

## Option F: Food chemistry (15/22 hours)

Food chemistry is a study of the composition and properties of food, the chemical changes it undergoes during handling, processing and storage, and the principles underlying the improvement of food. The aim of this option is to give students an understanding of the chemistry of important molecules in food and the contribution that chemistry has made (and continues to make) towards maintaining and improving the quality and cost of food, adequacy of food supplies and food safety. Students should be able to recognize some important structures and relevant functional groups, and to distinguish between them. It is not necessary to memorize complex formulas, as structures and examples of some food molecules are given in the *Chemistry data booklet*. Teachers are encouraged to take a contextual approach, and to foster local and global issues.

**Core material:** F1–F6 are core material for SL and HL (15 hours).

**Extension material:** F7–F10 are extension material for HL only (7 hours).

## F1 Food groups

2 hours

	Assessment statement	Obj	Teacher's notes
F.1.1	Distinguish between a <i>food</i> and a <i>nutrient</i> .	2	Food: "Any substance, whether processed, semi-processed or raw, which is intended for human consumption, and includes drink, chewing gum and any substance which has been used in the manufacture, preparation or treatment of 'food', but does not include cosmetics or tobacco or substances used only as drugs." (Codex Alimentarius (FAO/WHO) definition 2005)  Nutrient: Any substance obtained from food and used by the body to provide energy, regulate growth, maintenance and repair of the body's tissues. Proteins, lipids, carbohydrates, vitamins, minerals and water are considered nutrients.
F.1.2	Describe the chemical composition of lipids (fats and oils), carbohydrates and proteins.	2	Fats and oils are triesters (triglycerides) formed from three long-chain fatty acid (carboxylic acid) molecules and one glycerol molecule.  The simplest carbohydrates are monosaccharides. They contain one carbonyl group (C=O) and at least two hydroxyl (–OH) groups, and have the empirical formula CH <sub>2</sub> O. Monosaccharides are the building blocks of disaccharides and polysaccharides.  Proteins are made up of 2-amino acids.

## F2 Fats and oils

3 hours

	Assessment statement	Obj	Teacher's notes
F.2.1	Describe the difference in structure between saturated and unsaturated (mono- and poly-unsaturated) fatty acids.	2	Most naturally occurring fats contain a mixture of saturated, mono-unsaturated and poly-unsaturated fatty acids and are classified according to the predominant type of unsaturation present.
F.2.2	Predict the degree of crystallization (solidification) and melting point of fats and oils from their structure, and explain the relevance of this property in the home and in industry.	3	Solid fats are more likely to be crystalline, more saturated and/or have longer fatty acid hydrocarbon chains. Mono-unsaturated (olive, canola and peanut) and poly-unsaturated fats (safflower, sunflower, corn, fish, linoleic and linolenic) are liquids, and saturated fats (palm, coconut, lard, butter and shortening) are solids at room temperature.  The melting point of fatty acids increases with increasing relative molecular mass and increasing degree of saturation. Fats and oils are chosen for cooking on the basis of their melting temperature. For example, cocoa butter melts at close to body temperature, and fats chosen for cake-making melt over a wide range of temperatures.  <i>Cis</i> fatty acids (the hydrogen atoms are on the same side of the carbon–carbon double bond) have lower melting points than <i>trans</i> fatty acids (the hydrogen atoms are on opposite sides of the carbon–carbon double bond).

