National Genetics Education and Development Centre

Genetics in A level GCE Biology and International Baccalaureate Biology Courses: the foundation to a genetics education continuum

An overview for the teachers of health professional undergraduates

Rob Newton, Peter Farndon

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Project Team

- Mr Robert Newton
  Professor Peter Farndon

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Copies available from:
The NHS National Genetics Education and Development Centre
Morris House
c/o Birmingham Women's Hospital
Edgbaston
Birmingham
B15 2TG
Phone: 0121 623 6987
www.geneticseducation.nhs.uk

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SUMMARY

1. Summary

- The NHS National Genetics Education and Development Centre was established in 2004 to integrate relevant genetics education across the NHS. The Centre is currently working with medical professionals, nurses, midwives and health visitors, pharmacists and dietitians.

- The Centre has developed a continuum of genetics education based around the learning outcomes for pre-registration health professional students that underpin subsequent clinical practice. Learning in practice focuses on clinical competences; activities based on the patient pathway. This report will provide undergraduate educators with information about the genetics topics that students could have potentially covered at pre-university level.

- Data was analysed from the AS (Advanced Supplementary) and A2 (A level) Biology and Human Biology specifications of the five examination boards in England and Wales as well as the International Baccalaureate Biology curriculum.

- Students who have taken AS, A level or International Baccalaureate Biology, regardless of examination board, will have covered the following genetics topics:

  - The structure of prokaryotic and eukaryotic cells
  - The cell cycle
  - The stages of mitosis
  - The significance / role of mitosis
  - The role of meiosis in producing haploid cells
  - The structure of nucleotides
  - The structure of nucleic acids (including base pairing and hydrogen bonding)
  - The semi-conservative replication of DNA(including the role of DNA polymerase)
  - The nature of the genetic code
  - Transcription
  - Translation

- The information collated in this report could be used by health professional educators to inform the design of pre-registration courses in genetics.

2. Introduction

The publication of the initial sequencing and analysis of the human genome in February 2001 highlighted the potential impact of genetics on future patient care:

> The scientific work will have profound long-term consequences for medicine, leading to the elucidation of the underlying molecular mechanisms of disease and thereby facilitating the design in many cases of rational diagnostics and therapeutics aimed at those mechanisms.
> (Human Genome Sequencing Consortium, 2001)

There was subsequent acknowledgement that education would need to reflect these developments. A report published by the Public Health Genetics Unit in 2003 highlighted the importance of genetics education for UK health professionals. It recommended the integration of more genetics concepts into curricula during review processes and the 'active marketing' of genetics in other parts of the curriculum
(Burton, 2003).

Following recommendations in the Genetics White Paper (Department of Health, 2003) the NHS National Genetics Education and Development Centre was established in 2004 with the remit to encourage the integration of relevant genetics education across the NHS. At present, the Centre is co-ordinating programmes of work with medical professionals, nurses, midwives and health visitors, pharmacists and dietitians.

In collaboration with a range of stakeholders, the Centre has developed learning outcomes in genetics for a number of health professional groups. At undergraduate level these introduce core genetics concepts using clinical examples to highlight the relevance to patient care. At postgraduate level, where relevant, this education builds upon this undergraduate underpinning with specialty specific genetics concepts and skills. At practitioner level genetics education is structured around genetics workforce competences reflecting genetics activities appropriate to health professionals' clinical roles. These learning outcomes do not exist in isolation but form a continuum of genetics education appropriate to the stage that a health professional is at in his or her career (Figure 1). It is important that the continuum builds upon the conceptual framework and factual information gained in pre-university examinations. The NHS National Genetics Education and Development Centre therefore identified that it would be helpful for those planning and delivering undergraduate education in genetics to have an overview of what students might have previously covered in their pre-university studies.

This report will examine the genetics content of pre-university biology courses in England and Wales: A level GCE Biology and the International Baccalaureate Diploma Programme.

