FINAL REPORT

A Level Biology, Higher Education and Research in the Biological Sciences

Final Report

October 2003

Prepared for The Wellcome Trust by:
Centre for Education and Industry
University of Warwick
Coventry
CV4 7AL

Tel: 024 7652 3909
Fax: 024 7652 3617

CONTENTS

Authoring Team in the preparation of the report

Julian Stanley	Regional Director CEI University of Warwick
Peter Stagg	Regional Director CEI University of Warwick
Dr Ruchira Leisten	Research Fellow CEI University of Warwick
Dr Sue Barker	University of Warwick Institute of Education
Dr Paul Elliott	University of Warwick Institute of Education
Professor Prue Huddleston	Director CEI University of Warwick

Acknowledgements

The Centre for Education and Industry at the University of Warwick would like to thank all of the students, teachers, tutors, lecturers and representatives of key organisations in biological sciences who gave freely of their time and expertise to ensure the research was as comprehensive as possible.

SECTION 1: EXECUTIVE SUMMARY

Purpose of the Research

1.1 This research was carried out for the Wellcome Trust by the Centre for Education and Industry at the University of Warwick. Field research took place between July 2002 and March 2003. The Wellcome Trust was seeking to establish how well existing A Level Biology courses meet the needs of modern biological sciences, the aims of schools and FE colleges, the aspirations and concerns of young people, and the requirements of Higher Education.

1.2 The research set out to address the following key questions:

- How teachers and students are responding to the current A Level courses
- How effective current A Level Biology courses are in providing a foundation for undergraduate and post-graduate study
- Why Biology A and AS level are popular with students who may not wish to pursue a career in science
- Whether specific content can be identified which should be retained or removed in order to ensure that it retains its popularity, but also meet the needs of students progressing to higher level study
- How well A Level Biology reflects the changing research priorities of biological sciences

1.3 Specific objectives of the research were to:

- To inform teachers and curriculum designers about important research topics in the biological sciences that may be neglected at A Level
- To identify the skills and knowledge deemed essential at post-16 level to ensure progression to contemporary undergraduate and postgraduate life sciences
- To indicate the components of existing courses that enthuse and excite young people, notably those who study the subject for intrinsic interest rather than career aspiration

The Scope of the Research

1.4 The research incorporated surveys of views, opinions and perceptions of key stakeholder groups in the biological sciences, using qualitative and quantitative methods. The surveys included

- Questionnaire surveys of current AS and A level students
- Questionnaire survey of A level biology teachers

- Questionnaire surveys of current undergraduate and postgraduate students in biological sciences
- Focus group interviews with AS an A level students
- Focus group interviews with undergraduate and postgraduate students
- Individual interviews with university tutors in the biological sciences, and with university admissions tutors
- Collection of written responses, with some telephone responses from representatives from 'Learned Societies' for the biological sciences

The research was carried out in England, involving schools, colleges and universities across the country. The sample included a cross section of different types of school (e.g. state comprehensive, selective, independent). FE colleges were also included. The sample group of universities also reflected a range of institutions.

Overview of the Research Findings

1.5 AS and A2 Level Biology Students

1.5.1 The main factors motivating students to choose to study AS/A2 biology are interest, enjoyment and aptitude in the subject. In addition, students' aspirations in terms of high level study and employment are also significant motivators.

1.5.2 A level students show clear preferences for certain topics in biology. They are particularly interested in human and medical biology. Cell biology, genetics, biochemistry, and some aspects of physiology (brain, and reproduction) are also popular. The least favoured topics are ecology, plant biology and food production.

1.5.3 A level students agree that biology contains substantial factual content, both in terms of breadth and depth (more so than other sciences). However, the evidence does not show widespread concern that the factual content is excessive. Some students actively enjoy the descriptive nature of the subject, which may make it accessible to students with a broad range of interests, and perceived to be 'easier' than other sciences. Whilst the factual content was accepted by the majority of students, some did complain about the extent to which assessment relies on memory recall.

1.5.4 The survey indicated substantial variation in the amount of practical work undertaken during A level biology courses, with some students having far more experience than others. Students enjoy and value practical work and believe that it does promote understanding and retention. Most felt that the amount of practical work reduced significantly in A2. There was even more variation in experience of field work. Some students do no field work at all, while others have substantial, sometimes residential opportunities.

1.5.5 There were mixed views about coursework. Some students felt that coursework gave students an opportunity to show different capabilities. However others felt that coursework was excessively time consuming and unreliable as a form of assessment.

1.5.6 Evidence from this research does not suggest that A level students believe there is a need for fundamental change in the content or list of topics within biology A level. A substantial majority believe that biology A level should provide a broad foundation in the subject. Whilst significant numbers of

students may be negative about particular topics, this did not translate into a consensus for dropping these topics.

1.5.7 Student perceptions of current priorities in biological science tended to match their interests, with human health, and genetics featuring strongly. Students value opportunities to discuss current research, ethical and social issues. Although opportunities for this were limited, this process does generate enthusiasm. Students seemed more likely to gain an acquaintance with current research when they did optional units than through mandatory units.

1.5.8 Biology A level does seem to have a positive influence in confirming the aspirations of those students who were hoping to take biological sciences at university. However, less than half of these students felt that biology A level had helped them decide which branch of biological science they wanted to follow. A substantial (and unrealistic) proportion of students studying AS and A2 biology say that they plan to study medicine.

1.6 A Level Biology Teachers

1.6.1 A level biology teachers believe that students are motivated to choose the subject by interest, aptitude and prospects for progression. In addition, half of all teachers agreed that students believe biology is easier than other sciences, and that this may be a factor in its broader appeal to a wide range of students.

1.6.2 There was no clear consensus amongst the teachers in this survey on whether A level biology was 'overloaded' with facts. However, more than half the teachers felt that learning facts seemed more important than developing understanding or critical skills. Also a majority of teachers believed that there was insufficient opportunity for practical work and field work in A level biology. Experienced teachers reported that they were doing less practical work with their classes than in previous years. Course work was criticised by a number of teachers as being dull, contrived and time consuming, serving the purpose of assessment, rather than the development of scientific skills and techniques.

1.6.3 The topics in A level biology which most interest teachers correlate closely with the views of students, with human and medical biology and genetics being rated highly. Teachers share the students' relative lack of interest in plant biology and food production, although they do clearly identify these topics as 'important'.

1.6.4 A level biology teachers do report opportunities for professional development However, their professional development is heavily weighted towards mandatory training in generic issues (e.g. assessment) and attention to course specifications. Opportunities for biology teachers to develop their own subject knowledge and understanding are relatively rare, and experienced teachers report that such opportunities have been reduced in recent years, as other training requirements have taken precedence. There has been significant professional development provision in science at Key Stage 3, but this research suggests gaps in professional development for A level teaching.

1.6.5 A substantial majority of teachers felt that A level biology should offer a broad foundation in the subject, providing a qualification which offers a wide choice

of progression routes. However, a majority of teachers were also in favour of greater choice within the A level (e.g. through a core plus specialist options). This was regarded by some as a strategy which could allow current research issues to be addressed. Overall, there was a diversity of views on the extent to which A level biology can reflect developing research issues, although the importance of this was acknowledged.

1.6.6 Many teachers felt they were not fully up to date with the range of options available in biological science in higher education, and that it was difficult for students to make a choice. The provision of common foundation years or shared modules by universities was regarded as helpful in dealing with this situation.

1.6.7 Whilst some teachers expressed strong views about the content of A level biology, no clear consensus emerged about specific changes in content. Less than a third of teachers surveyed felt there were topics which could be dropped from the course. However, over half of the teachers felt that more time should be devoted to topical issues in biological sciences. A number of teachers identified a lack of knowledge of chemistry as a significant disadvantage for students taking A level biology.

1.7 Undergraduate and Postgraduate Students

1.7.1 The principal motivating factors which had led students to choose to study biology at A level and beyond were interest and aptitude in the subject and career prospects. Parents, teachers and the media are also influential. Biology has remained a popular subject and the strong human biology content provides intrinsic interest for many people.

1.7.2 Undergraduates and postgraduates show similar topic preferences to A level students within the subject. Evolution, genetics, human and medical biology are particularly popular. Plants and plant science tend to be the least popular topics. There is evidence that some students 'discover' an interest in aspects of plant biology through the options they study at university. However, the plant sciences clearly have greatest difficulty in recruiting students on to degree courses. Some topic areas showed more varied responses. Ecology appeared relatively unpopular with many students, although some students were much more enthusiastic.

1.7.3 Undergraduates and postgraduates reported widely differing experiences with regard to practical and field work during their biology A level courses. Some students recalled limited and rather dull practical work, and, in some cases, no experience at all of field work. In contrast, other students had clearly experienced a rich variety of practical work, and specialised field work, which, for some, had stimulated interest in ecology. Whilst the survey samples are too small to draw firm conclusions, the evidence does suggest that significant inequalities in opportunities for practical and, especially, field work, may be linked to type of school. Some independent schools may offer significantly more access to these opportunities than other types of school. The level of enthusiasm of individual teachers for this type of work is also likely to be a contributory factor

1.7.4 Undergraduates and postgraduates named similar topics to A level students when asked about current research priorities. Responses were weighted

towards human health issues. Research into major diseases (e.g. AIDS, cancer), genetics, genomes and environmental issues were identified by a number of respondents. Students did believe that ethical and controversial issues should be included in A Level biology and reported that they had engaged in discussion of such issues when they were doing A level, not only in biology, but, sometimes, also in general studies.

1.7.5 Undergraduates and postgraduates felt that A Level biology did provide a reasonably good foundation of knowledge for degree level studies in biological sciences. There were some mixed views about the extent to which A level might allow more specialisation, but the general consensus seemed to favour keeping the A level broad, and allowing specialisation at degree level.

1.8 University Tutors

1.8.1 University tutors identified the same motivating factors as other groups for the uptake of biology at A Level and beyond, i.e. interest, aptitude and career prospects. As with A level teachers, views were also expressed that biology gains some popularity through its perception as a relatively 'soft' science in comparison with physics and chemistry, making it more accessible to students with a less 'scientific' mentality and giving the subject broad appeal. Some university tutors noted that many students' interests were weighted towards human biology. Also, a significant number of students enrolling on degrees in biological sciences are hoping to use this route into medical or related professions

1.8.2 Most university tutors believe that A level biology should provide a broad foundation of knowledge in the subject and feel that most areas of biological knowledge are well covered. However, the structure of the A level and option choices seem to result in some students entering degree courses lacking this broad foundation. Areas such as biochemistry cell biology, and molecular biology seem well covered, and many students have experienced a course with an emphasis on human biology. There is evidence that environmental biology is less well covered at A level. Tutors, especially those specialising in the field, also felt that plant sciences were seriously under-represented at A level and that most students had little interest in plants. There was a feeling that A level biology had given students a rather disconnected view of living organisms, focusing on chemical, genetic and cellular, rather than developing an understanding of the functioning of whole organisms. The lack of confidence that A level biology provides a broad foundation has contributed to the development of 'foundation' courses or similar broad based first year degree programmes, which will mean some students are repeating work done previously. However, tutors feel it is important to establish common baselines from which to progress and specialise. Some tutors view this general introduction as being an appropriate role for the first year of degrees, given the extensive choice of specialist fields in modern biological sciences.

1.8.3 A number of tutors identified important gaps in students' knowledge of other subjects which had an adverse effect on their progress. Chemistry and mathematics were identified as being of particular importance. This issue was becoming more prominent given the more flexible range of subject choice at A level. Some universities feel it is necessary to provide special courses to fill knowledge gaps in these subjects.

1.8.4 University tutors reported that the practical skills of students were variable and often not well developed. However, this was not always defined as a problem, with some tutors saying that these skills could be developed at university, and, in any case, it was unrealistic to expect schools to be able to offer the range of equipment and technical support for sophisticated practical work. There were mixed views on the standard of analytical and reasoning skills, although some tutors believed these skills were improving. It was also felt that some research and information-finding skills were improving, especially in the use of the internet. However, students were not always very discerning about the quality of information, and their use of books and other sources was often under-developed.

1.8.5 Widespread concern seems to exist about weaknesses in numeracy and mathematical skills. Also, a number of tutors identified a lack of ability in students to structure an argument in an extended piece of writing, a skill which does matter in writing reports and scientific papers. However, the standard and confidence shown by students in oral communication, presentation and discussion was generally thought to have improved significantly in recent years.