	Assessment statement	Obj	Teacher's notes
F.2.3	Deduce the stability of fats and oils from their structure.	3	Saturated fats are more stable than unsaturated fats. The carbon–carbon double bonds in unsaturated fats react with oxygen (auto-oxidation), hydrogen (hydrogenation), light (photo-oxidation) and enzymes/heat/water (hydrolysis). <b>Aim 7:</b> Data banks and spreadsheets can be used here.
F.2.4	Describe the process of hydrogenation of unsaturated fats.	2	The addition of hydrogen to the carbon–carbon double bond of a fatty acid in the presence of heat (140–225°C), pressure and a finely divided metal catalyst (Zn, Cu, Ni) increases the amount of saturation, which can be partial or full.
F.2.5	Discuss the advantages and disadvantages of hydrogenating fats and oils.	3	Advantages: <ul style="list-style-type: none"> <li>• changes a liquid oil to a semi-solid or solid, to make the melting point of an unsaturated fat more like that of a saturated fat</li> <li>• decreases the rate of oxidation (stability increases with increasing saturation)</li> <li>• increases hardness</li> <li>• controls the feel and plasticity (stiffness).</li> </ul> Disadvantages: <ul style="list-style-type: none"> <li>• mono- and poly-unsaturated fats are healthier for the heart than saturated fats</li> <li>• in partial hydrogenation, <i>trans</i> fatty acids can form</li> <li>• <i>trans</i> fatty acids are hard to metabolize, accumulate in fatty tissue, are difficult to excrete from the body, increase levels of LDL (bad) cholesterol and are a low-quality energy source.</li> </ul>

### F3 Shelf life

4 hours

	Assessment statement	Obj	Teacher's notes
F.3.1	Explain the meaning of the term shelf life.	3	A food reaches its shelf life when it no longer maintains the expected quality desired by the consumer because of changes in flavour, smell, texture and appearance (colour, mass) or because of microbial spoilage.
F.3.2	Discuss the factors that affect the shelf life and quality of food.	3	Chemical factors that cause a decrease in the shelf life include: <ul style="list-style-type: none"> <li>• water content—loss of nutrients, browning and rancidity; dry foods become vulnerable to microbial spoilage if they take on moisture</li> <li>• chemical change, for example, pH—off flavours, colour changes, browning and loss of nutrients</li> <li>• light—rancidity, vitamin loss and fading of natural colours</li> <li>• temperature—changes the rate of other forms of spoilage</li> <li>• contact with air.</li> </ul>

	Assessment statement	Obj	Teacher's notes
F.3.3	Describe the rancidity of fats.	2	Rancidity is the perception of flavours in lipids, those that our senses perceive as off because they have a disagreeable smell, taste, texture or appearance.
F.3.4	Compare the processes of hydrolytic and oxidative rancidity in lipids.	3	<p>Hydrolytic rancidity: The breaking down of a lipid into its component fatty acids and glycerol. It takes place more rapidly in the presence of enzymes (lipase), heat and moisture. In deep frying, water present in food and high temperatures increase the rate of hydrolysis. Examples of off-flavoured fatty acids include:</p> <ul style="list-style-type: none"> <li>• butanoic, hexanoic and octanoic acid in rancid milk</li> <li>• palmitic, stearic and oleic acids give chocolate an oily or fatty flavour</li> <li>• lauric acid gives palm and coconut oil in cocoa butter substitutes a soapy flavour</li> <li>• butanoic acid in butter.</li> </ul> <p>Oxidative rancidity: The fatty acid chains are oxidized, typically by the addition of oxygen across the carbon–carbon double bond of the unsaturated fatty acid. Oily fish (such as herring and mackerel) contain a high proportion of unsaturated fatty acids and are prone to oxidative rancidity. The process can be catalysed by light (photo-oxidation) and enzymes. Details of the free-radical chain mechanism will not be assessed.</p>