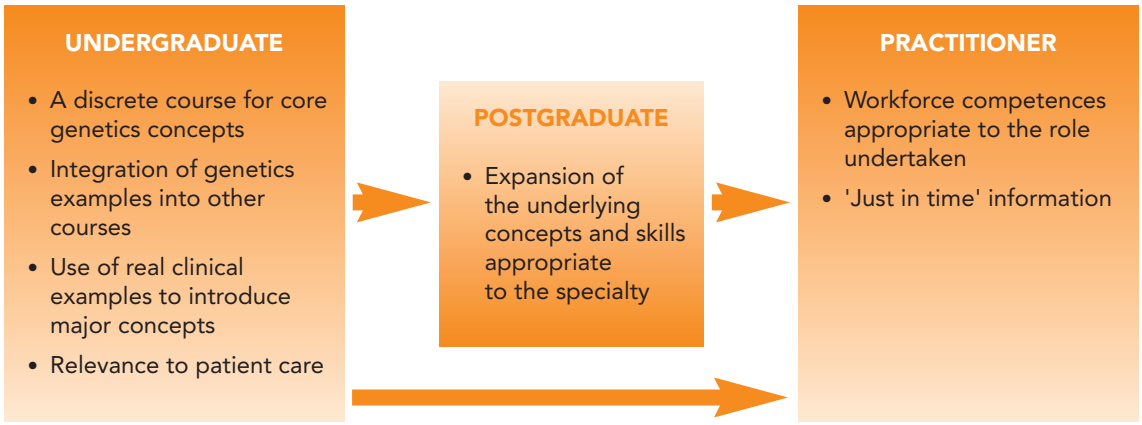


Figure 1: *The continuum of genetics education*

3. Background: Genetics in Pre-University Education

Advanced Level GCE Biology

In 2000, the traditional structure of the GCE A level system was altered with the implementation of 'Curriculum 2000.' This was in response to criticism that students in England were specialising their subject choices too early (for example taking maths and three sciences). Curriculum 2000 divided the A level into two parts, AS (Advanced Supplementary) and A2. An AS is taken in the first year of the A level course. At the end of the year, the student can choose either to claim the qualification and not take that subject any further, or continue the qualification and then take A2 modules in that subject to entitle them to the award of a full A level. The aim for these changes was for students to take AS courses in four or five subjects, therefore decreasing their level of specialism (Bell, Malacova and Shannon, 2005). In 2001-2002 period, 44,369 students were examined in A level Biology (Department for Education and Skills, 2008).

Genetics in Advanced Level Biology

In 2003, the Wellcome Trust commissioned a report into 'A level Biology, Higher Education and Research in the Biological Sciences' from the Centre for Education and Industry at the University of Warwick. Genetics was one of the topics in the A level course for which both students and teachers showed a strong preference, the students highlighting in particular the opportunities to discuss ethical issues. However, a point raised by university tutors was that the A level course focused on the chemical, genetic and cellular level, thus preventing students from appreciating a more holistic whole organism viewpoint. The tutors also discussed the issue of the incorporation of new topics into the syllabus, stating that the new topics chosen should be included in the belief that they will have lasting scientific significance. Using cell biology and genetics as two examples, the tutors felt overall that A level biology course content has responded to developments in biological science (Centre for Education and Industry, 2003).

International Baccalaureate

The International Baccalaureate (IB) Diploma programme is an internationally recognised course designed for 16-19 year olds, showing an ever-growing increase in popularity (Hayden and Wong, 1997). One hundred and twenty-one schools in the UK are currently offering the programme (International Baccalaureate Organization, 2008). Its aim is to promote a balanced education highlighting international understanding and citizenship and offering flexibility of subjects, allowing students to choose options corresponding to their interests and capacities (International Baccalaureate Organization 2002a).

The IB programme is based around a core consisting of three compulsory components: 'Theory of Knowledge,' 'Creativity, Action and Service' and an extended research essay of four thousand words. The core is surrounded by six subject groups. The student chooses a subject course from each of them:

1. Language (the student's first language)
2. Second language
3. Individuals and societies
4. Experimental sciences
5. Mathematics and computer sciences
6. The arts

When the students choose between the subject options within each of these groups, they also have to decide whether to take this subject at standard level (150 teaching hours) or higher level (240 teaching hours). This allows them to specialise in some subjects over others. Students must take either three or four subject groups at higher level.

Within the 'experimental sciences' subject group, students can choose between:

- Biology
- Chemistry
- Physics
- Environmental Systems (at standard level only)
- Design Technology

If a student wishes to choose two science subjects, she or he can do so by taking the second science subject instead of a group 6 arts subject (International Baccalaureate Organization, 2002b).

Biology within the International Baccalaureate Diploma Programme

The aim of the biology course, as with all of the group 4 subjects, is to make students aware of how scientists work and communicate with each other.
There is a strong emphasis on experimental approaches and practical work.

The structure of the biology course (figure 2) differs depending upon whether the student decides to opt for this subject at standard or higher level. The theoretical part of the course begins with a biology core unit, which is taken by both standard level and higher level students. The core is then extended by higher level students with the additional higher level (AHL) unit. Subsequently, both standard and higher level students take modules from a number of options, although the higher level students complete more teaching hours on these topics.

INTERNATIONAL BACCALAUREATE BIOLOGY

STANDARD LEVEL	STRUCTURE	HIGHER LEVEL
	Theory:	
80 hours	Core	80 hours
30 hours	Options	45 hours
-----	Additional Higher Level (AHL)	55 hours
	Practical:	
30 hours	Investigations	50 hours
10 hours	Group 4 project	10 hours
150 hours	**Total teaching time**	**240 hours**

Figure 2: *The structure of the International Baccalaureate Biology Course*

The practical component of the course consists of investigations and a project. The project is completed by both standard and higher level students. The investigations are also completed by both sets of students however the higher students complete an extra twenty hours of investigations as compared to those at standard level.

AIMS OF THIS REPORT
P10

4. Aims of this report

This report will present findings following an analysis of the genetics content of AS, A2 and International Baccalaureate Biology syllabuses.

It will:

- Highlight the genetics topics that pre-registration health professionals should be familiar with if they have undertaken Biology courses.
- Investigate the depth and detail to which this content is covered.
- Identify sources of further information for educators in genetics at the schools of health professional education.
- Suggest ways in which this syllabus information can be incorporated into genetics teaching to health professional students.
- Signpost useful educational resources to support the delivery of these genetics concepts.

