INTERNATIONAL BACCALAUREATE ORGANIZATION

DIPLOMA PROGRAMME

Biology

For first examinations in 2003

Biology
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International Baccalaureate Organization
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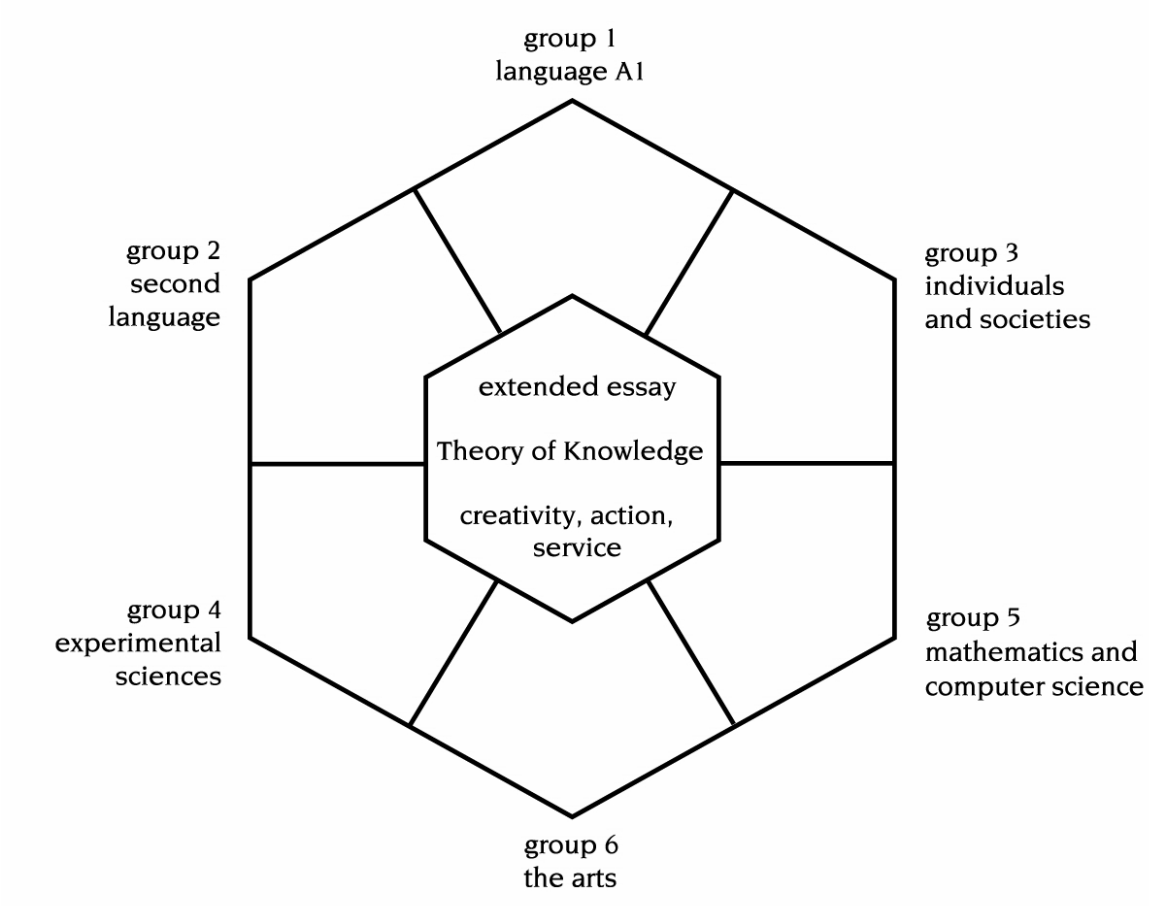
INTRODUCTION

The International Baccalaureate Diploma Programme is a rigorous pre-university course of studies, leading to examinations, that meets the needs of highly motivated secondary school students between the ages of 16 and 19 years. Designed as a comprehensive two-year curriculum that allows its graduates to fulfill requirements of various national education systems, the Diploma Programme model is based on the pattern of no single country but incorporates the best elements of many. The programme is available in English, French and Spanish.

The curriculum is displayed in the shape of a hexagon with six academic areas surrounding the core. Subjects are studied concurrently and students are exposed to the two great traditions of learning: the humanities and the sciences.



Diploma Programme candidates are required to select one subject from each of the six subject groups. At least three and not more than four are taken at higher level (HL), the others at standard level (SL). Higher level courses represent 240 teaching hours; standard level courses cover 150 hours. By arranging work in this fashion, students are able to explore some subjects in depth and some more broadly over the two-year period; this is a deliberate compromise between the early specialization preferred in some national systems and the breadth found in others.

Distribution requirements ensure that the science-orientated student is challenged to learn a foreign language and that the natural linguist becomes familiar with science laboratory procedures. While overall balance is maintained, flexibility in choosing higher level combinations allows the student to pursue areas of personal interest and to meet special requirements for university entrance.

Successful Diploma Programme candidates meet three requirements in addition to the six subjects. The interdisciplinary Theory of Knowledge (TOK) course is designed to develop a coherent approach to learning which transcends and unifies the academic areas and encourages appreciation of other cultural perspectives. The extended essay of some 4000 words offers the opportunity to investigate a topic of special interest and acquaints students with the independent research and writing skills expected at university. Participation in the creativity, action, service (CAS) requirement encourages students to be involved in artistic pursuits, sports and community service work.

For first examinations in 2003

CURRICULUM MODEL

A common curriculum model applies to all the Diploma Programme group 4 subjects: biology, chemistry, environmental systems, physics and design technology. (There are some differences in this model for design technology and these arise from the design project, a unique feature of this subject. A double asterisk (**) indicates where these differences occur.) A core of material is studied by both higher level and standard level students in all subjects, and this is supplemented by the study of options. Higher level students also study additional higher level (AHL) material. Higher level students and SL students both study two options. There are three kinds of options: those specific to SL students, those specific to HL students and those which can be taken by both SL and HL students. Schools wishing to develop their own school-based option should contact the IBCA office in the first instance.

This curriculum model is not designed to favour the teaching of SL and HL students together. The IBO does not support the joint teaching of students at different levels as this does not provide the greatest educational benefit for either level.

Higher level students are required to spend 60 hours, and SL students 40 hours, on practical/ investigative work**. This includes 10 to 15 hours for the group 4 project.

Group 4 Curriculum Model HL **

HL	Total teaching hours	**240**
Theory		**180**
	Core	80
	Additional higher level (AHL)	55
	Options	45
Internal assessment (IA)		**60**
	Investigations	45–50
	Group 4 project	10–15

Group 4 Curriculum Model SL **

SL	Total teaching hours	150
Theory		**110**
	Core	80
	Options	30
Internal assessment (IA)		**40**
	Investigations	25–30
	Group 4 project	10–15

Format of the Syllabus Details

Note: The order in which the syllabus content is presented is not intended to represent the order in which it should be taught.

The format of the syllabus details section of the group 4 guides is the same for each subject. The structure is as follows.

Topics or Options

Topics are numbered and options are indicated by a letter (eg Topic 6: Nucleic Acids and Proteins or Option C: Cells and Energy).

Sub-topics

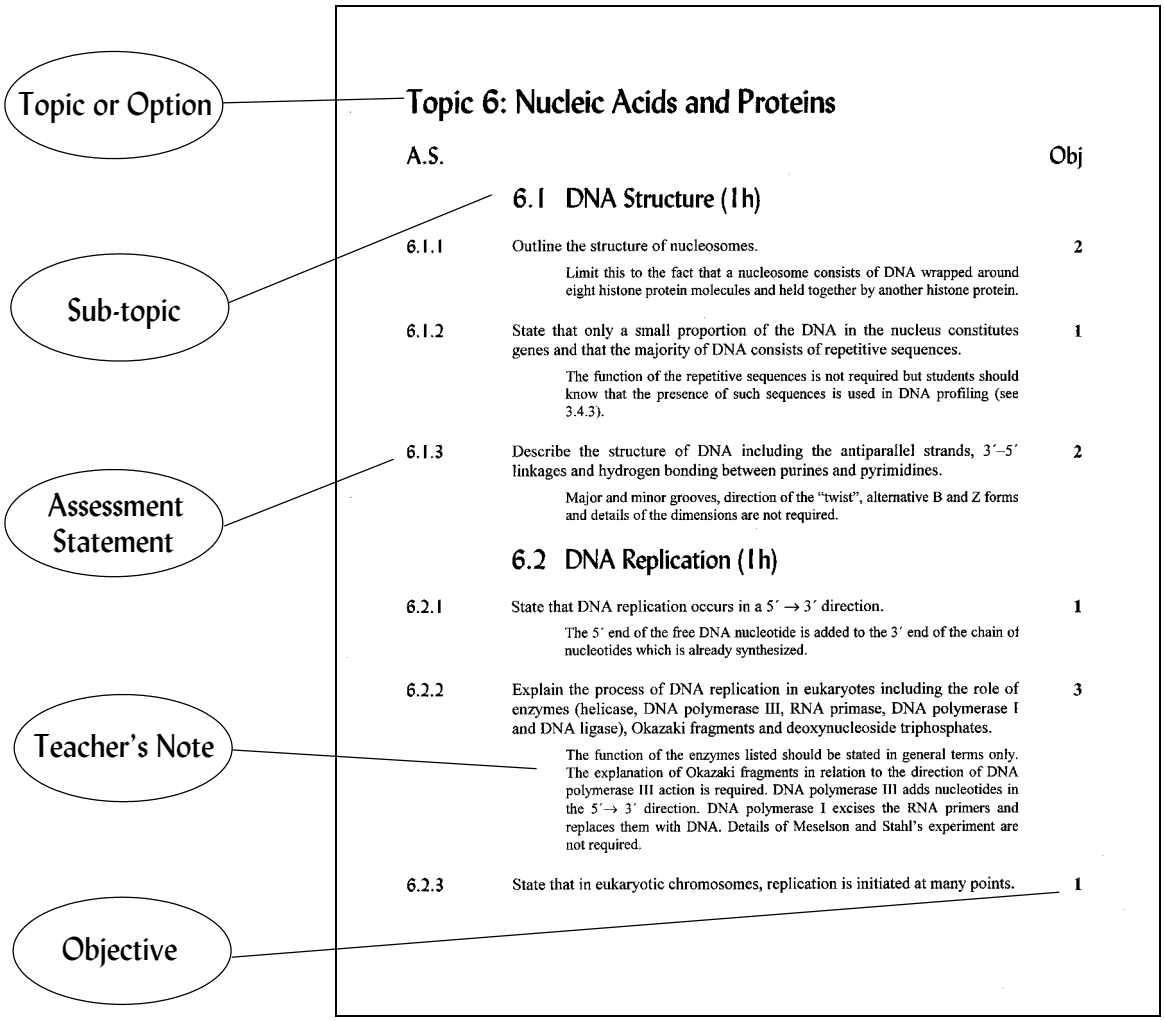
Sub-topics are numbered and the estimated teaching time required to cover the material is indicated (eg 6.1 DNA Structure (1h)). The times are for guidance only and do not include time for practical/investigative work.

Assessment Statements (A.S.)

Assessment statements, which are numbered, are expressed in terms of the outcomes that are expected of students at the end of the course (eg 6.1.1 Outline the structure of nucleosomes). These are intended to prescribe to examiners what can be assessed by means of the written examinations. Each one is classified as objective 1, 2 or 3 (see page 7) according to the action verb(s) used (see page 8). The objective levels are relevant for the examinations and for balance within the syllabus, while the action verbs indicate the depth of treatment required for a given assessment statement. It is important that students are made aware of the meanings of the action verbs since these will be used in examination questions.

Teacher's Notes

Teacher's notes, which are included below some assessment statements, provide further guidance to teachers.



AIMS

Through studying any of the group 4 subjects, students should become aware of how scientists work and communicate with each other. While the "scientific method" may take on a wide variety of forms, it will generally involve the formation, testing and modification of hypotheses through observation and measurement, under the controlled conditions of an experiment. It is this approach, along with the falsifiability of scientific hypotheses, that distinguishes the experimental sciences from other disciplines and characterizes each of the subjects within group 4.

It is in this context that all the Diploma Programme experimental science courses should aim to:

1. provide opportunities for scientific study and creativity within a global context which will stimulate and challenge students

2. provide a body of knowledge, methods and techniques which characterize science and technology

3. enable students to apply and use a body of knowledge, methods and techniques which characterize science and technology

4. develop an ability to analyse, evaluate and synthesize scientific information

5. engender an awareness of the need for, and the value of, effective collaboration and communication during scientific activities

6. develop experimental and investigative scientific skills

7. develop and apply the students' information technology skills in the study of science

8. raise awareness of the moral, ethical, social, economic and environmental implications of using science and technology

9. develop an appreciation of the possibilities and limitations associated with science and scientists

10. encourage an understanding of the relationships between scientific disciplines and the overarching nature of the scientific method.

OBJECTIVES

The objectives for all group 4 subjects reflect those parts of the aims that will be assessed. Wherever appropriate, the assessment will draw upon environmental and technological contexts and identify the social, moral and economic effects of science.

It is the intention of all the Diploma Programme experimental science courses that students should achieve the following objectives.

1. Demonstrate an understanding of:
    a. scientific facts and concepts
    b. scientific methods and techniques
    c. scientific terminology
    d. methods of presenting scientific information.
2. Apply and use:
    a. scientific facts and concepts
    b. scientific methods and techniques
    c. scientific terminology to communicate effectively
    d. appropriate methods to present scientific information.
3. Construct, analyse and evaluate:
    a. hypotheses, research questions and predictions
    b. scientific methods and techniques
    c. scientific explanations.
4. Demonstrate the personal skills of cooperation, perseverance and responsibility appropriate for effective scientific investigation and problem solving.
5. Demonstrate the manipulative skills necessary to carry out scientific investigations with precision and safety.

ACTION VERBS

These action verbs indicate the depth of treatment required for a given assessment statement. These verbs will be used in examination questions and so it is important that students are familiar with the following definitions.

Objective 1

Define	give the precise meaning of a word or phrase as concisely as possible
Draw	represent by means of pencil lines (add labels unless told not to do so)
List	give a sequence of names or other brief answers with no elaboration, each one clearly separated from the others
Measure	find a value for a quantity
State	give a specific name, value or other brief answer (no supporting argument or calculation is necessary)

Objective 2

Annotate	add brief notes to a diagram, drawing or graph
Apply	use an idea, equation, principle, theory or law in a new situation
Calculate	find an answer using mathematical methods (show the working unless instructed not to do so)
Compare	give an account of similarities and differences between two (or more) items, referring to both (all) of them throughout (comparisons can be given using a table)
Describe	give a detailed account, including all the relevant information
Distinguish	give the differences between two or more different items
Estimate	find an approximate value for an unknown quantity, based on the information provided and scientific knowledge
Identify	find an answer from a number of possibilities
Outline	give a brief account or summary (include essential information only)

Objective 3

Analyse	interpret data to reach conclusions
Construct	represent or develop in graphical form
Deduce	reach a conclusion from the information given
Derive	manipulate a mathematical equation to give a new equation or result
Design	produce a plan, object, simulation or model
Determine	find the only possible answer
Discuss	give an account including, where possible, a range of arguments, assessments of the relative importance of various factors or comparisons of alternative hypotheses
Evaluate	assess the implications and limitations
Explain	give a clear account including causes, reasons or mechanisms
Predict	give an expected result
Solve	obtain an answer using algebraic and/or numerical methods
Suggest	propose a hypothesis or other possible answer

INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)

The role of computers in developing and applying scientific knowledge is well established. Scientists make measurements, handle information and model ideas. They need to process information and communicate it effectively.

Why Use Computers in Science?

Skills in handling information are clearly important life skills. The use of ICT will enhance learning, increase awareness of the technology scientists use for processing information and prepare students better for a rapidly changing situation in the real world. Computers enable students to become more active participants in learning and research and offer a valuable resource for understanding the processes of science. Development of ICT skills will allow students to explore rich materials, access information quickly and easily and lead them into areas previously experienced only through the possession of higher order skills. The computer also allows the teacher more flexibility in both approach and presentation of materials. Creating an ICT culture in classrooms is an important endeavour for all schools.

It is for these reasons that the IBO has incorporated a new aim related to ICT for group 4—aim 7: develop and apply the students' information technology skills in the study of science.

When Should Computers be Used?

The use of computers should complement rather than replace hands-on practical work. However computers can be used in areas where a practical approach is inappropriate or limited.

For example: sensors may be used in data-logging to obtain data over long or very short periods of time, or in experiments that otherwise would not be feasible. Simulation software may be used to illustrate concepts and models which are not readily demonstrable in laboratory experiments because they require expensive equipment or materials that are hazardous or difficult to obtain. The experiments may also involve skills not yet achieved by students or which require more time than is available.

What Sort of Technologies are Available?

The technology for processing information includes such tools as word processors, spreadsheets, database programs, sensors and modelling programs.

Spreadsheets

These multipurpose programs may be used for generating results tables from experimental data, data handling, sorting and searching pre-existing data, and producing graphs. Perhaps their most interesting feature is their use in calculations and mathematical modelling.

Databases

Scientists use database programs to handle the vast amounts of data which may be generated in experiments, or to retrieve other scientists' data. The database may be on disc, CD-Rom or downloaded from the Internet. Scientists use their skills and experience to collect, organize and analyse data, look for patterns and check for errors. To appreciate the value of databases to the scientific community, students should be familiar with using a database to store, sort and graph data.

Data-logging

Sensors and control technology can help scientists by monitoring very fast or very slow changes. Data-logging has the advantage that students can see the data recorded in real time. They can therefore focus on the trends and patterns that emerge rather than on the process of gathering the data. Sensors can also measure with more precision allowing students to have greater confidence in their results.

Software for Modelling and Simulations

A wide range of software programs exist to model (amongst other things) photosynthesis, control of blood sugar, chemical equilibria, the cardiovascular system and wave phenomena such as interference and diffraction. Generic programs are also available which allow students to construct models of, for example, motion and gravity, heat loss or populations in an ecosystem. Some of these programs are available via the Internet.

The Internet, CD-Roms, DVDs and Multimedia

The powerful combination of the spoken word, animation and video in these multimedia products clearly motivates and stimulates the user. Interactive multimedia has considerable potential to link different representations and ways of learning to facilitate understanding in science. It provides information that can be selected or rejected, and search facilities allow many different routes through the material which illustrate new links and patterns.

There is clearly added value in the use of interactive multimedia through visualization and differentiation. To be able to represent visually, for example, the dynamic aspects of kinetic theory or electron movements, helps students imagine the situation and aids the learning of difficult concepts. This complements more traditional teaching approaches.

Word Processing and Graphics

Word processing is not merely a means of writing in electronic form. It can improve the quality of written work from the initial listing of ideas, their development and reworking, through to the final product. Drawing programs, scanners, digital cameras, video cameras, desktop publishing, multimedia authoring and CAD/CAM software also have their place, particularly in design technology and perhaps more widely through the group 4 project.

Internationalism

The ease and widespread use of email should encourage the networking of teachers and students, and this replicates the networking activities of the science community. Email (and web sites) could be used to collaborate with other schools world wide, perhaps as part of the group 4 project, or in established collaborative ventures such as the Science Across the World and Globe programs.

Ethical and Moral Dimension

This dimension of the use of ICT need not be made explicit in the group 4 subjects as students will be exposed to it through Theory of Knowledge (TOK), and it will also emerge in the day-to-day experiences of students inside and outside school. Such issues as plagiarism of extended essays, firewalls to prevent access to undesirable web sites, hacking, anti-social behaviour in local networks and on the Internet, privacy of information in databases, freedom of information and web site subscriptions may be encountered.

How to Proceed

Because of the variability of both hardware and software between IB schools, the use of ICT will not be monitored or assessed. For this reason, there is no new objective related to ICT in group 4. However, it is vital to encourage ICT use and to stress its importance in any modern science curriculum. (One common element is the use of graphic calculators in some IB Diploma Programme mathematics courses. This allows for portable, low cost data-logging, modelling and graph plotting.) The IB community can help disseminate ideas and guidance through its workshops and the online curriculum centre.

For further information teachers should access:

- the online curriculum centre to find up-to-date and relevant resources and web site addresses, and to share experiences and resources with other IB teachers
- the web sites of national and international educational bodies promoting ICT
- the web sites of the main educational suppliers and specialized educational software and hardware suppliers, many of whom now operate internationally.

EXTERNAL ASSESSMENT

The external assessment consists of three written papers.

Paper 1

Paper 1 is made up of multiple-choice questions which test knowledge of the core and additional higher level (AHL) material for higher level (HL) students and the core only for standard level (SL) students. The questions are designed to be short, one- or two-stage problems which address objectives 1 and 2 (see page 7). No marks are deducted for incorrect responses. Calculators are not permitted, but students are expected to carry out simple calculations.

Paper 2

Paper 2 tests knowledge of the core and AHL material for HL students and the core only for SL students. The questions address objectives 1, 2 and 3 and the paper is divided into two sections.

In section A, there is a data-based question which will require students to analyse a given set of data. The remainder of section A is made up of short-answer questions.

In section B, students are expected to answer two questions from a choice of four at HL** or one question from a choice of three at SL. These extended response questions may involve writing a number of paragraphs, solving a substantial problem, or carrying out a substantial piece of analysis or evaluation. A calculator is required for this paper.

Paper 3

Paper 3 tests knowledge of the options and addresses objectives 1, 2 and 3. At HL, students will answer several short-answer questions and an extended response question in each of the two options studied. At SL, students answer several short-answer questions in each of the two options studied. A calculator is required for this paper. (In biology, students will also answer a data-based question in each of the two options studied.)

The assessment specifications at HL and SL are summarized on the next page.

There are some variations in external assessment requirements for design technology, arising from the design project. A double asterisk(**) indicates where these variations occur. See the design technology guide for details.

Note: Wherever possible teachers should use, and encourage students to use, the Système International d'Unites (International System of Units—SI units).