	Assessment statement	Obj	Teacher's notes
F.3.5	Describe ways to minimize the rate of rancidity and prolong the shelf life of food.	2	<p>Processing—examples include:</p> <ul style="list-style-type: none"> <li>limiting lipase hydrolysis by storing dairy products at low temperatures (refrigeration)</li> <li>reducing light levels during storage or storing in coloured glass</li> <li>keeping moisture levels low during processing (adding salt or sugar, smoking).</li> </ul> <p>Packaging—examples include:</p> <ul style="list-style-type: none"> <li>using an inert gas, which minimizes contact with oxygen, by covering food</li> <li>using low-gas-permeability packaging film or hermetic sealing</li> <li>minimizing the amount of air in the headspace above oil and canning.</li> </ul> <p>Adding additives—examples include:</p> <ul style="list-style-type: none"> <li>sodium sulfite, sodium hydrogensulfite and citric acid to delay the onset of non-enzymic browning</li> <li>sodium and potassium nitrite and nitrate for curing meats, fixing colour and inhibiting micro-organisms</li> <li>sodium benzoate and benzoic acid as antimicrobial agents in fruit juices, carbonated beverages, pickles and sauerkraut</li> <li>sorbic acid, propanoic acid, calcium propanoate and sodium propanoate for delaying mould and bacterial growth in breads and cheeses</li> <li>ethanoic acid and benzoic acid for delaying mould and bacterial growth in pickled meats and fish products, and also adding to flavour.</li> </ul>
F.3.6	Describe the traditional methods used by different cultures to extend the shelf life of foods.	2	<b>Aim 8:</b> Examples include fermentation, preserving, pickling, salting, drying and smoking.
F.3.7	Define the term <i>antioxidant</i> .	1	A substance that delays the onset or slows the rate of oxidation. It is used to extend the shelf life of food.
F.3.8	List examples of common naturally occurring antioxidants and their sources.	1	<p>Naturally occurring antioxidants include:</p> <ul style="list-style-type: none"> <li>vitamin C (ascorbic acid) in citrus fruits, green peppers, broccoli, green leafy vegetables, strawberries, raw cabbage and potatoes</li> <li>vitamin E in wheat germ, nuts, seeds, whole grains, green leafy vegetables, vegetable oils like canola and soya bean (the antioxidants present in vitamin E are called tocopherols)</li> <li><math>\beta</math>-carotene in carrots, squash, broccoli, sweet potatoes, tomatoes, kale, cantaloupe melon, peaches and apricots</li> <li>selenium in fish, shellfish, red meat, eggs, grains, chicken and garlic.</li> </ul>

	Assessment statement	Obj	Teacher's notes
F.3.9	Compare the structural features of the major synthetic antioxidants in food.	3	Examples include 2- and 3- <i>tert</i> -butyl-4-hydroxyanisole (BHA), 3,5-di- <i>tert</i> -butyl-4-hydroxytoluene (BHT), propyl gallate (PG), 2,4,5-trihydroxybutyrophenone (THBP) and <i>tert</i> -butylhydroquinone (TBHQ).
F.3.10	Discuss the advantages and disadvantages associated with natural and synthetic antioxidants.	3	Advantages: <ul style="list-style-type: none"> <li>naturally occurring vitamins C, E and carotenoids reduce the risk of cancer and heart disease by inhibiting the formation of free radicals</li> <li>vitamin C is vital for the production of hormones and collagen</li> <li><math>\beta</math>-carotene can be used as an additive in margarine to give colour (yellow) and acts as a precursor for vitamin A.</li> </ul> Disadvantages: <ul style="list-style-type: none"> <li>consumers perceive synthetic antioxidants to be less safe because they are not naturally occurring in food</li> <li>natural antioxidants can add colour and an aftertaste to food, and can be less effective at slowing down the rate of rancidity than synthetic antioxidants</li> <li>synthetic antioxidants are food additives and need to be regulated by policies and legislation to ensure their safe use in food</li> <li>policies regarding the labelling and safe use of food additives can be difficult to implement and monitor, especially in developing countries and internationally.</li> </ul>
F.3.11	List some antioxidants found in the traditional foods of different cultures that may have health benefits.	1	Examples include green tea, turmeric, oregano, blueberries, cranberries and dark chocolate, which have been linked to lowering levels of LDL (bad) cholesterol and blood sugar levels, reducing high blood pressure and preventing cancerous cell development.