5. Obtaining evidence for this overview

AS and A2 Biology Courses

A number of examination boards in the United Kingdom offer AS and A level Biology courses. The decision of which examination board to use is normally made at the school level, although it may be left to the institution's science department or head of biology. The Qualifications and Curriculum Authority (QCA) website was consulted to identify the examination boards that currently offer an A level Biology course.

These were:

- The Assessment and Qualifications Alliance (AQA)
- Council for the Curriculum Examinations and Assessment (CCEA)
- Edexcel
- Oxford Cambridge and RSA Examinations (OCR)
- Welsh Joint Education Committee (WJEC)

The examination boards' websites were then visited in turn and their most recent A level Biology or Human Biology specification was downloaded. These were:

- AQA AS and A level GCE Biology Specification A (2008)
- AQA AS and A level GCE Human Biology Specification A (2008)
- AQA AS and A level GCE Biology Specification B (2008)
- CCEA AS and A level GCE Biology (2005)
- Edexcel AS and A level GCE Biology (2004)
- Edexcel AS and A level GCE Biology (Human) (2004)
- Edexcel AS and A level GCE Biology (Salters-Nuffield) (2005)
- OCR AS and A level GCE Biology (2001)
- OCR AS and A level GCE Human Biology (2001)
- WJEC AS and A level GCE Biology (2007 & 2008)

Each of these was analysed for its genetics content, producing a list of over 60 topics. The authors of this report analysed the scope of the topics which were felt to reflect six main categories:

- Cell structure and division
- Gene structure and mutation
- Patterns of inheritance
- Population genetics
- Applications of genetics
- Applied genetics and genetic conditions

For each of the genetics teaching topics identified, information was recorded in a table to show which syllabi cover the topics and whether they are part of the AS or A2 course. It was found that some of the syllabi offered optional modules in the A2 year, the topics of these being chosen by the teacher. Where the genetics topics fell in one of these optional modules, the topic was marked in green and with an asterisk(*) in the table.

This work is designed to provide an overview. However there may be some limitations to the study because the information analysed can only as complete as is available in the examination boards' downloadable curricula. The topics that have been included in the data tables are those which are explicitly expressed in these documents. Some curricula could intend more detail than they state, but this has not been documented in this report as it is open to individual interpretation.

International Baccalaureate

The International Baccalaureate Organization's website was consulted to obtain general information about the IB courses and the Biology Guide for the Diploma Programme was acquired. This document was analysed for its genetics content, which was subsequently presented in a table according to the teaching topic in which it is presented and whether it is covered at standard or higher level.

It was found that in many cases, the higher level genetics content covered the same subject matter as the standard level course, but in a greater level of depth. More detail is therefore included under the higher level genetics descriptions to reflect the level of depth at which these topics are taught.

6. The genetics content of A Level Biology courses

The genetics content of the A level courses analysed has been ordered under six topics:

- Cell structure and division
- Gene structure and mutation
- Patterns of inheritance
- Population genetics
- Applications of genetics
- Applied genetics and genetic conditions

Each of these will be considered in turn. Topics that are covered at AS level are indicated in yellow, topics that are covered at A2 level are marked in blue. Topics that are covered in optional modules are indicated in green and marked with an asterisk (*).

Cell structure and division

The basic structure of cells, the cell cycle and forms of cell division are covered by all A level courses in the first (AS) year. Issues surrounding variation and how it arises are, on the whole, not introduced until A2 level. This table suggests that some subjects, such as chromosome abnormalities and sex determination either have patchy coverage between examination boards or are not explicitly described in this way in the curricula documents.

Cell structure and division	AQA Biology Specification A	AQA Human Biology Specification A	AQA Biology Specification B	CCEA Biology	Edexcel Biology	Edexcel Biology (Human)	Edexcel Biology (Salters-Nuffield)	OCR Biology	OCR Human Biology	WJEC Biology
Structure of prokaryotic and eukaryotic cells	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
Cell cycle	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
Stages of mitosis	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
Significance of mitosis	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
Meiosis to produce haploid cells	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
Fertilisation as a source of variation										A2
Meiosis as a source of variation	A2	A2	A2	A2	AS	AS	A2	A2	A2	A2
Stages of meiosis	A2	A2	A2	A2	AS	AS	AS	A2	A2	AS
Random assortment, crossing over (chiasmata)	A2	A2	A2	A2	AS	AS	A2	A2	A2	A2
Chromosome abnormalities (e.g. trisomy)				A2	A2	A2				A2
Sex determination			A2	A2	A2	A2				

Gene structure and mutation

Within the AS Biology courses, the concept of biological molecules is usually introduced early on, hence the coverage of nucleic acid structure at AS level across all of the examination boards. The replication of DNA is covered by all boards at AS level, as are the underlying principles of protein synthesis. The concept of mutation is introduced by all syllabi although it varies whether this is at AS or A2 level. Some of the exam specifications mentioned particular types of mutation; these are indicated on the grid. Other specifications mentioned mutation in more general terms. It may be that in practice, the teacher describes the types of mutation, however this is not made explicit on the syllabus.