1.8.6 Some university tutors report that it is quite common for students initially to make a wrong choice of degree specialism. There is a very wide range of courses available in biological sciences and A level biology students do not always have sufficient information or knowledge to make the 'right' choice. This partly explains the popularity of general biology courses or common modules in the first year of degree programmes, allowing students to specialise later. Some tutors surveyed regarded this as a positive feature, rather than a problem, allowing students more time to mature and develop their interests. Also, it does not necessarily follow that a topic which is enjoyable to a student at A level will be a good choice of degree. Genetics was one area mentioned several times, where students find degree level work is very different to experiences at A level. Many university tutors have little or no contact with teachers of A level biology.

1.8.7 Some tutors expressed the view that the purpose of A level biology is not clear. Its function as a preparation for higher level study in biological sciences is not entirely compatible with its role as a popular, versatile and accessible subject which is part of a good general education and prepares people for a wide range of progression routes and careers, which may or may not be scientifically oriented. The present position was seen by some as a compromise, and careful reflection is needed to ensure the subject is clear about its purpose at A level and that future development should be based on this.

1.8.8 Most university tutors supported the principle that the content of A level biology should provide a broad foundation in the subject. Views were expressed that some areas were being marginalised due to emphasis on more 'popular' topics. Most notably, it was felt that plant biology was losing out to human biology. Tutors acknowledged that biology required extensive factual learning, but this was not generally viewed as a problem. Many tutors felt that it was too soon to judge whether recent changes in A level course structure were beneficial or not. Some did express concern that the new structure might reduce scope for exploration and reflection.

1.8.9 University tutors generally do believe that the A level course should include topical issues and priority areas. However, they urged caution in this, based on the possibility that some 'priorities' may turn out to be of little long term importance. Selection of new topics should be based on firm belief that the topics are of lasting scientific significance. Overall, tutors felt that the A level course has responded to developments in biological science (e.g. by reflecting the rapid advance in cell biology and genetics).

1.8.10 University tutors felt that biology A level had little influence on whether people pursued the subject through to postgraduate study. The first degree was felt to be the main influence on this decision. Tutors were not critical of A level in this respect and did not expect A level to do more than maintain and build interest and enthusiasm for students to progress onto first degree courses.

1.8.11 Admissions tutors felt that A level biology grades (and other A level grades) were poor indicators of final degree performance. School background was believed to play an important part in influencing A level grades, with some schools 'specialising' in achieving high grades. These students are often out-performed at final degree level by others who came from lower-performing schools with lower A level grades. Motivation, independence and determination, along with real ability are required for top performance at degree level. It is possible to achieve a high A level biology grade with only fairly average ability. Admissions tutors with these views supported active measures to widen participation, recruiting students with slightly lower A level grades from 'less advantaged' schools.

1.9 The Learned Societies

A range of learned societies were approached and feedback was gathered on their perceptions of A level biology in preparing students to progress in the biological sciences. All respondents commented on areas for potential development or improvement, although no clear consensus emerged from this relatively small sample. A significant number of respondents expressed concern about the character and volume of assessment within the reformed A level. Diverse views were expressed about the strength of links between current research priorities and A level biology. This diversity may arise from the complexity of the 'bioscience community', represented by a large number of learned societies, each with their own area of specialism. Key comments are described in the main body of the report.

1.10 Research Priorities

An investigation of possible indicators of current priorities in biological research found this to be a considerable challenge within the scope of the project. Further work would be required to test and refine indicators which can truly reflect the breadth of bioscience. However, some alternative approaches are suggested, though none of these can claim to be comprehensive. Research priorities are influenced by political, economic and social factors. Within the scope of the project, limited tests were carried out using the following indicators:

- Frequency of appearance of topics in scientific articles
- Levels of funding for research in topic areas

The results obtained are shown in the main body of the report. They do suggest identifiable trends in the shifting of research priorities. Recent reform of the A level and the comments of stakeholders indicate that the A level has responded to some of the most significant developments and changed

priorities in biological science. Amongst stakeholders, opinions vary as to whether this response has been adequate or appropriate.

Section 2: Background and Introduction

This research has been carried out for the Wellcome Trust by the Centre for Education and Industry at the University of Warwick. The research took place between July 2002 and March 2003.

The Wellcome Trust is seeking to establish how well existing A level biology courses meet the needs of modern biological sciences, the aims of schools and FE colleges, the aspirations and concerns of young people and the requirements of Higher Education. The work set out to identify:

- How teachers and students are responding to the current A level courses
- How current A level biology courses prepare students embarking on related degree courses
- How current A level biology courses act as a foundation for post-graduate study
- Why biology A an AS level are chosen by those students who do not wish to pursue a career in science, and what content should be retained or removed to ensure that it retains its popularity
- How well A level biology reflects the changing research priorities of biological sciences

Particular objectives of the research were to:

- To inform teachers and curriculum designers about important research topics in the biological sciences that may be neglected at A level
- To identify the skills and knowledge deemed essential at post-16 level to ensure progression to contemporary undergraduate and postgraduate life sciences
- To indicate the components of existing courses that enthuse and excite young people, notably those who study the subject for intrinsic interest rather than career aspiration

Biology has maintained its strong popularity as a subject at A level over the past decade. During that same period chemistry A level has shown some decline, whilst physics A level has declined substantially. The QCA records of candidate numbers since 1992 illustrate these trends clearly (Table 1).

Table 1: Number of candidates entered for A level sciences (1992- 2001)

	Number of Applicants by Subject		
	Biology	**Chemistry**	**Physics**
1992	48742	42697	41301
1995	52255	42293	34802
1998	57436	41893	33769
2001	52382	38702	30802

Prepared by SIM QCA - Source: Inter Examination Board Statistics (August 2002)

This research was carried out against a background of the reformed A level system, as part of Curriculum 2000, which has had a major effect on teaching, learning and assessment at sixth form level. In addition there has been a gathering concern about science education in general, and a variety of calls and proposals for change across the range of sciences, not just biology.

The Nuffield Foundation Report '*Beyond 2000'* (Miller and Osborne 1998) (focusing mainly on the pre-16 curriculum) asserted that the content of the science curriculum at secondary level:

"has remained fundamentally unaltered, and is, essentially, a diluted form of the 1960s GCE curriculum"

Osborne and Collins (1999) survey '*Pupils, Teachers and Parents' views"* found that:

"Amongst the sciences, biology was well received, particularly by girls, but also for boys, as its relevance to their own personal lives was easily recognised"

Osborne and Collins survey also refers to science curricula as being 'content-dominated'. This is a view which is widely expressed in other surveys and discussions (eg Jenkins E (2000))

There is widespread agreement about the importance of contemporary developments and ethical issues as part of the science curriculum. One of the main recommendations of from Osborne and Collins work was that:

"The study of some of the issues raised by contemporary science in any science course post-14 must be an integral part of the curriculum"

Previous research supported by the Wellcome Trust (*'Valuable Lessons'* Levinson R and Turner S (2001) recommended that:

"Social, moral and ethical issues should be more clearly set out in examination specifications and syllabuses than they are at present"

The Roberts Report (2002) (*'Set for Success*) gave further attention to a range of related issues. The Roberts Report referred to concerns that:

"the (science) curriculum is overcrowded and assessment is based too much on memorisation and recall, which is unrepresentative of how science is used in life;"

and sets itself as an aim for its recommendations:

"to ensure that pupils are able to make the transition smoothly from GCSE to AS and A Level, and in turn to further and higher education in science and mathematics".

With reference to biology in particular, the situation is described by the Salters-Nuffield Advanced Biology project, (www.advancedbiology.org/course/background.asp) as follows:

"We have just entered a century that is likely to be dominated by Biology, yet advanced level Biology has seen few significant curriculum initiatives in recent years. We need a course to which students can relate: students need to know why the concepts they are learning are important. In recent years advanced level biology has become very content-led, with few of the recent innovations for the delivery of courses or in biological developments being reflected in the classroom. Despite this large numbers of students continue to study Biology at AS and A2-level".

As part of the school science curriculum, A level biology has an important role in preparing future scientists to carry forward bioscience research. In recent years, there have been dramatic advances in some areas of bioscience, such as genetics and cell biology. These advances have been described as 'revolutionary'. With reference to undergraduate biology education, the National Academy of Science (2002) stated that:

"Biological sciences have been revolutionised, not only in the way research is conducted….with the introduction of techniques such as recombinant DNA and digital technology… but also in how research findings are communicated amongst professionals and the public. Yet the undergraduate programmes that train biology researchers remain much the same as they were before these fundamental changes came on the scene"

Recommendations in the book include:

"Building a strong interdisciplinary curriculum that includes physical science, information technology and mathematics"

(*BIO2010:* Transforming Undergraduate Education for Future Research Biologists, National Academy of Science (2002))

The trend towards a more interdisciplinary approach in scientific research is highlighted by the following extracts from a paper presented by Burton Richter (1998), Director of the Stanford Linear Accelerator Centre:

"*HIV protease inhibitors were synthesised by the chemists in the pharmaceutical industry, based on the structure of HIV protease determined by the biologists, using the physicists' x-ray diffraction techniques."*

and

"The human genome project shows promise of developing the information to treat many health-related problems. It needs the development by the applied mathematicians of systems to allow efficient searching of huge databases"

At the same time, some areas of biology may be struggling to maintain their profile e.g aspects of taxonomy, classification and biodiversity. The House of Lords Select Committee on Science and Technology, reporting on the paper "*What on Earth?: The Threat to the Science Underpinning Conservation":* (4th Report, House of Lords Paper 118.1 *(2001-2)*), emphasised how important it is*:*

"to understand the diversity of living things on the earth, and the crucial expertise that systematic biologists bring to this subject"

The Select Committee went on to express 'disappointment' with the Government's response to the paper:

"particularly where it concerns grant-in-aid to the major systematics institutions"

This relates to the Government decision not to increase funding for this type of work, despite recommendations derived from the Dainton Report (1991) for funding increases equivalent to the level of inflation since 1992.

Focusing on A level biology and its role, this research set out to explore the issues further through direct questioning of the key stakeholder groups with interests in A level biology and the biological sciences. In drawing conclusions and proposing a way forward, it will be important to keep in mind the evolving scene in science education. GCSE science is undergoing significant changes, including the introduction of applied science and the likely move towards a more modular approach, based on a core plus a range of 'applied' and 'general' modules. Also the A level itself, is likely to be subject to significant further change. The DfES paper *'14-19 Opportunity and Excellence'* announced that the government is *'ready to embark' on the longer term reform of 16 plus education to create a baccalaureate-style system 'if further work shows that such a unified system can prepare young people for the varied needs of higher education and employment'*

SECTION 3: RESEARCH METHODS

The research methodology was designed to collect information from a range of stakeholders with an interest in A level biology. The survey included AS and A2 biology students, teachers of A level biology, undergraduate and postgraduate students studying biological sciences, university tutors, research supervisors and admissions tutors. A combination of questionnaires, individual and focus group interviews was used to collect both quantitative and qualitative data. In addition, some background research was done to gather views from learned societies, and to explore possible indicators of research priorities in biological sciences. It is acknowledged that the scale of the research made it necessary to use 'opportunity sampling', and whilst every effort was made to achieve a balance, it cannot be assumed that the samples are fully representative.

The survey was carried out between November 2002 and March 2003.

3.1 The Questionnaire Survey

Questionnaires were designed to gather data from AS and A2 students, A level teachers and undergraduate and postgraduate students in biological sciences. The questions were customised to be appropriate to their target groups, but were designed to carry common themes and categories so that comparisons could be made during analysis. Draft questionnaires were piloted with 30 AS and 21 A2 biology students, and appropriate amendments were made to produce the final version. Guidance on how to access the questionnaires is provided in Appendix 1.

3.2 Interviews and Focus Groups

Face to face interviews or focus groups were carried with each category of respondent. These interviews were tape recorded to check the accuracy of notes later. The tape recordings were not fully transcribed. The interviews and focus groups provide qualitative data.

3.3 Survey of AS and A2 biology students

A sample of schools was selected to provide a range of different types of school (state comprehensive, independent, selective etc) in different regions of England. One list of schools was based on Warwick University's partner schools for initial teacher training (extending over much of the Midlands). Other schools were drawn from contacts and enquiries in parts of London, Southern and Northern England. All of the schools were sent a letter explaining the nature of the research, enclosing a draft questionnaire, and inviting them to participate by running the questionnaire with groups of A level biology students. A response form was enclosed to allow schools to request the appropriate numbers of questionnaires. This strategy was adopted to minimise wastage of questionnaires and maximise the returns.

