Core topics

Essential idea: Metabolic reactions involve a complex interplay between many different components in highly controlled environments.

B.1 Introduction to biochemistry

Nature of science:

Use of data—biochemical systems have a large number of different reactions occurring in the same place at the same time. As technologies have developed, more data has been collected leading to the discovery of patterns of reactions in metabolism. (3.1)

Understandings:

- The diverse functions of biological molecules depend on their structures and shapes.
- Metabolic reactions take place in highly controlled aqueous environments.
- Reactions of breakdown are called catabolism and reactions of synthesis are called anabolism.
- Biopolymers form by condensation reactions and are broken down by hydrolysis reactions.
- Photosynthesis is the synthesis of energy-rich molecules from carbon dioxide and water using light energy.
- Respiration is a complex set of metabolic processes providing energy for cells.

Applications and skills :

- Explanation of the difference between condensation and hydrolysis reactions.
- The use of summary equations of photosynthesis and respiration to explain the potential balancing of oxygen and carbon dioxide in the atmosphere.

Guidance:

- Intermediates of aerobic respiration and photosynthesis are not required.

International-mindedness:

- Metabolic reactions in the human body are dependent on the supply of nutrients through a regular balanced diet. Globally there are significant differences in the availability of nutritious food, which have major and diverse impacts on human health.

Utilization:

- Biochemistry is fundamental to the study of many other subjects, including genetics, immunology, pharmacology, nutrition and agriculture.

Syllabus and cross-curricular links:
Topic 10.2—S_N reactions (condensation and hydrolysis)
Topic 13.2 and Option B.9—metal complexes and light absorption
Option C.8—electronic conjugation and light absorption

Essential idea: Proteins are the most diverse of the biopolymers responsible for metabolism and structural integrity of living organisms.

B.2 Proteins and enzymes

Nature of science:

Collaboration and peer review—several different experiments on several continents led to the conclusion that DNA, and not protein as originally thought, carried the information for inheritance. (4.4)

Understandings:

- Proteins are polymers of 2-amino acids, joined by amide links (also known as peptide bonds).
- Amino acids are amphoteric and can exist as zwitterions, cations and anions.
- Protein structures are diverse and are described at the primary, secondary, tertiary and quaternary levels.
- A protein's three-dimensional shape determines its role in structural components or in metabolic processes.
- Most enzymes are proteins that act as catalysts by binding specifically to a substrate at the active site.
- As enzyme activity depends on the conformation, it is sensitive to changes in temperature and pH and the presence of heavy metal ions.
- Chromatography separation is based on different physical and chemical principles.

Applications and skills:

- Deduction of the structural formulas of reactants and products in condensation reactions of amino acids, and hydrolysis reactions of peptides.
- Explanation of the solubilities and melting points of amino acids in terms of zwitterions.
- Application of the relationships between charge, pH and isoelectric point for amino acids and proteins.

International-mindedness:

- The Universal Protein Resource (UniProt) is a consortium of bioinformatics institutes. Its mission is to act as a resource for the scientific community by providing comprehensive, high-quality and freely accessible data on protein sequence and functional information.

Utilization:

- Many synthetic materials are polyamides. Examples include nylon and Kevlar®.
- Electrophoresis is used in some medical diagnostics to identify patterns of unusual protein content in blood serum or urine.
- The first protein to be sequenced was insulin by Frederick Sanger in 1951, in a process that took over ten years. Today, protein sequencing is a routine and very efficient process, and is a major part of the study known as proteomics.

Syllabus and cross-curricular links:
Topics 8.3 and 18.2—pH and pK_a and pK_b values
Topic 20.3—stereoisomerism
Option A.9—condensation polymers
Option B.9—chromatography
Biology topics 2.4, 2.5 and 8.1—proteins and enzymes

Aims:

- **Aim 6**: Experiments could involve hydrolysis of a protein, separation and identification of amino acid mixtures by paper chromatography, or gel electrophoresis of proteins and DNA.
- **Aim 7**: Data logging experiments involving absorption/concentration studies for protein content using the Biuret reagent.