Gene structure and mutation	AQA Biology Specification A	AQA Human Biology Specification A	AQA Biology Specification B	CCEA Biology	Edexcel Biology	Edexcel Biology (Human)	Edexcel Biology (Salters-Nuffield)	OCR Biology	OCR Human Biology	WJEC Biology
Structure of nucleotides	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
Structure of nucleic acids (base pairing and hydrogen bonding)	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
Semi-conservative replication of DNA (DNA polymerase)	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
The nature of the genetic code	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
Transcription (mRNA)	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
Translation (ribosomes, tRNA, codons and anticodons)	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
'One gene-one polypeptide' hypothesis				AS	AS	AS		AS		AS
Control of gene expression					A2	A2	AS	A2		
Gene mutation	A2	A2	AS	A2	A2	A2	AS	A2	AS	A2
Addition	A2	A2	AS		A2	A2			AS	
Substitution	A2	A2	AS	A2	A2	A2			AS	
Deletion	A2	A2	AS	A2	A2	A2			AS	
Mutagens			AS	A2	A2	A2			AS	A2
Genetic causes of cancer		AS					AS	AS	AS	
Carcinogens		AS							AS	A2
Antibiotic resistance genes in bacteria			A2*					A2	AS	
Accumulation of genetic error in ageing			A2*							

Patterns of inheritance

The curriculum content related to patterns of inheritance is almost entirely taught in the second (A2) year of the A level course. It can be expected that all students who have completed an A level Biology course will have covered basic genetic terminology and the principles of Mendelian inheritance. Approximately half of the courses will have taken this further to introduce concepts of dihybrid crosses and co-dominance.

Patterns of inheritance	AQA Biology Specification A	AQA Human Biology Specification A	AQA Biology Specification B	CCEA Biology	Edexcel Biology	Edexcel Biology (Human)	Edexcel Biology (Salters-Nuffield)	OCR Biology	OCR Human Biology	WJEC Biology
Alleles as different forms of a gene	A2	A2	AS	A2	A2	A2	AS	A2	A2	A2
Genetic terminology: genotype, phenotype, recessive, dominant, homozygote, heterozygote	A2	A2	A2	A2	A2	A2	AS	A2	A2	A2
Monohybrid crosses	A2	A2	A2	A2	A2	A2	AS	A2	A2	A2
Dihybrid crosses	A2	A2	A2	A2			A2	A2		A2
Co-dominance (monohybrid)	A2	A2	A2	A2				A2	A2	A2
Polygenic inheritance	A2	A2		A2			A2	A2		
Sex linkage	A2	A2	A2	A2				A2		A2
ABO blood groups					A2	A2		A2*	A2	
Test crosses				A2				A2		
Epistasis			A2	A2						

Population genetics

All of the specifications include some aspect of population genetics, but almost all of it is covered in the second (A2) year of the course. None of the topics are covered by all of the A level Biology syllabi; it is therefore difficult to make assumptions about what students may already know about these topics.

Population genetics	AQA Biology Specification A	AQA Human Biology Specification A	AQA Biology Specification B	CCEA Biology	Edexcel Biology	Edexcel Biology (Human)	Edexcel Biology (Salters-Nuffield)	OCR Biology	OCR Human Biology	WJEC Biology
Continuous and discontinuous variation	A2	A2		A2	A2	A2				A2
Genes and environment leading to variation	A2	A2	A2				AS			A2
The gene pool and allele frequencies	A2	A2		A2	A2	A2		A2	A2	A2
Hardy-Weinberg equation	A2	A2		A2					A2	

Applications of genetics

The coverage of topics illustrating the applications of genetics shows a great degree of variability, both in the specifics of the syllabus content and the part of the A level course in which it is covered. In general a student completing A level Biology should have some understanding of the applications of genetics. In the case of the OCR Biology course almost all of these applications are covered in an optional module.

Applications of genetics	AQA Biology Specification A	AQA Human Biology Specification A	AQA Biology Specification B	CCEA Biology	Edexcel Biology	Edexcel Biology (Human)	Edexcel Biology (Salters-Nuffield)	OCR Biology	OCR Human Biology	WJEC Biology
Recombinant DNA (restriction endonuclease, DNA ligase, reverse transcriptase, antibiotic marker gene)	AS	AS	AS	AS	A2	A2		A2*	A2	AS
Polymerase Chain Reaction (PCR)	AS		AS		A2	A2				
Gel electrophoresis	AS	AS	A2*		A2	A2	AS	A2*		AS
Genetically Modified Organisms (GMO)			AS	AS	A2	A2	AS	A2*	A2	AS
Issues around GMO			AS	AS	A2	A2	AS	A2*	A2	AS
Human Genome Project					AS	AS	AS	A2	AS	AS
Ethical issues surrounding the HGP					AS	AS	AS		AS	AS
Cloning - advantages and disadvantages			AS		AS	AS				A2
Gene therapy			AS	AS		A2	AS	A2*	A2	AS
Vectors in gene therapy			AS	AS				A2*		AS

Applied genetics and genetic conditions

The applied and clinically related aspects of genetics are addressed to differing degrees by differing syllabi, from no coverage in the AQA Specification A documents to substantial coverage by the OCR Human Biology Specification. We have listed the genetic conditions specifically mentioned by the A level courses were also listed, highlighting some of the diseases with which students may be familiar.