## F4 Colour

3 hours

	Assessment statement	Obj	Teacher's notes
F.4.1	Distinguish between a <i>dye</i> and a <i>pigment</i> .	2	A dye is a food-grade synthetic water-soluble colourant. A pigment is a naturally occurring colourant found in the cells of plants and animals.
F.4.2	Explain the occurrence of colour in naturally occurring pigments.	3	Foods have colour because of their ability to reflect and absorb different wavelengths of visible light.

	Assessment statement	Obj	Teacher's notes
F.4.3	Describe the range of colours and sources of the naturally occurring pigments anthocyanins, carotenoids, chlorophyll and heme.	2	<p>Anthocyanins:</p> <ul style="list-style-type: none"> <li>the most widely occurring pigments in plants</li> <li>responsible for the pink, red, purple and blue colours in fruits and vegetables, including cranberries, blueberries, strawberries and raspberries.</li> </ul> <p>Carotenoids:</p> <ul style="list-style-type: none"> <li>the most widespread pigment in nature</li> <li>large majority produced by algae</li> <li>act as a precursor for vitamin A</li> <li>colours range from yellow to orange to red, including bananas, carrots, tomatoes, watermelon, red/yellow peppers and saffron</li> <li>red astaxanthin, when present as a complex with protein, gives the blue or green hue found in live lobsters and crabs and the pink colour of salmon.</li> </ul> <p>Chlorophyll: the major light-harvesting pigments found in green plants.</p> <p>Heme: the red pigment found in red blood cells and muscle tissue.</p> <p>Myoglobin is responsible for the purplish-red colour of meat.</p>

	Assessment statement	Obj	Teacher's notes
F.4.4	Describe the factors that affect the colour stability of anthocyanins, carotenoids, chlorophyll and heme.	2	<p>Factors should include the effects of oxidation, temperature change, pH change and the presence of metal ions. Students should analyse absorbance spectra that demonstrate these effects.</p> <p>Anthocyanins: In aqueous solution, equilibrium reaction exists between the four different structural forms depending on the pH and temperature. They are most stable and most highly coloured at low pH and temperature.</p> $  \begin{array}{ccccccc}  \text{(A)} & \rightleftharpoons & \text{(AH}^+) & \rightleftharpoons & \text{(B)} & \rightleftharpoons & \text{(C)} \\  \text{quinonoid} & & \text{flavylium} & & \text{carbinol base} & & \text{chalcone} \\  \text{(blue)} & & \text{(red)} & & \text{(colourless)} & & \text{(colourless)}  \end{array}  $ <p>They form deeply coloured coordination complexes with <math>\text{Fe}^{3+}</math> and <math>\text{Al}^{3+}</math> ions, a source of which can be the metal cans to which the fruit is exposed; this causes a discoloration in canned fruit. They become less stable when exposed to heat, causing a loss of colour and browning.</p> <p>Carotenoids: The presence of multiple unsaturated carbon–carbon double bonds makes carotenoids susceptible to oxidation catalysed by light, metals and hydroperoxides. Oxidation results in the bleaching of colour, loss of vitamin A activity and off odours.</p> <p>They are stable up to 50°C and in the pH range of 2–7, and, therefore, are not degraded by most forms of processing. With heating, the naturally occurring <i>trans</i> isomer rearranges to the <i>cis</i> isomer.</p> <p>Chlorophyll: Reaction with heat depends on pH. In a basic solution (pH 9), chlorophyll is stable, and in an acidic solution (pH 3) it is unstable. When heated, the cell membrane of the plant deteriorates, releasing acids, which decrease the pH. This results in the magnesium atom being displaced by two hydrogen ions, resulting in the formation of olive-brown pheophytin complex. This cell degradation during heating also makes the chlorophyll more susceptible to photo-degradation.</p> <p>Heme: During oxidation, oxygen binds to purple-red myoglobin (Mb), and red oxymyoglobin (<math>\text{MbO}_2</math>) forms. In Mb and <math>\text{MbO}_2</math> the heme iron is in the <math>\text{Fe}^{2+}</math> state. Mb and <math>\text{MbO}_2</math> can be oxidized, through auto-oxidation, changing the heme iron from <math>\text{Fe}^{2+}</math> to <math>\text{Fe}^{3+}</math>. In the <math>\text{Fe}^{3+}</math> state, it is called metmyoglobin (MMb) and has an undesirable brown-red colour. Interconversion between the three forms occurs readily.</p> $  \begin{array}{ccc}  \text{(MbO}_2\text{)} & \rightleftharpoons & \text{(Mb)} & \rightleftharpoons & \text{(MMb)} \\  \text{oxymyoglobin} & & \text{myoglobin} & & \text{metmyoglobin} \\  \text{(red, Fe}^{2+}\text{)} & & \text{(purple-red, Fe}^{2+}\text{)} & & \text{(brown, Fe}^{3+}\text{)}  \end{array}  $ <p>The stability of colour and the rate of brown MMb formation from auto-oxidation can be minimized if the meat is stored in conditions free of oxygen by using packaging films with low gas permeabilities. Air is removed from the package and a storage gas (100% <math>\text{CO}_2</math>) is injected.</p>