B.2 Proteins and enzymes	
• Description of the four levels of protein structure, including the origin and types of bonds and interactions involved. • Deduction and interpretation of graphs of enzyme activity involving changes in substrate concentration, pH and temperature. • Explanation of the processes of paper chromatography and gel electrophoresis in amino acid and protein separation and identification. **Guidance:** • The names and structural formulas of the amino acids are given in the data booklet in section 33. • Reference should be made to alpha helix and beta pleated sheet, and to fibrous and globular proteins with examples of each. • In paper chromatography the use of R_f values and locating agents should be covered. • In enzyme kinetics K_m and V_{max} are not required.	• **Aim 7**: Simulations can be used for gel electrophoresis.

Essential idea: Lipids are a broad group of biomolecules that are largely non-polar and therefore insoluble in water.

B.3 Lipids

Nature of science:

Significance of science explanations to the public—long-term studies have led to knowledge of the negative effects of diets high in saturated fat, cholesterol, and *trans*-fat. This has led to new food products. (5.2)

Understandings:

- Fats are more reduced than carbohydrates and so yield more energy when oxidized.
- Triglycerides are produced by condensation of glycerol with three fatty acids and contain ester links. Fatty acids can be saturated, monounsaturated or polyunsaturated.
- Phospholipids are derivatives of triglycerides.
- Hydrolysis of triglycerides and phospholipids can occur using enzymes or in alkaline or acidic conditions.
- Steroids have a characteristic fused ring structure, known as a steroidal backbone.
- Lipids act as structural components of cell membranes, in energy storage, thermal and electrical insulation, as transporters of lipid soluble vitamins and as hormones.

Applications and skills:

- Deduction of the structural formulas of reactants and products in condensation and hydrolysis reactions between glycerol and fatty acids and/or phosphate.
- Prediction of the relative melting points of fats and oils from their structures.
- Comparison of the processes of hydrolytic and oxidative rancidity in fats with respect to the site of reactivity in the molecules and the conditions that favour the reaction.

International-mindedness:

- There are large global and cultural differences in the dietary sources of lipids and methods used to prevent rancidity.

Theory of knowledge:

- Different countries have very different standards towards food labelling. Is access to information a human right? What knowledge should be universally available?
- What are the different responsibilities of government, industry, the medical profession and the individual in making healthy choices about diet? Public bodies can protect the individual but also limit their freedom. How do we know what is best for society and the individual?

Utilization:

- Alkaline hydrolysis of fats is used in the process of soap-making, known as saponification.
- Steroid abuse, especially in sports, and methods for detection.

Syllabus and cross-curricular links:
Topics 10.1 and 10.2—functional groups, hydrogenation of alkenes
Topic 10.2—free radical mechanisms
Topic 20.3—configurational isomerism
Biology topic 2.3—lipids

B.3 Lipids	
• Application of the concept of iodine number to determine the unsaturation of a fat. • Comparison of carbohydrates and lipids as energy storage molecules with respect to their solubility and energy density. • Discussion of the impact of lipids on health, including the roles of dietary high-density lipoprotein (HDL) and low-density lipoprotein (LDL) cholesterol, saturated, unsaturated and *trans*-fat and the use and abuse of steroids. **Guidance:** • The structures of some fatty acids are given in the data booklet in section 34. • Specific named examples of fats and oils do not have to be learned. • The structural differences between *cis*- and *trans*-fats are not required.	**Aims:** • **Aim 6**: Experiments could include the calculation of the iodine number of fats to measure degree of unsaturation, calorimetric experiments on different fats and oils, or the separation of lipids from common food sources using different solvents and a separating funnel.

Essential idea: Carbohydrates are oxygen-rich biomolecules, which play a central role in metabolic reactions of energy transfer.

B.4 Carbohydrates

Nature of science:

Construct models/visualizations—understanding the stereochemistry of carbohydrates is essential to understanding their structural roles in cells. Haworth projections help focus on the nature and position of attached groups by making carbon and hydrogen implicit. (1.10)

Obtaining evidence for scientific theories—consider the structural role of carbohydrates. (1.8)

Understandings:

- Carbohydrates have the general formula $C_x(H_2O)_y$.
- Haworth projections represent the cyclic structures of monosaccharides.
- Monosaccharides contain either an aldehyde group (aldose) or a ketone group (ketose) and several –OH groups.
- Straight chain forms of sugars cyclize in solution to form ring structures containing an ether linkage.
- Glycosidic bonds form between monosaccharides forming disaccharides and polysaccharides.
- Carbohydrates are used as energy sources and energy reserves.