Applied genetics and genetic conditions	AQA Biology Specification A	AQA Human Biology Specification A	AQA Biology Specification B	CCEA Biology	Edexcel Biology	Edexcel Biology (Human)	Edexcel Biology (Salters-Nuffield)	OCR Biology	OCR Human Biology	WJEC Biology
Risk of inherited disease (the role of family history)					A2				A2	
Genetic screening in identification of carriers, prenatal testing and embryo testing			A2*		A2		AS	A2*	AS	
Need for genetic testing					A2			A2*	A2	
Options available (treatment, termination of pregnancy)					A2					
Social, moral, ethical and cultural issues related to genetic screening					A2		AS		A2	
Issues surrounding IVF								A2*	A2	
Thalassaemia							A2			
Albinism							A2			
Huntington disease								A2*	A2	
Sickle cell anaemia					A2				AS	A2
Haemophilia										A2
Cystic fibrosis			AS				AS	A2*	A2	AS
Down syndrome				A2	A2	A2		A2*	A2	A2
Turner syndrome									AS	
Klinefelter syndrome									AS	

This section has highlighted the commonalities and differences between the UK examination boards' coverage of genetics in A level Biology. The next section of this report will examine the genetics content of International Baccalaureate Biology courses.

7. The genetics content of the International Baccalaureate Biology Course

Genetics in the Core and Additional Higher Level (AHL) modules:

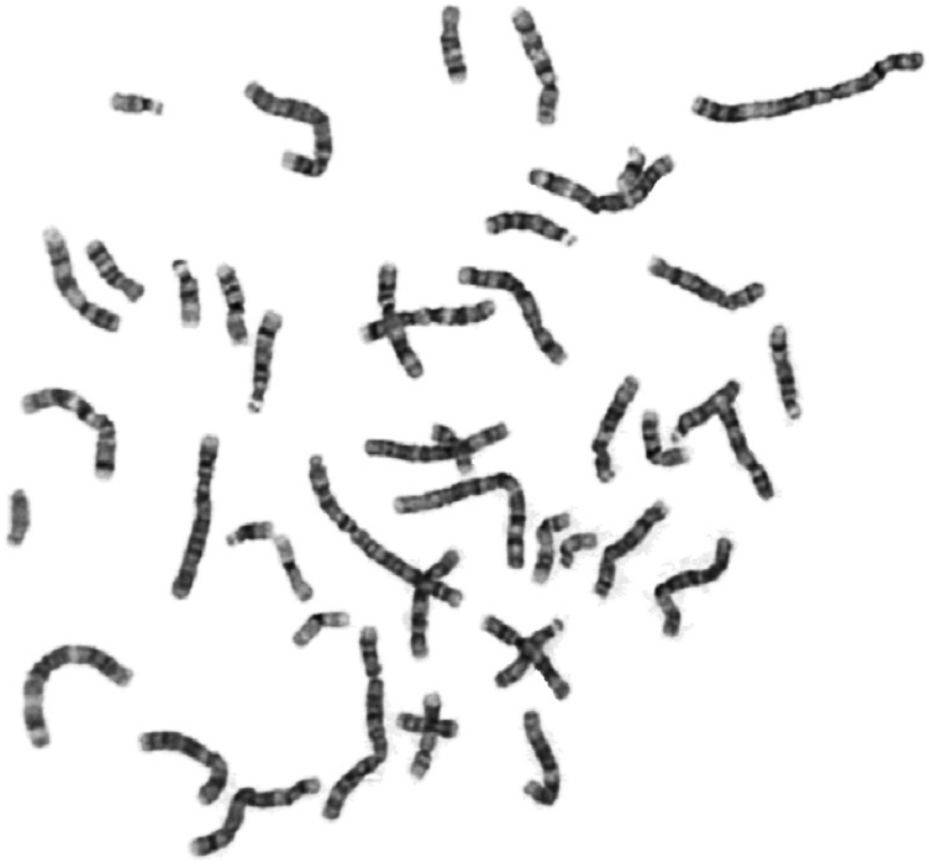
The Core component of the IB Biology course consists of six topics:

1. Statistical analysis
2. Cells
3. The chemistry of life
4. Genetics
5. Ecology and evolution
6. Human health and physiology

The concepts introduced here are extended in more detail for the Higher Level students by the five Additional Higher Level modules:

7. Nucleic acids and proteins
8. Cell respiration and photosynthesis
9. Plant science
10. Genetics
11. Human health and physiology

The genetics components of the course are presented in the subsequent tables:



Topic 2: *Cells (Standard level) and Topic 7: Nucleic acids and proteins (AHL):*

STANDARD LEVEL (Completed by all students)	ADDITIONAL HIGHER LEVEL (Completed by all higher level students)
Cell structure and division • Structure of prokaryotic and eukaryotic cells • Cell cycle • DNA replication and protein synthesis in interphase • Stages of mitosis • Role of mitosis • Tumours as the result of uncontrolled cell division	
Stem cells • Stem cells • Cloning - advantages and disadvantages • Ethical issues in cloning	
Structure and replication of DNA • Structure of nucleotides in DNA • Base pairing and hydrogen bonding • Semi-conservative replication of DNA (including the roles of DNA polymerase & helicase)	• Structure of DNA (antiparallel, 3'-5' linkages, hydrogen bonding between purines and pyrimidines • DNA replication (5'-3' direction, roles of helicase, DNA polymerase, RNA primase, DNA ligase, Okazaki fragments and deoxynucleoside triphosphates • Structure of nucleosomes • Satellite DNA • Exons and introns in eukaryotic genes
Protein synthesis • Transcription (including the role of RNA polymerase)	• Transcription (5'-3' direction) • Sense and antisense strands of DNA • Transcription in prokaryotes (including the role of the promoter, RNA polymerase, nucleoside triphosphates and the terminator) • Removal of introns in eukaryotic RNA
• Translation	• Ribosome structure, subunits and RNA binding sites • Role of free ribosomes and bound ribosomes • Translation (5'-3' direction) • Translation: initiation, elongation, translocation and termination • Translation: the binding of an amino acid to tRNA by tRNA-activating enzymes • Structure of a peptide bond between amino acids
The genetic code • The nature of the genetic code • One gene-one polypeptide hypothesis	

Topic 4: *Genetics (Standard level) and Topics 10: Genetics (AHL):*

STANDARD LEVEL (Completed by all students)	ADDITIONAL HIGHER LEVEL (Completed by all higher level students)
Genes and mutation • Genetics terminology (including gene, allele, genome and gene mutation) • Substitution mutation • Sickle-cell anaemia	
Chromosomes and meiosis • Chromosome structure • Meiosis to produce haploid cells • The stages of meiosis and crossing over	• Autosomes and sex chromosomes • The behaviour of chromosomes in meiosis • The formation of chiasmata in crossing over • Crossing over and exchange of alleles • Meiosis as a source of variation • Mendel's law of independent assortment
Chromosome abnormalities • Non-disjunction • Down syndrome • Karyotyping • Pre-natal diagnosis (chorionic villus sampling and amniocentesis)	
Inheritance patterns • Definitions (genotype, phenotype, dominant allele, recessive allele, codominant alleles, locus, homozygous, heterozygous, carrier and test cross) • Monohybrid cross (Punnett grid) • Multiple alleles • ABO blood group system • Inheritance of sex • Sex linkage • Colour blindness • Haemophilia • Interpreting pedigrees	• Dihybrid crosses • Dihybrid crosses involving linked genes • Polygenic inheritance • Continuous variation
Applications of genetics: • Polymerase Chain Reaction (PCR) • Gel electrophoresis • DNA profiling • Paternity testing • Forensic applications • The Human Genome Project • The nature of the genetic code	
Genetic modification: • Gene transfer (including plasmids, the host cell, restriction enzymes and DNA ligase) • Genetically Modified Organisms (GMO) • Ethical issues surrounding GMO • Cloning • Ethical issues surrounding cloning	

Genetics in the Optional modules:

There are number of optional modules available for IB students. Those offered at standard level only are:

- **A.** Human nutrition and health
- **B.** Physiology of exercise
- **C.** Cells and energy

Those offered at standard level with a higher level extension are:

- **D.** Evolution
- **E.** Neurobiology and behaviour
- **F.** Microbes and biotechnology
- **G.** Ecology and conservation

One module is offered at higher level only:

- **H.** Further human physiology

Genetics topics exist in options A, D and F:

Option A: *Human nutrition and health (Standard level only)*

STANDARD LEVEL (Completed by all students enrolled on this module)
• The causes and consequences of phenylketonuria • The need for early diagnosis and a special diet

Option D: *Evolution (Standard and Higher levels)*

STANDARD LEVEL (Completed by all students enrolled on this module)	ADDITIONAL HIGHER LEVEL (Completed by all higher level students enrolled on this module)
• The properties of RNA • Allele frequency and the gene pool • Sickle-cell anaemia	• Universality of DNA • Hardy-Weinberg principle

Option F: *Microbes and biotechnology (Standard level only)*

STANDARD LEVEL (Completed by all students enrolled on this module)
• Nucleic acids within viruses • Uses of reverse transcriptase • Somatic and germ-line therapy • Vectors in gene therapy • Risks of gene therapy

In the next section of this report, the ways in which the Biology curricula are assessed will be discussed.

8. Assessment

Assessment of A level Biology:
The methods used by examination boards in the assessment of AS and AS Biology are summarised in the table below. All of the boards rely upon end of module examinations and coursework for the assessment of the AS level courses, with two examination boards, OCR and WJEC including a practical examination or timed assessment. All of the A2 courses include end of module assessments and assessment of practical work (either coursework, examination or timed assessment). The A2 course also includes synoptic (combined) examinations designed to assess the underlying core biological concepts learned over the span of the two years. Some examination boards set a separate synoptic paper, others integrated synoptic questions into their A2 end of module tests.

