnH2n-x	more than 1	C17H31COOH

- 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:



glycerol + 3 fatty acids —> triglyceride + 3H20

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:

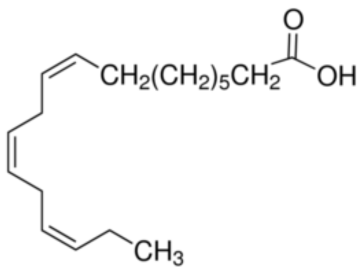
made from only saturated fatty acids, generally unreactive and exist as waxy solids at room temp e.g cheese

UNSATURATED FATS:

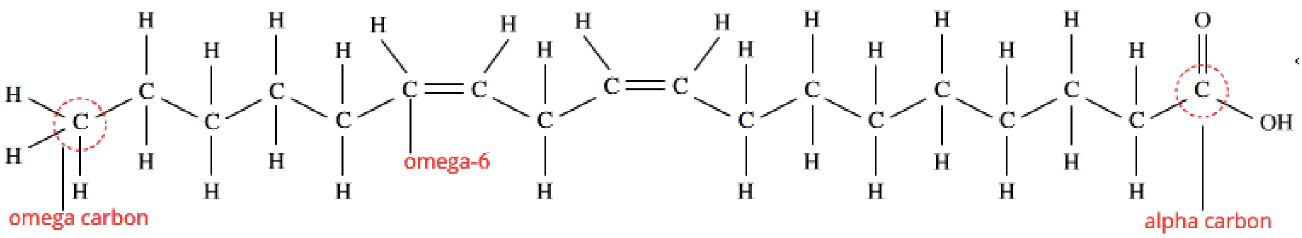
- classified according to the position of the first double bond from the end of the hydrocarbon chain

- omega carbon is the carbon atom in the methyl group at the end of the hydrocarbon chain

  e.g Linolenic Acid C17H31COOH 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 C17H31COOH 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

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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:

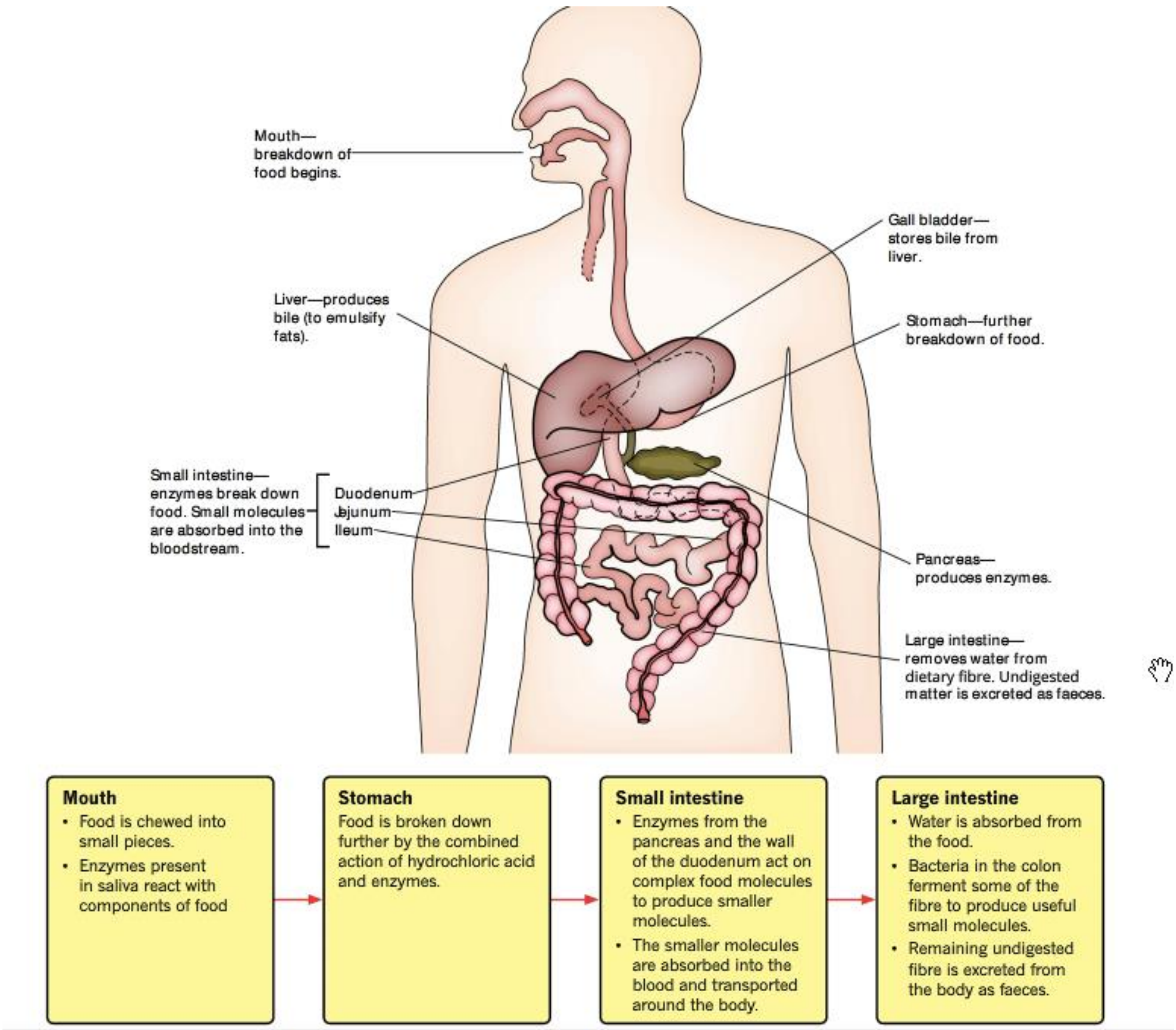
- the chemical processes which occur within an organism that are necessary for the maintenance of life