In total 108 schools were contacted, of which 38 agreed to take part in the survey (including 30 maintained secondary schools, 7 independent schools and one sixth form college. Five of the schools (four independent) were single sex (3 girls schools and 2 boys schools). Almost 1500 questionnaires were sent out to these schools

and 729 completed questionnaires were returned. These questionnaires provide quantitative data.

In addition to the questionnaire survey, the research team carried out 12 focus group interviews with A level students, 5 of which were at AS level, 5 at A2 level, and 2 were a mixture of AS and A2. The numbers of students in focus groups ranged from 3 to 17 and a total of 75 students took part.

3.4 Survey of A Level Biology Teachers

The letter sent to schools for the A level student survey also invited A level teachers at those 38 schools to complete questionnaires. Not all schools returned teacher questionnaires, and further sample schools were identified, including 39 schools identified through the network of the Association for Science Education. In total, 57 completed teacher questionnaires were collected from 34 different schools. These questionnaires provide mainly quantitative data, with some additional comments.

In addition to the questionnaire survey, face to face interviews were conducted with A level teachers. A total of 23 teachers were interviewed, of which 11 taught in mixed comprehensive schools, 7 in Colleges of Further Education, 4 in independent schools and one in a sixth form college. These interviews provide qualitative data.

3.5 Survey of Undergraduate and Postgraduate Students

A questionnaire survey was conducted with groups of undergraduate and postgraduate students. Groups were drawn from 9 different universities, (including Russell Group, new and 'other'). In total, 194 questionnaires were returned from undergraduates and 51 from postgraduates. The students were drawn from a range of disciplines across biological sciences. The questionnaires provide quantitative data with some additional comments.

In addition to the questionnaire survey, the research team carried out 5 focus group interviews, 3 of which were with undergraduates (14 students) and 2 with postgraduates (10 students) in 3 different universities. The students came from a range of disciplines including:

Molecular Biology	Biological Sciences	Biochemistry
Biomedical Science	Cellular Biology	Biology
Animal Behaviour	Sports Science and Biology	Ecology

These focus groups provide qualitative data.

Guidance on how to access the research instruments is provided in Appendix 1.

3.6 Survey of University Tutors, Research Supervisors and Admissions Tutors

Face to face interviews were carried out with 21 university tutors whose responsibilities included subject tutoring, research supervision and admissions. In addition one recruitment manager (administration) was also interviewed. These interviews took place in 11 different Universities, including Russell group, new and 'other' categories. The subject specialisms of the tutors interviewed included:

Animal behaviour/Biomechanics	Applied Biology	Biotechnology
Plant Science	Microbiology	Biochemistry
Biology	Life Sciences	Ecology
Cell and Molecular Biology	Biodiversity	Biological Science
Science Education		

These interviews provide qualitative data.

3.7 Learned Societies

The survey gathered some views from 'learned societies' about current needs in biological sciences. A letter with information about the aims of the research was sent to a range of learned societies, expressing the intention to seek their views. Information was also distributed on behalf of the research team through a network meeting of learning societies in November 2002. In January 2002 selected learning societies were contacted again and responses were received from 7 different organisations. Copies of the letters and papers used are attached at Appendix 2.

3.8 Research into Methods to indicate priorities in Biological Science Research

The research team was asked to explore ways to develop indicators which could give a measure of current priorities in biological sciences. In order to address this issue the following strategies were attempted:

- Analysis of A level curriculum to identify key subject categories
- Trial interrogation of Science Citation Index
- Consultation with experts on information analysis in related fields (CIBER Centre for Information Behaviour and the Evaluation of Research, City University), focusing on ways to utilise the Science Citation Index
- Survey of key funding council information, and more detailed links with the BBSRC (Biotechnology and Biological Research Council)

It was acknowledged that it was beyond the scope of this project to carry out a full survey in this area, but the aim was to identify some indicators or processes which might be developed further to provide a more complete measure of research priorities in the future.

SECTION 4: RESULTS

The qualitative research with teachers and students of A level biology in schools and colleges was designed to explore the kind of educational experience different participants were having. A considerable variety of responses were encountered. Not only were there different perspectives between students and teachers, but also between AS and A2 students, and between both teachers and students at different types of institution and between different individuals.

It is convenient to review findings by examining the responses of first students and then teachers.

4.1 Findings from Students of A Level Biology

There were 729 respondents to the questionnaire survey.
39% were male and 61% female. 68% were studying AS level biology and 32% A2 biology.
31% were taking two other sciences at A level
28% were taking one other science at A level
41% were taking no other sciences apart from biology

Focus groups were conducted with 75 students at 7 different schools and colleges. Focus group interviews took place with 12 groups, 5 of which were A2 students, 5 were AS students, and 2 were mixed groups of AS and A2 students

4.1.1 Choosing A Level Biology

The research team explored the reasons students cited as to why they had chosen to study biology A level. Two main themes of reasoning emerged. One was responding to an interest and/or enjoyment in the subject. The other pattern of responses concerned the necessity of the subject to fulfil university or career aspirations.

Students reported that their choice had been influenced by their success or enjoyment of GCSE biology. Students valued biology's *"relevance to everyday life"* and a number of students went on to say that they liked those topics, particularly the human biology, which most conspicuously had that relevance. 88% of questionnaire respondents agreed (of whom 40% agreed strongly) with the statement "I always found biology generally interesting".

Another motivating factor for choosing A level biology was its usefulness for future studies or work. A relatively large number of students – 54% of questionnaire respondents - were studying biology because they viewed it as a necessary preparation to some kind of medical career (including dentistry, pharmacology, pathology and physiotherapy) others expressed an interest in biochemistry. However, a substantial 38% of questionnaire respondents were strongly career orientated, implying the existence of a significant core who were already committed to study for careers that required A level biology. These career aspirations often influenced their judgement about what they found most interesting in the curriculum and it appears to have influenced the way that many students regarded the purpose of A level. For example, students often expressed an interest to learn more about particular mammalian organs or illnesses and were generally ready to value that factual knowledge which they judged as foundational to particular medical

professions but were less positive about knowledge which did not appear to be foundational in this way, e.g. botany.

Biology was also regarded as a complementary subject to support science A levels such as chemistry and psychology, *"I needed an extra science subject for university,"* or more simply biology was rated as a *"decent subject, I think it is respected".*

4.1.2 Topics of Particular Significance

The students were further asked whether there were topics within A level biology that were particularly interesting or important.

Topics that were enjoyed included human health (drug treatment for diseases, and medicine) but also simple cellular biology, biochemistry, genetics and the process of reproduction. Some students also mentioned evolution, microbiology and environmental issues. The questionnaire survey of A level students showed some clear differences in levels of interest in different topics. Those topics which are of most interest to most students include human biology, brain and behaviour, medical biology and genetics. The topics which emerged as being of least interest include plant biology and ecology. Results extracted from the questionnaires are shown in Table 2 below.

Table 2: GCE AS/A level student responses to questions about levels of interest in different biology topics (% of total sample – 729 students)

Topic	Level of Interest (expressed as % of students in each category)			
	Very Interesting	Quite Interesting	Not very/ not at all interesting	Not sure/ Don't Know
Human biology, structure, and physiology (how the body works)	**74.9**	**21.8**	**1.7**	**1.7**
Brain, nervous system and behaviour	**65.5**	**28.4**	**4.2**	**1.9**
Medical aspects of biology –health and fitness, disease, combating disease, Immunology	**59.1**	**33.2**	**6.0**	**1.7**
Genetics, genetic research (e.g. GM foods), DNA, inheritance and evolution	**52.3**	**35.4**	**10.6**	**1.7**
Ecology – relationship between organisms and their environment	**16.7**	**40.9**	**36.6**	**5.8**
Plant biology, structure and Physiology (how plants function)	**12.2**	**43.7**	**40.8**	**3.3**
Food production, agriculture, horticulture	**7.6**	**33.8**	**51.9**	**6.7**

Comments on topics that were deemed to be less interesting included:

"plant stuff.…there's too much on plants – particularly transport systems."

"ecology is a waste of time"

The majority of students took the view that there should be plant biology within the A level programme because it was foundational though there were few students who expressed strong interest in plants.

Some times students felt that particular learning activities were too drawn out. One student complained:

"there is too much stuff on yogurt!"

The quantitative data revealed a close correlation between A level students and teachers in the topics they found interesting. These results are shown in Table 3 (p23) Students and teachers share a very high level of interest in a range of topics, with human and medical biology featuring strongly. The brain, nervous system and behaviour, reproduction, cells and genetics are also highly rated. Their shared relative lack of interest in plant biology and food production is particularly striking. The widest divergence in perceptions of interest and importance is in the field of microbiology, which teachers view as significantly more interesting and important. The students' relative lack of interest in ecology is also shown, with teachers being more interested in this topic.

Table 3: Perceptions of 'interest' and 'importance' of different biological topics amongst A level students and teachers (combined results ('very + quite') expressed as % of total samples)

Topic	A Level Students		A Level Teachers	
	% finding topic "Very or Quite Interesting"	% finding topic "Very or Quite Important"	% finding topic "Very or Quite Interesting"	% finding topic "Very or Quite Important"
Molecules, biochemistry and the chemical basis of life	**79.4**	**85.3**	**79.7**	**93.1**
Cell biology and the structure of living organisms	**90.2**	**87.8**	**89.8**	**93.2**
The variety of living organisms – their characteristics/classification	**74.0**	**75.3**	**55.9**	**72.9**
Human biology, structure, and physiology (how the body works)	**96.7**	**97.9**	**98.3**	**100**
Animal biology, structure and physiology (how the animal's body works)	**89.4**	**85.7**	**96.6**	**94.9**
Brain, nervous system and behaviour	**93.9**	**95.9**	**98.3**	**94.9**
Growth, development, reproduction and fertility	**90.0**	**95.6**	**96.6**	**98.3**
Medical aspects of biology –health and fitness, disease, combating disease, Immunology	**92.4**	**97.5**	**94.9**	**100**
Microbiology	**65.0**	**71.8**	**83.1**	**94.9**
Genetics, genetic research (e.g. GM foods), DNA, inheritance and evolution	**87.7**	**94.1**	**94.9**	**100**
Ecology – relationship between organisms and their environment	**57.6**	**72.4**	**71.2**	**86.4**
Plant biology, structure and physiology (how plants function)	**55.9**	**65.7**	**50.8**	**74.1**
Food production, agriculture, horticulture	**41.4**	**75.3**	**52.5**	**86.4**
Environmental biology and the impact of humans on the environment	**75.2**	**90.8**	**86.2**	**96.6**
Biotechnology (e.g. use of micro-organisms for large scale production of insulin)	**74.8**	**87.4**	**86.4**	**93.2**

Chart 1

Comparing A level students and teachers level of interest in biology topics:

(Higher mean = Higher level of interest. The means are calculated from all questionnaire responses, using a 3 point scale where 1 = Not very/not at all interested, 2 = Quite interested, and 3 = Very interested)