	Assessment statement	Obj	Teacher's notes
F.4.5	Discuss the safety issues associated with the use of synthetic colourants in food.	3	The type of colourant permitted for use varies greatly among countries. Since international trade is becoming increasingly important, colour legislation is now of international concern.
F.4.6	Compare the two processes of non-enzymatic browning (Maillard reaction) and caramelization that cause the browning of food.	3	<p>Comparisons should include the chemical composition of the foods affected, factors that increase the rate of the browning, products and examples.</p> <p>Maillard reaction: Chemical composition of the foods affected—condensation reaction between an amino group on an amino acid or protein and a reducing sugar (glucose or lactose). The presence of the amino acid lysine results in the most browning colour and cysteine the least colour. Foods containing lysine, for example, milk, brown readily.</p> <p>Examples include:</p> <ul style="list-style-type: none"> <li>• heating sugar and cream to make toffees, caramels and fudges</li> <li>• milk chocolate.</li> </ul> <p>Products include:</p> <ul style="list-style-type: none"> <li>• desirable and undesirable colours (characteristic golden-brown colour is desirable)</li> <li>• change in smell and flavour (caramel aroma).</li> </ul> <p>Caramelization: Chemical composition of the foods affected—foods with a high carbohydrate content, especially sucrose and reducing sugars, without nitrogen-containing compounds. Factors that increase the rate of the reaction are acid- or base-catalysed at pH above 9 or below 3; a temperature above 120°C that occurs during the baking and roasting of foods with a high sugar content.</p> <p>Examples include the browning on the top of baked egg dishes.</p> <p>Products include:</p> <ul style="list-style-type: none"> <li>• volatile caramel aromas</li> <li>• brown caramel-coloured products.</li> </ul>

## F5 Genetically modified foods

1 hour

	Assessment statement	Obj	Teacher's notes
F.5.1	Define a <i>genetically modified</i> (GM) food.	1	A genetically modified food is one derived or produced from a genetically modified organism. The food can be substantially different from or essentially the same as the conventional food, in terms of composition, nutrition, taste, smell, texture and functional characteristics.