- 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:

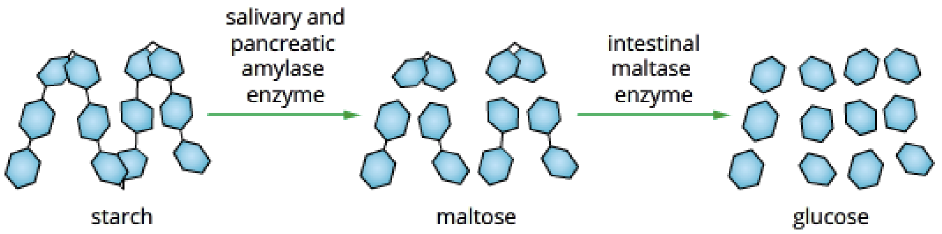
breakdown of large molecules in food into smaller molecules—a complex process involving separate and specific enzymes for each chemical reaction



CARBOHYDRATES: HYDROLYSIS

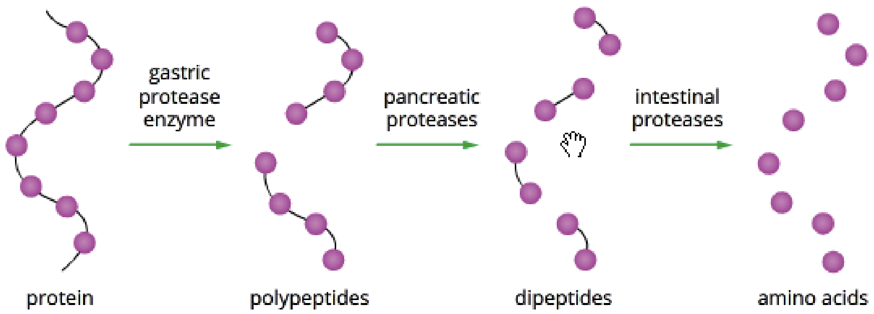
Polysaccharides e.g starch —> Disaccharides e.g maltose —> Glucose