Applications and skills:

- Deduction of the structural formulas of disaccharides and polysaccharides from given monosaccharides.
- Relationship of the properties and functions of monosaccharides and polysaccharides to their chemical structures.

International-mindedness:

- Sugar is a major international commodity and is produced in about 130 different countries. Approximately three-quarters of production comes from sugar cane in tropical and subtropical regions and the remainder comes from sugar beet which is cultivated in temperate climates.
- Diabetes is a chronic disease that occurs when the body cannot effectively regulate blood sugar, due to a failure in the production or functioning of insulin. The World Health Organization projects that deaths from diabetes will double between 2005 and 2030.
- Lactose intolerance is a condition in which the individual is not able to digest lactose, the sugar found in milk and dairy products. It is due to a failure to produce sufficient levels of lactase, the enzyme that hydrolyses lactose into glucose and galactose. Globally lactose intolerance is the norm. It is an example of a Western perspective invading science.

Theory of knowledge:

- The use of aspartame as an artificial sweetener has been controversial for many years as the side effects are not fully investigated. Should scientists be held morally responsible for the adverse consequences of their work?

B.4 Carbohydrates	
Guidance: • The straight chain and α-ring forms of glucose and fructose are given in the data booklet in section 34. • The component monosaccharides of specific disaccharides and the linkage details of polysaccharides are not required. • The distinction between α- and β- forms and the structure of cellulose are not required.	**Utilization:** • Carbohydrates are used in the pharmaceutical industry to bind preparations into tablets. • Ethanol is produced as a biofuel from the fermentation of carbohydrates in crops such as corn or sugar cane. Syllabus and cross-curricular links: Topics 10.1 and 10.2—organic functional groups Topic 20.1—organic reactions Topic 20.3—stereoisomerism Option C.4—biofuels Biology topic 2.3—carbohydrates **Aims:** • **Aim 6**: Experiments could include using Benedict's or Fehling's solution tests to distinguish between reducing sugars and non-reducing sugars or using iodine solution to test for the presence of starch. • **Aim 8**: The production of biofuels from crops raises many questions about related issues such as deforestation, soil erosion and sustainability. The "food vs fuel" debate refers to the controversies arising from developments that divert agricultural crops into biofuel production.

Essential idea: Vitamins are organic micronutrients with diverse functions that must be obtained from the diet.

B.5 Vitamins

Nature of science:

Making observations and evaluating claims—the discovery of vitamins (*vital amines*) is an example of scientists seeking a cause for specific observations. This resulted in the explanation of deficiency diseases (eg scurvy and beriberi). (1.8)

Understandings:

- Vitamins are organic micronutrients which (mostly) cannot be synthesized by the body but must be obtained from suitable food sources.
- The solubility (water or fat) of a vitamin can be predicted from its structure.
- Most vitamins are sensitive to heat.
- Vitamin deficiencies in the diet cause particular diseases and affect millions of people worldwide.

Applications and skills:

- Comparison of the structures of vitamins A, C and D.
- Discussion of the causes and effects of vitamin deficiencies in different countries and suggestion of solutions.

Guidance:

- The structures of vitamins A, C and D are provided in the data booklet section 35.
- Specific food sources of vitamins or names of deficiency diseases do not have to be learned.

International-mindedness:

- The food supplements industry, especially the sale of vitamin pills, has become very lucrative in many countries.
- Vitamin D deficiency is increasing, partly as a result of greater protection of the skin from sunlight.

Theory of knowledge:

- What are the ethical considerations in adding supplements to commonly consumed foods, such as fluoride to water or iodine to salt? Public bodies can protect the individual but also limit their freedom. How do we know what is best for society and the individual?
- Linus Pauling is the only man to win two individual Nobel Prizes. His claim that vitamin C supplements could prevent diseases such as the common cold led to their widespread use. What is the role of authority in communicating scientific knowledge to the public?

Utilization:

Syllabus and cross-curricular links:
Topics 4.1, 4.2 and 4.3—structure and physical properties
Topic 10.1—organic functional groups
Topic 20.3—configurational isomerism
Biology option D.2—human nutrition and health

Aims:

- **Aim 6**: Experiments could include the DCPIP determination of vitamin C levels in foods.