Assessment Specifications—Standard Level**

Component	Overall Weighting (%)	Approximate Weighting of Objectives 1+2	3	Duration (hours)	Format and Syllabus Coverage
Paper 1	20	20		¾	30 multiple-choice questions on the core
Paper 2	32	16	16	1¼	Section A: one data-based question and several short-answer questions on the core (all compulsory) Section B: one extended response question on the core (from a choice of three)
Paper 3	24	12	12	1	several short-answer questions in each of the two options studied (all compulsory)

Assessment Specifications—Higher Level**

Component	Overall Weighting (%)	Approximate Weighting of Objectives 1+2	3	Duration (hours)	Format and Syllabus Coverage
Paper 1	20	20		1	40 multiple-choice questions (± 15 common to SL plus about five more on the core and about 20 more on the AHL)
Paper 2	36	18	18	2¼	Section A: one data-based question and several short-answer questions on the core and the AHL (all compulsory) Section B: two extended response questions on the core and AHL (from a choice of four)
Paper 3	20	10	10	1¼	several short-answer questions and one extended response question in each of the two options studied (all compulsory)

For both SL and HL, calculators are not permitted in paper 1 but are required in papers 2 and 3, where programmable graphic display calculators are allowed.

INTERNAL ASSESSMENT

General Introduction

The internal assessment (IA) requirements are the same for all group 4 subjects, with the exception of design technology which has an additional element. The IA, worth 24% of the final assessment (design technology 36%) consists of an interdisciplinary project, a mixture of short- and long-term investigations (such as practicals and subject-specific projects) and, for design technology only, the design project

Student work is internally assessed by the teacher and externally moderated by the IBO. The performance in IA at both higher level and standard level is judged against assessment criteria each consisting of achievement levels 0–3.

Rationale for Practical Work

Although the requirements for IA are mainly centred on the assessment of practical skills, the different types of experimental work that a student may engage in serve other purposes, including:

- illustrating, teaching and reinforcing theoretical concepts
- developing an appreciation of the essential hands-on nature of scientific work
- developing an appreciation of the benefits and limitations of scientific methodology.

Therefore, there may be good justification for teachers to conduct further experimental work beyond that required for the IA scheme.

Practical Scheme of Work

The practical scheme of work (PSOW) is the practical course planned by the teacher and acts as a summary of all the investigative activities carried out by a student. Higher level and standard level candidates in the same subject may carry out some of the same investigations and, where more than one group of students is taught in a subject and level, common investigations are acceptable.

Syllabus Coverage

The range of investigations carried out should reflect the breadth and depth of the subject syllabus at each level, but it is not necessary to carry out an investigation for every syllabus topic. However, all candidates must participate in the group 4 project and the IA activities should ideally include a spread of content material from the core, options and, where relevant, AHL material. A minimum number of investigations to be carried out is not specified.

Choosing Investigations

Teachers are free to formulate their own practical schemes of work by choosing investigations according to the requirements outlined. Their choices will be based on:

- subjects, levels and options taught
- the needs of their students
- available resources
- teaching styles.

Teachers should not feel that all investigations must form part of the practical scheme of work, however their scheme must meet the IB requirements. Each scheme must include at least a few complex investigations which make greater conceptual demands on the students. A scheme made up entirely of simple experiments, such as ticking boxes or exercises involving filling in tables, will not provide an adequate range of experience for students.

Teachers are encouraged to use the online curriculum centre to share ideas about possible investigations by joining in the discussion forums and adding resources they use onto the relevant sections of the online subject guides.

> Note: Any investigation or part investigation that is to be used to assess candidates should be specifically designed to match the relevant assessment criteria.

Flexibility

The IA model is flexible enough to allow a wide variety of investigations to be carried out. These could include:

- short laboratory practicals over one or two lessons and long-term practicals or projects extending over several weeks
- computer simulations
- data-gathering exercises such as questionnaires, user trials and surveys
- data analysis exercises
- general laboratory and fieldwork.

The Group 4 Project

The group 4 project is an interdisciplinary activity in which all Diploma Programme science students must participate. The intention is that students analyse a topic or problem which can be investigated in each of the science disciplines offered by a school. The exercise should be a collaborative experience where the emphasis is on the **processes** involved in scientific investigation rather than the **products** of such investigation.

In most cases all students in a school would be involved in the investigation of the same topic. Where there are large numbers of students, it is possible to divide them into several smaller groups containing representatives from each of the science subjects. Each group may investigate the same topic or different topics, ie there may be several group 4 projects in the same school.

Design Technology

In design technology, each student must carry out the design project in addition to several investigations and the group 4 project. Higher level students are required to spend 31 hours on the design project and SL students 19 hours.

Practical Work Documentation

Details of an individual student's practical scheme of work are recorded on **form 4/PSOW** provided in the *Vade Mecum*, section 4. Electronic versions may be used as long as they include all necessary information.

In design technology, each candidate must compile a log book. This is a candidate's record of his/her development of the design project and an informal personal record of investigative activities.

IA Time Allocation

The recommended teaching times for the IB Diploma Programme courses are 240 hours for HL and 150 hours for SL. Higher level students are required to spend 60 hours, and SL students 40 hours, on practical activities (excluding time spent writing up work). These times include 10 to 15 hours for the group 4 project.

> Note: For design technology, HL students are required to spend 81 hours, and SL students 55 hours, on practical activities.

The time allocated to IA activities should be spread throughout most of the course and not confined to just a few weeks at the beginning, middle or end. Only 2–3 hours of investigative work can be carried out after the deadline for submission of work to the moderator and still be counted in the total hours for the practical scheme of work.

Guidance and Authenticity

All candidates should be familiar with the requirements for IA. It should be made clear to them that they are entirely responsible for their own work. It is helpful if teachers encourage candidates to develop a sense of responsibility for their own learning so that they accept a degree of ownership and take pride in their own work. In responding to specific questions from candidates concerning investigations, teachers should (where appropriate) guide candidates into more productive routes of enquiry rather than respond with a direct answer.

When completing an investigation outside the classroom candidates should work independently where possible. Teachers are required to ensure that work submitted is the candidate's own. If in doubt, authenticity may be checked by one or more of the following methods:

- discussion with the candidate
- asking the candidate to explain the methods used and to summarize the results
- asking the candidate to repeat the investigation.

Safety

While teachers are responsible for following national or local guidelines which may differ from country to country, attention should be given to the mission statement below which was developed by the International Council of Associations for Science Education (ICASE) Safety Committee.

ICASE Safety Committee

Mission Statement

The mission of the ICASE Safety Committee is to promote good quality, exciting practical science, which will stimulate students and motivate their teachers, in a safe and healthy learning environment. In this way, all individuals (teachers, students, laboratory assistants, supervisors, visitors) involved in science education are entitled to work under the safest possible practicable conditions in science classrooms and laboratories. Every reasonable effort needs to be made by administrators to provide and maintain a safe and healthy learning environment and to establish and require safe methods and practices at all times. Safety rules and regulations need to be developed and enforced for the protection of those individuals carrying out their activities in science classrooms and laboratories, and experiences in the field. Alternative science activities are encouraged in the absence of sufficiently safe conditions.

It is a basic responsibility of everyone involved to make safety and health an ongoing commitment. Any advice given will acknowledge the need to respect the local context, the varying educational and cultural traditions, the financial constraints and the legal systems of differing countries.

Criteria and Aspects

There are eight assessment criteria which are used to assess the work of both higher level and standard level candidates:

- *planning (a)*—Pl (a)
- *planning (b)*—Pl (b)
- *data collection*—DC
- *data processing and presentation*—DPP
- *conclusion and evaluation*—CE
- *manipulative skills*—MS
- *personal skills (a)*—PS (a)
- *personal skills (b)*—PS (b)

Each candidate must be assessed at least twice on each of the eight criteria. The two marks for each of the criteria are added together to determine the final mark out of 48 for the IA component. This will then be scaled at IBCA to give a total out of 24%.

General regulations and procedures relating to IA can be found in the *Vade Mecum*.

Each of the assessment criteria can be separated into two or three **aspects** as shown on the following pages. Descriptions are provided to indicate what is expected in order to meet the requirements of a given aspect **completely (c)** and **partially (p)**. A description is also given for circumstances in which the requirements are not satisfied, **not at all (n)**.

Planning (a)

	ASPECTS		
LEVELS	Defining the problem or research question	Formulating a hypothesis or prediction	Selecting variables
Complete	Identifies a focused problem or research question.	Relates the hypothesis or prediction directly to the research question and explains it, quantitatively where appropriate.	Selects the relevant independent and controlled variable(s).
Partial	States the problem or research question, but it is unclear or incomplete.	States the hypothesis or prediction but does not explain it.	Selects some relevant variables.
Not at all	Does not state the problem or research question **or** repeats the general aim provided by the teacher.	Does not state a hypothesis or prediction.	Does not select any relevant variables.

Planning (b)

	ASPECTS		
LEVELS	Selecting appropriate apparatus or materials*	Designing a method for the control of variables	Designing a method for the collection of sufficient relevant data
Complete	Selects appropriate apparatus or materials.	Describes a method that allows for the control of the variables.	Describes a method that allows for the collection of sufficient relevant data.
Partial	Selects some appropriate apparatus or materials.	Describes a method that makes some attempt to control the variables.	Describes a method that allows for the collection of insufficient relevant data.
Not at all	Does not select any apparatus or materials.	Describes a method that does not allow for the control of the variables.	Describes a method that does not allow any relevant data to be collected.

* suitable diagrams are acceptable

Data Collection

	ASPECTS	
LEVELS	Collecting and recording raw data	Organizing and presenting raw data
Complete	Records appropriate raw data (qualitative and/or quantitative), including units and uncertainties where necessary.	Presents raw data clearly, allowing for easy interpretation.
Partial	Records some appropriate raw data.	Presents raw data but does not allow for easy interpretation.
Not at all	Does not record any appropriate raw data.	Does not present raw data **or** presents it incomprehensibly.

Data Processing and Presentation

	ASPECTS	
LEVELS	Processing raw data	Presenting processed data
Complete	Processes the raw data correctly.	Presents processed data appropriately, helping interpretation and, where relevant, takes into account errors and uncertainties.
Partial	Some raw data is processed correctly.	Presents processed data appropriately but with some errors and/or omissions.
Not at all	No processing of raw data is carried out **or** major errors are made in processing.	Presents processed data inappropriately **or** incomprehensibly.

Conclusion and Evaluation

	ASPECTS		
LEVELS	Drawing conclusions	Evaluating procedure(s) and results	Improving the investigation
Complete	Gives a valid conclusion, based on the correct interpretation of the results, with an explanation and, where appropriate, compares results with literature values.	Evaluates procedure(s) and results including limitations, weaknesses or errors.	Identifies weaknesses and states realistic suggestions to improve the investigation.
Partial	States a conclusion that has some validity.	Evaluates procedure(s) and results but misses some obvious limitations or errors.	Suggests only simplistic improvements.
Not at all	Draws a conclusion that misinterprets the results.	The evaluation is superficial **or** irrelevant.	Suggests unrealistic improvements.

Manipulative Skills

	ASPECTS	
LEVELS	Carrying out techniques safely	Following a variety of instructions*
Complete	Is competent and methodical in the use of the technique(s) and the equipment, and pays attention to safety issues.	Follows the instructions accurately, adapting to new circumstances (seeking assistance when required).
Partial	Requires assistance in the use of a routine technique. Works in a safe manner with occasional prompting.	Follows the instructions but requires assistance.
Not at all	Does not carry out the technique(s) **or** misuses the equipment, showing no regard for safety.	Does not follow the instructions **or** requires constant supervision.

* Instructions may be given in a variety of forms: oral, written worksheets, diagrams, photographs, videos, flowcharts, audiotapes, models, computer programs etc.

Personal Skills (a)

	ASPECTS		
LEVELS	Working within a team*	Recognizing the contributions of others	Exchanging and integrating ideas
Complete	Collaborates with others, recognizing their needs, in order to complete the task.	Expects, actively seeks and acknowledges the views of others.	Exchanges ideas with others, integrating them into the task.
Partial	Requires guidance to collaborate with others.	Acknowledges some views.	Exchanges ideas with others but requires guidance in integrating them into the task.
Not at all	Is unsuccessful when working with others.	Disregards views of others.	Does not contribute.

* A team is defined as two or more people.

Personal Skills (b)

	ASPECTS		
LEVELS	Approaching scientific investigations with self-motivation and perseverance	Working in an ethical manner	Paying attention to environmental impact
Complete	Approaches the investigation with self-motivation and follows it through to completion.	Pays considerable attention to the authenticity of the data and information, and the approach to materials (living or non-living).	Pays considerable attention to the environmental impact of the investigation.
Partial	Approaches the investigation with self-motivation or follows it through to completion.	Pays some attention to the authenticity of the data and information, and the approach to materials (living or non-living).	Pays some attention to the environmental impact of the investigation.
Not at all	Lacks perseverance and motivation.	Pays little attention to the authenticity of the data and information, and the approach to materials (living or non-living).	Pays little attention to the environmental impact of the investigation.

Achievement Level Matrixes

For a particular criterion, a piece of work is judged to see whether the requirements of each aspect have been fulfilled completely, partially or not at all. This can then be translated into an achievement level 0, 1, 2 or 3 using the achievement level matrixes below. The lowest level of achievement is represented by 0, and 3 represents the highest level of achievement.

Planning (a), Planning (b), Conclusion and Evaluation, Personal Skills (a), Personal Skills (b)

The matrix below refers to *planning (a)*, *planning (b)*, *conclusion and evaluation*, *personal skills (a)* and *personal skills (b)*, where each criterion has three aspects.

Level	3			2			2			2			1		
Completely	✓	✓	✓	✓	✓		✓	✓		✓					
Partially						✓					✓	✓	✓	✓	✓
Not at all									✓						
	Aspects			Aspects			Aspects			Aspects			Aspects		
Level	1			1			1			0			0		
Completely	✓			✓											
Partially		✓					✓	✓		✓					
Not at all			✓		✓	✓			✓		✓	✓	✓	✓	✓
	Aspects			Aspects			Aspects			Aspects			Aspects		

Data Collection, Data Processing and Presentation, Manipulative Skills

The matrix below applies to *data collection*, *data processing and presentation*, and *manipulative skills*, where each criterion has two aspects.

Level	3		2		1		1		0		0	
Completely	✓	✓	✓		✓							
Partially				✓			✓	✓	✓			
Not at all						✓				✓	✓	✓
	Aspects		Aspects		Aspects		Aspects		Aspects		Aspects	

Guidance on the Criteria

Planning (a)

It is generally not appropriate to assess *planning (a)* for most experiments or investigations found in standard textbooks, unless the experiments are modified. It is essential that students are given an open-ended problem to investigate. Although the general aim of the investigation may be provided by the teacher, students must be able to identify a focused problem or specific research question.

For example, the teacher might present the aim of the investigation generally in the form "investigate the factors that affect X". Students should be able to recognize that certain factors will influence X and clearly define the aim of the experiment or identify a focused research question. A hypothesis or prediction should then be formulated in the light of any independent variables that have been chosen. Such a hypothesis must contain more than just an expected observation. It must include a proposed relationship between two or more variables, or at least an element of rational explanation for an expected observation, the basis of which can be investigated experimentally. A typical formulation for a hypothesis might be "if *y* is done, then *z* will occur". Other variables that might affect the outcome should also be mentioned, even if they are not to be specifically investigated. Controlled variables should also be selected.

Planning (b)

The student must design a realistic and appropriate method that allows for the control of variables and the collection of sufficient relevant data. The experimental set-up and measurement techniques must be described.

Data Collection

Data collection skills are important in accurately recording observed events and are critical to scientific investigation. Data collection involves all quantitative or qualitative raw data, such as a column of results, written observations or a drawing of a specimen. Qualitative data is defined as those observed with more or less unaided senses (colour, change of state, etc) or rather crude estimates (hotter, colder, etc), whereas quantitative data implies actual measurements.

Investigations should allow students opportunities to deal with a wide range of observations and data. It is important that the practical scheme of work includes:

- the collection of qualitative and quantitative data
- various methods or techniques
- different variables (time, mass, etc)
- various conditions
- subject-specific methods of collection.

In addition:

- attention to detail should be reflected in the accuracy and precision of the data recorded
- use of data collection tables should be encouraged
- methods of collection and the measurement techniques must be appropriate to each other
- units of measurement must be relevant to the task at hand.

Data Processing and Presentation

The practical scheme of work should provide sufficient investigations to enable a variety of methods of data processing to be used.

Students should also be exposed to the idea of error analysis. That is not to say that error analysis must be carried out for every investigation, nor should it overshadow the purpose of an investigation.

Students should show that they can take raw data, transform it and present it in a form suitable for evaluation.

Processing raw data may include:

- subjecting raw data to statistical calculations (eg producing percentages or means), with the calculations correct and accurate to the level necessary for evaluation
- converting drawings into diagrams
- converting tabulated data into a graphical form
- correctly labelling drawings
- sketching a map from measurements and observations in land form
- proceeding from a sketched idea to a working drawing (eg orthographic projection or sectional views).

The data should be presented so that the pathway to the final result can be followed. Features which should be considered when presenting data include:

- quality of layout (eg choice of format, neatness)
- choice of correct presentation (eg leave as a table, convert to a graph, convert to a flow diagram)
- use of proper scientific conventions in tables, drawings and graphs
- provision of clear, unambiguous headings for drawings, tables or graphs.

Conclusion and Evaluation

Once the data has been processed and presented in a suitable form, the results can be interpreted, conclusions can be drawn and the method evaluated.

Students are expected to:

- analyse and explain the results of experiments and draw conclusions
- evaluate the results.

Analysis may include comparisons of different graphs or descriptions of trends shown in graphs.

Students are also expected to evaluate the procedure they adopted, specifically looking at:

- the processes
- use of equipment
- management of time.

Modifications to improve the investigation should be suggested.

Manipulative Skills

Indications of manipulative ability are the amount of assistance required in assembling equipment, the orderliness of carrying out the procedure(s), the ability to follow the instructions accurately and adherence to safe working practices.

Personal Skills (a)

Working in a team is when two or more students work on a task collaboratively, face-to-face, with individual accountability. Effective teamwork includes recognizing the contributions of others, which begins with each member of the team expecting every other member to contribute. The final product should be seen as something that has been achieved by all members of the team participating in the tasks involved. Encouraging the contributions of others implies not only recognizing, but also actively seeking, contributions from reluctant or less confident members of the team.

Personal Skills (b)

Issues such as plagiarism, the integrity of data collection and data analysis, may be considered here. Sources of data should be acknowledged and data must be reported accurately, even when anomalous or when an experiment has not given rise to the results expected. Due attention to environmental impact may be demonstrated in various ways including avoidance of wastage, using proper procedures for disposal of waste, and minimizing damage to the local environment when conducting experiments.

Assessing an Investigation

In assessing an investigation it must be noted that:

- the same standards must be applied to both HL and SL students
- level 3 does not imply faultless performance
- only whole numbers should be awarded, not fractions or decimals.

The work being assessed must be that of the student. For example in work on *planning (a)*, the student should define the problem, formulate the hypothesis and select the variables; this information should not be provided by the teacher. In work on *data collection*, the student must decide how to collect, record, organize and present the raw data. The teacher should not, for instance, specify how the data should be acquired or provide a table in which the data is recorded. This principle extends to the other criteria.

To illustrate the use of the achievement level matrixes, consider the following example. A student's work is assessed against the criterion *data processing and presentation*. The teacher feels that the first aspect, *processing raw data*, is met completely whereas the second aspect, *presenting processed data*, is only achieved partially. Using the achievement level matrix for *data processing and presentation*, this translates to a level of 2.

THE GROUP 4 PROJECT

Summary of the Group 4 Project

The group 4 project allows students to appreciate the environmental, social and ethical implications of science. It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the products of such investigation.

The exercise should be a collaborative experience where concepts and perceptions from across the group 4 disciplines are shared. The intention is that students analyse a topic or problem which can be investigated in each of the science disciplines offered by a school. The topic can be set in a local, national or international context.

Project Stages

The 10–15 hours allocated to the group 4 project, which are part of the teaching time set aside for internal assessment, can be divided into four stages: planning, definition of activities, action and evaluation.

Planning

This stage is crucial to the whole exercise and should last 2–4 hours.

- The planning stage could consist of a single session, or two or three shorter ones.
- This stage must involve all science students meeting to "brainstorm" and discuss the central topic, sharing ideas and information.
- The topic can be chosen by the students themselves or selected by the teachers.
- Where large numbers of students are involved, it may be advisable to have more than one mixed discipline group.

After selecting a topic or issue, the activities to be carried out must be clearly defined before moving from the planning stage to the action and evaluation stages.

Definition of Activities

A possible strategy is that students define specific tasks for themselves, either individually or as members of groups, and investigate various aspects of the chosen topic. Contact with other schools, if a joint venture has been agreed, is an important consideration at this time.

Action

This stage should take 6–8 hours in total and may be carried out over one or two weeks in normal scheduled class time. Alternatively a whole day could be set aside if, for example, the project involves fieldwork.

- The students (as individuals, single subject groups or mixed subject groups) should investigate the topic from the perspective of the individual science disciplines.
- There should be collaboration in the action stage; findings of investigations should be shared with others working on the project. This may be difficult if the action stage takes place during normal lessons, but it is possible to use bulletin boards (either physical or electronic) to exchange information or to use times when students are together, such as lunchtimes. Enthusiastic students will no doubt share information informally.
- During this stage it is important to pay attention to safety, ethical and environmental considerations.

Evaluation

The emphasis during this stage, for which 2–4 hours is probably necessary, is on students sharing their findings, both successes and failures, with other students. How this is achieved can be decided by the teachers, the students or jointly.

- One solution is to devote a morning, afternoon or evening to a symposium where all the students, as individuals or as groups, give brief presentations (perhaps with the aid of an overhead projector, flip charts, posters, video player, computers, etc).
- Alternatively the presentation could be more informal and take the form of a science fair where students circulate around displays summarizing the activities of each student or group.

The symposium or science fair could also be attended by parents, members of the school board and the press. This would be especially pertinent if some issue of local importance has been researched. Some of the findings might influence the way the school interacts with its environment or local community.

In addition to the presentation, each student must show evidence of their participation in the project.

Preparation

The impact the project has on the organization of the school is an important consideration. The key is the formulation of an action plan, perhaps in the form of a list of questions, to help draw up a strategy for all the activities involved. The following are suggestions for such a list (these could be adapted to suit the needs of an individual school).

- How might a topic be selected? Possibilities are a questionnaire to students, discussions with students and/or teacher selection.
- Will teachers from other non-science departments be involved?
- Will people from outside the school be used as a source of ideas for the project? If so, what is their availability?
- What communication methods are available for the coordination of activities, exchange of data and joint presentations?
- When should the project be conducted, and over what time period?
- What are the implications in terms of staff and resources?