Chart 1a: Topic interest levels for A level students

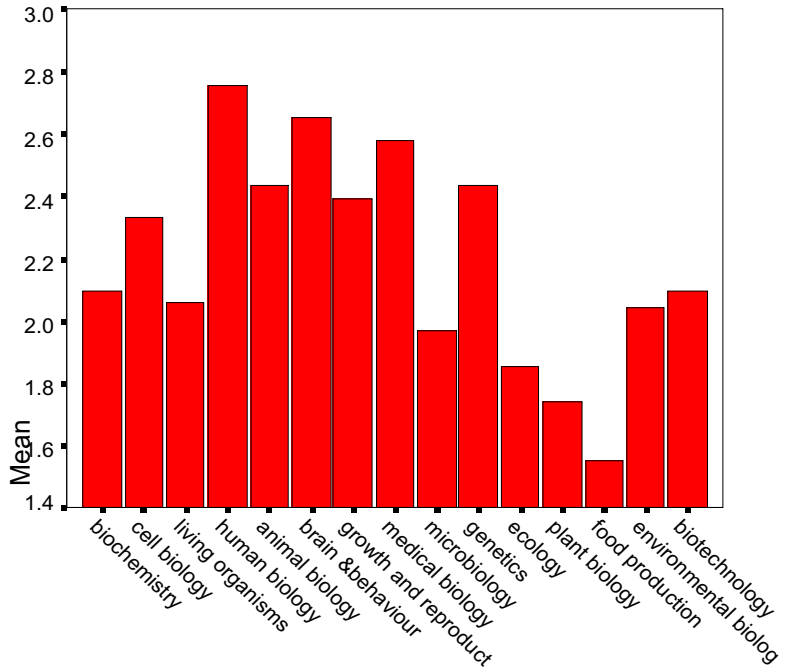


Chart 1b: Topic interest levels for A level teachers

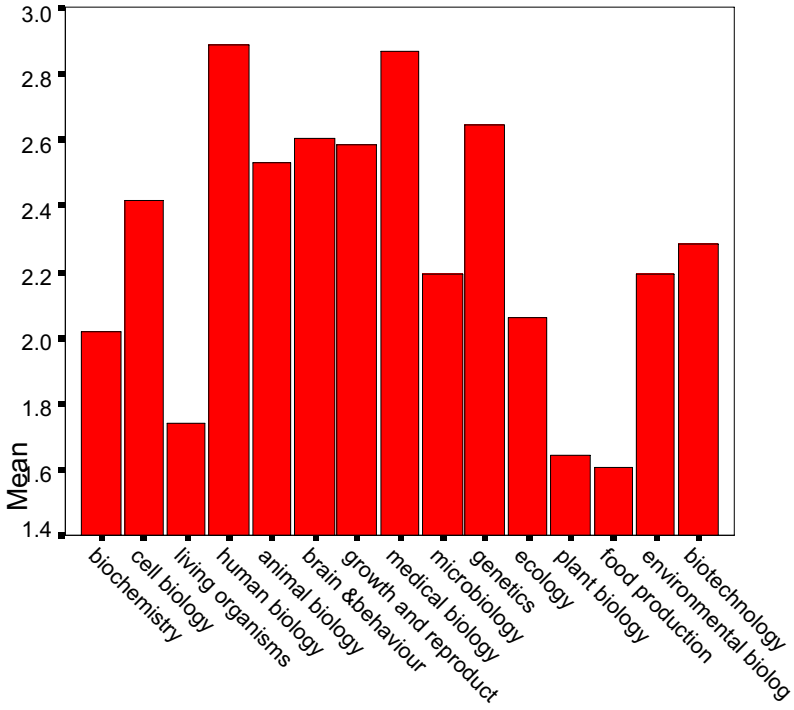


Chart 2:

Comparing A level students and teachers perceptions of importance of biology topics:

(Higher mean = Higher level of importance. The means are calculated from all questionnaire responses, using a 3 point scale where 1 = Not very/not at all important, 2 = Quite important, and 3 = Very important)

Chart 2a: Perceptions of importance - A level students

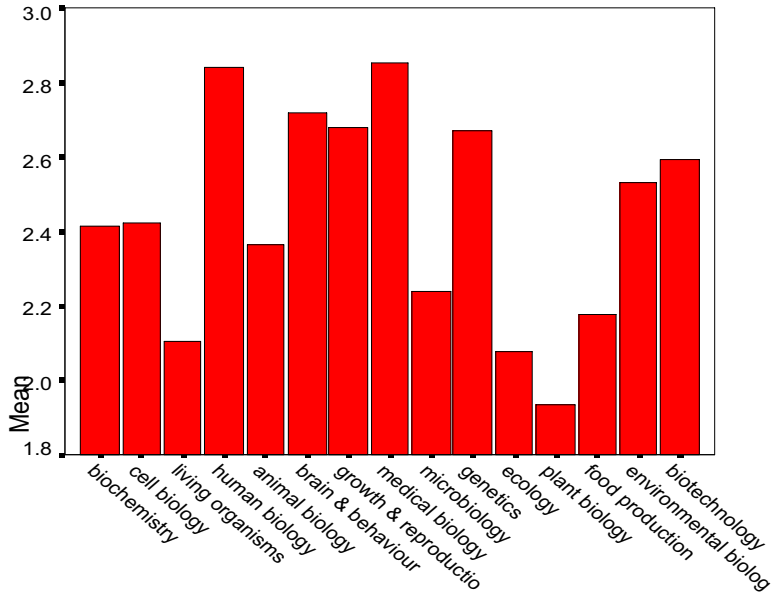
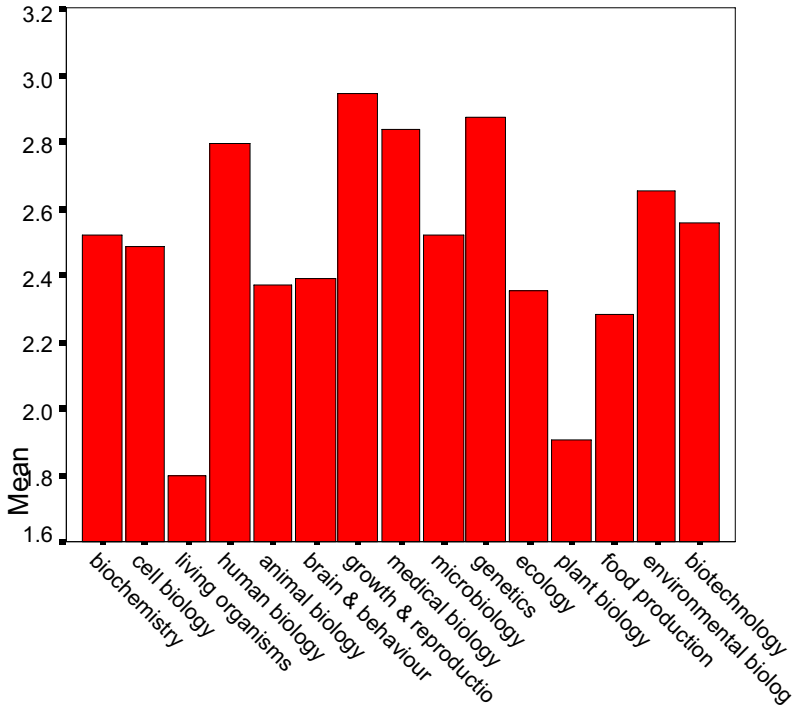


Chart 2b: Perceptions of importance - A level teachers



4.1.3 A Level Students' Perceptions of Research in Biological Sciences

Topics that were frequently perceived as the current priorities in biological sciences included genetics and gene technology, human health, the human genome, GM food issues and environmental issues. Also mentioned were, crop disease and application of enzymes.

Students by and large confirmed that they shared these priorities, though some individuals emphasised particular diseases or issues.

The majority of students took the view that the existing curriculum did not give them much opportunity to find out about current research and most A level students would welcome more opportunity to learn more about current research into these kinds of topic. Students seemed more likely to gain an acquaintance with current research when they did optional units than when they followed mandatory units: "*We do have unit on genetic engineering… otherwise we are dealing with basic principles."*

On the other hand, only 29% of questionnaire respondents agreed or strongly agreed that there were significant topics that didn't get enough attention and 62% agreed or strongly agreed that "all the most significant topics were covered". These figures do not suggest a substantial consensus among students for change in content or balance. It appears that while a substantial proportion of students were negative about particular topics (as recorded above) this did not convert into a consensus to change the balance of attention between topics.

Students were positive about the opportunities to learn about research that they had enjoyed; some described with enthusiasm accounts that teachers had given or special lectures they had attended. Several students mentioned television programmes they had watched, (as was the case with undergraduates): TV documentaries would seem to be a significant source for accessing information about current research.

However, many students expressed an anxiety that they might be expected to cover **additional material** and they argued that any new topics on current research should replace existing material. Students were able to volunteer topics that they thought were "boring" or that they thought were allocated excessive time though students did not always agree which they were (see above).

Some students were attracted to the possibility of selectively exploring current research. One student proposed an optional unit on "Current Research Issues." Others were attracted to the proposal that courses might allow students to carry out individual investigations in greater depth which might allow them to gain a more substantial experience of research.

Some students were sceptical or unenthusiastic about such proposals. A substantial proportion preferred what they perceived as a safer and less risky learning route where learning focused on receiving and understanding facts and theories passed on by teachers and textbooks.

A few students considered that they themselves might undertake biological or medical research in the future – this did not seem to be a career prospect which the existing course either explored or encouraged to any significant degree.

.

4.1.4 Difficulty and Sequence

Some students took the view that their first AS unit was very demanding in relation to the work that they did at GCSE Level. This view seemed to relate to the required depth of understanding, volume of material and pace or learning. A number of students expressed the view that there was some overlap of material from the GCSE course. Generally, this was welcomed – students appeared to be reassured by this degree of familiarity. However, a number of students felt that the work on ecosystems was simply "repetition" and a waste of time.

Other students commented that there is a big step to the A2 level. However, here the challenge appeared to arise from the difficulty of the material and the demands of synoptic assessment rather than from the quantity of the material.
One college student commented that it:

"would make it better if AS and A2 were more equal…A2 is a lot harder. AS is too easy…there should be better balance….both of amount and difficulty. Every single hard topic is in A2."

A number of students expressed concerns that a particular topic had been dealt with in only one or two lessons. Some students also expressed concern that topics were divided between different Units and different years and that they had been told on returning to a topic *"that they would have to unlearn some material that they had learnt."*

4.1.5 Coursework

Students were divided about coursework:

"Coursework should go!"

"Coursework is an opportunity for those not good at exams to show their capabilities."

There was some concern that coursework activities could be excessively time consuming. Against that a number of students rated highly the study of enzymes which was the topic that they had based their coursework around and expressed the desire to do more investigative work.

4.1.6 Assessment

In general assessment loomed large for students. Most of the students interviewed were either preparing for assessment or had just experienced assessment. Not surprisingly students were often critical of assessment practices. In particular students found the synoptic assessment challenging and found it difficult to relate this assessment to the learning that they had or were doing. Several students perceived particular synoptic questions as making disproportionate or inappropriate demands on their factual knowledge – though it is likely that these questions were actually seeking to assess pupils' ability to apply principles to a particular context.

The detailed operation of mark schemes such as the requirement to use specialist words in assessment came in for some criticism:

"Need to learn loads of names, unfair to recall exact word – doesn't show you understand."

4.1.7 Specialisation & Options

Some students were attracted by the proposal that A level biology should provide more opportunity for more detailed investigation of particular topics. Some students said that they did have particular interests which usually related to their career aspirations which they would like to be able to explore further. Some students were enthusiastic about the specialist options that they had been able to follow: Genetics appeared to be relatively popular.

However, the majority of A level students expressed the view that the A level should remain a foundational, comprehensive course and that the place for specialisation was the university rather than in the A level curriculum. Several students were sceptical about the ability of schools or colleges to provide opportunities for specialist study at A level. It was pointed out that existing options are chosen by the school, and not the students. It was difficult to accommodate the specialist interests of all of the students in a group. Some students expressed disappointment that a different optional unit had not been offered to them.

4.1.8 Knowledge, Content and Learning Style

Most A level students shared the view that the A level biology was characterised by having a relatively large amount of factual content which had to be learnt. Some students regarded this process as "a necessary chore" while others were extremely positive about this style of learning. Many students valued the facts and principles they learnt which they found interesting and foundational for further study or work. Many students also valued the style of learning which they found "easy" and which appeared to them to be a relatively secure and manageable way of preparing for assessment. A number of students commented that they felt that they were developing a capacity for revision which itself was an extremely valuable study skill.

Students who were studying several sciences at A level contrasted biology to chemistry and physics. Chemistry was more "analytical" and involved more "thinking". Students disagreed as to whether this was good or bad: some students favoured biology simply because they found it "easier" others had a more subtle view*:*

"I think that biology is a lot about memory, more so than chemistry. People who do well are the people who are going to work hard. Revision is a valuable skill. You learn how to do it and to go over things. You can build up the connections."

The quantitative research confirms the impression that the majority of students are content with the volume and the descriptive character of A level biological knowledge: 51% of students judged that there was about the right amount of material in the syllabus; 29% agreed or strongly agreed that the course contains too much material – though only 8% agreed strongly. 58% confirmed that the amount of factual material that they were expected to learn was "about right".

However, a substantial 45% of students agreed or strongly agreed that "Biology AS/A2 relies too much on memorising facts" and only 26% disagreed or strongly disagreed with this statement. At first sight this might seem inconsistent. However, burdensome *memorising* is not the only way of engaging with *factual material.* These students may well be saying that they like the descriptive character of biology but dislike a learning style which focuses too much on absorption and recall.