Essential idea: Our increasing knowledge of biochemistry has led to several environmental problems, while also helping to solve others.

B.6 Biochemistry and the environment

Nature of science:

Risk assessment, collaboration, ethical considerations—it is the responsibility of scientists to consider the ways in which products of their research and findings negatively impact the environment, and to find ways to counter this. For example, the use of enzymes in biological detergents and to break up oil spills, and green chemistry in general. (4.8)

Understandings:

- Xenobiotics refer to chemicals that are found in an organism that are not normally present there.
- Biodegradable/compostable plastics can be consumed or broken down by bacteria or other living organisms.
- Host–guest chemistry involves the creation of synthetic host molecules that mimic some of the actions performed by enzymes in cells, by selectively binding to specific guest species, such as toxic materials in the environment.
- Enzymes have been developed to help in the breakdown of oil spills and other industrial wastes.
- Enzymes in biological detergents can improve energy efficiency by enabling effective cleaning at lower temperatures.
- Biomagnification is the increase in concentration of a substance in a food chain.
- Green chemistry, also called sustainable chemistry, is an approach to chemical research and engineering that seeks to minimize the production and release to the environment of hazardous substances.

Applications and skills:

- Discussion of the increasing problem of xenobiotics such as antibiotics in sewage treatment plants.
- Description of the role of starch in biodegradable plastics.

International-mindedness:

- The term green chemistry was first coined in 1991, and acceptance of its philosophy has led to developments in education and legislation in many countries.
- Use of the pesticide DDT is banned in most countries due to its toxic effects and biomagnification. Its use continues, however, in countries where malaria remains a major public health challenge.

Utilization:

Syllabus and cross-curricular links:
Topic 4.4—intermolecular forces
Topic 10.1—natural and synthetic organic compounds
Options A.5 and A.7—environmental impact of plastics
Option D.2—antibiotics

Aims:

- **Aim 6**: Experiments could include the comparison of the breakdown of biodegradable and non-biodegradable plastics in the environment.
- **Aim 6**: Risk assessment, including the risks to the environment, is an essential part of all experimental work.
- **Aim 8**: The development of the science of green chemistry has raised awareness of the environmental and ethical implications of using science and technology.

B.6 Biochemistry and the environment	
• Application of host–guest chemistry to the removal of a specific pollutant in the environment. • Description of an example of biomagnification, including the chemical source of the substance. Examples could include heavy metals or pesticides. • Discussion of the challenges and criteria in assessing the “greenness” of a substance used in biochemical research, including the atom economy. **Guidance:** • Specific names of “green chemicals” such as solvents are not expected. • The emphasis in explanations of host–guest chemistry should be on non-covalent bonding within the supramolecule.	

Additional higher level topics

Essential idea: Analyses of protein activity and concentration are key areas of biochemical research.

B.7 Proteins and enzymes

Nature of science:

Theories can be superseded—"lock and key" hypothesis to "induced fit" model for enzymes. (1.9)

Collaboration and ethical considerations—scientists collaborate to synthesize new enzymes and to control desired reactions (ie waste control). (4.5)

Understandings:

- Inhibitors play an important role in regulating the activities of enzymes.
- Amino acids and proteins can act as buffers in solution.
- Protein assays commonly use UV-vis spectroscopy and a calibration curve based on known standards.

Applications and skills:

- Determination of the maximum rate of reaction (V_{max}) and the value of the Michaelis constant (K_m) for an enzyme by graphical means, and explanation of its significance.
- Comparison of competitive and non-competitive inhibition of enzymes with reference to protein structure, the active site and allosteric site.
- Explanation of the concept of product inhibition in metabolic pathways.
- Calculation of the pH of buffer solutions, such as those used in protein analysis and in reactions involving amino acids in solution.
- Determination of the concentration of a protein in solution from a calibration curve using the Beer–Lambert law.

International-mindedness:

- Technologies based on enzyme activity go back to ancient times in many parts of the world. Brewing and cheese-making are often associated with particular place names.

Theory of knowledge:

- The term "lock-and-key" is an effective metaphor but the "induced fit" model is a better model. How are metaphors and models used in the construction of knowledge?