		End of module examination	Separate synoptic examination	Synoptic questions as part of an end of module	Centre (School) assessed coursework	Practical examination / assessment
AQA A level GCE Biology Specification A	AS	✓			✓	
	A2	✓	✓	✓	✓	
AQA A level GCE Human Biology Specification A	AS	✓			✓	
	A2	✓	✓	✓	✓	
AQA A level GCE Biology Specification B	AS	✓			✓	
	A2	✓	✓	✓	✓	
CCEA A level GCE Biology	AS	✓			✓	
	A2	✓	✓		✓	
Edexcel A level GCE Biology	AS	✓			✓	
	A2	✓	✓	✓	✓	
Edexcel A level GCE Biology (Human)	AS	✓			✓	
	A2	✓	✓	✓	✓	
Edexcel A level GCE Biology (Salters-Nuffield)	AS	✓			✓	
	A2	✓	✓		✓	
OCR A level GCE Biology	AS	✓			✓	✓
	A2	✓	✓		✓	✓
OCR A level GCE Human Biology	AS	✓			✓	✓
	A2	✓	✓		✓	✓
WJEC A level GCE Biology	AS	✓				✓
	A2	✓		✓		✓

Specimen papers for these examinations can be accessed from the examination boards' websites. Further details are provided in Section 11.

Assessment of International Baccalaureate Biology:
The assessment of the International Baccalaureate Biology Programme is outlined below (modified from International Baccalaureate Organization, 2007):

	STANDARD LEVEL ASSESSMENT	HIGHER LEVEL ASSESSMENT
Paper 1	30 multiple-choice questions on the core	40 multiple-choice questions (±15 common to Standard Level plus about five more on the core and about twenty more on the Additional Higher Level)
Paper 2	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)	Section A: one data-based question and several shore-answer questions on the core and the Additional higher Level (all compulsory) Section B: two extended-response questions on the core and the Additional Higher Level (from a choice of four)
Paper 3	Several short-answer questions in each of the two options studied (all compulsory)	Several short-answer questions an done extended-response question in each of the two options studied (all compulsory)

9. Summary of findings

A level Biology Courses

Approximately a quarter (26%) of the genetics topics identified in this study are covered by all of the different examination boards' A level Biology specifications.

All students who have completed AS level Biology will have covered the following topics:

- The structure of prokaryotic and eukaryotic cells
- The cell cycle
- The stages of mitosis
- The significance of mitosis
- The role of meiosis in producing haploid cells
- The structure of nucleotides
- The structure of nucleic acids (including base pairing and hydrogen bonding)
- The semi-conservative replication of DNA (including the role of DNA polymerase)
- The nature of the genetic code
- Transcription
- Translation

Those students who have gone on to take Biology at A2 level, regardless of examination board, will also have covered:

- The stages of meiosis
- Meiosis as a source of variation
- The random assortment of chromosomes and crossing over
- Gene mutation
- Alleles as different forms of a gene
- Genetics terminology including genotype, phenotype, recessive, dominant, homozygote, heterozygote
- Monohybrid crosses

International Baccalaureate Biology Courses

All students who have completed Biology as their group 4 experimental science option at International Baccalaureate will have covered the following topics:

- The structure of prokaryotic and eukaryotic cells
- The cell cycle
- DNA replication and protein synthesis in interphase
- Stages of mitosis
- Role of mitosis
- Tumours as the result of uncontrolled cell division
- Stem cells
- Structure of nucleotides in DNA
- Base pairing and hydrogen bonding
- Semi-conservative replication of DNA
- Transcription
- Translation
- One-gene-one polypeptide hypothesis
- Genetics terminology (including gene, allele, genome and gene mutation)
- Substitution mutation

- Sickle-cell anaemia
- Chromosome structure
- Meiosis to produce haploid cells
- The stages of meiosis and crossing over
- Non-disjunction
- Down syndrome
- Karyotyping
- Pre-natal diagnosis (chorionic villus sampling and amniocentesis)
- Definitions (genotype, phenotype, dominant allele, recessive allele, codominant alleles, locus, homozygous, heterozygous, carrier and test cross)
- Monohybrid cross (Punnett grid)
- Multiple alleles
- ABO blood group system
- Inheritance of sex
- Sex linkage
- Colour blindness
- Haemophilia
- Interpreting pedigrees
- Polymerase chain reaction (PCR)
- Gel electrophoresis
- DNA profiling
- Paternity testing
- Forensic applications
- The Human Genome Project
- The nature of the genetic code
- Gene transfer (including plasmids, the host cell, restriction enzymes and DNA ligase)
- Genetically modified organisms (GMO)
- Ethical issues surrounding GMO
- Cloning
- Ethical issues surrounding cloning

A level Biology and International Baccalaureate findings combined

Students who have taken AS, A level or International Baccalaureate Biology, regardless of examination board, will have covered the following genetics topics:

- The structure of prokaryotic and eukaryotic cells
- The cell cycle
- The stages of mitosis
- The significance / role of mitosis
- The role of meiosis in producing haploid cells
- The structure of nucleotides
- The structure of nucleic acids (including base pairing and hydrogen bonding)
- The semi-conservative replication of DNA(including the role of DNA polymerase)
- The nature of the genetic code
- Transcription
- Translation

10. Applying the findings to pre-registration health professional genetics teaching

The findings from this report have identified the topics in genetics that will have been covered by pre-registration health professional students if they have completed A level or International Baccalaureate Biology courses. Many students may therefore have previously learned aspects of cell biology, molecular biology, patterns of inheritance and applications of genetics in their pre-university studies.