	Assessment statement	Obj	Teacher's notes
F.5.2	Discuss the benefits and concerns of using GM foods.	3	<p><b>Aim 8:</b> Potential benefits are as follows.</p> <ul style="list-style-type: none"> <li>• Crops: Enhanced taste and quality, reduced maturation time, increase in nutrients and yield, improved resistance to disease, pests and herbicides, enrichment of rice with vitamin A.</li> <li>• Animals: Increased resistance, productivity and feed efficiency, better yields of milk and eggs, improved animal health.</li> <li>• Environment: "Friendly" bio-herbicides and bio-insecticides, conservation of soil, water and energy, improved natural waste management.</li> </ul> <p>Potential concerns are as follows:</p> <ul style="list-style-type: none"> <li>• Links to increased allergies (for people involved in their processing).</li> <li>• The risk of changing the composition of a balanced diet by altering the natural nutritional quality of foods.</li> </ul> <p><b>TOK:</b> GM foods raise issues of conflict of concepts and values. Examine the facts, language, statistics and images used in the debate over their use.</p> <p>Is science, or ought it to be, value-free? What implications does your answer have for the regulation of science? Who should decide whether particular directions in research are pursued? Who should determine priorities in the funding of research?</p>

## F6 Texture

2 hours

	Assessment statement	Obj	Teacher's notes
F.6.1	Describe a dispersed system in food.	2	A dispersed system is a kinetically stable mixture of one phase in another largely immiscible phase.
F.6.2	Distinguish between the following types of dispersed systems: <i>suspensions, emulsions</i> and <i>foams</i> in food.	2	
F.6.3	Describe the action of emulsifiers.	2	<p>Emulsifiers:</p> <ul style="list-style-type: none"> <li>• help with the formation of emulsions and foams</li> <li>• act as the interface (surface) between the liquid, solid and gas phases in the dispersed system</li> <li>• are soluble in fat and water.</li> </ul> <p>To make an emulsion, oil, water, an emulsifier and mechanical energy (beating or mixing) are needed. Stabilizers prevent emulsions and foams from separating out.</p>

**HL F7 Oxidative rancidity (auto-oxidation)**

1 hour

	Assessment statement	Obj	Teacher's notes
F.7.1	Describe the steps in the free-radical chain mechanism occurring during oxidative rancidity.	2	<p>The key intermediates are hydroperoxides (ROOH), which degrade to volatile aldehydes and ketones with strong off flavours. They undergo further oxidation and decomposition to produce even more free radicals.</p> <ol style="list-style-type: none"> <li>1. Initiation: formation of free radicals. The <math>E_a</math> for the formation of the first free radicals is high and ROOH decomposition needs metal catalysis or exposure to light.  <math display="block">RH \longrightarrow R\cdot + H\cdot</math>           RH is any unsaturated fatty acid that can lose a hydrogen to form free radicals.</li> <li>2. Propagation: free-radical chain reaction. The free radicals are propagators in these reactions.  <math display="block">R\cdot + O_2 \longrightarrow ROO\cdot</math> <math display="block">ROO\cdot + RH \longrightarrow R\cdot + ROOH</math></li> <li>3. Termination: free radicals combine to form non-radical products.  <math display="block">R\cdot + R\cdot \longrightarrow RR</math> <math display="block">R\cdot + ROO\cdot \longrightarrow ROOR</math> <math display="block">ROO\cdot + ROO\cdot \longrightarrow ROOR + O_2</math></li> </ol>

**HL F8 Antioxidants**

1 hour

	Assessment statement	Obj	Teacher's notes
F.8.1	Explain the differences between the three main types of antioxidants.	3	<ol style="list-style-type: none"> <li>1. Antioxidants (AH) inhibit the formation of free radicals in the initiation step of auto-oxidation or interrupt the propagation of the free-radical chain.            Free-radical quenchers form stable and less reactive free radicals:  <math display="block">ROO\cdot + AH \longrightarrow ROOH + A\cdot</math>           Examples include BHA, BHT, TBHQ and tocopherols.</li> <li>2. Chelating agents reduce the concentration of free metal ions in solution. Examples include salts of EDTA and plant extracts (rosemary, tea, ground mustard).</li> <li>3. Reducing agents (electron donors) and agents that remove or reduce concentrations of oxygen. Examples include ascorbic acid (vitamin C) and carotenoids.</li> </ol>