Strategies

Considerations

Teachers will find that there are many factors to consider when planning the project work, besides deciding at what point to carry out the project and what the starting and completion dates should be. These factors include:

- the way the school's year is organized into terms or semesters
- the number of sciences offered
- the number of IB students
- whether or not the school wishes to collaborate with other schools either locally, nationally or internationally.

The needs of the students should be of foremost importance when weighing up the advantages and disadvantages of the various possibilities.

Ensuring that carrying out the project is a group experience (not restricted to a single science in group 4) may present organizational problems for some schools. The options may be limited because, for example, there is a small number of students, only one science is offered or other IB schools are some distance away. Teachers should take into account factors specific to their school and the general points made in this section when planning their strategies.

Timing

The time-span for carrying out the project is not a full two years.

- The project must be finished, at the latest, 19 months after starting teaching. Therefore, allowing for the planning stages, there may only be 18 months during which the project can be carried out. In the case of those completing the course in one year, such as anticipated SL candidates, the time available is limited further.
- Before starting work on the project students should, ideally, have some experience of working in a team.
- It is very important that students have reached a point where they have a certain degree of scientific knowledge and skills, and have experience of experimental techniques, before undertaking the project.

The 10–15 hours that the IBO recommends should be allocated to the project may be spread over a number of weeks. The distribution of these hours needs to be taken into account when selecting the optimum time to carry out the project. However, it is possible for a group to dedicate a period of time exclusively to project work if all other school work is suspended.

Year 1

In the first year students' experience and skills may be limited and it would be inadvisable to start the project too soon in the course. However, doing the project in the final part of the first year may have the advantage of reducing pressure on students later on. This strategy provides time for solving unexpected problems.

Year 1–Year 2

The planning stage could start, the topic could be decided and provisional discussion in individual subjects could take place at the end of the first year. Students could then use the vacation to think about how they are going to tackle the project and would be ready to start work early in the second year.

Year 2

Delaying the start of the project until some point in the second year, particularly if left too late, increases pressure on students in many ways: the schedule for finishing the work is much tighter than for the other options; the illness of any student or unexpected problems will present extra difficulties. Nevertheless, this choice does mean students know one another and their teachers by this time, have probably become accustomed to working in a team and will be more experienced in the relevant fields than in the first year.

Combined HL and SL

Where circumstances dictate that the project is only carried out every two years, HL beginners and more experienced SL students are combined.

General Strategies

1. Collaborate with other IB schools, including:
   - direct contact with local schools
   - post, fax, telephone, email, video conferencing.

   This is particularly useful for small schools or those with a single science, and where schools have well-established contacts they wish to exploit, or new ones they wish to develop. Where schools in different countries are linked, the importance of internationalism can be reinforced.
2. Carry out the project only every two years so that first- and second-year students can work together to make a larger group, bearing in mind the restriction on timing. (This is perhaps only necessary for small schools and may be difficult in terms of timing.)
3. Encourage IB students to work with non-IB students in the school who may be following courses leading to national or other equivalent qualifications. (This may be useful for small schools or those with a single science.)
4. Encourage participation of local teachers or experts from local industries, businesses, colleges or universities. (This may be helpful to small schools or those distant from other IB schools.)
5. Collaborate with students taking group 3 subjects such as geography, psychology or economics. (This is only relevant to schools not offering the full IB Diploma Programme.)

Selecting a Topic

In most cases all students in a single school will be involved in the investigation of the same topic. Where there are large numbers of students, it is possible to divide them into several smaller groups, each undertaking their own project. The students may choose the topic or propose possible topics; teachers then decide which one is the most viable based on resources, staff availability etc. Alternatively, the teachers select the topic or propose several topics from which students make a choice.

Student Selection

Students are likely to display more enthusiasm and feel a greater sense of ownership for a topic that they have chosen themselves. A possible strategy for student selection of a topic, which also includes part of the planning stage, is outlined below. At this point, subject teachers may provide advice on the viability of proposed topics.

- Identify possible topics by using a questionnaire or a survey of the students.
- Conduct an initial "brainstorming" session of potential topics or issues.
- Discuss, for 10 minutes, two or three topics that seem interesting.
- Select one topic by consensus.
- Examine the topic. Students in each science subject write down relevant aspects that could be studied given the local circumstances, resources etc.
- Each subject group reads out their list and a master copy is made.
- Students in each discipline make a list of potential investigations that could be carried out. All students then discuss issues such as possible overlap and collaborative investigations.

Assessment

The group 4 project forms one part of a candidate's overall practical experience and does not contribute any fixed percentage to internal assessment. A school may choose:

- not to assess the project at all
- to assess the project according to the criteria for the school's local or national requirements
- to assess the project against one or more of the IB Diploma Programme internal assessment criteria.

The project may produce evidence for the full range of criteria, particularly *planning (a)* and *(b)*, and *personal skills (a)* and *(b)*.

Given the diverse nature of the activities associated with the project, it may be difficult for a single teacher to gain a fair overview of an individual student's contribution, especially in regard to *planning* and *personal skills*. It may be necessary for teachers to exchange observations and comments concerning student performance. Group, peer and self-evaluation can also contribute valuable extra information.

Participation

The evidence of a candidate's involvement in the project, required by the IBO in a moderation sample, can take a variety of forms. It must be accompanied by a copy of the written instructions and/or a summary of the verbal instructions given in relation to the project.

For each student in the moderation sample, the evidence may be:

- a statement written by the student about his/her own individual contributions
- a copy of a self-evaluation form
- a copy of a peer-evaluation form
- an individual laboratory report or complete project report
- rough work or a record of data collected by the student
- photographs, eg of a final poster produced by the group.

PART 2—BIOLOGY

NATURE OF THE SUBJECT

Biologists have accumulated huge amounts of information about living organisms and it would be easy to confuse students by teaching large numbers of seemingly unrelated facts. In Diploma Programme biology, it is hoped that students will acquire a limited body of facts and at the same time develop a broad, general understanding of the principles of the subject.

Although the Diploma Programme biology courses at standard level (SL) and higher level (HL) have been written as a series of discrete statements (for assessment purposes), there are four basic biological concepts that run throughout.

Structure and Function

This relationship is probably one of the most important in a study of biology and operates at all levels of complexity. Students should appreciate that structures permit some functions while, at the same time, limiting others.

Universality Versus Diversity

At the factual level it soon becomes obvious to students that some molecules (eg enzymes, amino acids, nucleic acids and ATP) are ubiquitous, and so are processes and structures. However, these universal features exist in a biological world of enormous diversity. Species exist in a range of habitats and show adaptations that relate structure to function. At another level students can grasp the idea of a living world in which universality means that a diverse range of organisms (including ourselves) are connected and interdependent.

Equilibrium Within Systems

Checks and balances exist both within living organisms and within ecosystems. The state of dynamic equilibrium is essential for the continuity of life.

Evolution

The concept of evolution draws together the other themes. It can be regarded as change leading to diversity within constraints, and this leads to adaptations of structure and function.

These concepts serve as themes which unify the various topics that make up the three sections of the course: the core, the additional higher level (AHL) material and the options.

The order in which the syllabus is arranged is **not** the order in which it should be taught, and it is up to individual teachers to decide on an arrangement that suits their circumstances. Option material may be taught within the core or the AHL material, if desired.

SYLLABUS OVERVIEW

The syllabus for the Diploma Programme biology course is divided into three parts: the core, the additional higher level material (AHL) and the options. A syllabus overview is provided below.

Core [80h]

Topics		Teaching hours
1	Cells	12
2	The chemistry of life	17
3	Genetics	15
4	Ecology and evolution	14
5	Human health and physiology	22

Additional Higher Level [55h]

Topics		Teaching hours
6	Nucleic acids and proteins	9
7	Cell respiration and photosynthesis	10
8	Genetics	7
9	Human reproduction	5
10	Defence against infectious disease	4
11	Nerves, muscles and movement	7
12	Excretion	5
13	Plant science	8

Options

Options Standard Level

		Teaching hours
A	Diet and human nutrition	15
B	Physiology of exercise	15
C	Cells and energy	15

Options Standard Level/Higher Level

D	Evolution	15/22
E	Neurobiology and behaviour	15/22
F	Applied plant and animal science	15/22
G	Ecology and conservation	15/22

Options Higher Level

H	Further human physiology	22

Standard level candidates are required to study any **two** options from A–G. The duration of each option is 15 hours.

Higher level candidates are required to study any **two** options from D–H. The duration of each option is 22 hours.

SYLLABUS OUTLINE

Core [80h]

Teaching hours

Topic 1 Cells [12]

1.1	Cell theory	3
1.2	Prokaryotic cells	1
1.3	Eukaryotic cells	3
1.4	Membranes	3
1.5	Cell division	2

Topic 2 The chemistry of life [17]

2.1	Chemical elements and water	2
2.2	Carbohydrates, lipids and proteins	4
2.3	Enzymes	2
2.4	DNA structure	1
2.5	DNA replication	1
2.6	Transcription and translation	2
2.7	Cell respiration	2
2.8	Photosynthesis	3

Topic 3 Genetics [15]

3.1	Chromosomes, genes, alleles and mutations	1
3.2	Meiosis	2
3.3	Theoretical genetics	6
3.4	Genetic engineering and other aspects of biotechnology	6

Topic 4 Ecology and evolution [14]

4.1	Communities and ecosystems	5
4.2	Populations	3
4.3	Evolution	2
4.4	Classification	2
4.5	Human impact	2

Topic 5 Human health and physiology [22]

5.1	Digestion	3
5.2	The transport system	3
5.3	Pathogens and disease	2
5.4	Defence against infectious disease	2
5.5	Gas exchange	2
5.6	Homeostasis and excretion	5
5.7	Reproduction	5

Additional Higher Level [55h]

		Teaching hours
Topic 6	**Nucleic acids and proteins**	**[9]**
6.1	DNA structure	1
6.2	DNA replication	1
6.3	Transcription	2
6.4	Translation	2
6.5	Proteins	1
6.6	Enzymes	2
Topic 7	**Cell respiration and photosynthesis**	**[10]**
7.1	Cell respiration	5
7.2	Photosynthesis	5
Topic 8	**Genetics**	**[7]**
8.1	Meiosis	2
8.2	Dihybrid crosses	2
8.3	Autosomal gene linkage	2
8.4	Polygenic inheritance	1
Topic 9	**Human reproduction**	**[5]**
9.1	Production of gametes	3
9.2	Fertilization and pregnancy	2
Topic 10	**Defence against infectious disease**	**[4]**
10.1	Types of defence	4
Topic 11	**Nerves, muscles and movement**	**[7]**
11.1	Nerves	3
11.2	Muscles and movement	4
Topic 12	**Excretion**	**[5]**
12.1	Excretion	1
12.2	The human kidney	4
Topic 13	**Plant science**	**[8]**
13.1	Plant structure	2
13.2	Transport in angiospermophytes	4
13.3	Reproduction in flowering plants	2

Options Standard Level

Teaching hours

Option A Diet and human nutrition [15]

A.1	Diet	4
A.2	Biochemistry of nutrition	6
A.3	Diet and health	5

Option B Physiology of exercise [15]

B.1	The skeleton, joints and muscles	4
B.2	Coordination of muscle activity	3
B.3	Muscles and energy	4
B.4	Fitness and training	2
B.5	Injuries	2

Option C Cells and energy [15]

C.1	Proteins	1
C.2	Enzymes	2
C.3	Cell respiration	6
C.4	Photosynthesis	6

Options Standard Level/Higher Level

Standard level students study the core of these options, and higher level students study the whole option (ie the core and the extension material).

Teaching Hours

Option D Evolution

Core (SL + HL) [15]

D.1	Origin of life on Earth	2
D.2	Origin of species	3
D.3	Evidence for evolution	5
D.4	Human evolution	5

Extension (HL only) [7]

D.5	Neo-Darwinism	4
D.6	The Hardy–Weinberg principle	3

Option E Neurobiology and behaviour

Core (SL + HL) [15]

E.1	Introduction and examples of behaviour	4
E.2	Perception of stimuli	3
E.3	Innate behaviour	3
E.4	Learned behaviour	3
E.5	Social behaviour	2

Extension (HL only) [7]

E.6	The ANS (autonomic nervous system)	3
E.7	Neurotransmitters and synapses	4

		Teaching Hours
Option F	**Applied plant and animal science**	
	Core (SL + HL)	[15]
F.1	Applied plant science	5
F.2	Applied animal science	4
F.3	Plant growth regulators	3
F.4	Plant and animal breeding	3
	Extension (HL only)	[7]
F.5	Genetic engineering in agriculture	3.5
F.6	Flowering and propagation of plants	3.5
Option G	**Ecology and conservation**	
	Core (SL + HL)	[15]
G.1	Ecology of species	3
G.2	Ecology of communities	5
G.3	Biodiversity and conservation	7
	Extension (HL only)	[7]
G.4	The nitrogen cycle	4
G.5	Impacts of humans on ecosystems	3

Options Higher Level

Option H	**Further human physiology**	[22]
H.1	Hormonal control	3
H.2	Digestion	4
H.3	Absorption of digested foods	2
H.4	Functions of the liver	3
H.5	The transport system	5
H.6	Gas exchange	5

SYLLABUS DETAILS

Topic 1: Cells

A.S.		Obj
	1.1 Cell Theory (3h)	
1.1.1	Discuss the theory that living organisms are composed of cells. Skeletal muscle and some fungal hyphae are not divided into cells but have a multinucleate cytoplasm. Some biologists consider unicellular organisms to be acellular.	**3**
1.1.2	State that a virus is a non-cellular structure consisting of DNA or RNA surrounded by a protein coat.	**1**
1.1.3	State that all cells are formed from other cells.	**1**
1.1.4	Explain three advantages of using light microscopes. Advantages include colour images instead of monochrome, a larger field of view, easily prepared sample material, the possibility of examining living material and observing movement.	**3**
1.1.5	Outline the advantages of using electron microscopes. In comparing electron and light microscopes, the terms *resolution* and *magnification* should be explained. Scanning and transmission electron microscopes should be mentioned briefly, but the principles of how they work need not be discussed.	**2**
1.1.6	Define *organelle*. An organelle is a discrete structure within a cell, and has a specific function.	**1**
1.1.7	Compare the relative sizes of molecules, cell membrane thickness, viruses, bacteria, organelles and cells, using appropriate SI units. Appreciation of relative size is required, such as molecules (1 nm), thickness of membranes (10 nm), viruses (100 nm), bacteria (1 μm), organelles (up to 10 μm), most cells (up to 100 μm). The three-dimensional nature/shape of cells should be emphasized.	**2**

A.S.		Obj
1.1.8	Calculate linear magnification of drawings. Drawings should show cells and cell ultrastructure with scale bars (eg ├──┤ 1 μm). Magnification could also be stated, eg × 250.	2
1.1.9	Explain the importance of the surface area to volume ratio as a factor limiting cell size. Mention the concept that the rate of metabolism of a cell is a function of its mass:volume ratio, whereas the rate of exchange of materials and energy (heat) is a function of its surface area. Simple mathematical models involving cubes and the changes in the ratio that occur as the sides increase by one unit could be compared.	3
1.1.10	State that unicellular organisms carry out all the functions of life.	1
1.1.11	Explain that cells in multicellular organisms differentiate to carry out specialized functions by expressing some of their genes but not others.	3
1.1.12	Define *tissue*, *organ* and *organ system*.	1

1.2 Prokaryotic Cells (1h)

1.2.1	Draw a generalized prokaryotic cell as seen in electron micrographs. Use images of bacteria as seen in electron micrographs to show the structure. The diagram should show the cell wall, plasma membrane, mesosome, cytoplasm, ribosomes and nucleoid (region containing naked DNA).	1
1.2.2	State one function for each of the following: cell wall, plasma membrane, mesosome, cytoplasm, ribosomes and naked DNA.	1
1.2.3	State that prokaryotes show a wide range of metabolic activity including fermentation, photosynthesis and nitrogen fixation.	1

1.3 Eukaryotic Cells (3h)

1.3.1	Draw a diagram to show the ultrastructure of a generalized animal cell as seen in electron micrographs. The diagram should show ribosomes, rough endoplasmic reticulum (rER), lysosome, Golgi apparatus, mitochondrion and nucleus.	1
1.3.2	State one function of each of these organelles: ribosomes, rough endoplasmic reticulum, lysosome, Golgi apparatus, mitochondrion and nucleus. The term *Golgi apparatus* will be used in place of Golgi body, Golgi complex or dictyosome.	1

A.S.		Obj
1.3.3	Compare prokaryotic and eukaryotic cells. Differences should include naked DNA versus DNA associated with protein, DNA in cytoplasm versus DNA enclosed in a nuclear envelope, no mitochondria versus mitochondria, 70S versus 80S ribosomes.	2
1.3.4	Describe three differences between plant and animal cells.	2
1.3.5	State the composition and function of the plant cell wall. The composition of the plant cell wall should be considered only in terms of cellulose microfibrils.	1

1.4 Membranes (3h)

1.4.1	Draw a diagram to show the fluid mosaic model of a biological membrane. The diagram should show the phospholipid bilayer, cholesterol, glycoproteins and integral and peripheral proteins. Use the term *plasma membrane* not cell surface membrane for the membrane surrounding the cytoplasm. Integral proteins are embedded in the phospholipid of the membrane whereas peripheral proteins are attached to its surface. Variations in composition related to the type of membrane, and the functions of cholesterol and glycoproteins, are not required.	1
1.4.2	Explain how the hydrophobic and hydrophilic properties of phospholipids help to maintain the structure of cell membranes.	3
1.4.3	List the functions of membrane proteins including hormone binding sites, enzymes, electron carriers, channels for passive transport and pumps for active transport.	1
1.4.4	Define *diffusion* and *osmosis*. Osmosis is the passive movement of water molecules, across a partially permeable membrane, from a region of lower solute concentration to a region of higher solute concentration.	1
1.4.5	Explain passive transport across membranes in terms of diffusion. Mention channels for facilitated diffusion.	3
1.4.6	Explain the role of protein pumps and ATP in active transport across membranes.	3
1.4.7	Explain how vesicles are used to transport materials within a cell between the rough endoplasmic reticulum, Golgi apparatus and plasma membrane.	3
1.4.8	Describe how the fluidity of the membrane allows it to change shape, break and reform during endocytosis and exocytosis.	2

A.S. Obj

1.5 Cell Division (2h)

1.5.1 State that the cell-division cycle involves interphase, mitosis and cytokinesis. **1**

1.5.2 State that interphase is an active period in the life of a cell when many biochemical reactions occur, as well as DNA transcription and DNA replication. **1**

1.5.3 Describe the events that occur in the four phases of mitosis (prophase, metaphase, anaphase and telophase). **2**

Include supercoiling of chromosomes, attachment of spindle microtubules, splitting of centromeres, movement of sister chromosomes to opposite poles and breakage and reformation of nuclear membranes.

Textbooks vary in the use of the terms *chromosome* and *chromatid*. In this course, the two DNA molecules formed by DNA replication are considered to be sister chromatids until the splitting of the centromere at the start of anaphase; after this they are individual chromosomes. The terms centrosome and kinetochore are not expected.

1.5.4 Explain how mitosis produces two genetically identical nuclei. **3**

1.5.5 Outline the differences in mitosis and cytokinesis between animal and plant cells. **2**

Limit this to the lack of the centrioles in plant cells and the formation of the cell plate.

1.5.6 State that growth, tissue repair and asexual reproduction involve mitosis. **1**

1.5.7 State that tumours (cancers) are the result of uncontrolled cell division and that these can occur in any organ. **1**

Topic 2: The Chemistry of Life

A.S. Obj

2.1 Chemical Elements and Water (2h)

2.1.1 State that the most frequently occuring chemical elements in living things are carbon, hydrogen and oxygen. **1**

2.1.2 State that a variety of other elements are needed by living organisms including nitrogen, calcium, phosphorus, iron and sodium. **1**

2.1.3 State one role for each of the elements mentioned in 2.1.2. **1**

Refer to the roles in both plants and animals.

2.1.4 Outline the difference between an atom and an ion. **2**

2.1.5 Outline the properties of water that are significant to living organisms including transparency, cohesion, solvent properties and thermal properties. Refer to the polarity of water molecules and hydrogen bonding where relevant. **2**

Quantitative details of bond angles, bond strengths or electronegativity are not required. One example to illustrate the importance of each property is sufficient.

- Thermal properties—refer to the large amounts of energy required to heat up water and change its state (and the reverse).
- Solvent properties—water is capable of dissolving many organic and inorganic substances.

2.1.6 Explain the significance to organisms of water as a coolant, transport medium and habitat, in terms of its properties. **3**

Both plants and animals should be mentioned. No physical, chemical or quantitative details are required.

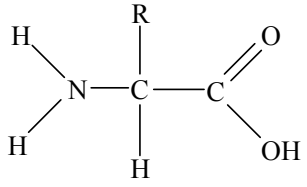
2.2 Carbohydrates, Lipids and Proteins (4h)

2.2.1 Define *organic*. **1**

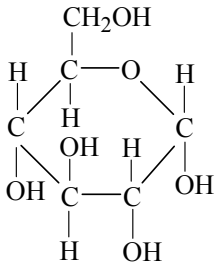
Compounds containing carbon that are found in living organisms (except hydrogencarbonates, carbonates and oxides of carbon) are regarded as organic.

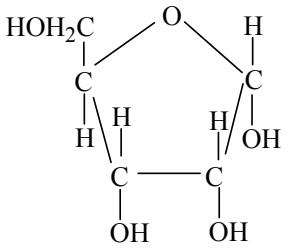
2.2.2 Draw the basic structure of a generalized amino acid. **1**

No details about the R group are required.