Utilization:

- Enzymes are widely used in industrial and domestic applications. Examples include biological detergents, textiles, foods and beverages, and biodegradable plastics. Advances in protein engineering have led to the synthesis of enzymes that are effective in a wide range of conditions.

Syllabus and cross-curricular links:
Topic 6.1—chemical kinetics
Topics 8.1, 8.3 and 8.4—the pH scale and conjugate acids and bases
Topics 18.2 and 18.3—acid–base calculations and pH curves

B.7 Proteins and enzymes	
Guidance: • The effects of competitive and non-competitive inhibitors on K_m and V_{max} values should be covered. • The Henderson–Hasselbalch equation is given in the data booklet in section 1. • For UV-vis spectroscopy, knowledge of particular reagents and wavelengths is not required.	**Aims:** • **Aim 6**: Experiments could include measuring enzyme activity with changing conditions of temperature, pH and heavy metal ion concentration. • **Aim 7**: Data-logging experiments with temperature or pH probes to investigate enzyme activity under different conditions; or computer modelling of enzyme–substrate interactions. • **Aim 8**: Many enzyme technologies help mitigate damaging environmental effects of chemicals, such as from leather, paper and oil industries.

Essential idea: DNA is the genetic material that expresses itself by controlling the synthesis of proteins by the cell.

B.8 Nucleic acids

Nature of science:

Scientific method—the discovery of the structure of DNA is a good example of different approaches to solving the same problem. Scientists used models and diffraction experiments to develop the structure of DNA. (1.3)

Developments in scientific research follow improvements in apparatus—double helix from X-ray diffraction provides explanation for known functions of DNA. (3.7)

Understandings:

- Nucleotides are the condensation products of a pentose sugar, phosphoric acid and a nitrogenous base—adenine (A), guanine (G), cytosine (C), thymine (T) or uracil (U).
- Polynucleotides form by condensation reactions.
- DNA is a double helix of two polynucleotide strands held together by hydrogen bonds.
- RNA is usually a single polynucleotide chain that contains uracil in place of thymine, and a sugar ribose in place of deoxyribose.
- The sequence of bases in DNA determines the primary structure of proteins synthesized by the cell using a triplet code, known as the genetic code, which is universal.
- Genetically modified organisms have genetic material that has been altered by genetic engineering techniques, involving transferring DNA between species.

Applications and skills:

- Explanation of the stability of DNA in terms of the interactions between its hydrophilic and hydrophobic components.
- Explanation of the origin of the negative charge on DNA and its association with basic proteins (histones) in chromosomes.
- Deduction of the nucleotide sequence in a complementary strand of DNA or a molecule of RNA from a given polynucleotide sequence.

International-mindedness:

- The Human Genome Project was an international research programme whose goal was to complete the mapping and sequencing of all the genes in the human genome.
- The policies on the labelling of genetically modified (GM) foods vary greatly in different countries.
- Most of the genetically modified organisms are protected by international patents. What effect does this have on the global economy and scientific community?

Theory of knowledge:

- DNA stores information but not knowledge.
- What are the differences between information and knowledge?
- The Nobel Prize in Physiology or Medicine 1962 was awarded jointly to Crick, Watson and Wilkins "for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material". What is the role of collaboration in advancing knowledge?
- The existence of DNA databases opens up questions of individual privacy and the extent to which government has the right of access to personal information. Who has the right to access knowledge of an individual's DNA?

B.8 Nucleic acids	
• Explanation of how the complementary pairing between bases enables DNA to replicate itself exactly. • Discussion of the benefits and concerns of using genetically modified foods. **Guidance:** • Structures of the nitrogenous bases and ribose and deoxyribose sugars are given in the data booklet in section 34. • Knowledge of the different forms of RNA is not required. • Details of the process of DNA replication are not required. • Limit expression of DNA to the concept of a four-unit base code determining a twenty-unit amino acid sequence. Details of transcription and translation are not required.	**Utilization:** • Knowledge of DNA sequencing has transformed several aspects of legal enquiry, including forensics and paternity cases. It is also widely used in studies of ancestry and human migration. • DNA sequencing is an important aspect of the study of biochemical evolution. Syllabus and cross-curricular links: Topic 4.4—hydrogen bonding, intermolecular interactions Topic 8.1—acid–base interactions Biology topics 2.6 and 7.1—DNA and RNA structure **Aims:** • **Aim 5**: The story of the rivalry between the different teams involved in the elucidation of DNA structure in the 1950s is an example of a failure of effective collaboration and communication during scientific activities. • **Aim 6**: Experiments could include DNA extraction from cells and investigation of its physical properties, and model building exercises of DNA structure, including the specific base pairings between a purine and a pyrimidine. • **Aim 7**: Databases exist of genetic sequences from different organisms. • **Aim 8**: Many ethical questions are raised by our knowledge of the human genome, including cloning, genetic engineering, gene therapy, and so on.