Some students favoured more analytical subjects and found the quantity of material in biology irksome. One student spoke critically of a unit on cellular biology saying that we spent too much time *"just learning names when I wanted to learn how they do what they do."* For such students the A2 was said to be "better" on this point because it involved more "interpretation".

One student was concerned that: "*sometimes we do get spoon fed…"* and felt that more project work would be more challenging; several students spoke disparagingly of too much "cramming." Another student welcomed the cycle of learning, revision and testing because the *"material is difficult to understand on first hearing.. you have to master it which means that it may need to be repeated."*

Some of these differences of opinion may relate to differences in the ability of students, the quality of teaching, or to the difficulties of teaching and learning in mixed ability groups.

4.1.9 Practicals and Research

The amount of practical work being done varied between institutions though students agreed that practical work fell away significantly in the A2.

The vast majority of students enjoyed practical work and were very positive about its value as a learning style. Students expressed the view that practical work increased their understanding and retention of material. Some students believed that practical work contributed to their learning even when practical skills were not directly assessed.

44% of questionnaire respondents agreed that there was enough opportunity for laboratory practicals overall, however, closer analysis suggested that AS students were largely content with the amount of practicals but A2 students were not. In general those students studying more science subjects were more content with the amount of practical work than those studying fewer science subjects.

Where students had the opportunity to go on field work they appeared to have benefited and enjoyed themselves. A substantial 57% of respondents disagreed or disagreed strongly with the statement "that there is enough opportunity for biological study outside of the class room, eg. visits and field work." However, a number were critical about the actual activities which they did within ecology, describing research activities as dull or tedious.

Students were fairly evenly divided about whether there should be more practical assessment. Some took the view that you could develop "critical thinking" with practical work but others were concerned that it was not a reliable method of assessment and that things could go wrong.

There was also a marked dissent (59%) from the view that the course "makes sufficient use of computers and IT" suggesting that the appetite for learning through IT is not yet satisfied.

4.1.10 Social and Ethical Issues

Students expressed interest in these topics and talked enthusiastically of the opportunities that they had had to learn about them. A significant 48% agreed or strongly agreed that more time should be spent on topics which are "regarded as most significant to society (e.g. genetic modification)". One student commented that "we don't really have time to discuss these issues fully….don't really have time to relate biology to society". Opinion was divided as to whether the understanding of social and ethical issues should be assessed. Some students believed that there had been relatively little emphasis on social and ethical issues in recent examinations. Some thought that there should be more but others felt that either it would be difficult to assess properly or that "If you were good at English you could do well at this stuff…I would just like to discuss it."

4.1.11 Futures

A very substantial (and unrealistic) proportion of all students studying AS or A2 biology plan to study medicine at university: 24% of respondents. A relatively low proportion of biology students (14%) plan to study other sciences at university.

Those who planned to study biological sciences at university were largely (55%) confirmed in this choice by their AS/A2 biology experience. However, only 42% of those planning to take biological science degrees reported that "their experience of AS/A2 level has helped me make up my mind about which kind of biological science I want to take further." This confirms the view that the A level courses are not wholly effective at supporting students in choosing between higher biology courses.

4.2 Findings from A Level Teachers

A total of 23 A level biology teachers were interviewed. Of these 11 taught in mixed comprehensive schools, 7 in FE (further education) colleges, 4 in independent schools and one in a sixth form college.

All of these 23 teachers appeared to find the A level workable and all appeared to have, after two years of Curriculum 2000, found satisfactory ways of teaching and organising the course. However, virtually all of these teachers had strongly held criticisms of the course – though these criticisms were by no means consistent.

A further 59 Teachers returned questionnaires though many more were invited to do so.

Of these teachers 31% had up to 5 years teaching experience, 24% between 6 and 10 years and 45% over 10 years. 83% of respondents had a PGCE.

4.2.1 Attraction to study Biology

Teachers reported that the main factors attracting students into the A level biology courses were interest (93% of respondents), aptitude (83%), potential for progression (73%). Also significant was an interest in "living things", fostered by enthusiastic teaching (78% of teachers either agreed or strongly agreed that some students are motivated to choose A level biology "by the teaching staff" – though only 31% of students shared this view). 49% of teachers thought students were influenced by the perception that biology is a descriptive and relatively "easy" science. Teachers also spoke of parental and family interest with a number of siblings following one another through the course. There is often an interest in the many topical and current issues that are addressed by the A level course curriculum. Some students, particularly in colleges, are combining biology with "fashionable" A levels like psychology and with non science A levels.

The subject is seen as a popular subject at A level and there is perceived to be a high conversion from AS to A2.

4.2.2 Skills and Knowledge in the Biology A Level

Teachers were asked whether they thought that the mix of knowledge and skills in the current A level was right. Reponses varied. Although the numbers involved in the qualitative survey were low, one could categorise responses as follows:

Radicals: these teachers thought that the A level was overloaded with knowledge. They approved of the removal of knowledge that has already taken place, e.g. of large numbers of organs and organisms, of botany, but they favoured further change. They believed that the A level should be more investigative, more up to date in its focus on topics, technologies and issues and more responsive to the interests and capabilities of students.

Moderates: these teachers also felt that the A levels were overloaded with knowledge and assessment and that this limited the scope for more open investigative work, the exploration of social issues and more intelligent learning. However, they were unenthusiastic about the destabilising effect of further change or they were sceptical about the impact of change, arguing that, in practice, investigative tasks such as coursework did not achieve what was intended. Furthermore they were reluctant to lose any topics to make room for any more investigative or open ended work.

Traditionalists: these teachers regretted the removal of one or more components of traditional syllabi, e.g. botany. They spoke of a "dumbing down" and were concerned about the lack of essay type assessment. They were concerned about the students' incomplete knowledge – some of which they attributed to the current GCSE.

The questionnaire survey, also based on a relatively small return, found that 40% of teachers agreed or strongly agreed with the view that the AS biology course is overloaded with content; 33% disagreed; 27% were unsure. In the case of the A2 the figures were similar: 45% agreed or agreed stongly, 31% disagreed or disagreed strongly , 22% were unsure.

Of this 40-45% some 14-17% might be taken as "radicals" as identified above, who "strongly agree" with these criticisms. Again 19% of respondents were strongly in favour of substantial change to the AS, tho' only 9% were strongly in favour of substantial change to the A2.

46% agreed or agreed strongly with the view that "the course relies too much on memory" while 29% disagreed. This suggests that perhaps 30% of respondents might be loosely classified as "traditionalists" while the remaining 40% are moderates or "don't knows". Clearly this classification is by no means absolute: teachers are not always "moderate" or "radical" in their views.

4.2.3 Sequence and Organisation of Material

A number of teachers were critical of the way that the more difficult material was postponed to A2. A common view was that the AS was overloaded with material and some favoured the redistribution of some material from the AS to the A2.

However, one teacher judged that the material load in the AS was about right and it was the mandatory units in the A2 that were challenging in terms of content and difficulty:

"All the complex biochemistry is in one paper. Tough on those who have not done chemistry. There's too much in one paper. Some students can't cope. It should be redistributed not dropped – it all belongs essential preparation of degree."

A number of teachers felt that time was wasted through the repetition of topics already dealt with in GCSE, e.g. ecosystems.

There was some concern that some 'foundational' material was optional for example that contained in an optional unit: "Growth, development and reproduction."

A number of teachers had definite proposals about how they might rearrange material between units or across the calendar:

"Ecology wrongly timed. All AS exams finished by early June. You need to do ecology in the summer."

"Some topics could be transferred from Unit 2 to A2. eg oxygen dissociation curves, control of systems in heart and breathing….could go across into nervous system.."

The AS unit 1 came in for a certain amount of criticism. One spoke of a

"long, boring first term"

Some said that students found it off-putting after the more "macro-organism" content of GCSE and that it required a lot of learning by rote.

One teacher spoke of her experience of running a one year access course where you

"can build more rapidly and make more rapid progress…covering a narrower range of topics."

This teacher would like more freedom to route her own way through the material to develop understanding more quickly and to engage and excite. But she feels that cannot do this with A level because of the modular system of assessment.

4.2.4 Skills and Knowledge

A number of teachers expressed concerns that students lacked adequate scientific knowledge or numerical skills which undermined their success in A level biology. Chemistry was mentioned most often as a deficient area.

It was generally felt that the A level biology course gives a good general grounding of knowledge, thus giving students a good academic preparation for further study. The teachers see the AS level course as having a factual knowledge building function. There were complaints that the course was too crowded with facts and theory and that the modular structure and assessment reduced coherence. The function of the A2 level course was seen as being integrative with less emphasis on knowledge and more on understanding and application.

Only 30% of respondents believed that there were topics which could be dropped from A level biology and there was no consensus on what they might be, though 9% suggested a reduction in plant biology and 7% rejected "the classification of life cycles". 50% of teachers could identify topics which should be added or developed within A level biology, though there was little consensus on which topics.

This analysis confirms the view that there are more candidate topics to come into a crowded curriculum than there are candidates for retirement and that there is no consensus about which topics should be preferred. However, a majority of teachers (59%) favoured "a further development of the core plus option structures for A level biology in order to allow greater choice and specialisation in specific topics." Against this 60% maintained that "All A level biology courses should provide the same broad foundation in the subject by including all the major topics."

4.2.5 Teaching and Learning Styles

56% of teacher respondents agreed or strongly agreed (24%) with the view that "learning facts seems more important than developing understanding or critical skills"; 29% disagreed or disagreed strongly. 46% agreed or agreed strongly with the view that "the course relies too much on memory" while only 29% disagreed.

'Radical' teachers were highly critical of the amount of memorisation required:

"There is an awful lot of memory involved. The AS biology could be passed by anyone with a decent short term memory."

Another 'radical' teacher would:

"like to see more emphasis on skills development and skills assessment. More emphasis in skills in AS in particular – because these skills are transferable into other subjects and into life."

'Traditional' teachers took the view that biology is a fundamentally descriptive subject and that the knowledge students learn is foundational:

"Lots of university work does depend on memorisation. Did so myself in my recent MSc."

There are alternative A level Biology courses available, which offer different approaches. For example, the Salters-Nuffield Advanced Biology Project provides a possible model, in that it is based on a thematic approach, and places emphasis on understanding, application, critical thinking, and social and ethical context, as much as on factual content. The themes are selected for their real and direct relevance to society, and links with contemporary bioscience research.

4.2.6 Thinking and Reasoning Skills

While teachers differed as to whether there was excessive emphasis on memorisation many agreed that the A level offered insufficient scope for developing scientific thinking/reasoning skills, which are:

"not well developed in our students and that there should be more opportunity to raise their understanding."

One teacher said that the inclusion of key skills had supported learning in this area. Another took the view that thinking skills are developed through the frequent use of practice papers. This perceived deficit may correspond to the difficulties that some students encounter when tackling synoptic questions which demand more "thinking" as opposed to recall.

A greater focus on understanding rather than memorisation appears to unite traditionalists and radicals: 67% of respondents favoured a revision to "provide greater emphasis on developing skills and understanding rather than learning of facts."

4.2.7 Practical Skills

Virtually all teachers valued practical work and felt that it added greatly to students' understanding. Most of them, particularly older teachers, believed that they had less time for practicals and field work and were doing less of them than they had done in the past.

53% of teachers disagreed or strongly disagreed (26%) with the view that there was sufficient opportunity for lab work and 56% disagreed or strongly disagreed (14%) with the view that there was sufficient opportunity for field work.

Some teachers complained that their ability to deliver practicals and fieldwork is limited by the lack of a laboratory technician and laboratory equipment, by health and safety regulations, by lack of time or by budgetary constraints. A number of teachers mentioned that without fieldwork it became difficult to deliver ecology successfully. Some teachers expressed concern that their students might be disadvantaged in comparison to students from other centres who might have better access to laboratories, equipment or field centres.

4.2.8 Coursework

There was evident unease about the coursework component.

One teacher commented that the coursework component is: "*absolutely rubbish!"*. Another that "*jumping through hoops doesn't develop investigative thinking."*

Another teacher had a particular concern about assessment of "planning skills" within the coursework which he believed had little value.

Another teacher believed that "coursework" assessment was no longer reliable because in practice all the students in a class were likely to conduct the same experiment and it was difficult to detect plagiarism. Another teacher was concerned about the burden of marking coursework which was likely to be repeated and would then need to be remarked.