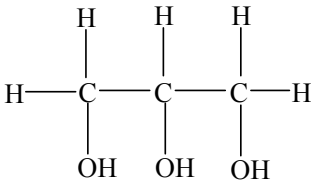


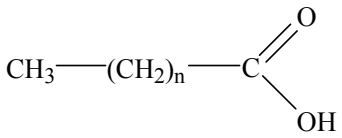
A.S.		Obj
2.2.3	Draw the ring structure of glucose and ribose. Diagrams such as the following are acceptable.	1





2.2.4	Draw the structure of glycerol and a generalized fatty acid. The IUPAC name of glycerol will not be used. The term *fatty acid* can refer to aliphatic and aromatic fatty acids.	1





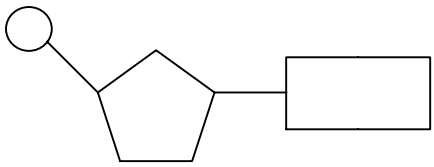
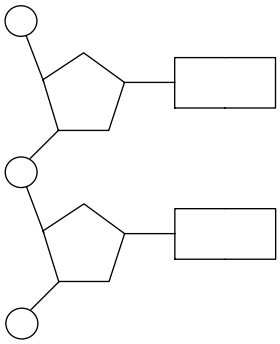
2.2.5	Outline the role of condensation and hydrolysis in the relationships between monosaccharides, disaccharides and polysaccharides; fatty acids, glycerol and glycerides; amino acids, dipeptides and polypeptides.	2
2.2.6	Draw the structure of a generalized dipeptide, showing the peptide linkage. Neither the fact that the linkage is planar, nor that it permits rotation about the C–N bond, is required.	1
2.2.7	List two examples for each of monosaccharides, disaccharides and polysaccharides. The names of the component monomer units of the dissacharide and polysaccharide examples are required, but not the structural formulas.	1
2.2.8	State one function of a monosaccharide and one function of a polysaccharide.	1
2.2.9	State three functions of lipids.	1
2.2.10	Discuss the use of carbohydrates and lipids in energy storage.	3

2.3 Enzymes (2h)

2.3.1	Define *enzyme* and *active site*.	1
2.3.2	Explain enzyme–substrate specificity. The lock-and-key model can be used as a basis for the explanation. The induced fit model is not expected at SL.	3

A.S.		Obj
2.3.3	Explain the effects of temperature, pH and substrate concentration on enzyme activity. Cross reference with 5.6.1. For temperature and pH, refer to denaturation of the active site.	3
2.3.4	Define *denaturation*. Denaturation—a structural change in a protein that results in a loss (usually permanent) of its biological properties. Refer only to heat and pH as agents.	1
2.3.5	Explain the use of pectinase in fruit juice production, and one other commercial application of enzymes in biotechnology. Applications could include the use of enzymes in biological washing powder, tenderizing meat or production of glucose syrup. Detailed chemistry is not expected, but reasons for the use of biotechnology as well as the advantages conferred by it are required.	3

2.4 DNA Structure (1h)

2.4.1	Outline DNA nucleotide structure in terms of sugar (deoxyribose), base and phosphate. Chemical formulas and the purine/pyrimidine subdivision are not required. Simple shapes can be used to represent the component parts. Only the spatial arrangement is required. 	2
2.4.2	State the names of the four bases in DNA.	1
2.4.3	Outline how the DNA nucleotides are linked together by covalent bonds into a single strand. Only the spatial arrangement is required. 	2
2.4.4	Explain how a DNA double helix is formed using complementary base pairing and hydrogen bonds.	3

A.S.		Obj
2.4.5	Draw a simple diagram of the molecular structure of DNA. An extension of the diagram in 2.4.3 is sufficient to show the complementary base pairs of A–T and G–C, held together by hydrogen bonds and the sugar-phosphate backbone. The number of hydrogen bonds between pairs and details of purine/pyrimidines are not required.	1

2.5 DNA Replication (1h)

2.5.1	State that DNA replication is semi-conservative.	1
2.5.2	Explain DNA replication in terms of unwinding of the double helix and separation of the strands by helicase, followed by formation of the new complementary strands by DNA polymerase. It is not necessary to mention that there is more than one DNA polymerase.	3
2.5.3	Explain the significance of complementary base pairing in the conservation of the base sequence of DNA.	3

2.6 Transcription and Translation (2h)

2.6.1	Compare the structure of RNA and DNA. Limit this to the names of sugars, bases and the number of strands.	2
2.6.2	Outline DNA transcription in terms of the formation of an RNA strand complementary to the DNA strand by RNA polymerase.	2
2.6.3	Describe the genetic code in terms of codons composed of triplets of bases.	2
2.6.4	Explain the process of translation, leading to peptide linkage formation. Include the roles of messenger RNA (mRNA), transfer RNA (tRNA), codons, anticodons and ribosomes.	3
2.6.5	Define the terms *degenerate* and *universal* as they relate to the genetic code. • Degenerate—having more than one base triplet to code for one amino acid. • Universal—found in all living organisms.	1
2.6.6	Explain the relationship between one gene and one polypeptide.	3

2.7 Cell Respiration (2h)

2.7.1	Define *cell respiration*. Cell respiration—controlled release of energy in the form of ATP from organic compounds in cells.	1

A.S.		Obj
2.7.2	State that in cell respiration glucose in the cytoplasm is broken down into pyruvate with a small yield of ATP.	1
2.7.3	Explain that in anaerobic cell respiration pyruvate is converted into lactate or ethanol and carbon dioxide in the cytoplasm, with no further yield of ATP. Mention that ethanol and carbon dioxide are produced in yeast whereas lactate is produced in humans.	3
2.7.4	Explain that in aerobic cell respiration pyruvate is broken down in the mitochondrion into carbon dioxide and water with a large yield of ATP.	3

2.8 Photosynthesis (3h)

2.8.1	State that photosynthesis involves the conversion of light energy into chemical energy.	1
2.8.2	State that white light from the sun is composed of a range of wavelengths (colours). Reference to actual wavelengths or frequencies is not expected.	1
2.8.3	State that chlorophyll is the main photosynthetic pigment.	1
2.8.4	Outline the differences in absorption of red, blue and green light by chlorophyll. Students should appreciate that pigments actively absorb certain colours of light due to their structure. The remaining colours of light are reflected and give rise to the colour perceived by the brain of the observer. It is not necessary to mention wavelengths or the structure responsible for the absorption.	2
2.8.5	State that light energy is used to split water molecules (photolysis) to give oxygen and hydrogen, and to produce ATP.	1
2.8.6	State that ATP and hydrogen (derived from the photolysis of water) are used to fix carbon dioxide to make organic molecules.	1
2.8.7	Explain that the rate of photosynthesis can be measured directly by the production of oxygen or the uptake of carbon dioxide, or indirectly by the increase in biomass. The recall of details of specific experiments to indicate that photosynthesis has occurred or to measure the rate of photosynthesis will not be expected.	3
2.8.8	Outline the effects of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis. The shape of the graphs is required. The concept of limiting factors is not expected.	2

Topic 3: Genetics

A.S. Obj

3.1 Chromosomes, Genes, Alleles and Mutations (1h)

3.1.1 State that eukaryote chromosomes are made of DNA and protein. **1**

The names of the proteins (histones) are not required, nor is the structural relationship between DNA and the proteins. See 1.3.3.

3.1.2 State that in karyotyping, chromosomes are arranged in pairs according to their structure. **1**

Karyotyping can be done by using enlarged photocopies of chromosomes.

3.1.3 Describe one application of karyotyping. **2**

Cross reference with 3.2.5.

3.1.4 Define *gene*, *allele* and *genome*. **1**

- Gene—a heritable factor that controls a specific characteristic. (The differences between structural genes, regulator genes and genes coding for tRNA and rRNA are not expected at SL).
- Allele—one specific form of a gene, differing from other alleles by one or a few bases only and occupying the same gene locus as other alleles of the gene.
- Genome—the whole of the genetic information of an organism.

3.1.5 Define *gene mutation*. **1**

The terms point mutation or frameshift mutation will not be used.

3.1.6 Explain the consequence of a base substitution mutation in relation to the process of transcription and translation, using the example of sickle cell anemia. **3**

GAG has mutated to GTG causing glutamic acid to be replaced by valine, and hence sickle cell anemia. The relationship between the frequency of the sickle cell allele and the distribution of malaria should be discussed.

3.2 Meiosis (2h)

3.2.1 State that meiosis is a reduction division in terms of diploid and haploid numbers of chromosomes. **1**

3.2.2 Define *homologous chromosomes*. **1**

3.2.3 Outline the process of meiosis, including pairing of chromosomes followed by two divisions, which results in four haploid cells. **2**

A.S.		Obj
3.2.4	Explain how the movement of chromosomes during meiosis can give rise to genetic variety in the resulting haploid cells. Crossing over is not required.	3
3.2.5	Explain that non-disjunction can lead to changes in chromosome number, illustrated by reference to Down's syndrome (trisomy 21). The recognition of Down's syndrome in a person is not required. Translocation of part of chromosome 21 possibly resulting in Down's syndrome is not required.	3
3.2.6	State Mendel's law of segregation.	1
3.2.7	Explain the relationship between Mendel's law of segregation and meiosis. A simple monohybrid cross can be used in the explanation.	3

3.3 Theoretical Genetics (6h)

3.3.1	Define: *genotype*, *phenotype*, *dominant allele*, *recessive allele*, *codominant alleles*, *locus*, *homozygous*, *heterozygous*, *carrier* and *test cross*. • Genotype—the alleles possessed by an organism. • Phenotype—the characteristics of an organism. • Dominant allele—an allele that has the same effect on the phenotype whether it is present in the homozygous or heterozygous state. • Recessive allele—an allele that only has an effect on the phenotype when present in the homozygous state. • Codominant alleles—pairs of alleles that both affect the phenotype when present in a heterozygote. (The terms incomplete and partial will no longer be used.) • Locus—the particular position on homologous chromosomes of a gene. • Homozygous—having two identical alleles of a gene. • Heterozygous—having two different alleles of a gene. • Carrier—an individual that has a recessive allele of a gene that does not have an effect on their phenotype. • Test cross—testing a suspected heterozygote by crossing it with a known homozygous recessive. (The term backcross is no longer used.)	1
3.3.2	Construct a Punnett grid.	3
3.3.3	Construct a pedigree chart.	3
3.3.4	State that some genes have more than two alleles (multiple alleles).	1

A.S.		Obj
3.3.5	Describe ABO blood groups as an example of codominance and multiple alleles.	2

Phenotype	Genotype
O	ii
A	I^AI^A or I^Ai
B	I^BI^B or I^Bi
AB	I^AI^B

3.3.6	Outline how the sex chromosomes determine gender by referring to the inheritance of X and Y chromosomes in humans.	2
3.3.7	State that some genes are present on the X chromosome and absent from the shorter Y chromosome in humans.	1
3.3.8	Define *sex linkage*.	1
3.3.9	State two examples of sex linkage.	1

Examples from any species where the female is the homogametic sex can be used, although humans will probably be referred to most commonly.

Colour blindness and hemophilia—both these conditions are produced by a recessive sex-linked allele on the X chromosome. X^b and X^h is the notation for the alleles concerned. The corresponding dominant alleles are X^B and X^H.

3.3.10	State that a human female can be homozygous or heterozygous with respect to sex-linked genes.	1
3.3.11	Explain that female carriers are heterozygous for X-linked recessive alleles.	3
3.3.12	Calculate and predict the genotypic and phenotypic ratios of offspring of monohybrid crosses involving any of the above patterns of inheritance.	2, 3
3.3.13	Deduce the genotypes or phenotypes of individuals in pedigree charts.	3

For dominant and recessive alleles upper-case and lower-case letters respectively should be used. Letters representing alleles should be chosen with care to avoid confusion between upper and lower case.

For codominance, the main letter should relate to the gene and the suffix to the allele, both upper case. For example, red and white codominant flower colours should be represented as C^R and C^w respectively. For sickle cell anemia, Hb^A is normal and Hb^s is sickle cell.

A.S. Obj

3.4 Genetic Engineering and Other Aspects of Biotechnology (6h)

3.4.1 State that PCR (polymerase chain reaction) copies and amplifies minute quantities of nucleic acid. **1**

Details of methods are not required.

3.4.2 State that gel electrophoresis involves the separation of fragmented pieces of DNA according to their charge and size. **1**

3.4.3 State that gel electrophoresis of DNA is used in DNA profiling. **1**

3.4.4 Describe two applications of DNA profiling. **2**

Applications could include paternity suits or criminal investigations (murder or rape) or the identification of people who died a long time ago (eg the dead tsars of Russia and some Egyptian mummies). The problems caused by contamination of samples should be mentioned.

3.4.5 Define *genetic screening*. **1**

Genetic screening—testing an individual for the presence or absence of a gene.

3.4.6 Discuss three advantages and/or disadvantages of genetic screening. **3**

Discuss three advantages, three disadvantages or any combination of the two. These may include ethical issues, pre-natal diagnosis of genetic diseases, immigration disputes and confirmation of animal pedigrees.

3.4.7 State that the Human Genome Project is an international cooperative venture established to sequence the complete human genome. **1**

3.4.8 Describe two possible advantageous outcomes of this project. **2**

It should lead to an understanding of many genetic diseases, the development of genome libraries and the production of gene probes to detect sufferers and carriers of genetic diseases (eg Duchenne muscular dystrophy). It may also lead to production of pharmaceuticals based on DNA sequences.

3.4.9 State that genetic material can be transferred between species because the genetic code is universal. **1**

Cross reference with 2.6.5.

3.4.10 Outline a basic technique used for gene transfer involving plasmids, a host cell (bacterium, yeast or other cell), restriction enzymes (endonuclease) and DNA ligase. **2**

The use of *E. coli* in gene technology is well documented. Most of its DNA is in one circular chromosome but it also has plasmids (smaller circles of DNA helix). These plasmids can be removed and cleaved by

A.S.		Obj
	restriction enzymes at target sequences. DNA fragments from another organism can also be cleaved by the same restriction enzyme and these pieces can be added to the open plasmid and spliced together by ligase. The recombinant plasmids formed can be inserted into new host cells and cloned.	
3.4.11	State two examples of the current uses of genetically modified crops or animals.	**1**
	Examples include salt tolerance in tomato plants, delayed ripening in tomatoes, herbicide resistance in crop plants, factor IX (human blood clotting) in sheep milk.	
3.4.12	Discuss the potential benefits and possible harmful effects of one example of genetic modification.	**3**
	Some gene transfers are regarded as potentially harmful. A possible problem exists with the release of genetically engineered organisms in the environment. These can spread and compete with the naturally occurring varieties. Some of the engineered genes could also cross species barriers. Benefits include more specific (less random) breeding than with traditional methods.	
3.4.13	Outline the process of gene therapy using a named example.	**2**
	This involves replacement of defective genes. One method involves the removal of white blood cells or bone marrow cells and, by means of a vector, the introduction and insertion of the normal gene into the chromosome. The cells are replaced in the patient so that the normal gene can be expressed. Examples are the use in cystic fibrosis and SCID (a condition of immune deficiency, where the replaced gene allows for the production of the enzyme ADA—adenosine deaminase). A cure for thalassemia is also possible.	
3.4.14	Define *clone*.	**1**
	Clone—a group of genetically identical organisms or a group of cells artificially derived from a single parent cell.	
3.4.15	Outline a technique for cloning using differentiated cells.	**2**
	The method used to clone Dolly the sheep is a good example.	
3.4.16	Discuss the ethical issues of cloning in humans.	**3**
	Cloning happens naturally, for example monozygotic twins. Some may regard the in vitro production of two embryos from one to be acceptable. Others would see this as leading to the selection of those "fit to be cloned" and visions of "eugenics and a super-race".	

Topic 4: Ecology and Evolution

A.S. Obj

4.1 Communities and Ecosystems (5h)

4.1.1 Define *ecology*, *ecosystem*, *population*, *community*, *species* and *habitat*. **1**

- Ecology—the study of relationships between living organisms and between organisms and their environment.
- Ecosystem—a community and its abiotic environment.
- Population—a group of organisms of the same species who live in the same area at the same time.
- Community—a group of populations living and interacting with each other in an area.
- Species—a group of organisms which can interbreed and produce fertile offspring.
- Habitat—the environment in which a species normally lives or the location of a living organism.

4.1.2 Explain how the biosphere consists of interdependent and interrelated ecosystems. **3**

4.1.3 Define *autotroph* (producer), *heterotroph* (consumer), *detritivore* and *saprotroph* (decomposer). **1**

4.1.4 Describe what is meant by a food chain giving three examples, each with at least three linkages (four organisms). **2**

Food chains are best determined using real examples and information based on natural ecosytems. A → B indicates that A is being "eaten" by B (ie the arrow indicates the direction of energy flow). Each food chain should include a producer and consumers, but not decomposers. Named organisms at either species or genus level should be used. Common species names can be used instead of binomial names.

4.1.5 Describe what is meant by a food web. **2**

4.1.6 Define *trophic level*. **1**

4.1.7 Deduce the trophic level of organisms in a food chain and a food web. **3**

The student should be able to place an organism at the level of producer, primary consumer, secondary consumer etc, as the terms herbivore and carnivore are not always applicable.

4.1.8 Construct a food web containing up to 10 organisms, given appropriate information. **3**

See 4.1.4.

A.S.		Obj
4.1.9	State that light is the initial energy source for almost all communities. Reference to communities that start with chemical energy is not required.	1
4.1.10	Explain the energy flow in a food chain. Energy losses between trophic levels include material not consumed or material not assimilated, and heat loss through cell respiration.	3
4.1.11	State that when energy transformations take place, including those in living organisms, the process is never 100% efficient, commonly being 10–20%. Reference to the second law of thermodynamics is not expected.	1
4.1.12	Explain what is meant by a pyramid of energy and the reasons for its shape. A pyramid of energy shows the flow of energy from one trophic level to the next in a community. The units of pyramids of energy are therefore energy per unit area per unit time, eg J m^{-2} yr^{-1}.	3
4.1.13	Explain that energy can enter and leave an ecosystem, but that nutrients must be recycled.	3
4.1.14	Draw the carbon cycle to show the processes involved. The details of the carbon cycle should include the interaction of living organisms and the biosphere through the processes of photosynthesis, respiration, fossilization and combustion. Recall of specific quantitative data is not required.	1
4.1.15	Explain the role of saprotrophic bacteria and fungi (decomposers) in recycling nutrients. Specific names of decomposer organisms are not required.	3

4.2 Populations (3h)

4.2.1	Outline how population size can be affected by natality, immigration, mortality and emigration.	2
4.2.2	Draw a graph showing the sigmoid (S-shaped) population growth curve.	1
4.2.3	Explain reasons for the exponential growth phase, the plateau phase and the transitional phase between these two phases.	3
4.2.4	Define *carrying capacity*.	1
4.2.5	List three factors which set limits to population increase.	1
4.2.6	Define *random sample*.	1

A.S.		Obj
4.2.7	Describe one technique used to estimate the population size of an animal species based on a capture-mark-release-recapture method.	2

Various mark and recapture methods exist. Knowledge of the Lincoln index (which involves one mark, release and recapture cycle) is required.

$$\text{population size} = \frac{n_1 \times n_2}{n_3}$$

n_1 = number of individuals initially caught, marked and released

n_2 = total number of individuals caught in the second sample

n_3 = number of marked individuals in the second sample

Although simulations can be carried out (eg sampling beans in sawdust), it is much more valuable if this is accompanied by a real exercise on a population of animals. The limitations and difficulties of the method can be fully appreciated and some notion of the importance of sample size can be explained.

It is important that students appreciate the need for choosing an appropriate method for marking organisms.

4.2.8	Describe one method of random sampling used to compare the population numbers of two plant species, based on quadrat methods.	2
4.2.9	Calculate the mean of a set of values.	2

Candidates will be expected to know the formula for calculating the mean.

4.2.10	State that the term *standard deviation* is used to summarize the spread of values around the mean and that 68% of the values fall within ±1 standard deviation of the mean.	1

For normally distributed data about 68% of all values lie within ±1 standard deviation (s.d. or s or σ) of the mean. This rises to about 95% for ±2 standard deviations.

4.2.11	Explain how the standard deviation is useful for comparing the means and the spread of ecological data between two or more populations.	3

A small standard deviation indicates that the data is clustered closely around the mean value. Conversely a large standard deviation indicates a wider spread around the mean. Details of statistical tests to quantify variations between populations, such as standard error, or details about confidence limits are not required.

4.3 Evolution (2h)

4.3.1	Define *evolution*.	1

Evolution—the process of cumulative change in the heritable characteristics of a population.

4.3.2	State that populations tend to produce more offspring than the environment can support.	1
4.3.3	Explain that the consequence of the potential overproduction of offspring is a struggle for survival.	3

A.S.		Obj
4.3.4	State that the members of a species show variation.	1
4.3.5	Explain how sexual reproduction promotes variation in a species. Limit this to meiosis (see 3.2) and fertilization (see 5.7.4).	3
4.3.6	Explain how natural selection leads to the increased reproduction of individuals with favourable heritable variations. The Darwin–Wallace theory is accepted by most as the origin of ideas about evolution by means of natural selection.	3
4.3.7	Discuss the theory that species evolve by natural selection.	3
4.3.8	Explain two examples of evolution in response to environmental change; one must be multiple antibiotic resistance in bacteria.	3

4.4 Classification (2h)

4.4.1	Define *species*. Cross reference with 4.1.1.	1
4.4.2	Describe the value of classifying organisms. This refers to natural classification. Include how the organization of data assists in identifying organisms, shows evolutionary links and enables prediction of characteristics shared by members of a group.	2
4.4.3	Outline the binomial system of nomenclature.	2
4.4.4	State that organisms are classified into the kingdoms Prokaryotae, Protoctista, Fungi, Plantae and Animalia. This system uses the five kingdom classification system of Margulis and Schwartz (based on Whittaker), which is found in most textbooks.	1
4.4.5	List the seven levels in the hierarchy of taxa—kingdom, phylum, class, order, family, genus and species—using an example from two different kingdoms for each level.	1
4.4.6	Apply and/or design a key for a group of up to eight organisms. A dichotomous key should be used.	2, 3

A.S. Obj

4.5 Human Impact (2h)

4.5.1 Outline two local or global examples of human impact causing damage to an ecosystem or the biosphere. One example must be the increased greenhouse effect. **2**

In studying the greenhouse effect students should be made aware that it is a natural phenomenon and that without it organisms may have evolved differently. The problem lies in its enhancement by certain human activities. Knowledge that gases other than carbon dioxide exert a greenhouse effect is required (eg methane and CFCs).