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



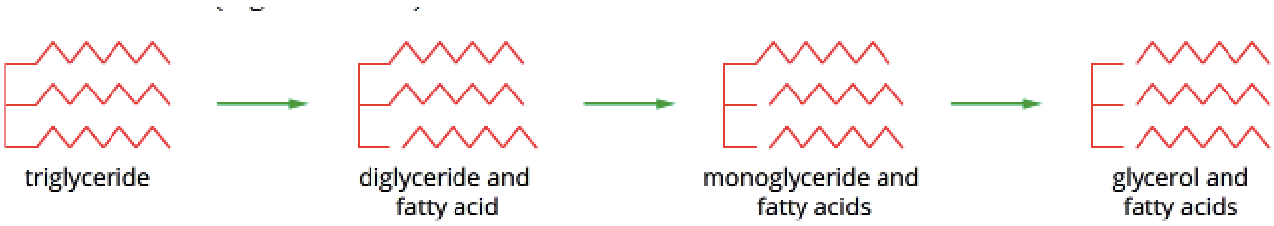
PROTEIN: HYDROLYSIS

- 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 tools of the bile is 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 former 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 peroxyl 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 —> R + H*
2) *PROPAGATION:*
   - *free radical chain reaction in which free radicals react with O2 to form other free radicals*
   - *R + O2 —> RCOO —> RCOOH (hydroperoxide) + R*
   - *ROOH—> R'CHO (aldehyde) + R'' +OH*
3) *TERMINATION:*
   - *process is completed when two radicals combine*
   - *R +ROO + ROOR + R2 +O2*

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 Mg2+ 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 COCH3 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—$C6H12O6 + 6O2 \rightarrow 6CO2 + 6H2O$ + 38 ATP Δ =-2860kg/mol

  Anaerobic—$C6H12O6$ —> $2CH3CH(OH)COO^- + 2H^+$ (lactic acid) -120kg/mol
  or $C6H12O6$—> $2C2H5OH + 2CO2$ (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 then 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 if often high then 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

29x17 =493kj of carbs
18x17 =306kj of protein
46x37 =1702kj of fat

(1702 + 306 +493)/100 =25kj/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 1degree 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

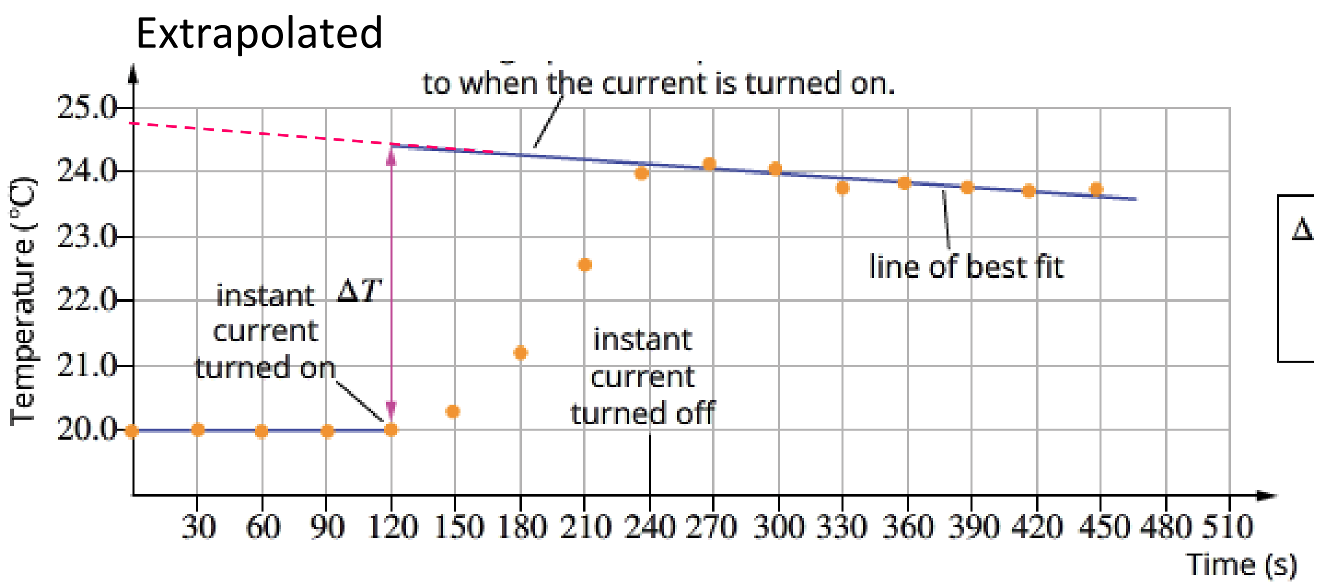
$$CF = \frac{E}{\Delta T} = \frac{VIt}{\Delta T}$$

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 (C6H5COOH) enthalpy of combustion -3227kj/mol

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