**HL F9 Stereochemistry in food**

2 hours

	Assessment statement	Obj	Teacher's notes
F.9.1	Explain the three different conventions used for naming the different enantiomeric forms.	3	<p>The D and L system is commonly used for carbohydrates and amino acids, while the R and S notation is commonly used for other stereoisomers. Both relate to the difference in the enantiomers' spatial configuration.</p> <p>For D and L isomers, glyceraldehyde is a reference molecule. The "CORN" rule is used for amino acids. The <math>+(d)</math> and <math>-(l)</math> notation labels stereoisomers according to the direction they rotate the plane of polarized light. This property does not correspond to D, L or R, S configurations.</p>
F.9.2	Distinguish between the properties of the different enantiomeric forms of stereoisomers found in food.	2	<p>The different enantiomeric forms vary in their tastes, odours and toxicity. They can be used to determine the authenticity of food and the extent of processing. For example, <math>+(d)</math>-carvone tastes of caraway seeds and dill and <math>-(l)</math>-carvone tastes of spearmint.</p> <p>Most naturally occurring amino acids are in the L form. The D amino acids taste sweet; the L amino acids are tasteless. Most naturally occurring sugars exist in the D form and are sweet. For example:</p> <ul style="list-style-type: none"> <li>• <math>+(d)</math>-limonene smells of oranges and <math>-(l)</math>-limonene smells of lemons</li> <li>• natural raspberry flavour is due to R-alpha-ionone; synthetic raspberry flavourings contain both the R- and S-isomers; other synthetically made foods often contain a racemic mixture of each enantiomer.</li> </ul>

**HL F10 Chemical structure and colour**

3 hours

	Assessment statement	Obj	Teacher's notes
F.10.1	Compare the similarities and differences in the structures of the natural pigments: anthocyanins, carotenoids, chlorophyll and heme.	3	<p>Anthocyanins: Contain the characteristic <math>C_6C_3C_6</math> flavonoid skeleton with conjugated double bonds. They differ in the number of hydroxyl and/or methoxy groups present; the types, numbers and sites of attachments of sugars to the molecule; and the types and numbers of aliphatic or aromatic acids that are attached to the sugars in the molecule. Examples include quercetin.</p> <p>Carotenoids: The majority are derived from a 40-carbon polyene chain, which may be terminated by cyclic end-groups and may be complemented with oxygen-containing functional groups. The hydrocarbon carotenoids are known as carotenes, while the oxygenated derivatives are known as xanthophylls. Examples include <math>\alpha</math>- and <math>\beta</math>-carotene, vitamin A.</p> <p>Heme and chlorophyll contain a planar heterocyclic unit called a porphin whose structure contains a cyclic system of conjugated double bonds. Porphins with substituents in positions 1 to 8 are called porphyrins.</p> <p>Chlorophyll: This is a magnesium porphyrin complex with the original double bond between positions 7 and 8 now saturated and an R group on C3. It is found in two forms: chlorophyll a and b, which differ in the substituent R group. In chlorophyll a, R is a <math>CH_3</math> group and in chlorophyll b, R is a CHO group.</p> <p>Heme: Myoglobin is the primary pigment in muscle tissue and hemoglobin is the pigment in blood. Myoglobin is a complex of globin (a protein) and heme (porphyrin ring containing a central iron atom).</p>
F.10.2	Explain why anthocyanins, carotenoids, chlorophyll and heme form coloured compounds while many other organic molecules are colourless.	3	<p>The nature of chromophores, conjugation effects and characteristic absorptions are required. Students should understand how the wavelength of energy absorbed relates to the colour the food appears.</p>
F.10.3	Deduce whether anthocyanins and carotenoids are water- or fat-soluble from their structures.	3	<p>Anthocyanins are water-soluble and carotenoids are fat-soluble.</p>