4.5.2 Explain the causes and effects of the two examples in 4.5.1, supported by data. **3**

4.5.3 Discuss measures which could be taken to contain or reduce the impact of the two examples, with reference to the functioning of the ecosystem. **3**

Topic 5: Human Health and Physiology

A.S.		Obj

5.1 Digestion (3h)

5.1.1	Explain why digestion of large food molecules is essential. Cross reference with topic 2.	**3**
5.1.2	Explain the need for enzymes in digestion. Cross reference with topic 2. The need for increasing the rate of digestion at body temperature is the important point.	**3**
5.1.3	State the source, substrate, products and optimum pH conditions for one amylase, one protease and one lipase. Any human enzymes can be selected. Details of structure or mechanisms of action are not required.	**1**
5.1.4	Draw a diagram of the digestive system. The diagram should show the mouth, esophagus, stomach, small intestine, large intestine, anus, liver, pancreas and gall bladder.	**1**
5.1.5	Outline the function of the stomach, small intestine and large intestine.	**2**
5.1.6	Distinguish between absorption and assimilation.	**2**
5.1.7	Explain how the structure of the villus is related to its role in absorption of the end products of digestion.	**3**

5.2 The Transport System (3h)

5.2.1	Draw a diagram of the heart showing all four chambers, associated blood vessels and valves. All blood vessels connected directly to the heart, including coronary vessels, should be shown. Care should be taken to show relative wall thickness of the four chambers. The histology of the heart is not required.	**1**
5.2.2	Describe the action of the heart in terms of collecting blood, pumping blood and opening and closing valves. A basic understanding is required, limited to the collection of blood by the atria which is then pumped out by the ventricles into the arteries. The direction of flow is controlled by atrio-ventricular and semilunar valves.	**2**
5.2.3	Outline the control of the heartbeat in terms of the pacemaker, nerves and adrenalin. Histology of the heart muscle, names of nerves or transmitter substances are not required. Students should understand that the heart beats "of its own accord" (myogenic) and speeds up or slows down through involuntary control.	**2**

A.S.		Obj
5.2.4	Explain the relationship between the structure and function of arteries, capillaries and veins.	3
5.2.5	State that blood is composed of plasma, erythrocytes, leucocytes (phagocytes and lymphocytes) and platelets.	1
5.2.6	State that the following are transported by the blood: nutrients, oxygen, carbon dioxide, hormones, antibodies and urea. No chemical details are required.	1

5.3 Pathogens and Disease (2h)

5.3.1	Define *pathogen*. Pathogen—an organism or virus that causes a disease.	1
5.3.2	State one example of a disease caused by members of each of the following groups: viruses, bacteria, fungi, protozoa, flatworms and roundworms. Students should know to which group the pathogen that causes each disease belongs.	1
5.3.3	List six methods by which pathogens are transmitted and gain entry to the body. Note that this is simply a list and no descriptions or details of methods are required.	1
5.3.4	Describe the cause, transmission and effects of one human bacterial disease. A locally occurring disease would be of greatest relevance to students.	2
5.3.5	Explain why antibiotics are effective against bacteria but not viruses. Antibiotics block specific metabolic pathways found in bacteria, but not in eukaryotic cells. Viruses reproduce using the host cell metabolic pathways that are not affected by antibiotics.	3
5.3.6	Explain the cause, transmission and social implications of AIDS. AIDS is selected as one syndrome where the immune system fails and opportunistic pathogens cause further harm.	3

5.4 Defence Against Infectious Disease (2h)

5.4.1	Explain how skin and mucous membranes act as barriers against pathogens. A diagram of the skin is not required.	3
5.4.2	Outline how phagocytic leucocytes ingest pathogens in the blood and in body tissues. Details of the sub-divisions and classifications of phagocytes are not required.	2
5.4.3	State the difference between antigens and antibodies.	1

A.S.		Obj
5.4.4	Explain antibody production. Many different types of lymphocyte exist. Each type recognizes one specific antigen and responds by dividing to form a clone. This clone then secretes a specific antibody against the antigen. No other details are required.	3
5.4.5	Outline the effects of HIV on the immune system. The effects of HIV should be limited to a reduction in the number of active lymphocytes and a loss of the ability to produce antibodies.	2

5.5 Gas Exchange (2h)

5.5.1	List the features of alveoli that adapt them to gas exchange. This should include a large total surface area, a wall consisting of a single layer of flattened cells, a moist lining and a dense network of capillaries.	1
5.5.2	State the difference between ventilation, gas exchange and cell respiration.	1
5.5.3	Explain the necessity for a ventilation system. A ventilation system is needed to maintain concentration gradients in the alveoli.	3
5.5.4	Draw a diagram of the ventilation system including trachea, bronchi, bronchioles and lungs.	1
5.5.5	Explain the mechanism of ventilation in human lungs including the action of the internal and external intercostal muscles, the diaphragm and the abdominal muscles.	3

5.6 Homeostasis and Excretion (5h)

5.6.1	State that homeostasis involves maintaining the internal environment at a constant level or between narrow limits, including blood pH, oxygen and carbon dioxide concentrations, blood glucose, body temperature and water balance. The internal environment consists of blood and tissue fluid. Cross reference with 2.3.3.	1
5.6.2	Explain that homeostasis involves monitoring levels of variables and correcting changes in levels by negative feedback mechanisms.	3
5.6.3	State that the nervous and the endocrine systems are both involved in homeostasis.	1
5.6.4	State that the nervous system consists of the central nervous system (CNS) and peripheral nerves and is composed of special cells called neurons that can carry electrical impulses rapidly. No structural or functional division of the nervous system or details of impulse transmission or synapses are required.	1

A.S.		Obj
5.6.5	Describe the control of body temperature including the transfer of heat in blood, the role of sweat glands and skin arterioles, and shivering.	2
5.6.6	State that the endocrine system consists of glands which release hormones that are transported in the blood. The nature and action of hormones or direct comparisons between nerve and endocrine systems are not required.	1
5.6.7	Explain the control of blood glucose concentration, including the roles of glucagon, insulin and α and ß cells in the pancreatic islets. α islet cells produce glucagon; ß islet cells produce insulin. The regulation of glucose concentration within normal limits and the feedback mechanisms should be stressed. The effects of adrenaline are not required here.	3
5.6.8	Define *excretion*.	1
5.6.9	Outline the role of the kidney in excretion and the maintainance of water balance. Details of structure or physiology are not required. Mention that, by adjusting the volume and content of the urine, the kidney removes urea, excess salts and water.	2

5.7 Reproduction (5h)

5.7.1	Draw diagrams of the adult male and female reproductive systems. The relative positions of the organs is important. Do not include any histological details, but include the bladder and urethra.	1
5.7.2	Explain the role of hormones in regulating the changes of puberty (testosterone, estrogen) in boys and girls, and in the menstrual cycle (follicle stimulating hormone (FSH), luteinizing hormone (LH), estrogen and progesterone). Reference to the fact that in males LH is called interstitial cell stimulating hormone (ICSH) and the involvement of the hypothalamus (releasing factors) in both sexes are not expected. Emphasize feedback control. The menstrual cycle explanation should include graphs showing relative changes of hormone levels and the endometrium.	3
5.7.3	List the secondary sexual characteristics in both sexes.	1
5.7.4	State the difference between copulation and fertilization. Acrosome reaction, meiotic details etc are required for higher level (HL) only. (See topic 9.)	1
5.7.5	Describe early embryo development up to the implantation of the blastocyst. Limit this to several mitotic divisions resulting in a hollow ball of cells called the blastocyst.	2

A.S.		Obj
5.7.6	State that the fetus is supported and protected by the amniotic sac and amniotic fluid. Embryonic details of the fetus and the structure of amniotic membranes or placenta are not expected.	1
5.7.7	State that materials are exchanged between the maternal and fetal blood in the placenta.	1
5.7.8	Outline the process of birth and its hormonal control, including progesterone and oxytocin. Limit this to the reduction in the level of progesterone that results in the release of oxytocin. Oxytocin causes uterine contractions that trigger further release of oxytocin. This is an example of positive feedback.	2
5.7.9	Describe four methods of family planning and contraception. At least one method from each of the following types should be studied: mechanical, chemical, behavioural.	2
5.7.10	Discuss the ethical issues of family planning and contraception.	3
5.7.11	Outline the technique of amniocentesis. Amniocentesis involves withdrawing some amniotic fluid containing embryonic cells using a syringe. It can be used to diagnose nearly 400 conditions from chromosomal abnormalities to biochemical disorders. Mention possible risks from the procedure. Cross reference with 3.4.6.	2
5.7.12	Outline the process of in vitro fertilization (IVF).	2
5.7.13	Discuss the ethical issues of IVF.	3

Topic 6: Nucleic Acids and Proteins

A.S.		Obj

6.1 DNA Structure (1h)

6.1.1	Outline the structure of nucleosomes. Limit this to the fact that a nucleosome consists of DNA wrapped around eight histone protein molecules and held together by another histone protein.	**2**
6.1.2	State that only a small proportion of the DNA in the nucleus constitutes genes and that the majority of DNA consists of repetitive sequences. The function of the repetitive sequences is not required but students should know that the presence of such sequences is used in DNA profiling (see 3.4.3).	**1**
6.1.3	Describe the structure of DNA including the antiparallel strands, 3′–5′ linkages and hydrogen bonding between purines and pyrimidines. Major and minor grooves, direction of the "twist", alternative B and Z forms and details of the dimensions are not required.	**2**

6.2 DNA Replication (1h)

6.2.1	State that DNA replication occurs in a 5′ → 3′ direction. The 5′ end of the free DNA nucleotide is added to the 3′ end of the chain of nucleotides which is already synthesized.	**1**
6.2.2	Explain the process of DNA replication in eukaryotes including the role of enzymes (helicase, DNA polymerase III, RNA primase, DNA polymerase I and DNA ligase), Okazaki fragments and deoxynucleoside triphosphates. The function of the enzymes listed should be stated in general terms only. The explanation of Okazaki fragments in relation to the direction of DNA polymerase III action is required. DNA polymerase III adds nucleotides in the 5′→ 3′ direction. DNA polymerase I excises the RNA primers and replaces them with DNA. Details of Meselson and Stahl's experiment are not required.	**3**
6.2.3	State that in eukaryotic chromosomes, replication is initiated at many points.	**1**

A.S. Obj

6.3 Transcription (2h)

6.3.1 State that transcription is carried out in a 5′→ 3′ direction. **1**

The 5′ end of the free RNA nucleotide is added to the 3′ end of the RNA molecule which is already synthesized.

6.3.2 Outline the lac operon model as an example of the control of gene expression in prokaryotes. **2**

Operons are found only in prokaryotes. Mention only the idea of a regulator gene producing a protein that prevents RNA polymerase binding to the promoter region.

6.3.3 Explain the process of transcription in eukaryotes including the role of the promoter region, RNA polymerase, nucleoside triphosphates and the terminator. **3**

The following details are not required: there is more than one type of RNA polymerase, features of the promoter region, the need for transcription protein factors for RNA polymerase binding, TATA boxes (and other repetitive sequences), the exact sequence of the bases which act as terminators.

Gene regulation can be limited to the presence of other genes (often on other chromosomes) that affect binding of RNA polymerase to the promoter region, and to the control of both the post-transcriptional modification of RNA and post-translational modification of proteins.

6.3.4 Distinguish between the sense and antisense strands of DNA. **2**

The sense strand is the coding strand and has the same base sequence as mRNA (with uracil instead of thymine). The antisense strand is transcribed and has the same base sequence as tRNA.

6.3.5 State that eukaryotic RNA needs the removal of introns to form mature mRNA. **1**

Further details of the process of post-transcriptional modification of RNA are not required.

6.3.6 State that reverse transcriptase catalyses the production of DNA from RNA. **1**

This is an opportunity to relate some aspects of the DNA viral life cycle to that of the AIDS virus (an RNA virus).

6.3.7 Explain how reverse transcriptase is used in molecular biology. **3**

This enzyme can make DNA from mature mRNA (eg human insulin), which can then be spliced into host DNA (eg *E. coli*), without the introns.

A.S. Obj

6.4 Translation (2h)

6.4.1 Explain how the structure of tRNA allows recognition by a tRNA-activating enzyme that binds a specific amino acid to tRNA, using ATP for energy. **3**

Each amino acid has a specific tRNA-activating enzyme (the name aminoacyl-tRNA synthetase is not required). The shape of tRNA and CCA at the 3′ end should be included. Degeneracy (some amino acids having more than one tRNA) should also be included.

6.4.2 Outline the structure of ribosomes including protein and RNA composition, large and small subunits, two tRNA binding sites and mRNA binding sites. **2**

6.4.3 State that translation consists of initiation, elongation and termination. **1**

6.4.4 State that translation occurs in a 5′→ 3′ direction. **1**

During translation, the ribosome moves along the mRNA towards the 3′ end. The start codon is nearer to the 5′end than the stop codon.

6.4.5 Explain the process of translation including ribosomes, polysomes, start codons and stop codons. **3**

Naming of the P and A sites, initiating methionine, details of the T factor and recall of actual stop codons are not required.

6.4.6 State that free ribosomes synthesize proteins for use primarily within the cell and that bound ribosomes synthesize proteins primarily for secretion or for lysosomes. **1**

Cross reference with 1.4.7.

6.5 Proteins (1h)

6.5.1 Explain the four levels of protein structure, indicating each level's significance. **3**

Quaternary structure may involve the binding of a prosthetic group to form a conjugated protein.

6.5.2 Outline the difference between fibrous and globular proteins, with reference to two examples of each protein type. **2**

6.5.3 Explain the significance of polar and non-polar amino acids. **3**

Limit this to controlling the position of proteins in membranes, creating hydrophilic channels through membranes and the specificity of active sites in enzymes. Cross reference with 1.4.

6.5.4 State six functions of proteins, giving a named example of each. **1**

Membrane proteins should not be included.

A.S. Obj

6.6 Enzymes (2h)

6.6.1 State that metabolic pathways consist of chains and cycles of enzyme catalysed reactions. **1**

6.6.2 Describe the induced fit model. **2**

This is an extension of the lock-and-key model. Its importance in accounting for the broad specificity of some enzymes (the ability to bind several substrates) should be mentioned.

6.6.3 Explain that enzymes lower the activation energy of the chemical reactions that they catalyse. **3**

Graphical representation of both exergonic and endergonic reactions should be covered, but specific energy values do not need to be recalled.

6.6.4 Explain the difference between competitive and non-competitive inhibition, with reference to one example of each. **3**

Competitive—an inhibiting molecule structurally similar to the substrate molecule binds to the active site, preventing substrate binding. Examples include inhibition of butanedioic acid (succinate) dehydrogenase by propanedioic acid (malonate) in the Krebs cycle, and inhibition of folic acid synthesis in bacteria by the sulfonamide Prontosil™ (an antibiotic).

Non-competitive—limited to an inhibitor molecule binding to an enzyme (not to its active site) that causes a conformational change in its active site, resulting in a decrease in activity. Examples include Hg^{2+}, Ag^{+}, Cu^{2+} and CN^{-} inhibition of many enzymes (eg cytochrome oxidase) by binding to -SH groups, thereby breaking -S-S- linkages; and nerve gases like Sarin and DFP (diisopropyl fluorophosphate) inhibiting ethanoyl (acetyl) cholinesterase.

Reversible inhibition, as compared to irreversible inhibition, is not required.

6.6.5 Explain the role of allostery in the control of metabolic pathways by end-product inhibition. **3**

Allostery is a form of non-competitive inhibition. Mention that the shape of allosteric enzymes can be altered by the binding of end products to an allosteric site, thereby decreasing its activity. Metabolites can act as allosteric inhibitors of enzymes earlier in a metabolic pathway and regulate metabolism according to the requirements of organisms; a form of negative feedback. Examples include ATP inhibition of phosphofructokinase in glycolysis and inhibition of aspartate carbamoyltransferase (ATCase) which catalyses the first step in pyrimidine synthesis.

Topic 7: Cell Respiration and Photosynthesis

A.S. Obj

7.1 Cell Respiration (5h)

7.1.1 State that oxidation involves the loss of electrons from an element whereas reduction involves a gain in electrons, and that oxidation frequently involves gaining oxygen or losing hydrogen, whereas reduction frequently involves loss of oxygen or gain in hydrogen. **1**

7.1.2 Outline the process of glycolysis including phosphorylation, lysis, oxidation and ATP formation. **2**

In the cytoplasm, one hexose sugar is converted into two three-carbon atom compounds (pyruvate) with a net gain of two ATP and two NADH + H^+. Phosphorylation is a process in which ATP is made in vivo (in glycolysis the process is substrate level phosphorylation).

7.1.3 Draw the structure of a mitochondrion as seen in electron micrographs. **1**

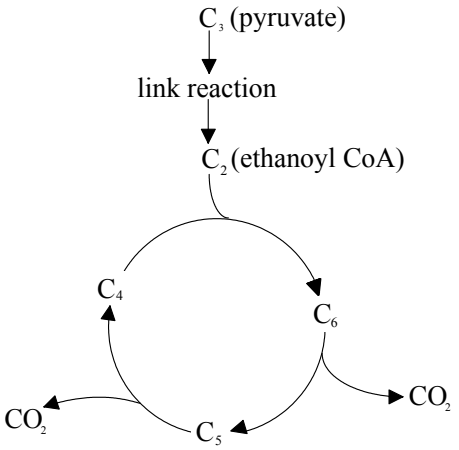
7.1.4 Explain aerobic respiration including oxidative decarboxylation of pyruvate, the Krebs cycle, NADH + H^+, the electron transport chain and the role of oxygen. **3**

In aerobic respiration (in mitochondria in eukaryotes) each pyruvate is decarboxylated (CO_2 removed). The remaining two-carbon molecule (acetyl group) reacts with reduced coenzyme A, and at the same time one NADH + H^+ is formed. This is known as the link reaction.

In the Krebs cycle each acetyl group (CH_3CO) formed in the link reaction yields two CO_2. The names of the intermediate compounds in the cycle are not required. Thus it would be acceptable to note: $C_2 + C_4 = C_6 \rightarrow C_5 \rightarrow$ etc. Students should also note that the hydrogen atoms removed are collected by "hydrogen-carrying coenzymes".

One turn of the Krebs cycle yields:

- 2 CO_2
- 3 x NADH + H^+
- 1 x $FADH_2$
- 1 x ATP (by substrate level phosphorylation)



A.S.		Obj
7.1.5	Explain oxidative phosphorylation in terms of chemiosmosis. Cross reference with 7.2.4. The synthesis of ATP is coupled to electron transport and the movement of protons (H^+ ions)—the chemiosmotic theory. Briefly, the electron transport carriers are strategically arranged over the inner membrane of the mitochondrion. As they oxidize NADH + H^+ and $FADH_2$, energy from this process forces protons to move, against the concentration gradient, from the mitochondrial matrix to the space between the two membranes (using proton pumps). Eventually the H^+ ions flow back into the matrix through protein channels in the ATP synthetase molecules in the membrane. As the ions flow down the gradient, energy is released and ATP is made.	3
7.1.6	Explain the relationship between the structure of the mitochondrion and its function. Limit this to cristae forming a large surface area for the electron transport chain, the small space between inner and outer membranes for accumulation of protons and the fluid matrix containing enzymes of the Krebs cycle.	3
7.1.7	Describe the central role of acetyl CoA in carbohydrate and fat metabolism. Acetyl CoA is an intermediate in carbohydrate (glucose) metabolism. In lipid metabolism the oxidation of the fatty acid chains results in the formation of two-carbon atom (acetyl) fragments which then pass through the Krebs cycle.	2

7.2 Photosynthesis (5h)

7.2.1	Draw the structure of a chloroplast as seen in electron micrographs.	1
7.2.2	State that photosynthesis consists of light-dependent and light-independent reactions. Not "light" and "dark" reactions.	1
7.2.3	Explain the light-dependent reactions. Include the photoactivation of photosystem II, photolysis of water, electron transport, cyclic and non-cyclic photophosphorylation, photoactivation of photosystem I and reduction of $NADP^+$.	3
7.2.4	Explain photophosphorylation in terms of chemiosmosis. Electron transport causes the pumping of protons to the inside of the thylakoids. They accumulate (pH drops) and eventually move out to the stroma through protein channels in the ATP synthetase enzymes. This provides energy for ATP synthesis. Cross reference 7.1.5.	3
7.2.5	Explain the light-independent reactions. Include the roles of ribulose bisphosphate (RuBP) carboxylase, reduction of glycerate 3-phosphate (GP) to triose phosphate (TP), NADPH + H^+, ATP, regeneration of RuBP and synthesis of carbohydrate.	3

A.S.		Obj
7.2.6	Explain the relationship between the structure of the chloroplast and its function. Limit this to the large surface area of thylakoids for light absorption, the small space inside thylakoids for accumulation of protons and the fluid stroma for the enzymes of the Calvin cycle.	3
7.2.7	Draw the action spectrum of photosynthesis.	1
7.2.8	Explain the relationship between the action spectrum and the absorption spectrum of photosynthetic pigments in green plants. A separate spectrum for each pigment (chlorophyll a, chlorophyll b, etc) is not required.	3
7.2.9	Explain the concept of limiting factors with reference to light intensity, temperature and concentration of carbon dioxide.	3

Topic 8: Genetics

A.S.		Obj

8.1 Meiosis (2h)

8.1.1 Describe the behaviour of the chromosomes in the phases of meiosis. **2**

Students will be expected to know the names of the phases. The subdivisions of prophase I will not be required.

8.1.2 Outline the process of crossing over and the formation of chiasmata. **2**

Cross reference with 8.3.2.

8.1.3 Explain how meiosis results in an effectively infinite genetic variety in gametes through crossing over in prophase I and random orientation in metaphase I. **3**

Cross reference with 3.2.4. The number of different types of gamete produced is 2^n (where n = haploid number).

8.1.4 Define *recombination*. **1**

Recombination—the reassortment of genes or characters into different combinations from those of the parents.

Recombination occurs for linked genes by crossing over and, for unlinked genes, by chromosome assortment.

8.1.5 State Mendel's law of independent assortment. **1**

8.1.6 Explain the relationship between Mendel's law of independent assortment and meiosis. **3**

8.2 Dihybrid Crosses (2h)

8.2.1 Calculate and predict the genotypic and phenotypic ratios of offspring of dihybrid crosses involving unlinked autosomal genes. **2, 3**

8.2.2 Identify which of the offspring in dihybrid crosses are recombinants. **2**

Recombination has often been restricted to linked genes but it also applies to non-linked situations. For example, in the cross tall, white [Ttrr] with short, red [ttRr], the F_1 will contain four different phenotypes—tall, white [Ttrr], short, red [ttRr], tall, red [TtRr] and short, white [ttrr]. The tall, red and the short, white are the recombinants.