Essential idea: Biological pigments include a variety of chemical structures with diverse functions which absorb specific wavelengths of light.

B.9 Biological pigments

Nature of science:

Use of data—quantitative measurements of absorbance are a reliable means of communicating data based on colour, which was previously subjective and difficult to replicate. (3.1)

Understandings:

- Biological pigments are coloured compounds produced by metabolism.
- The colour of pigments is due to highly conjugated systems with delocalized electrons, which have intense absorption bands in the visible region.
- Porphyrin compounds, such as hemoglobin, myoglobin, chlorophyll and many cytochromes are chelates of metals with large nitrogen-containing macrocyclic ligands.
- Hemoglobin and myoglobin contain heme groups with the porphyrin group bound to an iron(II) ion.
- Cytochromes contain heme groups in which the iron ion interconverts between iron(II) and iron(III) during redox reactions.
- Anthocyanins are aromatic, water-soluble pigments widely distributed in plants. Their specific colour depends on metal ions and pH.
- Carotenoids are lipid-soluble pigments, and are involved in harvesting light in photosynthesis. They are susceptible to oxidation, catalysed by light.

Applications and skills:

- Explanation of the sigmoidal shape of hemoglobin's oxygen dissociation curve in terms of the cooperative binding of hemoglobin to oxygen.
- Discussion of the factors that influence oxygen saturation of hemoglobin, including temperature, pH and carbon dioxide.
- Description of the greater affinity of oxygen for foetal hemoglobin.

International-mindedness:

- Artificial colours are commonly added during the commercial preparation and processing of food. The list of approved food colours varies greatly by country, which raises questions for international trade.

Theory of knowledge:

- Experiments show that our appreciation of food is based on an interaction between our senses. How do the different senses interact in giving us empirical knowledge about the world?

Utilization:

- Different tones of skin, eye and hair colour are the result of differences in the concentration of the pigment melanin.
- People whose ancestors have lived at high altitude for many generations have developed hemoglobin with a higher affinity for oxygen.
- The purplish-red colour of meat is largely due to the presence of myoglobin. The change in colour to brown on cooking occurs as the iron ion becomes oxidized to Fe^{3+}.
- Anthocyanins and carotenoids provide visible signals for plants to attract insects and birds for pollination and seed dispersal. They also protect plants from damage caused by UV light.

Syllabus and cross-curricular links:
Topic 8.2—indicators
Topic 13.2—complex ions
Option C.8—electronic conjugation and dye-sensitized solar cells

B.9 Biological pigments	
• Explanation of the action of carbon monoxide as a competitive inhibitor of oxygen binding. • Outline of the factors that affect the stabilities of anthocyanins, carotenoids and chlorophyll in relation to their structures. • Explanation of the ability of anthocyanins to act as indicators based on their sensitivity to pH. • Description of the function of photosynthetic pigments in trapping light energy during photosynthesis. • Investigation of pigments through paper and thin layer chromatography. **Guidance:** • The structures of chlorophyll, heme B and specific examples of anthocyanins and carotenoids are given in the data booklet in section 35; details of other pigment names and structures are not required. • Explanation of cooperative binding in hemoglobin should be limited to conformational changes occurring in one polypeptide when it becomes oxygenated. • Knowledge of specific colour changes with changing conditions is not required.	**Aims:** • **Aim 6**: Experiments could include the extraction and isolation of pigments from plant sources using solvents and separating funnel or the use of anthocyanins as pH indicators. • **Aim 7**: Use of data loggers for collecting absorption data.

Essential idea: Most biochemical processes are stereospecific and involve only molecules with certain configuration of chiral carbon atoms.