As many health professional courses do not specify A level Biology as a pre-requisite course, educators will face the challenge of teaching students with varied levels of understanding, from little or no knowledge of genetics through to a reasonable understanding of the underlying concepts. Should the educator move too quickly through the genetics material, they may lose the less knowledgeable students; move too slowly and they may not challenge the more knowledgeable.

The use of clinical scenarios in teaching genetics to health professional students may assist genetics educators in delivering concepts. Using a patient story to connect the relevant aspects of cell biology, molecular biology, inheritance patterns and applications of genetics (such as genetic testing), the students who have not previously completed advanced level Biology courses will be introduced to the concepts that they will require in their future profession. For the students who have completed advanced level Biology courses, they will revisit topics to which they have previously been introduced, but from a new, clinically relevant and practically focused perspective.

A number of patient stories that could be used for teaching pre-registration health professional students are available from the 'Telling Stories - Understanding Real Life Genetics' website (www.geneticseducation.nhs.uk/tellingstories) The stories can be searched, are available in a number of formats and are supported by teaching and learning resources such as activities, points for reflection and sources of further information. In addition, case histories with questions and answers covering concepts such as Mendelian inheritance and chromosome anomalies are available in the 'teaching genetics' section of the website.

11. Sources of further information

Examination boards

Examination board websites make curricula specification documents freely available in pdf format. The International Baccalaureate Organisation charges a fee. Many examination boards provide resources and courses for teachers as well as specimen examination papers and marking schemes.

- The Assessment and Qualifications Alliance (AQA) (http://www.aqa.org.uk/)
- Council for the Curriculum Examinations and Assessment (CCEA) (http://www.rewardinglearning.org.uk/)
- Edexcel (http://www.edexcel.org.uk/home/)
- Oxford Cambridge and RSA Examinations (OCR) (http://www.ocr.org.uk/index.html)
- Welsh Joint Education Committee (WJEC) (http://www.wjec.co.uk/)
- International Baccalaureate Organization (IBO) (http://www.ibo.org/diploma/)

12. Resources to support advanced level Biology topics

Books

There are a large number of A level Biology textbooks available. Some covering a wide range of topics, others are specific to an examination board and some are specific to a particular module within an examination board's specification. The following list was generated using a popular commercial website specialising in book sales and is by no means exhaustive.

Generic A level Biology textbooks

This short list provides a snapshot of the large number of A level Biology texts available:

- Kent, M. (2000). Advanced Biology. Oxford University Press. ISBN: 0199141959
- Toole, G. & Toole, S. (1999). New Understanding Biology for Advanced Level (4th edition). Nelson Thornes. ISBN: 0748739572.
- Roberts, M., Reiss, M. & Monger, G. (2000). Advanced Biology. Nelson Thornes. ISBN: 0174387326.
- Williams, G. (2000). Advanced Biology for You. Nelson Thornes. ISBN: 0748752986.

Syllabus specific A level Biology textbooks

AQA Biology Specification A:

- Indge, B., Baker, M. & Rowland, M. (2000). A New Introduction to Human Biology. Hodder Murray. ISBN: 0340781661.
- Baker, M., Indge, B. & Rowland, M. 2001). Further Studies in Human Biology. Hodder Murray. ISBN: 0340802456.

AQA Biology Specification B:

- Lea, C., Lowrie, P. & McGuigan, S. (2000). AS Level Biology for AQA Specification B. Heinemann Educational Publishers. ISBN: 0435580833.
- Lea, C., McGuigan, S., Pauline, A. & Lowrie, P. (2001). Advanced Level Biology A2: For AQA Specification B. Heinemann Educational Publishers. ISBN: 0435580817.

AQA Human Biology Specification A:

- Indge, B., Rowland, M. & Baker, M. (2000). A New Introduction to Human Biology. Hodder Murray. ISBN: 0340781661.
- Baker, M., Indge, B. & Rowland, M. (2001). Further Studies in Human Biology. Hodder & Stoughton Ltd. ISBN: 0340802456.

CCEA Biology

No specifically tailored textbooks to support the CCEA specification were found during the search.

Edexcel Biology and Human Biology:

Books are available from Philip Allan publishers to support each of the individual modules that make up these courses.

Edexcel Biology (Salters-Nuffield)

- Salters-Nuffield (2005). Salters-Nuffield Advanced Biology AS: Student Book. Heinemann Educational Publishers. ISBN: 0435628577.
- Salters-Nuffield (2005). Salters-Nuffield Advanced Biology A2: Student Book. Heinemann Educational Publishers. ISBN: 0435628585.

OCR Biology and Human Biology:

A range of books are available from a number of publishers to support the OCR specifications.

WJEC Biology:

No specifically tailored textbooks to support the WJEC Biology specification were found during the search.

International Baccalaureate Biology textbooks

Course companions for the Biology International Baccalaureate course are available from Oxford University Press.

13. References

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Supporting genetics education for health
www.geneticseducation.nhs.uk