8.2.3 Outline the use of the chi-squared test in analysing monohybrid and dihybrid crosses using given values. **2**

Students should appreciate that the test can be used to establish whether an observed ratio differs significantly from the expected one.

A.S. Obj

8.3 Autosomal Gene Linkage (2h)

8.3.1 State the difference between autosomes and sex chromosomes. **1**

8.3.2 Explain how crossing over in prophase I (between non-sister chromatids of a homologous pair) can result in an exchange of alleles. **3**

The fact that crossing over does not occur in male *Drosophila* will not be expected.

8.3.3 Define *linkage group*. **1**

8.3.4 Explain an example of a cross between two linked genes. **3**

Alleles are usually shown side-by-side in dihybrid crosses eg TtBb. In representing crosses involving linkage it is more common to show them as vertical pairs:

$$\frac{T\ B}{t\ b}$$

This format will be used in examination papers, or candidates will be given sufficient information to allow them to deduce which alleles are linked.

There are several advantages arising from this format. The line(s) can be taken to represent the chromosome(s) thereby indicating linkage visually. Also, the linked alleles and the cross-over allele combinations are clear. In a side-by-side format it is impossible to tell which allele is linked to which.

8.3.5 Identify which of the offspring in such dihybrid crosses are recombinants. **2**

In a test cross of $\frac{T\ B}{t\ b}$ the recombinants will be $\frac{T\ b}{t\ b}$ and $\frac{t\ B}{t\ b}$.

8.4 Polygenic Inheritance (1h)

8.4.1 Define *polygenic inheritance*. **1**

8.4.2 Explain that polygenic inheritance can contribute to continuous variation using two examples. One example must be human skin colour. **3**

Human melanin production seems to be controlled by three or four genes. Dealing with all four genes at once is unwieldy and the principle can be explained clearly enough using two genes.

Topic 9: Human Reproduction

A.S. Obj

9.1 Production of Gametes (3h)

9.1.1 Draw the structure of testis tissue as seen using a light microscope. **1**

Light microscopes show the presence of seminiferous tubules with blood capillaries and interstitial cells. Draw one seminiferous tubule in transverse section (TS) with adjacent interstitial cells. The sectioned tubules have an outer germ cell layer with basement membrane, developing spermatozoa and the Sertoli cells that provide nourishment.

9.1.2 Outline the processes involved in spermatogenesis including mitosis, cell growth, the two divisions of meiosis and cell differentiation. **2**

Cross reference with 1.5 and 8.1. The names of the intermediate stages are not required.

9.1.3 Outline the origin and the role of the hormones FSH, testosterone and LH in spermatogenesis. **2**

The name ICSH will not be used.

9.1.4 Draw the structure of the ovary as seen using a light microscope. **1**

Developing oocytes can be seen. The stages of developing Graafian follicles are visible. The primary oocytes are surrounded by the zona pellucida.

9.1.5 Outline the processes involved in oogenesis including mitosis, cell growth, the two divisions of meiosis, the unequal division of cytoplasm and the degeneration of polar bodies. **2**

Cross reference with 1.5 and 8.1. Names of the stages are not required.

9.1.6 Draw the structure of a mature sperm and egg. **1**

9.1.7 Outline the role of the epididymis, seminal vesicle and prostate gland in the production of semen. **2**

9.1.8 Compare the processes of spermatogenesis and oogenesis including the number of gametes and the timing of the formation and release of gametes. **2**

A.S. Obj

9.2 Fertilization and Pregnancy (2h)

9.2.1 Describe the process of fertilization including the acrosome reaction, penetration of the egg membrane by a sperm and the cortical reaction. **2**

9.2.2 Outline the role of human chorionic gonadotrophin (HCG) in early pregnancy. **2**

9.2.3 Describe the structure and functions of the placenta including its hormonal role in the maintenance of pregnancy (secretion of estrogen and progesterone). **2**

Details of the embryological development of humans, formation and evolutionary origins of the extra-embryonic membranes and hormonal control of lactation are not required. Prolactin in connection with 5.7.9 and 5.7.10 might also be discussed here.

Topic 10: Defence Against Infectious Disease

A.S. Obj

10.1 Types of Defence (4h)

10.1.1 Describe the process of clotting. **2**

Limit this to the release of clotting factors from platelets and damaged cells resulting in the formation of thrombin. Thrombin catalyses the conversion of soluble fibrinogen into the fibrous protein fibrin which captures red blood cells.

10.1.2 Outline the principle of challenge and response, clonal selection and memory cells as the basis of immunity. **2**

This is intended to be a simple introduction to the complex topic of immunity. The idea of a polyclonal response can be introduced here.

10.1.3 Define *active immunity*, *passive immunity*, *natural immunity* and *artificial immunity*. **1**

- Active immunity—immunity due to the production of antibodies by the organism itself after the body's defence mechanisms have been stimulated by invasion of foreign micro-organisms.
- Passive immunity—immunity due to the acquisition of antibodies from another organism in which active immunity has been stimulated, including via the placenta or in colostrum.
- Natural immunity—immunity due to infection.
- Artificial immunity—immunity due to inoculation with vaccine.

10.1.4 Explain antibody production. **3**

Limit the explanation to antigen presentation by macrophages and activation of helper T-cells leading to activation of B-cells, which divide to form clones of antibody secreting plasma cells and memory cells.

10.1.5 State that cytotoxic T-cells destroy cancer cells and body cells infected with viruses. **1**

10.1.6 Describe the production of monoclonal antibodies; one use of them in diagnosis and one use in treatment. **2**

Production should be limited to the fusion of tumour and B-cells and their subsequent proliferation and production of antibodies. Detection of antibodies to HIV is one example in diagnosis. Others are detection of a specific cardiac isoenzyme in suspected cases of heart attack and detection of HCG in pregnancy test kits. Examples of the use of these antibodies for treatment include targeting of cancer cells with drugs attached to monoclonal antibodies, emergency treatment of rabies or cancer, blood and tissue typing for transplant compatibility and purification of industrially made interferon.

A.S.		Obj
10.1.7	Outline the principle of vaccination. Emphasize the role of memory cells here. The primary and secondary responses can be clearly illustrated by a graph. Precise details of all the types of vaccine (attenuated virus, inactivated toxins, etc) for specific diseases are not required.	2
10.1.8	Discuss the benefits and dangers of vaccination against bacterial and viral infection, including the MMR vaccine (combined measles/mumps/rubella) and two other examples.	3

Topic 11: Nerves, Muscles and Movement

A.S.		Obj
	11.1 Nerves (3h)	
11.1.1	Outline the general organization of the human nervous system including the CNS (brain and spinal cord) and the PNS (nerves).	2
11.1.2	Draw the structure of a motor neuron. Include dendrites, cell body with nucleus, elongated axon, myelin sheath, nodes of Ranvier and motor end plates.	1
11.1.3	Define *resting potential* and *action potential*.	1
11.1.4	Explain how a nerve impulse passes along a non-myelinated neuron (axon). Include the role of Na^+ ions, K^+ ions, voltage-gated ion channels, active transport and changes in membrane polarization.	3
11.1.5	Explain the principles of synaptic transmission. Include Ca^{2+} influx; the release, diffusion and binding of the neurotransmitter; depolarization of the post-synaptic membrane and subsequent removal of the neurotransmitter.	3
	11.2 Muscles and Movement (4h)	
11.2.1	Outline the great diversity of locomotion in the animal kingdom as exemplified by movement in an earthworm, swimming in a bony fish, flying in a bird and walking in an arthropod.	2
11.2.2	Describe the roles of nerves, muscles and bones in producing movement or locomotion.	2
11.2.3	Draw a diagram of the human elbow joint. Include cartilage, synovial fluid, tendons, ligaments, named bones and named antagonistic muscles. The only muscles expected are the biceps and triceps.	1
11.2.4	Outline the functions of the above-named structures of the human elbow joint.	2
11.2.5	Draw the structure of skeletal muscle fibres as seen in electron micrographs. Electron micrographs can be interpreted to show sarcomeres and their characteristic dark and light bands. The detailed structure can be deduced so that thin actin filaments and thick myosin filaments interdigitate. The sarcoplasmic reticulum and mitochondria should be included. No names of lines or bands are expected.	1

A.S.		Obj
11.2.6	Explain how skeletal muscle contracts by the sliding of filaments. Include the roles of the sarcoplasmic reticulum, Ca^{2+} ions, troponin, tropomyosin, actin, myosin; the formation, movement and breakage of cross-bridges; and ATP.	3

Topic 12: Excretion

A.S.		Obj

12.1 Excretion (1h)

12.1.1	Outline the need for excretion in all living organisms.	2
12.1.2	State that excretory products in plants include oxygen, and in animals they include carbon dioxide and nitrogenous compounds.	1
12.1.3	Discuss the relationship between the different nitrogenous waste products and habitat in mammals, birds and freshwater fish. Surplus amino acids must be degraded to relatively harmless nitrogen-containing compounds. Freshwater fish can get rid of ammonia, although highly toxic (due to its basicity), because it can be diluted by the readily available water. Birds are unable to carry too much water so they excrete uric acid which is insoluble and expelled as a paste (most of the water is removed before excretion). Mammals excrete urea. Some desert mammals produce very concentrated urine (having a long loop of Henlé). See 12.2.6.	3

12.2 The Human Kidney (4h)

12.2.1	Draw the structure of the kidney. Include the cortex, medulla, pelvis, ureter and renal blood vessels.	1
12.2.2	Draw the structure of a glomerulus and associated nephron.	1
12.2.3	Explain the process of ultrafiltration including blood pressure, fenestrated blood capillaries and basement membrane.	3
12.2.4	Define *osmoregulation*. Osmoregulation—the control of the water balance of the blood, tissue or cytoplasm of a living organism.	1
12.2.5	Explain the reabsorption of glucose, water and salts in the proximal convoluted tubule, including the roles of microvilli, osmosis and active transport.	3
12.2.6	Explain the roles of the loop of Henlé, medulla, collecting duct and ADH in maintaining the water balance of the blood. Cross reference with 5.6.1 and 5.6.2. Details of the control of ADH secretion are only required in option H.	3
12.2.7	Compare the composition of blood in the renal artery and renal vein, and compare the composition of glomerular filtrate and urine.	2
12.2.8	Outline the structure and action of kidney dialysis machines.	2

Topic 13: Plant Science

A.S. Obj

13.1 Plant Structure (2h)

13.1.1 Outline the wide diversity in the plant kingdom as exemplified by the structural differences between bryophytes, filicinophytes, coniferophytes and angiospermophytes. **2**

No details of internal structures or life cycles are expected.

13.1.2 Draw a diagram to show the external parts of a named dicotyledonous plant. **1**

Include the root, stem, leaf, axillary and terminal buds.

13.1.3 Draw plan diagrams to show the distribution of tissues in the stem, root and leaf of a generalized dicotyledonous plant. **1**

Either one species could be selected for the whole study or different species could be used for the stem, root and leaf, depending on the availability of material and/or local interest. Note that plan diagrams show distribution of tissues (eg xylem, phloem) and do not show individual cells. They are sometimes called "low power" diagrams.

13.1.4 Explain the relationship between the distribution of tissues in the leaf and the functions of these tissues. **3**

The functions should include absorption of light, gas exchange, support, water conservation, transport of water and products of photosynthesis.

13.1.5 Outline four adaptations of xerophytes. **2**

These could include: CAM and C_4 physiology, reduced leaves, rolled leaves, spines, deep roots, thickened waxy cuticle, reduced number of stomata, stomata in pits surrounded by "hairs", water storage tissue, low growth form and annual plants with short life cycles.

13.1.6 Outline two structural adaptations of hydrophytes. **2**

These could include air spaces, flotation, pliable parts with little strengthening tissue, "breathing" roots, reduced roots and finely divided submerged leaves.

13.2 Transport in Angiospermophytes (4h)

13.2.1 Explain how the root system provides a large surface area for mineral ion and water uptake by means of branching, root hairs and cortex cell walls. **3**

13.2.2 Describe the process of mineral ion uptake into roots by active transport. **2**

13.2.3 Explain the process of water uptake by root epidermis cells and its movement by the symplastic and apoplastic pathways across the root to the xylem. **3**

Water potential terminology is not expected. Water movement should be explained in terms of differences in solute concentration and pressure.

A.S.		Obj
13.2.4	State that terrestrial plants support themselves by means of thickened cellulose, cell turgor and xylem.	1
13.2.5	Define *transpiration*. Transpiration—the loss of water vapour from the leaves and stems of plants.	1
13.2.6	Explain how water is carried by the transpiration stream, including the structure of xylem vessels, transpiration pull, cohesion and evaporation. Limit the structure of xylem vessels to one type of primary xylem.	3
13.2.7	State that guard cells can open and close stomata to regulate transpiration.	1
13.2.8	Explain how the abiotic factors, light, temperature, wind and humidity, affect the rate of transpiration in a typical terrestrial mesophytic plant.	3
13.2.9	Outline the role of phloem in active translocation of biochemicals.	2
13.2.10	Describe an example of food storage in a plant.	2

13.3 Reproduction in Flowering Plants (2h)

13.3.1	Draw the structure of a dicotyledonous animal-pollinated flower, as seen with the naked eye and hand lens. Limit the diagram to sepal, petal, anther, filament, stigma, style and ovary.	1
13.3.2	Define *pollination*.	1
13.3.3	Distinguish between pollination, fertilization and seed dispersal.	2
13.3.4	Draw the external and internal structure of a named dicotyledonous seed. The named seed should be non-endospermic. The structure in the diagram should be limited to testa, micropyle, embryo root, embryo shoot and cotyledons.	1
13.3.5	Describe the metabolic events of germination in a typical starchy seed. Absorption of water precedes the formation of gibberellin in the cotyledon. This stimulates the production of amylase which catalyses the breakdown of starch to maltose. This subsequently diffuses to the embryo for energy production and growth. No further details are expected.	2
13.3.6	Explain the conditions needed for the germination of a typical seed. Seeds vary in their light requirements and therefore this factor need not be included.	3

Options Outline

Options Standard Level

A Diet and human nutrition

B Physiology of exercise

C Cells and energy

Options Standard Level/Higher Level

D Evolution

E Neurobiology and behaviour

F Applied plant and animal science

G Ecology and conservation

Note: Standard level candidates are required to study the core of each option chosen. Higher level candidates study both the core and the extension material.

Option Higher Level

H Further human physiology

Standard level candidates are required to study any **two** options from A–G. The duration of each option is 15 hours.

Higher level candidates are required to study any **two** options from D–H. The duration of each option is 22 hours.

Option A: Diet and Human Nutrition

A.S.		Obj

A.1 Diet (4h)

A.1.1	State that diet is the total food taken in by an individual.	1
A.1.2	Define *nutrient*.	1
A.1.3	List the constituents of a diet including carbohydrate, protein, lipid, minerals, vitamins, water and fibre.	1
A.1.4	Explain the functions of the constituents listed above. The main functions of each group listed in A.1.3 are required; sub-categories do not need to be considered.	3
A.1.5	Describe a balanced diet as an equilibrium between food intake and energy expenditure and in terms of meeting bodily needs for growth, replacement and healthy functioning.	2
A.1.6	Evaluate common packaged food items by interpreting the dietary information printed on them.	3
A.1.7	Calculate, compare and evaluate the nutritional content of foods and diets. All energy values must be quoted in Joules (J) or kJ. Some food labels show both the food content and RDAs (recommended daily allowances) of certain food. Recall of such values is not required.	2, 3

A.2 Biochemistry of Nutrition (6h)

A.2.1	List two sources for each of monosaccharides, disaccharides and polysaccharides in a diet. Cross reference with 2.2.7 and 2.2.8.	1
A.2.2	Outline the uses of absorbed carbohydrates including cell respiration, energy storage (glycogen or fat), synthesis of glycoproteins, nucleic acids and some amino acids.	2
A.2.3	List three sources of lipids in the diet.	1
A.2.4	Outline the uses of absorbed lipids including energy storage, insulation, membranes and cell respiration.	2
A.2.5	Discuss the variation in energy requirements (in kJ or MJ) depending on age, gender, activity and condition.	3
A.2.6	List four sources of protein in a diet.	1

A.S.		Obj
A.2.7	Outline the fate of the products of ingested protein including protein synthesis and deamination.	2
A.2.8	State that essential amino acids are those which must be ingested and cannot be synthesized.	1
A.2.9	Explain the general importance of vitamins and minerals in the diet.	3
A.2.10	State one function of iodine and zinc. Zinc is a component of certain digestive enzymes and other proteins. Iodine is a component of thyroxine.	1
A.2.11	Outline the functions of the following vitamins: retinol, cyanocobalamin, ascorbic acid, calciferol and tocopherol.	2
A.2.12	Discuss the importance of fibre in a diet.	3

A.3 Diet and Health (5h)

A.3.1	Discuss the significance of diets which are rich in lipids in relation to obesity and coronary heart disease.	3
A.3.2	Explain the significance of saturated and unsaturated lipids in relation to a healthy diet.	3
A.3.3	State that the liver synthesizes cholesterol.	1
A.3.4	Outline how the body uses cholesterol in cell membranes and in the synthesis of some hormones.	2
A.3.5	Discuss the effects of additional dietary cholesterol.	3
A.3.6	Distinguish between vegan and vegetarian diets.	2
A.3.7	Discuss the ethical issues surrounding the eating of meat, fish, eggs and dairy products.	3
A.3.8	Discuss the possibility of a deficiency in calcium, iron, calciferol (vitamin D) and cyanocobalamin (vitamin B_{12}) in vegetarian and vegan diets. Deficiencies are unlikely in vegetarian diets. Vegans risk cyanocobalamin deficiency and could benefit from a supplement of it. Zinc, found in red meat, seafood and egg yolks, can also be obtained from yeast and cereals. Calciferol, found in milk, egg yolks and liver, is not needed as long as vegans receive sufficient sunlight.	3
A.3.9	Define *malnutrition*.	1
A.3.10	Suggest how malnutrition can be caused by any (or a combination) of social, economic, cultural and environmental conditions.	3

A.S.		Obj
A.3.11	Discuss one example of global malnutrition using published data. This data can be obtained from the Food and Agriculture Organization and/or the World Health Organization. Recall of some relevant quantitative data is expected.	3
A.3.12	Discuss the relationship between nutrition and each of rickets, anemia and osteoporosis.	3
A.3.13	State that chemical additives can act as preservatives, antioxidants, colourings, flavourings, stabilizers and acid-regulators.	1
A.3.14	Outline three possible harmful effects of named food additives.	2
A.3.15	Explain the importance of using hygienic methods to handle and prepare food.	3

Option B: Physiology of Exercise

A.S.		Obj

B.1 The Skeleton, Joints and Muscles (4h)

B.1.1	State that the skeleton is sub-divided into axial and appendicular parts.	**1**
B.1.2	Explain the structure of a long bone, including the hollow shaft and spongy head, in relation to strength and shock absorption.	**3**
B.1.3	Draw a diagram of the human elbow joint. Include cartilage, synovial fluid, tendons, ligaments, named bones and named antagonistic muscles. The only muscles expected are the biceps and the triceps.	**1**
B.1.4	Outline the functions of the above-named structure of the human elbow joint.	**2**
B.1.5	Describe the movements at the hip joint and the knee joint.	**2**
B.1.6	Outline the structure of skeletal muscle in terms of muscle fibres, myofibrils and tendons.	**2**
B.1.7	Draw the structure of skeletal muscle fibres as seen in electron micrographs. Electron micrographs can be interpreted to show sarcomeres and their characteristic dark and light bands. The detailed structure can be deduced so that thin actin filaments and thick myosin filaments interdigitate. The sarcoplasmic reticulum and mitochondria should be included. No names of lines or bands are expected.	**1**
B.1.8	Explain how skeletal muscle contracts by the sliding action of actin and myosin filaments, with ATP as an energy source. The depth of treatment is stated and is less than that required in 11.2.6.	**3**
B.1.9	Explain the differences in speed and stamina of fast (twitch) and slow (tonic) muscle fibres. Note that all human muscles have both types of fibre. Slow muscle fibres (typical of marathon athletes) have a very good blood supply, plenty of myoglobin, and are capable of sustained activity (stamina) and high rates of aerobic respiration. Fast muscle fibres (typical of sprinters) have greater oxygen needs, low myoglobin levels and provide a maximum work rate over shorter periods (strength).	**3**

B.2 Coordination of Muscle Activity (3h)

B.2.1	Outline the general organization of the human nervous system including the CNS (brain and spinal cord) and the PNS (nerves). Further details about the organization are not required.	**2**
B.2.2	Draw the structure of a sensory neuron and a motor neuron.	**1**

A.S.		Obj
B.2.3	Outline synaptic transmission. Include arrival of an electrical impulse; release, diffusion and destruction of a neurotransmitter substance; and the subsequent propagation of another electrical impulse.	2
B.2.4	Explain how the contraction of a muscle is controlled by motor areas of the cerebral cortex, motor neurons, synapses, muscle fibres and feedback to the brain by means of proprioceptors and sensory neurons. Brain structure, specific transmitters, potential differences and movement of ions are not required.	3
B.2.5	Explain the role of inhibitory neurons in coordinating the activity of antagonistic muscles at a joint. Refer to inhibitory neurons forming synapses with motor neurons in the grey matter of the CNS.	3

B.3 Muscles and Energy (4h)

B.3.1	Explain how and why ventilation rate varies with exercise. Limit this to the effects of changes in carbon dioxide concentration leading to a lowering of blood pH, which is detected by chemosensors in arteries that send impulses to the breathing centre of the brain. This then sends nerve impulses to the diaphragm and intercostal muscles to increase contraction/relaxation rates.	3
B.3.2	Explain that ATP supplies in muscles provide enough energy for only the first few seconds of exercise, that anaerobic respiration can supply energy for up to two minutes of high-intensity exercise and aerobic respiration can supply energy indefinitely for low-intensity activity. An explanation of the biochemistry of aerobic and anaerobic respiration is not required.	3
B.3.3	State that lactate produced in anaerobic respiration is passed to the liver and creates an oxygen debt.	1
B.3.4	State that this oxygen debt is repaid by breaking down lactate in the liver, which requires continued heavy breathing after exercise. Knowledge of the biochemistry of lactate breakdown is not required.	1
B.3.5	Outline the role of myoglobin in muscles. Oxygen dissociation curves are not required.	2
B.3.6	Explain the role of adrenaline in increasing supplies of oxygen and glucose to muscles.	3
B.3.7	Explain the causes of muscle fatigue in terms of lactate accumulation and depletion of carbohydrate supplies in muscles.	3

A.S. Obj

B.4 Fitness and Training (2h)

B.4.1 Define *fitness*. **1**

B.4.2 Describe the principles of training including specificity, progressive overload, frequency, intensity and duration. **2**

- Specificity—ensuring the training programme is relevant to the particular demands of the event/sport.
- Progressive overload—periodically increasing the load on a muscle(s) (resistance against which a given muscle(s) works) in order to develop strength and stamina.
- Frequency—how often training takes place.
- Intensity—how "hard" the training is. (Intensity of training can be measured in a number of ways, but generally involves monitoring the heart rate, which is an indirect way of estimating oxygen utilization by the body.)
- Duration—length of a training session. (Duration is dependent on the intensity of the activity.)