A general view seemed to be that the good intentions of the coursework were being subverted by the pressures on students and teachers to deliver results:

"There is an attempt to do research in A2 with coursework, to write it up as a science paper and try to apply science to a problem. Edexcel tend to do microbiology some statistical test and research. But the end is to get coursework done…"

There was a concern that the skills developed for a particular piece of coursework were too narrow:

"Of course there were a lot of problems with the practical exam. But you could develop the skills for that exam. Not so artificial as preparing skills just for one piece of coursework"

4.2.9 Assessment

Most teachers found the volume of assessment burdensome and some teachers felt that the course was over-assessed:

"There should be less assessment. They should not sit so many exams and do so much coursework. We have to teach and assess every unit. There is no freedom to learn in a more investigative manner."

Many teachers had found the time available for each A level subject had been reduced because students were doing 4 or more AS levels and there were substantial time losses due to repeated exam periods and additional responsibilities such as the assessment of selective key skills:

"We have also lost out on time: we used to have 10 lessons per fortnight now down to 9. The lack of time is making us go a lot faster. We lost 12 students this year because of pressure…going so fast it's too much."

A number of teachers were very concerned about the setting of 3 unit test papers on a single day.

Some teachers regretted that essay-writing is no longer a mode of assessment and that with the emphasis on short questions comes a reduction in higher order thinking and exegetical skills. However, other teachers, particularly those teaching in multi-cultural colleges of further education, expressed concerns that their students were disadvantaged by the language demands of existing papers.

There were quite a few concerns about the synoptic assessment and the way it combined with separate unit assessment:

*"There's not enough assessment on unit 5 – only half the paper geared to it. Also the wholly synoptic assessment in 6 is split too, could have some synoptic in all A2 papers. Students should be able to deal with it in A2***."**

A general point was that students found the transition between modular and synoptic assessment challenging:

*"they had fireflies in unit 5 one year: actually about enzymes but some students didn't see that***"**

The questionnaires confirmed these discontents: 51% of respondents disagreed or strongly disagreed (24%) with view that *"recent changes in the assessment of cousework have had a positive effect."*

4.2.10 Does A level biology adequately reflect current priorities in biology?

Teachers were divided on the extent to which and way in which A level biology could or should prepare students to understand current research. Traditionalist took the view that A level biology performed this function by providing a foundation of underlying principles and knowledge. Moderates and radicals wanted students to have more direct contact.

"There is not a huge amount. They need the grounding of basic principles, that does take time. Could be a bit more in A2. Human genome does come into AS. There is a bit of gene technology. We do microbiology (as an option*). Immunity has gone. We do bits on HIV – not much. Would be nice to have a couple of topic areas where they could take it further – explore research. You'd have to keep it selective and maybe some cuts elsewhere. There should be more on skills teaching".*

Some 'radical' teachers were pressing to address current topics and technologies – particularly through the optional units:

"There is some recognition already there – genetic engineering. If there were less knowledge you could look more at research, eg bacterial transformation and genetic fingerprinting. The items are there in syllabus but there is not actually time to do experiments."

One teacher regretted that they had not been able to offer either the micro-biology or the biotechnology optional units because they felt that they could not afford the equipment for one and lack the expertise for the other.

A 'traditional' teacher argued:

"There is a tension. It is important that people in A level are aware. But there's not the time to get to grips - to fully understand those issues - not in place of doing foundations. Demands of research can call the need for more (not less) foundational knowledge. Genetical work must be set within a broader biological understanding. It is difficult to fully teach something like human genome project within the course."

And further:

"It is more difficult to concretise the underlying ideas (of new research*)– eg cloning – difficult to do lab work. Could do cauliflower experiment… Were the support material to be there then there could be more. Otherwise it's too theoretical."*

Teachers were asked whether the syllabus should take more account of controversial issues such as those featured in the media. Teachers divided on this. The 'radicals' wanted more attention to these issues but 'moderates' and 'traditionalists' tended to be more cautious:

*"…this material should be in AS level (*and not just in Public Understanding of Science). *It can shape student perceptions of biology. It should be in AS and should carry through into A2 but it is less significant in A2. There would have to be other changes to make room for it."*

"There is already enough scope. The students are interested in these issues. I am satisfied with current opportunities but I wouldn't assess as I would be anxious that it would focus on English skills…"

or

"I wouldn't want to pare down biology further any more to make room for social issues"

However, a substantial 45% of questionnaire respondents did favour a revision that provided "greater emphasis on current priorities in biological research" and very few teachers disagreed (22%).

4.2.11 Continued Professional Development

The majority of teachers said that all of their training was concerned with changes in examination and assessment and they had received no training which addressed teaching or subject knowledge at A level.

One teacher at a college which taught the biotechnology unit said that he "recently went on course on gene technology and teaching" and he was keen to build on this to systematically train up all members of the department and spoke of " inviting in representatives from biotechnology companies." The same teacher said that he knew that there were good residential courses but that these were "not an option for a family man"

It was suggested that teachers need opportunities to meet and share ideas.

The majority of questionnaire respondents believed that they have a good understanding of the expectations of degree courses in biological science (76%) and that they are aware of research priorities in biological sciences (62%). However, 63% agreed or strongly agreed (22%) that they found it difficult to stay in touch with current developments in biological research and 58% regarded their professional development opportunities as insufficient in this respect.

Nevertheless, a substantial 38% said that they regularly consult specialised scientific resources to keep up to date on research and a substantial 51% said that they did not rely only on the popular media as a source of information about scientific research. This suggests that many biology teachers do continue to follow developments in research to a greater degree than a layperson might.

4.2.12 Transition to Higher Education

Most teachers believed that students were reasonably well prepared for biological degree courses. Teachers reported that former students visiting from university told them that they

"do repeat quite a lot of stuff that we have done. But because they are used to being hand-fed they find independent learning very demanding. The overlap of foundation year does offset the trauma of leaving. Gives them a bit of a buffer. Gives them confidence."

Some teachers were concerned that their students lacked the necessary skills for practical work at university:

"….it's difficult to prepare for HE at only four and a half hours a week … Some students have never seen a pipette…"

Others thought that their students would be challenged by the demand for extended writing and by independent study – judgements that were confirmed by university tutors.

Some teachers were concerned that overspecialisation at A level might reduce options for students later on and they saw this as a strong reason for keeping a substantial mandatory core.

The majority of teachers felt that they lacked up to date knowledge about the various options available in universities to study biological sciences. Those who felt more confident in this area were either relatively recent graduates or had attended a link course at a local university. Some institutions provided specialist tutorials to able prepare A Level students for entry processes.

A number of teachers stated that some students found it difficult to choose the right biological science degree though this difficulty was much ameliorated by the fact that many universities offered common foundational years.

4.3 Tutors in Higher Education (HE)

Face to face interviews were conducted with 21 tutors from 11 different universities. The sample included a range of different universities, and tutors from a variety of disciplines within biological sciences, many of whom had additional responsibilities as research supervisors or admissions tutors.

4.3.1 Why young people study biology?

In the view of HE tutors the principle factors which attract young people to study biology are:

- enjoyment and intrinsic interest in the subject
- aptitude
- potential for future career

The popularity of biology is enhanced by its perception as a 'soft science' in comparison with physical sciences. Students are often surprised by the 'harder' (analytical and mathematical) demands of the subject at degree level.

Students' interest in subjects in frequently limited to particular areas of the subject, especially human biology.

A significant proportion of students study biology as a route into medical or related professions. Some do not achieve the A level grades required for direct entry into medical degrees, and opt for degree courses in biological sciences with the intention of using this as an alternative route into these professions (eg fast-track route to medical degree if they achieve high standard on another degree course).

4.3.2 How well does biology A level prepare young people for degree level study in biological sciences?

a) Knowledge

The majority of HE tutors sampled felt that A level biology does provide a good knowledge base in at least some areas of the subject. However, there are important areas of concern. The key issues raised by respondents were:

- Over 90% of tutors surveyed believed that biology A level should provide a broad foundation in the subject.
- A majority of tutors surveyed believe that biology A level provides a good grounding in some aspects of the subject.
- Over a third of tutors believed that many A level students had followed a course which had heavy emphasis on human biology. Even the parts of the course which are not directly about humans tended to be very 'homo-centric,' e.g. studying other organisms and processes only because of their importance to humans
- More than a third of tutors surveyed believed that biology A level students seem to have a poor understanding of living things as 'whole organisms'. The subject seems to have focused more at the cellular and biochemical level, leaving students with inadequate knowledge of whole systems, structure and anatomy
- About a third of tutors surveyed believed that plant biology (apart from photosynthesis) is seriously under-represented in the A level. Students seem to come into HE with very little interest in, or knowledge of plants. Plant scientists

are horrified that students with A level biology do not seem to know the structure of a flower. The lack of plant biology was described by one tutor as

"…. the single most irksome thing for teachers of biology generally. There is a perception from both students coming in and the staff who teach them that A level biology teaches you that all animals are fascinating as long as they are human, all diseases are fascinating as long as they are human diseases, physiology is fascinating as long as it is human physiology……most of the things they learn are related to man"

- A few tutors made specific references to topics covered in A level biology which sometimes do not prepare students well for degree level studies in those topics. One example is the field of genetics, which is popular at A level. However, a significant number of students choosing genetics at degree level are surprised by the nature of the work required, and sometimes put off by the mathematical content.
- Many respondents referred to the importance of knowledge gaps or weakness in other subjects, especially chemistry and mathematics. This problem is highlighted by the increased variety of A level combinations now offered to students.
- There is increasing use of additional courses or modules at universities to address gaps in underpinning knowledge (e.g. maths, chemistry).

As part of this research, a comparison was carried out between the subject criteria for A level biology, as defined by the QCA, and the QAA Benchmarks (2002) which give an overview of expectations of undergraduate bioscience programmes. This comparison suggests that there is a disparity in overlap between A level biology and different bioscience courses. For example, A level biology appears to prepare students better for molecular biology degrees than environmental biology:

- Environmental biology - 22% benchmark statements in common with A level
- Organismal biology – 44% benchmark statements in common with A level
- Molecular biology – 66% benchmark statements in common with A level

b) Skills

The survey collected views from HE tutors about a range of skills, including laboratory practical skills, 'thinking' skills (reflection and analysis), skills in researching and finding information, and other 'key' skills. The following issues were highlighted:

- Laboratory practical skills were judged to be very variable, and often not well developed. 75% of tutors surveyed felt that practical skills were not well developed, and many students seem to have had limited experience. However, it is important to note that several respondents who identified this feature did not regard this as a major problem. It was felt that these skills could be taught relatively easily at university, and indeed, in many cases the equipment and facilities may not be available in schools. A number of tutors expressed concern about microscopy skills, one tutor commented that skills were:

  "…hopeless. They don't know how to use a microscope"

  Their concerns included general microscopy and the use of specific accessories.

- Views on scientific reasoning, analysis and thinking did vary, but a number of respondents felt that these skills were improving.
- Some tutors commented that students were improving in their ability and readiness to search for information, especially using the internet but that students' ability to use other library sources was more limited. Some contradictions are apparent in this set of responses, with concern expressed about students' ability to be discerning or to show initiative.
- There is widespread concern about weakness in numeracy and mathematics of many students with A level biology. Over 75% of tutors surveyed expressed concern about students' capability in these areas.
- A number of respondents commented on the inability of many students to produce good quality extended writing. There was a view that A level biology does not require any essay writing, and that these skills are lacking. Respondents insisted that this is important for scientists, in developing the skills to write reports, papers and present a full, well argued case.
- Oral communication and presentation skills were generally thought to have improved, and students were thought to be more confident in discussions and group work.

c) Attitudes

HE Tutors encounter a similar range of attitudes amongst students as has been typical of the past. Most show reasonable enthusiasm and motivation. There were some comments about needing to be 'spoon fed', and 'lacking attention to detail', but no strong feelings that attitudes have changed significantly in this respect. One significant factor that tutors identified, is the increase in numbers with part-time jobs. This was becoming a necessity for many and may influence their attitude and approach to study, particularly if parts of the programme take place out of term time eg field courses.

d) Choices

The wide choice of degree courses offered was acknowledged as a potential problem for students. It was clear that a significant number of students initially make an inappropriate choice for their first degree. However this does not seem to be a major problem. There has been a general move to modular courses in HE biological sciences, and it is often not difficult for students to change course before Year 2 because several related degrees in effect share a common foundational year. Many students start by choosing a general biology degree.