B.10 Stereochemistry in biomolecules

Nature of science:

Theories used to explain natural phenomena/evaluate claims—biochemistry involves many chiral molecules with biological activity specific to one enantiomer. Chemical reactions in a chiral environment act as a guiding distinction between living and non-living matter. (2.2)

Understandings:

- With one exception, amino acids are chiral, and only the L-configuration is found in proteins.
- Naturally occurring unsaturated fat is mostly in the *cis* form, but food processing can convert it into the *trans* form.
- D and L stereoisomers of sugars refer to the configuration of the chiral carbon atom furthest from the aldehyde or ketone group, and D forms occur most frequently in nature.
- Ring forms of sugars have isomers, known as α and β, depending on whether the position of the hydroxyl group at carbon 1 (glucose) or carbon 2 (fructose) lies below the plane of the ring (α) or above the plane of the ring (β).
- Vision chemistry involves the light activated interconversion of *cis*- and *trans*-isomers of retinal.

Applications and skills:

- Description of the hydrogenation and partial hydrogenation of unsaturated fats, including the production of *trans*-fats, and a discussion of the advantages and disadvantages of these processes.
- Explanation of the structure and properties of cellulose, and comparison with starch.
- Discussion of the importance of cellulose as a structural material and in the diet.
- Outline of the role of vitamin A in vision, including the roles of opsin, rhodopsin and *cis*- and *trans*-retinal.

International-mindedness:

- Different countries have very different standards of food labelling with respect to its chemical content, including the type of fats present.

Utilization:

Syllabus and cross-curricular links:
Topic 10.1—organic functional groups
Topic 20.1—organic reactions
Topic 20.3—stereoisomerism
Option A.4—intermolecular/London forces

Aims:

- **Aim 8**: Ethical questions arise through the use of saturated and *trans*-fats, particularly in the fast-food industry.

B.10 Stereochemistry in biomolecules	
Guidance: • Names of the enzymes involved in the visual cycle are not required. • Relative melting points of saturated and *cis*-/*trans*-unsaturated fats should be covered.	

Core topics

Essential idea: Societies are completely dependent on energy resources. The quantity of energy is conserved in any conversion but the quality is degraded.

C.1 Energy sources

Nature of science:

Use theories to explain natural phenomena—energy changes in the world around us result from potential and kinetic energy changes at the molecular level.

Energy has both quantity and quality. (2.2)

Understandings:

- A useful energy source releases energy at a reasonable rate and produces minimal pollution.
- The quality of energy is degraded as heat is transferred to the surroundings. Energy and materials go from a concentrated into a dispersed form. The quantity of the energy available for doing work decreases.
- Renewable energy sources are naturally replenished. Non-renewable energy sources are finite.
- $\text{Energy density} = \frac{\text{energy released from fuel}}{\text{volume of fuel consumed}}$.
- $\text{Specific energy} = \frac{\text{energy released from fuel}}{\text{mass of fuel consumed}}$.
- $\text{The effeciency of an energy transfer} = \frac{\text{useful output energy}}{\text{total input energy}} \times 100\%$.

Applications and skills:

- Discussion of the use of different sources of renewable and non-renewable energy.
- Determination of the energy density and specific energy of a fuel from the enthalpies of combustion, densities and the molar mass of fuel.
- Discussion of how the choice of fuel is influenced by its energy density or specific energy.

International-mindedness:

- The International Energy Agency is an autonomous organization based in Paris which works to ensure reliable, affordable and clean energy for its 28 member countries and beyond.
- The International Renewable Energy Agency (IRENA), based in Abu Dhabi, UAE, was founded in 2009 to promote increased adoption and sustainable use of renewable energy sources (bioenergy, geothermal energy, hydropower, ocean, solar and wind energy).

Theory of knowledge:

- "I have no doubt that we will be successful in harnessing the sun's energy. If sunbeams were weapons of war we would have had solar energy centuries ago." (Lord George Porter). In what ways might social, political, cultural and religious factors affect the types of research that are financed and undertaken, or rejected?
- There are many ethical issues raised by energy generation and its consequent contributions to pollution and climate change.What is the influence of political pressure on different areas of knowledge?

Utilization:

Syllabus and cross-curricular links:
Topic 5.1—enthalpies of combustion
Topic 10.2—the combustion of hydrocarbons
Environmental systems and societies topics—3.2, 3.3, 3.5 and 3.6
Physics topic 8.1—energy density