B.4.3 Discuss flexibility, agility, speed and stamina as measures of fitness. **3**

- Flexibility—the range of motion about a joint or series of joints.
- Agility—the ability to perform a series of movements in rapid succession in opposing directions (eg zig-zag running).
- Speed—the quickness of movement of a limb (eg the legs of a runner or the arms of a boxer).
- Stamina—the ability to maintain prolonged physical activity.

B.4.4 Explain how training affects the cardiovascular system, the lungs and the muscles. **3**

B.4.5 Discuss the ethics of using performance-enhancing drugs in sport. **3**

B.5 Injuries (2h)

B.5.1 Discuss the need for warm-up and cool-down routines. **3**

B.5.2 Describe injuries to muscles and joints including sprains, torn muscles, torn ligaments, dislocation of joints and intervertebral disc damage. **2**

B.5.3 Explain the use of rest, ice, compression and elevation in the treatment of soft-tissue injuries. **3**

Option C: Cells and Energy

Note: The content of this option is taken entirely from AHL material.

A.S.		Obj

C.1 Proteins (1h)

C.1.1	Explain the four levels of protein structure, indicating each level's significance. Quaternary structure may involve the binding of a prosthetic group to form a conjugated protein.	3
C.1.2	Outline the difference between fibrous and globular proteins, with reference to two examples of each protein type.	2
C.1.3	Explain the significance of polar and non-polar amino acids. Limit this to controlling the position of proteins in membranes, creating hydrophilic channels through membranes and the specificity of active sites in enzymes. Cross reference with 1.4.	3
C.1.4	State six functions of proteins, giving a named example of each. Membrane proteins should not be included.	1

C.2 Enzymes (2h)

C.2.1	State that metabolic pathways consist of chains and cycles of enzyme catalysed reactions.	1
C.2.2	Describe the induced fit model. This is an extension of the lock-and-key model. Its importance in accounting for the broad specificity of some enzymes (the ability to bind several substrates) should be mentioned.	2
C.2.3	Explain that enzymes lower the activation energy of the chemical reactions that they catalyse. Graphical representation of both exergonic and endergonic reactions should be covered, but specific energy values do not need to be recalled.	3
C.2.4	Explain the difference between competitive and non-competitive inhibition with reference to one example of each. Competitive—an inhibiting molecule structurally similar to the substrate molecule binds to the active site, preventing substrate binding. Examples include inhibition of butanedioic acid (succinate) dehydrogenase by propanedioic acid (malonate) in the Krebs cycle, and inhibition of folic acid synthesis in bacteria by the sulfonamide Prontosil™ (an antibiotic). Non-competitive—limited to an inhibitor molecule binding to an enzyme (not to its active site) that causes a conformational change in its active site, resulting in a decrease in activity. Examples include Hg^{2+}, Ag^{+}, Cu^{2+} and	3

A.S. Obj

CN^- inhibition of many enzymes (eg cytochrome oxidase) by binding to -SH groups, thereby breaking -S-S- linkages; and nerve gases like Sarin and DFP (diisopropyl fluorophosphate) inhibiting ethanoyl (acetyl) cholinesterase.

Reversible inhibition, as compared to irreversible inhibition, is not required.

C.2.5 Explain the role of allostery in the control of metabolic pathways by end-product inhibition. **3**

Allostery is a form of non-competitive inhibition. Mention that the shape of allosteric enzymes can be altered by the binding of end products to an allosteric site, thereby decreasing its activity. Metabolites can act as allosteric inhibitors of enzymes earlier in a metabolic pathway and regulate metabolism according to the requirements of organisms; a form of negative feedback. Examples include ATP inhibition of phosphofructokinase in glycolysis and inhibition of aspartate carbamoyltransferase (ATCase) which catalyses the first step in pyrimidine synthesis.

C.3 Cell Respiration (6h)

C.3.1 State that oxidation involves the loss of electrons from an element whereas reduction involves a gain in electrons, and that oxidation frequently involves gaining oxygen or losing hydrogen, whereas reduction frequently involves loss of oxygen or gain in hydrogen. **1**

C.3.2 Outline the process of glycolysis including phosphorylation, lysis, oxidation and ATP formation. **2**

In the cytoplasm, one hexose sugar is converted into two three-carbon atom compounds (pyruvate) with a net gain of two ATP and two NADH + H^+. Phosphorylation is a process in which ATP is made in vivo (in glycolysis the process is substrate level phosphorylation).

C.3.3 Draw the structure of a mitochondrion as seen in electron micrographs. **1**

C.3.4 Explain aerobic respiration including oxidative decarboxylation of pyruvate, the Krebs cycle, NADH + H^+, the electron transport chain and the role of oxygen. **3**

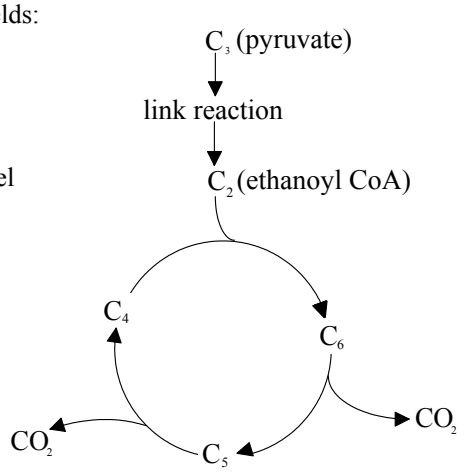
In aerobic respiration (in mitochondria in eukaryotes) each pyruvate is decarboxylated (CO_2 removed). The remaining two-carbon molecule (acetyl group) reacts with reduced coenzyme A, and at the same time one NADH + H^+ is formed. This is known as the link reaction.

In the Krebs cycle each acetyl group (CH_3CO) formed in the link reaction yields two CO_2. The names of the intermediate compounds in the cycle are not required. Thus it would be acceptable to note: $C_2 + C_4 = C_6 \rightarrow C_5 \rightarrow$ etc. Students should also note that the hydrogen atoms removed are collected by "hydrogen-carrying coenzymes".

A.S. Obj

One turn of the Krebs cycle yields:

- $2 \times CO_2$
- $3 \times NADH + H^+$
- $1 \times FADH_2$
- $1 \times ATP$ (by substrate level phosphorylation)



C.3.5 Explain oxidative phosphorylation in terms of chemiosmosis. **3**

Cross reference with C.4.4. The synthesis of ATP is coupled to electron transport and the movement of protons (H^+ ions)—the chemiosmotic theory. Briefly, the electron transport carriers are strategically arranged over the inner membrane of the mitochondrion. As they oxidize $NADH + H^+$ and $FADH_2$, energy from this process forces protons to move, against the concentration gradient, from the mitochondrial matrix to the space between the two membranes (using proton pumps). Eventually the H^+ ions flow back into the matrix through special gates in the ATP synthetase molecules in the membrane. As the ions flow down the gradient, energy is released and ATP is made.

C.3.6 Explain the relationship between the structure of the mitochondrion and its function. **3**

Limit this to cristae forming a large surface area for the electron transport chain, the small space between inner and outer membranes for accumulation of protons and the fluid matrix containing enzymes of the Krebs cycle.

C.3.7 Describe the central role of acetyl CoA in carbohydrate and fat metabolism. **2**

Acetyl CoA is an intermediate in carbohydrate (glucose) metabolism. In lipid metabolism the oxidation of the fatty acid chains results in the formation of two-carbon atom (acetyl) fragments which then pass through the Krebs cycle.

C.3.8 Analyse data relating to respiration. **3**

C.4 Photosynthesis (6h)

C.4.1 Draw the structure of a chloroplast as seen in electron micrographs. **1**

C.4.2 State that photosynthesis consists of light-dependent and light-independent reactions. **1**

Not “light” and “dark” reactions.

A.S.		Obj
C.4.3	Explain the light-dependent reactions. Include the photoactivation of photosystem II, photolysis of water, electron transport, cyclic and non-cyclic photophosphorylation, photoactivation of photosystem I and reduction of $NADP^+$.	3
C.4.4	Explain photophosphorylation in terms of chemiosmosis. Electron transport causes the pumping of protons to the inside of the thylakoids. They accumulate (pH drops) and eventually move out to the stroma through protein channels in the ATP synthetase enzymes. This provides energy for ATP synthesis. Cross reference C.3.5.	3
C.4.5	Explain the light-independent reactions. Include the roles of ribulose bisphosphate (RuBP) carboxylase, reduction of glycerate 3-phosphate (GP) to triose phosphate (TP), NADPH + H^+, ATP, regeneration of RuBP and synthesis of carbohydrate.	3
C.4.6	Explain the relationship between the structure of the chloroplast and its function. Limit this to the large surface area of thylakoids for light absorption, the small space inside thylakoids for accumulation of protons and the fluid stroma for the enzymes of the Calvin cycle.	3
C.4.7	Draw the action spectrum of photosynthesis.	1
C.4.8	Explain the relationship between the action spectrum and the absorption spectrum of photosynthetic pigments in green plants. A separate spectrum for each pigment (chlorophyll a, chlorophyll b, etc) is not required.	3
C.4.9	Explain the concept of limiting factors with reference to light intensity, temperature and concentration of carbon dioxide.	3
C.4.10	Analyse data relating to photosynthesis.	3

Option D: Evolution

A.S.	*Core Material—SL and HL*	Obj

D.1 Origin of Life on Earth (2h)

D.1.1	Outline the conditions of pre-biotic Earth, including high temperature, lightning, UV light penetration and a reducing atmosphere.	2
D.1.2	Outline the experiments of Miller and Urey into the origin of organic compounds.	2
D.1.3	Discuss the hypothesis that the first catalysts responsible for polymerization reactions were clay minerals and RNA.	3
D.1.4	Discuss the possible role of RNA as the first molecule capable of replicating.	3
D.1.5	Discuss a possible origin of membranes and prokaryotic cells.	3
D.1.6	Discuss the endosymbiotic theory for the origin of eukaryotes.	3

D.2 Origin of Species (3h)

D.2.1	Outline Lamarck's theory of evolution by the inheritance of acquired characteristics.	2
D.2.2	Discuss the mechanism of, and lack of evidence for, the inheritance of acquired characteristics.	3
D.2.3	Explain the Darwin–Wallace theory of evolution by natural selection.	3
D.2.4	Discuss other theories for the origin of species including special creation and panspermia. Panspermia is the theory concerned with the arrival of material from outer space. Special creation is mentioned by several religions; a study of all of them is not required.	3
D.2.5	Discuss the evidence for all these theories and the applicability of the scientific method for further investigation.	3

D.3 Evidence for Evolution (5h)

D.3.1	Describe the evidence for evolution as shown by the geographical distribution of living organisms, including the distribution of placental, marsupial and monotreme mammals.	2

A.S.	*Core Material—SL and HL*	Obj
D.3.2	Outline how remains of past living organisms have been preserved. Include petrified remains, prints and moulds, and preservation in amber, tar, peat and ice.	2
D.3.3	Outline the method for dating rocks and fossils using radioisotopes, with reference to ^{14}C and ^{40}K. Knowledge of the degree of accuracy and the choice of isotope to use is expected. Details of the apparatus used are not required.	2
D.3.4	Define *half-life*.	1
D.3.5	Deduce the approximate age of materials based on a simple decay curve for a radioisotope.	3
D.3.6	Outline the palaeontological evidence for evolution using one example.	2
D.3.7	Explain the biochemical evidence provided by the universality of DNA and protein structures for the common ancestry of living organisms.	3
D.3.8	Explain how variations in specific molecules can indicate phylogeny.	3
D.3.9	Discuss how biochemical variations can be used as an evolutionary clock.	3
D.3.10	Explain the evidence for evolution provided by homologous anatomical structures, including vertebrate embryos and the pentadactyl limb. Homologous anatomical structures are structures derived from the same part of a common ancestor.	3
D.3.11	Outline two modern examples of observed evolution. One example must be the changes to the size and shape of the beaks of Galapagos finches. Other examples could include pesticide resistance, bird predation on moths and heavy metal tolerance in plants.	2

D.4 Human Evolution (5h)

D.4.1	State the full classification of human beings from kingdom to sub-species.	1
D.4.2	Describe the major physical features, such as the adaptations for tree life, that define humans as primates.	2
D.4.3	Discuss the anatomical and biochemical evidence which suggests that humans are a bipedal and neotenous species of African ape that spread to colonize new areas. Attention should be drawn to the main features only. Neoteny in this case is in relation to the delayed onset of puberty leading to the increased period of parental care.	3

A.S.	*Core Material—SL and HL*	Obj
D.4.4	Outline the trends illustrated by the fossils of *Australopithecus* including *A. afarensis*, *A. africanus* and *A. robustus*, and *Homo* including *H. habilis*, *H. erectus*, *H. neanderthalensis* and *H. sapiens*.	2
D.4.5	Discuss the possible ecology of these species and the ecological changes that may have prompted their origin.	3
D.4.6	Discuss the incompleteness of the fossil record and the resulting uncertainties with respect to human evolution. Knowledge of approximate dates and distribution for the named species is expected. Details of sub-species or particular groups (Cro-Magnon, Peking etc) are not required. Reasons for the incompleteness of the fossil record should be included.	3
D.4.7	Discuss the origin and consequences of bipedalism and increase in brain size.	3
D.4.8	Outline the difference between genetic and cultural evolution.	2
D.4.9	Discuss the relative importance of genetic and cultural evolution in the evolution of humans.	3

A.S.	*Extension Material—HL only*	Obj

D.5 Neo-Darwinism (4h)

D.5.1	State that mutations are changes to genes or chromosomes due to chance, but with predictable frequencies.	1
D.5.2	Outline phenylketonuria (PKU) and cystic fibrosis as examples of gene mutation, and Klinefelter's syndrome as an example of chromosome mutation.	2
D.5.3	Explain that variation in a population results from the recombination of alleles during meiosis and fertilization.	3
D.5.4	State that adaptations (or micro-evolutionary steps) may occur as the result of an allele frequency increasing in a population's gene pool over a number of generations.	1
D.5.5	Describe how the evolution of one species into another species involves the accumulation of many advantageous alleles in the gene pool of a population over a period of time.	2
D.5.6	State that a species is a potentially interbreeding population having a common gene pool.	1
D.5.7	Discuss the definition of the term *species*.	3
D.5.8	Discuss the process of speciation in terms of migration, geographical or ecological isolation and adaptation, leading to reproductive or genetic isolation of gene pools.	3
D.5.9	Discuss ideas on the pace of evolution including gradualism and punctuated equilibrium.	3

Gradualism is the slow change from one form to another. Punctuated equilibrium, however, implies long periods with no change and short periods of rapid evolution. Mention could be made of the effects of volcanic eruptions and meteor impacts in affecting evolution on Earth.

D.6 The Hardy–Weinberg Principle (3h)

D.6.1	Describe an adaptation in terms of the change in frequency of a gene's alleles.	2
D.6.2	Explain how the Hardy–Weinberg equation ($p^2 + 2pq + q^2 = 1$) is derived.	3
D.6.3	Calculate allele, genotype and phenotype frequencies for two alleles of a gene, using the Hardy–Weinberg equation.	2
D.6.4	State that the Hardy–Weinberg principle can also be used to calculate allele, genotype and phenotype frequencies for genes with two alleles.	1

The ability to calculate such frequencies is not expected.

A.S.	*Extension Material—HL only*	Obj
D.6.5	State the Hardy–Weinberg principle and the conditions under which it applies.	1
	For the principle to be followed, it must be assumed that a population is large, with random mating and a constant allele frequency over time. This implies no allele-specific mortality, no mutation, no emigration and no immigration.	
D.6.6	Describe one example of transient polymorphism and sickle cell anemia as an example of balanced polymorphism.	2
	An example of transient polymorphism is industrial melanism. Sickle cell anemia is an example of balanced polymorphism where heterozygotes (sickle cell trait) have an advantage in malarial regions because they are fitter than either homozygote.	

Option E: Neurobiology and Behaviour

A.S.	*Core Material—SL and HL*	Obj

E.1 Introduction and Examples of Behaviour (4h)

E.1.1 State that the behaviour of animals is related to the environmental context. **1**

E.1.2 State that innate behaviour develops independently of the environmental context, whereas learned behaviour reflects conditions experienced by individuals during development. **1**

E.1.3 Explain the role of natural selection in the development of behaviour patterns. **3**

Innate behaviour patterns (instincts) are inherited and are stereotyped responses to environmental stimuli (see E.3). The behaviour patterns are adaptive and suit the organism to its environment. Possessing a certain gene makes it more likely that a specific behaviour pattern will develop. This reflects the role of natural selection.

E.1.4 Explain, using species of birds or mammals (other than humans), one example of each of the following types of behaviour: migration, grooming, communication, courtship and mate selection. **3**

Examples could include:

- migration—arctic tern, swallow, white stork, blue whale
- grooming—baboon
- communication—bird songs, alarm responses and hierarchal dominance patterns in wolves and red deer
- courtship—male display (peacock, mallard duck, great crested grebe)
- mate selection—territory and song (birds) or combat (stags).

E.1.5 Explain the need for quantitative data in studies of behaviour. **3**

E.2 Perception of Stimuli (3h)

E.2.1 State that sensory receptors act as energy transducers. **1**

E.2.2 State that human sensory receptors are classified as *mechanoreceptors*, *chemoreceptors*, *thermoreceptors* or *photoreceptors*. **1**

E.2.3 Describe what is meant by each of the terms in E.2.2 with reference to one named example of each type of receptor. **2**

Details of how each receptor functions are not required.

E.2.4 Draw the structure of the human eye. **1**

The diagram should include the sclera, cornea, conjunctiva, eyelid, choroid, aqueous humour, pupil, lens, iris, vitreous humour, retina, fovea, optic nerve and blind spot.

A.S.	*Core Material—SL and HL*	Obj
E.2.5	Annotate diagrams of the human retina. Include names of rod and cone cells, bipolar neurones, ganglion cells and the direction of light movement.	2
E.2.6	Distinguish between rod and cone cells. Include: • use in dim light versus bright light • one type sensitive to all wavelengths versus three types sensitive to red, blue and green light • passage of impulses from a group of rod cells to a single neurone of the optic nerve versus passage from a single cone cell to a single neurone.	2
E.2.7	Outline how visual stimuli are processed in the retina and the visual cortex.	2

E.3 Innate Behaviour (3h)

E.3.1	Define *innate behaviour*. Innate behaviour—behaviour which normally occurs in all members of a species despite natural variation in environmental influences. Some texts refer to innate behaviour as species-specific behaviour.	1
E.3.2	Outline the pain withdrawal reflex and one other human spinal reflex.	2
E.3.3	Draw the structure of the spinal cord and its spinal nerves to show the components of a reflex arc. Include receptor, effector and association neurons (relay, internuncial or intermediate neurons will not be used), ascending and descending nerve tracts, central canal, white and grey matter, and ventral and dorsal roots.	1
E.3.4	Outline the pupil reflex and one other cranial reflex.	2
E.3.5	Draw the gross structure of the brain including the medulla oblongata, cerebellum, hypothalamus, pituitary gland and cerebral hemispheres.	1
E.3.6	State one function for each of the parts of the brain in E.3.5.	1
E.3.7	Discuss the use of the pupil reflex in testing for brain death. Some discussion about what is meant by death could be included here.	3
E.3.8	Define *taxis* and *kinesis*. Reference should be made to the distinction between positive and negative responses. Klino-, ortho-, etc are not required.	1

A.S.	*Core Material—SL and HL*	Obj
E.3.9	Explain, using one example of each behaviour, how the responses in E.3.8 improve animals' chances of survival. Examples include: • taxes—flatworms moving towards food (chemotaxis) and *Euglena* moving towards light (phototaxis) • kineses—woodlice moving about less in optimum (humid) conditions and more in an unfavourable (dry) atmosphere.	**3**
E.3.10	Discuss the importance of innate behaviour to the survival of animals.	**3**

E.4 Learned Behaviour (3h)

E.4.1	Define *classical conditioning*. Classical conditioning is referred to in some textbooks as Pavlovian conditioning.	**1**
E.4.2	Outline Pavlov's experiments on conditioning of dogs. The terms *unconditioned stimulus*, *conditioned stimulus*, *unconditioned response* and *conditioned response* should be included.	**2**
E.4.3	Define *operant conditioning*.	**1**
E.4.4	Outline Skinner's experiments into operant conditioning. The terms *operant response* and *reinforcement* should be included.	**2**
E.4.5	Define *imprinting*.	**1**
E.4.6	Outline Lorenz's experiments on imprinting in geese. The terms *sign stimulus*, *species-specific behaviour* and *innate releasing mechanism* should be included.	**2**
E.4.7	Discuss how the process of learning improves the chances of survival.	**3**

E.5 Social Behaviour (2h)

E.5.1	List three examples of animals that show social behaviour. Suitable examples include honey bees, ants, termites, chimpanzees and naked mole rats.	**1**
E.5.2	Describe the social organization of honey bee colonies. Detailed structural differences and the life cycle of bees are not expected.	**2**
E.5.3	Discuss the role of altruistic behaviour in social organizations using two examples. Parental care is not considered to be altruism.	**3**

A.S.	*Extension Material—HL only*	Obj

E.6 The ANS (Autonomic Nervous System) (3h)

E.6.1	State that the ANS consists of sympathetic and parasympathetic motor neurons.	**1**
E.6.2	State that the roles of the sympathetic and parasympathetic system are largely antagonistic.	**1**
E.6.3	State that the ANS serves the heart, blood vessels, digestive system and smooth muscles.	**1**
E.6.4	Explain the effects of the sympathetic and parasympathetic system by referring to the control of the heart, salivary glands and iris of the eye.	**3**
E.6.5	Discuss the relationships between the influence of the conscious part of the brain and automatic reflexes as shown by bladder or anus control, meditation and yoga.	**3**

E.7 Neurotransmitters and Synapses (4h)

E.7.1	State that synapses of the peripheral nervous system (PNS) are classified according to the neurotransmitter used, including acetylcholine and noradrenaline.	**1**
E.7.2	Explain how presynaptic neurons can either encourage or inhibit postsynaptic transmission by depolarization or hyperpolarizaton of the postsynaptic membrane.	**3**
E.7.3	Outline how pain is sensed and how endorphins and enkephalins can act as painkillers.	**2**
E.7.4	Outline the symptoms of Parkinson's disease and the involvement of dopamine.	**2**
E.7.5	Explain that psychoactive drugs affect the brain and personality by either increasing or decreasing synaptic transmission. An outline of the ways synaptic transmission can be increased or decreased is expected. Details of the organization and functioning of the entire brain, and theories of personality or explanations for personality are not required.	**3**
E.7.6	Discuss the behavioural effects of the excitatory psychoactive drugs nicotine, cocaine and amphetamines. The structure of these chemicals and details of their effects on the nervous system are not required. Refer to "crack" when dealing with cocaine and "ecstasy" (methylenedioxymethamphetamine) as a derivative of amphetamines.	**3**
E.7.7	Discuss the behavioural effects of the inhibitory psychoactive drugs benzodiazepines, cannabis and alcohol. The structures of these chemicals and details of their effects on the nervous system are not required. Examples of benzodiazepines are Valium™ and Temazepam™.	**3**

Option F: Applied Plant and Animal Science

A.S.	*Core Material—SL and HL*	Obj

F.1 Applied Plant Science (5h)

F.1.1	Outline the importance of plants to people in terms of food, fuel, clothing, building materials and aesthetic value.	**2**
F.1.2	State one example of a plant in each of the five categories above.	**1**
F.1.3	Define *harvestable dry biomass* and *net assimilation rate*.	**1**
F.1.4	Describe how plant productivity can be measured in terms of relative growth rate, harvestable dry biomass and net assimilation rate.	**2**
F.1.5	Outline how the following factors affect plant productivity: light, water, concentration of carbon dioxide, temperature, availability of nutrients, disease, predators and genotype.	**2**
F.1.6	Explain how plant productivity can be optimized using greenhouses.	**3**
F.1.7	Outline the production of crops by hydroponics.	**2**
F.1.8	Describe the cultivation of a plant of economic importance using wheat, maize or rice as an example. Cultivation includes all stages from seed bed preparation to harvest.	**2**
F.1.9	Explain how intensive monoculture can lead to nutrient depletion and pest invasion and, subsequently, why fertilizers and pesticides are required.	**3**
F.1.10	Explain how intensive monoculture can lead to increased crop production in terms of efficient land use, timing of interventions and harvest.	**3**
F.1.11	Discuss the biological and ethical issues surrounding *organic* versus *non-organic* farming methods. Although there is some variation in how organic farming is defined, it can be regarded as a production system which avoids or largely excludes the use of synthetic fertilizers, pesticides, growth regulators and feed additives. Organic farming systems rely as much as possible upon crop rotation, crop residues, animal manure, mechanical cultivation, approved mineral-bearing rocks and aspects of biological pest control to maintain soil productivity, to supply plant nutrients and to control insects, weeds and other pests.	**3**
F.1.12	Discuss the biological and ethical issues surrounding biological and chemical pest control.	**3**

A.S.	*Core Material—SL and HL*	Obj

F.2 Applied Animal Science (4h)

F.2.1 State that animals have been domesticated to produce breeds suitable for plowing, transport, food, fur and skins, and for keeping as pets, providing one example of each. **1**

F.2.2 Describe the rearing of an animal of economic importance using cattle, chickens or sheep as an example. **2**

F.2.3 Discuss intensive animal rearing techniques in terms of yield and ethical issues. **3**

F.2.4 Explain how veterinary techniques have been applied to improve the health and fecundity of animals. **3**

Include artificial insemination, vaccination and nutrient supplementation.

F.2.5 Discuss the use and misuse of antibiotics and growth hormones in livestock production. **3**

F.3 Plant Growth Regulators (3h)

F.3.1 Distinguish between plant growth regulators (plant growth hormones) and fertilizers. **2**

Fertilizers are mineral nutrients that are needed for plant growth. Plant growth regulators are chemical messengers that stimulate or inhibit plant growth and development.

F.3.2 Explain the role of auxin in phototropism as an example of the control of plant growth. **3**

It is generally accepted that light affects the distribution of auxin within the shoot. When a shoot is illuminated from one side, auxin is transported laterally to the other side where it causes bending to occur by stimulating cell elongation. However, recent research questions this explanation.

F.3.3 Describe the role of auxins in terms of apical dominance and how pruning can result in a bushy, decorative plant. **2**

F.3.4 Describe how plant growth regulators can be used commercially to promote rooting, to kill weeds, to induce fruit ripening at the required time and to produce fruits without seeds. **2**

F.3.5 Explain the techniques used in cloning by micropropagation. **3**

Include growth media, aseptic techniques, auxin, cytokinin and gibberellin.

A.S.	*Core Material—SL and HL*	Obj

F.4 Plant and Animal Breeding (3h)

F.4.1	Define *inbreeding*, *outbreeding*, *interspecific hybridization*, *polyploidy* and *F_1 hybrid vigour*.	**1**
F.4.2	Outline one example for each of the terms in F.4.1.	**2**
F.4.3	Discuss the need to maintain the biodiversity of wild plants or ancient farm breeds as a reservoir of alleles which may have future value.	**3**
F.4.4	Explain, using wheat, maize or rice as an example, how plant breeding programmes have led to an improvement in the yield of a cereal crop.	**3**
F.4.5	Outline how animal breeding programmes have led to an improvement in one of the following: milk yield in cattle, meat yield in sheep or egg yield in poultry.	**2**

A.S.	*Extension Material—HL only*	Obj

F5 Genetic Engineering in Agriculture (3.5h)

F.5.1 Describe three examples of the use of transgenic techniques in agriculture, including at least one plant and one animal example. **2**

Examples include:

- α-1-antitrypsin (emphysema drug) genes introduced into sheep, expressed as protein in milk
- winter flounder fish gene to make tomatoes frost resistant
- transfer of T toxin gene from *Bacillus thuringiensis* into tomatoes
- tomato resistance to tobacco mosaic virus
- glyphosphate (a herbicide) resistance in soybean
- factor IX (human blood clotting) in sheep milk
- VEF (viral enhancement factor) in plants for pest control.

F.5.2 Discuss gene manipulation involving sense/antisense technology with reference to Flavr-Savr ™ tomatoes. **3**

Flavr-Savr™ tomatoes ripen but stay firm. The over-ripening gene is blocked because the antisense RNA strand is introduced to this region so that the double-stranded part does not allow the gene to be expressed.

F.5.3 Discuss the ethical issues arising from the use of transgenic techniques, including environmental and economic aspects. **3**

F.6 Flowering and Propagation of Plants (3.5h)

F.6.1 Draw the structure of a monocotyledonous wind-pollinated flower, as seen with the naked eye and hand lens. **1**

The example taken should be a cereal crop plant with hermaphrodite flowers such as wheat or rice.

F.6.2 Distinguish between typical adaptations of wind-pollinated and insect-pollinated flowers. **2**

F.6.3 State that plants can reproduce asexually by forming tubers, runners and bulbs. **1**

F.6.4 State that plants can be propagated asexually by taking cuttings, grafting and layering. **1**

F.6.5 Discuss the use of asexual reproduction in the artificial propagation of plants. **3**

This should include rapid reproduction, propagation of the best clones, susceptibilty to disease because of genetic uniformity and transmission of viral diseases.

F.6.6 Explain how flowering is controlled in long-day and short-day plants, including the role of phytochrome. **3**

F.6.7 Explain how manipulation of day length is used in the production of flowers. **3**

Option G: Ecology and Conservation

A.S.	*Core Material—SL and HL*	Obj

G.1 Ecology of Species (3h)

G.1.1	Outline the factors that affect the distribution of plant species including temperature, water, light, soil pH, salinity and mineral nutrients.	2
G.1.2	Explain the factors that affect the distribution of animal species including temperature, water, breeding sites, food supply and territory.	3
G.1.3	Deduce the significance of the difference between two sets of data using calculated values for *t* and the appropriate tables. The *t*-test can be used to compare two sets of data and measure the amount of overlap. Students will not be expected to calculate values of *t*.	3
G.1.4	Explain what is meant by the niche concept, including an organism's spatial habitat, its feeding activities and its interactions with other organisms.	3
G.1.5	Explain the principle of competitive exclusion.	3

G.2 Ecology of Communities (5h)

G.2.1	Explain the following interactions between species, giving two examples of each: competition, herbivory, predation, parasitism and mutualism. Mutualism is where two members of different species benefit and neither suffers. Examples include rumen bacteria/protozoa, lichens and *Chlorella/Chlorohydra*.	3
G.2.2	Define *gross production*, *net production* and *biomass*.	1
G.2.3	Calculate values for gross production, net production and biomass from given data. Gross production – respiration = net production	2
G.2.4	Discuss the difficulties of classifying organisms into trophic levels.	3
G.2.5	Explain the small biomass and low numbers of organisms in higher trophic levels.	3
G.2.6	Construct a pyramid of energy given appropriate information. The lowest bar of the pyramid of energy represents gross primary productivity, the next bar represents the energy ingested as food by primary consumers, and so on. The units are energy per unit area per unit time.	3
G.2.7	Describe ecological succession using one example.	2

A.S.	*Core Material—SL and HL*	Obj

G.2.8 Explain the effects of living organisms on the abiotic environment with reference to the changes occurring during ecological succession to climax communities. **3**

Include soil development, accumulation of minerals and reduced erosion.

G.3 Biodiversity and Conservation (7h)

G.3.1 Discuss reasons for the conservation of biodiversity using rainforests as an example. Reasons should include ethical, ecological, economic and aesthetic arguments. **3**

G.3.2 Outline the factors that caused the extinction of one named animal and one named plant species. **2**

Choose examples from recent historical time.

G.3.3 Outline the use of the Simpson diversity index. **2**

$$D = \frac{N(N-1)}{\sum n(n-1)}$$

D = diversity index
N = total number of organisms of all species found
n = number of individuals of a particular species

The Simpson diversity index is a measure of species richness. A high value of D suggests a stable and ancient site and a low D value could suggest pollution, recent colonization or agricultural management. The index is normally used in studies of vegetation but can also be applied to comparisons of animal (or even all species) diversity.

G.3.4 Explain the use of biotic indices and indicator species in monitoring environmental change. **3**

G.3.5 Outline the damage caused to marine ecosystems by the overexploitation of fish. **2**

G.3.6 Discuss international measures that would promote the conservation of fish. **3**

G.3.7 Discuss the advantages of in situ conservation of endangered species (terrestrial and aquatic nature reserves). **3**

G.3.8 Outline the management of nature reserves. **2**

Include control of alien species, restoration of degraded areas, promotion of the recovery of threatened species and control of human exploitation.

G.3.9 Outline the use of ex situ conservation measures including captive breeding of animals, botanic gardens and seed banks. **2**

G.3.10 Discuss the role of international agencies and conservation measures including CITES and WWF. **3**

CITES—Convention on International Trade in Endangered Species
WWF—World Wildlife Fund

A.S.	*Extension Material—HL only*	Obj

G.4 The Nitrogen Cycle (4h)

G.4.1	State that all chemical elements occuring in organisms are part of biogeochemical cycles and that these cycles involve water, land and the atmosphere.	1
G.4.2	Explain that all biogeochemical cycles summarize the movement of elements through the biological components of ecosystems (food chains) to form complex organic molecules, and subsequently simpler inorganic forms which can be used again.	3
G.4.3	Explain that chemoautotrophs can oxidize inorganic substances as a direct energy source to synthesize ATP.	3
G.4.4	State that chemoautotrophy is found only among bacteria.	1
G.4.5	Draw a diagram of a nitrogen cycle. Include the process of nitrogen fixation (free-living, symbiotic and industrial), denitrification, nitrification, feeding, excretion, root absorption, and putrefaction (ammonification).	1
G.4.6	Outline the roles of *Rhizobium*, *Azotobacter*, *Nitrosomonas*, *Nitrobacter* and *Pseudomonas denitrificans* in the nitrogen cycle.	2
G.4.7	Describe the conditions that favour denitrification and nitrification.	2
G.4.8	Discuss the actions taken by farmers/gardeners to increase the nitrogen fertility of the soil including fertilizers, plowing/digging and crop rotation (use of legumes).	3

G.5 Impacts of Humans on Ecosystems (3h)

G.5.1	Describe the role of atmospheric ozone in absorbing ultra violet (UV) radiation.	2
G.5.2	Outline the effects of UV radiation on living tissues and biological productivity.	2
G.5.3	Outline the chemical effect of chlorine on the ozone layer.	2
G.5.4	Discuss methods of reducing the manufacture and release of ozone-depleting substances including recycling refrigerants, reducing production of gas-blown plastics and using CFC-free propellants.	3
G.5.5	Outline the consequences of releasing raw sewage and nitrate fertilizer into rivers. Include pathogens in bathing or drinking water, eutrophication, algal blooms, deoxygenation, increase in biochemical oxygen demand (BOD) and subsequent recovery. Names of specific organisms are not expected.	2
G.5.6	Outline the origin, formation and biological consequences of acid precipitation on plants and animals.	2

A.S.	*Extension Material—HL only*	Obj
G.5.7	State that biomass can be used as a source of fuels such as methane and ethanol.	**1**
G.5.8	Explain the principles involved in the generation of methane from biomass, including the conditions needed, organisms involved and the basic chemical reactions that occur.	**3**

Option H: Further Human Physiology

A.S.		Obj

H.1 Hormonal Control (3h)

H.1.1	State that hormones are chemical messengers secreted by endocrine glands into the blood and transported by the blood to specific target cells.	**1**
H.1.2	State that hormones can be steroids, peptides and tyrosine derivatives, and provide one example of each.	**1**
H.1.3	Distinguish between the mode of action of steroid hormones and peptide hormones. Steroids enter cells and affect genes directly. Peptides bind to receptors in the membrane which causes the release of a secondary messenger inside the cell.	**2**
H.1.4	Draw a diagram of the hypothalamus and the pituitary gland. Include the portal vein connecting the hypothalamus and the anterior pituitary gland and the neurosecretory cells connecting the hypothalamus and posterior pituitary gland. Exclude the pars intermedia.	**1**
H.1.5	Explain the control of thyroxin secretion by negative feedback. Include the secretion of TRH (thyrotropin-releasing hormone), transport to the anterior pituitary in the portal vein, secretion of TSH (thyroid stimulating hormone) and secretion of thyroxin. Negative feedback to the hypothalamus involves thyroxin level, TSH level and body temperature.	**3**
H.1.6	Explain the control of ADH secretion by negative feedback. Include neurosecretory cells in the hypothalamus, transport of ADH (antidiuretic hormone) to the posterior pituitary for storage and release under stimulus by osmoreceptors in the hypothalamus.	**3**

H.2 Digestion (4h)

H.2.1	State that digestive juices are secreted into the alimentary canal by glands including salivary, stomach wall, pancreas and wall of small intestine. Cross reference with 5.1.4.	**1**
H.2.2	Draw the structural features of exocrine glands including secretory cells grouped into acini and ducts.	**1**
H.2.3	Explain the structural features of exocrine gland cells as seen in electron micrographs.	**3**
H.2.4	State the contents of saliva, gastric juice and pancreatic juice.	**1**

A.S.		Obj
H.2.5	Outline the control of digestive juice secretion by nerves and hormones. Use the example of gastric juice. Limit this to initial release of gastric juice under nerve stimulation after sight or smell of food, and sustained release under the influence of gastrin secreted when food is in the stomach.	2
H.2.6	Outline the role of membrane-bound enzymes in the surface cells of the small intestine in completing digestion. Some digestive enzymes (eg maltase) are immobilized in the surface membrane of cells on the surface of intestinal villi. These enzymes continue working even if the cell is rubbed off the villus and mixed into the intestinal contents.	2
H.2.7	Explain why cellulose remains undigested in the human alimentary canal.	3
H.2.8	Explain why pepsin and trypsin are initially synthesized as inactive precursors, and how they are subsequently activated.	3
H.2.9	Outline the action of endopeptidases and exopeptidases.	2
H.2.10	Explain the problem of lipid digestion in a hydrophilic medium and the role of bile in overcoming this problem. Lipid molecules tend to coalesce and are only accessible to lipase at the lipid–water interface. Mention could be made of the need for lipase to be water soluble and to have an active site to which a hydrophobic substrate binds. Bile molecules have a hydrophilic end and a lipophilic (hydrophobic) end and thus prevent lipid droplets coalescing with each other. The maximum surface is exposed to lipases.	3

H.3 Absorption of Digested Foods (2h)

H.3.1	Draw a portion of the ileum (in transverse section) as seen under a light microscope. Cross reference with 5.1.7. Include mucosa and layers of longitudinal and circular muscle.	1
H.3.2	Explain the structural features of an epithelium cell of a villus as seen in electron micrographs including microvilli, mitochondria, pinocytotic vesicles and tight junctions.	3
H.3.3	Explain the mechanisms used by the ileum to absorb and transport food, including facilitated diffusion, active transport and endocytosis.	3
H.3.4	List the materials that are not absorbed and are egested. Include cellulose, lignin, bile pigments, bacteria and intestinal cells.	1

A.S. Obj

H.4 Functions of the Liver (3h)

H.4.1 Outline the circulation of blood through liver tissue including the hepatic artery, hepatic portal vein, sinusoids and hepatic vein. **2**

Reference to lobules or acini is not required. Students should understand the route taken by blood from both the hepatic portal vein and hepatic artery to the hepatic vein. The difference in structure between sinusoids and capillaries should be mentioned.

H.4.2 Explain the need for the liver to regulate levels of nutrients in the blood. **3**

H.4.3 Outline the role of the liver in the storage of nutrients including carbohydrate, iron, retinol and calciferol. **2**

H.4.4 Describe the process of bile secretion. **2**

Mention should be made of the contents of bile (HCO_3^- ions, bile salts and bile pigments) and of canaliculi, the gall bladder and the bile duct.

H.4.5 Describe the process of erythrocyte and hemoglobin breakdown in the liver including phagocytosis, digestion of globin and bile pigment formation. **2**

Red blood cells are destroyed, after about four months, by Kupffer cells (phagocytic) in the liver. Hemoglobin is converted to a yellow pigment (bilirubin), the iron is stored and the protein is broken down to amino acids. Bilirubin is transferred to the bile, released into the intestine and converted by bacteria to a yellow pigment which gives the characteristic colour to feces.

H.4.6 State that the liver synthesizes plasma proteins and cholesterol. **1**

H.5 The Transport System (5h)

H.5.1 Explain the events of the cardiac cycle including atrial and ventricular systole and diastole, and heart sounds. **3**

Cross reference with 5.2.1–5.2.3.

H.5.2 Analyse data showing pressure and volume changes in the left atrium, left ventricle and the aorta, during the cardiac cycle. **3**

Recall of quantitative data is not expected.

H.5.3 Outline the mechanisms that control the heartbeat including the SA (sinoatrial) node, AV (atrioventricular) node and conducting fibres in the ventricular walls. **2**

H.5.4 Outline atherosclerosis and the causes of coronary thrombosis. **2**

Atherosclerosis involves deposition of lipids on the inner surfaces of arteries. This impedes blood flow, induces clot formation and could lead to heart attacks by blocking coronary arteries and the flow of blood to cardiac muscle (myocardial infarction).

A.S.		Obj
H.5.5	Discuss factors which affect the occurance of coronary heart disease. Risk factors include: having parents who have experienced heart attacks (genetic), old age, being male (more risk than being female), smoking, obesity, eating too much saturated fat and cholesterol and lack of exercise.	3
H.5.6	Outline how tissue fluid and lymph are formed in body tissues. Calculations of pressure differences are not required.	2
H.5.7	Outline the transport functions of the lymphatic system.	2

H.6 Gas Exchange (5h)

H.6.1	Define *partial pressure*.	1
H.6.2	Explain the oxygen dissociation curves of adult and fetal hemoglobin and myoglobin.	3
H.6.3	Describe how carbon dioxide is carried by the blood, including the action of carbonic anhydrase, the chloride shift and buffering by plasma proteins.	2
H.6.4	Explain the role of the Bohr shift in the supply of oxygen to respiring tissues.	3
H.6.5	Explain how and why ventilation rate varies with exercise. Limit this to the effects of changes in carbon dioxide concentration leading to a lowering of blood pH. This is detected by chemosensors in the aorta and carotid arteries that send impulses to the breathing centre of the brain. Nerve impulses are then sent to the diaphragm and the intercostal muscles to increase contraction or relaxation rates.	3
H.6.6	Outline the possible causes of lung cancer and asthma and their effects on the gas exchange system.	2
H.6.7	Explain the problem of gas exchange at high altitudes and the way the body acclimatizes. Mountain sickness may occur when a person travels quickly from a low to a high altitude. Over a period of time the person becomes acclimatized: red blood cell production and ventilation rate increase. People living permanently at high altitude have greater lung surface area and larger vital capacity than those living at sea level.	3

MATHEMATICAL REQUIREMENTS

All Diploma Programme biology students should be able to:

- perform the basic arithmetic functions: addition, subtraction, multiplication and division
- recognize basic geometric shapes
- carry out simple calculations within a biological context involving means, decimals, fractions, percentages, ratios, approximations, reciprocals and scaling
- use standard notation (eg 3.6×10^6)
- use direct and inverse proportion
- represent and interpret frequency data in the form of bar charts, column graphs and histograms, and interpret pie charts and nomograms
- determine the mode and median of a set of data
- plot and interpret graphs (with suitable scales and axes) involving two variables which show linear or non-linear relationships
- plot and interpret scattergrams to identify a correlation between two variables, and appreciate that the existence of a correlation does not establish a causal relationship
- demonstrate sufficient knowledge of probability to understand how Mendelian ratios arise and to calculate such ratios using a Punnett grid
- make approximations of numerical expressions
- recognize and use the relationship between length, surface area and volume.