"Unsurprisingly, our biggest honours school (in the first year) is biology, but, equally unsurprisingly, by the end of the year, 25% have become (for example) molecular biology, or plant sciences, or zoology because they have found their niche. What we attempt to do is to present a shop window in that first year, from which they can choose"

One situation where A level biology may misinform choice is where the A level content and approach is very different from that at degree level (eg in genetics).

4.3.3 Communication between Universities and Schools

Many of the HE tutors surveyed admitted to having very little knowledge about current A level biology courses. However, some have considerable knowledge due to specific circumstances e.g. their role as an admissions tutor, or having a son or daughter currently or recently taking A level biology. Tutors are not likely to have any real contact with teachers of A level biology, unless they have been involved in specific organised sessions or meetings with teachers (some are involved in programmes offered by their university). Those who do not have contact with teachers tend to regard this as regrettable.

4.3.4 What is the purpose of A level biology?

The research exposed a debate about the purpose of A level biology which may be worthy of further investigation. A number of HE tutors felt that the purpose of the A level was not currently clear and that further development of biology at this level should start from a clarification of its purpose. There are at least two major strands to the debate:

- The extent to which biology A level is a popular, versatile and accessible subject (based on the opportunity for students to focus on the parts which interest them most eg human biology), which 'mixes' well with other subjects, and is a respected subject for progression to many routes in HE and employment
- The extent to which biology A level is designed to provide a broad introduction to the science which seeks to understand the wide range of living organisms and provides the foundation for progression into higher level work in the subject.

Some tutors took the view that the current A level biology is compromising between different purposes. With reference to the purpose of A level biology, one tutor said:

"I don't have good view of that, and that is the A level biology specification writers' fault. It does not have good aims and objectives"

4.3.5 What should be the content of A level biology?

HE tutor views were based mainly on their perceptions of what the students did or did not know when they entered degree courses. There was virtually unanimous support for the principle that biology should provide a broad foundation about the subject. Gaps in knowledge and lack of balance in content were identified (as described above). There was concern that important and fundamental parts of biology were becoming neglected, due to concentration on popular areas of interest. In particular, over a third of tutors surveyed believed that plant biology was losing out to human biology.

Tutors were asked if they believed the A level might be overloaded with facts. Responses to this were mixed. It was acknowledged that the subject does require considerable factual learning, with extensive terminology (probably more so than physics, for example), but this was not necessarily seen as a problem in itself. The issue seems to be more one of balance, in which some topics are studied in considerable detail (e.g. aspects of biochemistry) while others are not.

A small number of tutors who had good knowledge of the recent restructuring of the A level into AS and A2 did not regard this as an improvement. If anything, there was marginal preference for the previous system. However, it was acknowledged that it

was possibly too soon to make a judgement. The introduction of AS and A2 may be making the course seem more pressured, and there was concern that there may be insufficient time for reflection and exploration. AS level is not regarded as an adequate preparation for a degree course in biological sciences

Tutors were asked about the extent to which the A level course should change and adapt to reflect current research priorities. Whilst it was agreed that A level should keep in touch with key developments in the science, caution was advised. Research priorities (as defined by current research activity) could be ephemeral, with some avenues quickly closing down. It was important to ensure that A level reflects those priorities which do prove to be of lasting importance, rather than attempting to shadow every latest trend.

There was no strong feeling that the A level course was out of date.

"For such a fast moving subject, I think the current specifications are remarkably up to date. It is impossible to keep pace, but the advances that have happened will be understood in context with what is in the specifications. The emphasis of the specifications is on the areas which are growing fastest"

Several tutors took the view that reference to current research helped to stimulate and motivate students. A teacher should include them in order to get the students to see the value of more fundamental learning.

With regard to the inclusion of ethical issues in A level biology, most respondents felt it was important to do so, especially since many of the issues are raised in the popular media. There was some concern about the distortion of ethical discussions by lack of depth of knowledge and understanding of the underpinning science.

4.3.6 How do tutors view teaching and learning in A level?

A reduction in laboratory practical skills and experience had been noticed by many respondents (about 75%), reflecting the reduction in the amount and range of practical work included in A Level courses as identified in this research. Students, it was claimed, enter degree courses with little idea of the nature of 'real' biology experiments and expect instant or very quick results. This expectation may come from their experience at school. However, most tutors did not regard this as a serious problem.

There was some awareness of the fact that many A level students do not carry out any field work. There may be a link between lack of field work experience, the relative lack of interest in ecology, and the reported lack of interest and knowledge about 'whole' organisms.

Some respondents commented on assessment methods in relation to the increasing dominance of short answer approaches, and the loss of extended writing. This was regarded as a device for the convenience of assessors and markers of examinations, which was actually detrimental to the students, because they were not developing their capability to structure full, reasoned arguments. This is still required in degree courses and in research work, and is an area in which current A level students are not well prepared.

4.3.7 How well does A level prepare young scientists for research?

Respondents felt that A level biology had little influence on whether people pursued the subject through to post-graduate research. There did not seem to be an expectation that A level could or should have this function. Whilst the A level clearly has a role in maintaining and developing interest and enthusiasm in the subject, most students do not make a decision about progressing to post-graduate study until they are well in to their first degree course.

4.3.8 Views on Admissions

Admissions tutors use A level grades as the main determinant for admissions. Amongst the respondents in this survey, biological science degrees usually require A level biology, with at least one other science A level (geography sometimes accepted). The evidence suggests that there is a fair degree of flexibility in the range of subject combinations accepted within these limits. There is also variation between different disciplines within the biological sciences which reflects widely differing popularity in the different disciplines (e.g. entry requirements at one university are AAB in biology, but CCC in plant science).

Admissions tutors have adapted to changes in the A level introduced by Curriculum 2000. There is increasing attention paid to widening participation and the use of foundation and access courses for students from disadvantaged backgrounds or without 'traditional' qualifications though the significance of these programmes varies between universities. Local geography and the reputation of a department or a university was believed to be very influential upon the composition of the undergraduate body.

Several respondents pointed to clear evidence that A level grades (including biology) were poor indicators of final degree score. They reported that it was not uncommon for students entering with top A level grades to be outperformed by others who entered with lower grades. This was often linked with school background, in that some schools (often fee-paying) specialise in ensuring high grade achievement. Students with lower grades from 'lower performing' schools often do better in the long run. Motivation, independence, determination and real ability are all relevant factors. The evidence was sufficiently strong to encourage admissions tutors to make lower grade offers in appropriate circumstances. This appeared to be happening independently of current government pressure.

There was support from several admissions tutors for movement towards a baccalaureate approach to post-16 arrangement. The greater educational breadth and maturity of baccalaureate students was highly valued. There was a perception that A levels still produce students with a rather narrow base and attitude to learning. Other tutors expressed concern and uncertainty about the fate of A level biology within a baccalaureate system.

4.4 Views from Undergraduate and Postgraduate Students

Focus group sessions were conducted with three groups of undergraduates (14 students) from three different universities and two groups of postgraduates (10 students), from two different universities.

In addition to the focus group sessions, a questionnaire survey gathered responses from 194 undergraduates and 51 postgraduates.

The students came from a range of different areas of biological science, including biology, biological sciences, biochemistry, cellular biology, molecular biology, sports science and biology, animal behaviour, and ecology. Many of the points raised were common to both undergraduates and postgraduates, and the findings are presented together, except for points of difference covered under a separate sub heading.

4.4.1 Choosing A Level Biology

From the responses received, there are three main motivators in attracting students into A level biology. These are:

- Interest (over 90% of respondents)
- Aptitude (over 80% of respondents
- Career interests and prospects (59.3% undergraduates and 72.5% postgraduates)

The origin of the student's interest in the subject is often due to either background or inspiration. Sometimes the interest stems from the student's own parents whose career may be science orientated. Secondly, the teacher at A level or further studies is seen as a source of inspiration, by about half of all students. The focus group discussions confirmed that individual teachers can be highly influential in student choices. It is often the teacher who inspires and enthuses students, rather than, (or even *despite*) the course. These experiences together contributed to the development of the students' own perception of their aptitude for the subject:

"good at it; favourite subject."

The background of many students who have parents who have followed a science career leads them to be able to make an informed career choice:

"Job prospects are better."

Many students aspire to follow careers in medicine (in the broadest sense) or teaching. There are a significant number of students who started with some kind of medical career ambition which has developed, for one reason or another, into a different area of interest within the biological sciences.

As might be expected, students become more focused on careers in the biological sciences, as they progress through their studies of the subject. From the questionnaire survey, 44% of undergraduates expressed an intention to continue on to postgraduate work in biological sciences. 18% of undergraduates stated that it was quite likely or very likely that they would go into medicine, veterinary or dentistry, despite the fact that all were currently studying some other branch of biological

science. A large majority (83.9%) said that they were quite likely or very likely to pursue a career in biology.

The postgraduate questionnaire survey showed that, at this stage, students had formed a very strong commitment to careers in the biological sciences. 96.1% were quite likely or very likely to pursue careers in biology. 64% said they were quite likely or very likely to continue into university research.

The results from the research overall suggest that there is a strong progression route through the biological sciences, in which A level biology plays an effective part. However, the progression tends to be channelled into those fields of biological science which are popular, leaving significant gaps in the less popular areas such as plant sciences.

4.4.2 Topics of Particular Interest

Respondents identified a range of topic areas of particular interest, which was broadly similar to those identified by A level students. They cited evolution, genetics, human biology and medical aspects as being particularly of interest. Certain aspects of physiology were perceived as interesting by some students (e.g. neuroscience). These were usually linked to human biology. There was approval of practical work and fieldwork although there was evidence that the amount of practical work seems to vary significantly from school to school. There was broad consensus with the A level students concerning the subjects that they did not enjoy: plant biology was again notable for its lack of popularity:

"anything other than plants!"

However, there were individual students who commented that they had been surprised to discover how interesting plants could be at undergraduate or post-graduate level.

There were very mixed views about ecology. Whilst several students had found this "boring", others felt very differently. Students who were enthusiastic about ecology tended to have had significant fieldwork experience, including extended residentials. There has been pressure on fieldwork at A Level and many students do not have this opportunity. There seems to be unequal access to fieldwork (and some other experiences such as attendance at lectures), with more opportunities being available in schools with larger budgets (e.g. fee paying). Where available, field work sometimes seems to have a major impact, stimulating interest in ecology, and assisting awareness of "whole" organisms, a feature which seems lacking in the rest of the A level course. A summary of their perceptions is given in Table 4 below.

Table 4: Perceptions of 'interest' and 'importance' of different biological topics amongst undergraduates and postgraduates (combined results ('very + quite') expressed as % of total samples)

Topic	UnderGrads Perceived levels of Interest and Importance for each topic		PostGrads Perceived levels of Interest and Importance for each topic	
	% finding topic "Very or Quite Interesting"	% finding topic "Very or Quite Important"	% finding topic "Very or Quite Interesting"	% finding topic "Very or Quite Important"
Molecules, biochemistry and the chemical basis of life	**63.9**	**94.8**	**81.6**	**94.1**
Cell biology and the structure of living organisms	**90.2**	**93.2**	**86.0**	**94.1**
The variety of living organisms – their characteristics/classification	**72.7**	**70.3**	**62.0**	**72.5**
Human biology, structure, and Physiology (how the body works)	**90.1**	**97.4**	**88.0**	**96.1**
Animal biology, structure and physiology (how the animal's body works)	**85.1**	**88.0**	**82.0**	**86.0**
Brain, nervous system and behaviour	**88.1**	**91.6**	**78.0**	**86.0**
Growth, development, reproduction and fertility	**88.5**	**95.3**	**82.0**	**94.0**
Medical aspects of biology –health and fitness, disease, combating disease, Immunology	**90.1**	**96.8**	**88.0**	**96.0**
Microbiology	**66.5**	**89.4**	**61.2**	**88.0**
Genetics, genetic research (e.g. GM foods), DNA, inheritance and evolution	**85.9**	**97.9**	**89.8**	**98.0**
Ecology – relationship between organisms and their environment	**59.6**	**82.1**	**63.3**	**84.0**
Plant biology, structure and physiology (how plants function)	**49.0**	**73.3**	**45.8**	**80.0**
Food production, agriculture, horticulture	**45.3**	**76.3**	**34.7**	**92.0**
Environmental biology and the impact of humans on the environment	**71.9**	**91.1**	**72.9**	**95.8**
Biotechnology (e.g. use of micro-organisms for large scale production of insulin)	**77.6**	**94.7**	**79.2**	**95.8**

Chart 3:

Undergraduate and postgraduate level of interest in biology topics:

(Higher mean = Higher level of interest. The means are calculated from all questionnaire responses, using a 3 point scale where 1 = Not very/not at all interested, 2 = Quite interested, and 3 = Very interested)

Chart 3a: Topic interest levels for undergraduates

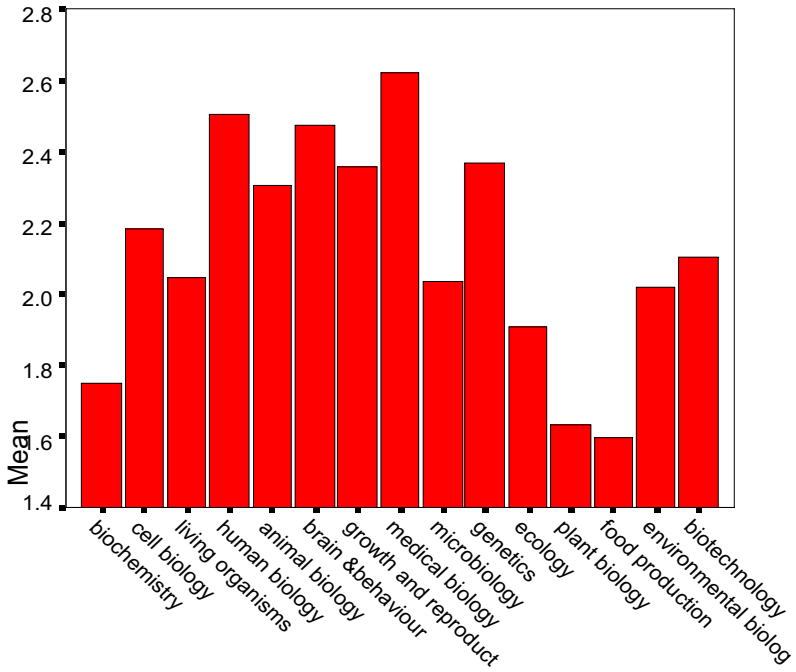


Chart 3b: Topic interest levels for postgraduates

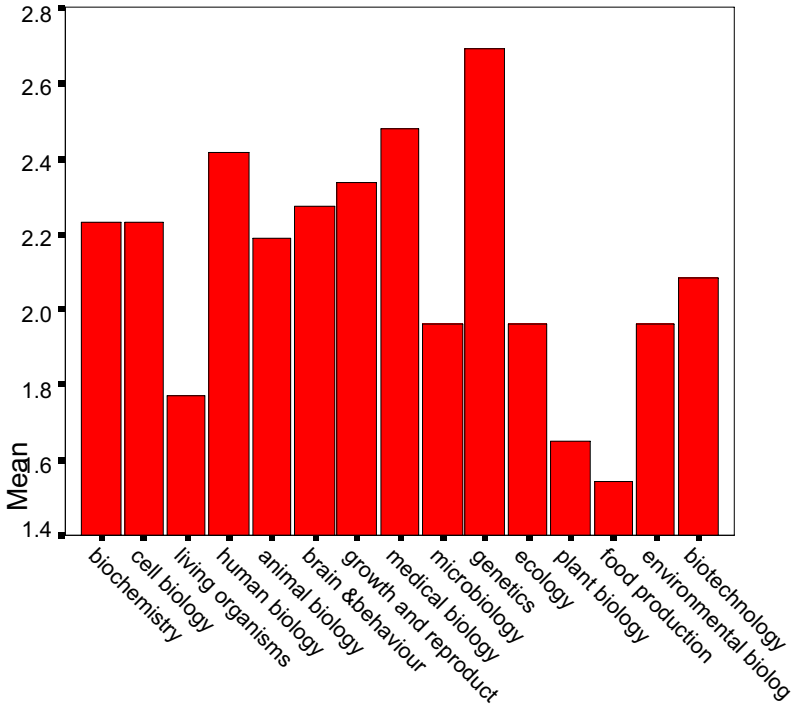


Chart 4:

Undergraduate and postgraduate perceptions of importance of biology topics:

(Higher mean = Higher level of importance. The means are calculated from all questionnaire responses, using a 3 point scale where 1 = Not very/not at all important, 2 = Quite important, and 3 = Very important))

Chart 4a: Perceptions of importance - Undergraduates

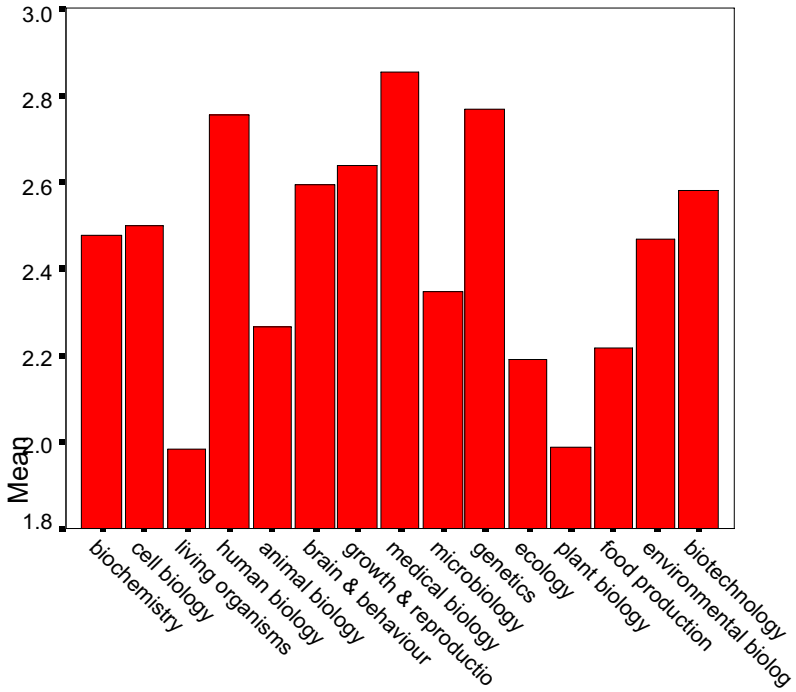
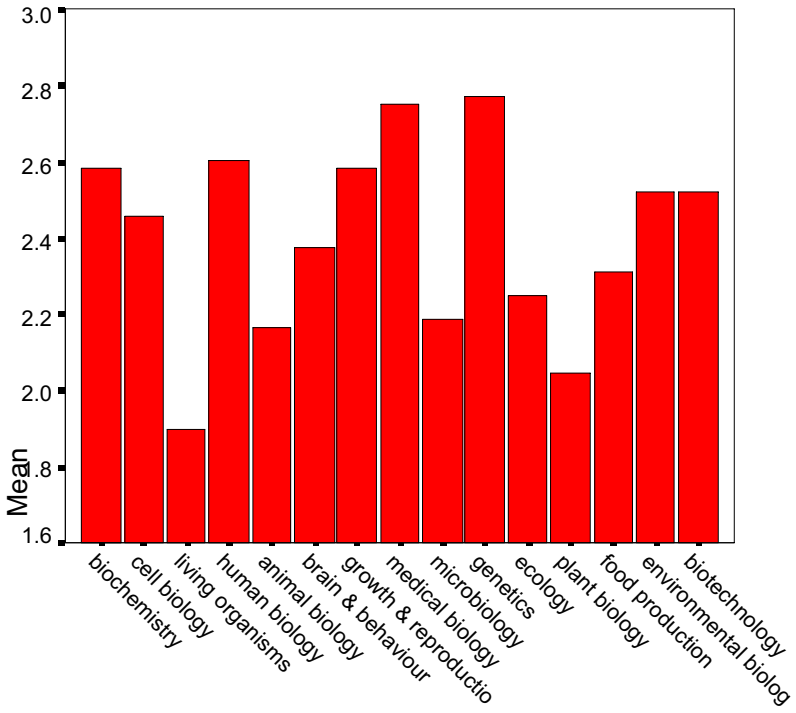


Chart 4b: Perceptions of importance - Postgraduates



4.4.3 Views of Research Priorities

Like the A level students the university students tended to cite topical issues of major current interest as the priorities of the moment. Examples of priorities offered include the study of major diseases (for example AIDS, cancer vaccines etc), genetics, genomes and environmental issues. As with the A level students, there was a strong emphasis on research into human health issues. There was very little reference to any biological research which did not have immediate and direct connections to human well-being.

4.4.4 Views on Ethics and Controversial Issues

The respondents did believe that it was important to include ethical considerations in A Level Biology education and the ethics of scientific research should be scrutinised. A number of students reported that they had enjoyed lively debates about controversial issues as part of A level biology. A few students had tackled controversial biological issues in general studies and thought that this worked well. However, the majority took the view that it was better if controversial issues could be tackled in a fully scientific context so that the debate turned on the science and not just on values.

A number of students put forward the view that it should be a mission of the biology A level curriculum to put right some of the misunderstandings of how science works. It was seen as being important to counteract the imprecise way that science is reported and presented in the media. Public debate about ethical issues was often ill-informed.

4.4.5 Knowledge

In general, respondents felt that A level biology did provide a good preparation for further studies, by giving a broad understanding.

"*It was wide but it wasn't very deep"*

The A level does seem to cover plenty of topics with interesting knowledge content, and this encourages progression. In terms of preparation, however, students do not always feel they were prepared for their experience of the degree course. There seems to be two main dimensions to this. Firstly, the extent and scope of further work was sometimes a surprise:

"There is a realisation of how much more there is to know, and that you're a bit naïve at the time"

Secondly, in some topic areas the work done at A level was found to be very different to degree level work; genetics and biochemistry were mentioned in this context. There were some respondents who had chosen topics based on their 'favourites' at A level, only to find their experience at degree level was very different. There were references to the work becoming "very hard, very quickly", raising questions about the transition from A level to degree level study.

During the focus groups there was debate and some mixed views on the merits of specialisation at A level. Students do have strong feelings about those topics they found interesting and those they did not. However, the general consensus about knowledge content seemed to be to:

"Keep it broad!"

The questionnaire surveys supported these findings, with views on whether more time should be devoted to 'topical' issues being fairly evenly split. Amongst undergraduates, 32% agreed that there should be more time spent on topical issues, and 37% disagree (31% not sure). Postgraduate students were only slightly more in favour, with 42% agreeing, 28% disagreeing and 28% not sure.

4.4.6 Skills

Respondents reported a wide range of experience and opportunity in laboratory practical work during A level. Some felt their experience was very limited and did not prepare them well for higher level work. Others had done more practical work covering a wider range of skills and techniques. Experience of fieldwork was particularly variable. A minority of students had participated in an extended field course, and this seems to have been a significant and memorable part of their experience, stimulating their interest in ecology and whole organisms. One respondent specifically referred to fieldwork as the context in which plant biology became interesting. In general students enjoy and value laboratory and fieldwork and the marked variation in access to these activities at A level reported in these focus groups was a notable feature.

Some students reported that A level biology contributed to the development of analytical and thinking skills to some extent. However, it was felt that there was further need to develop critical and analytical skills, which it was believed would help them to see more clearly how topics interconnect. Some students felt there should be more investigative work (in particular practical work) and more opportunities to develop skills in solving problems

Some respondents commented that the A level biology course itself did little to help develop mathematical skills. The mathematics content of some aspects of degree level biological science was a surprise to some and any deficiency in mathematical skills made the work difficult. Interestingly a number of students proposed that debating skills should enter into the A level curriculum to enable them to discuss controversial issues such as GM foods effectively. On the same theme they saw a need to develop essay writing skills rather than exclusively short answer forms of reasoning.

4.4.7 Teaching and Learning Styles

Evidence from the focus groups confirmed the important influence of the individual teacher. The term 'inspirational' was used, and the enthusiasm and personal interest of the teacher was perceived to have had a powerful motivating effect on the students. In considering ways to enhance A level biology, this suggests that it is not sufficient to look at the course itself, but attention should also be given to supporting the teachers in developing their style and approach.

Students reported that traditional teaching methods are still used, often quite effectively, with good opportunities for class discussion. Variety of learning activities

is welcomed, with practical work and demonstrations offering the main alternatives to teacher exegesis. Some students did comment on techniques used by teachers to enhance opportunities for learning and discussion.

"My A level biology teacher used to get the newspaper and talk about stuff that's in the news, lots of genetics….. That's much more interesting than the actual curriculum which can be quite dry. You feel like you are doing something more topical as well, when you are doing that."

Generally the university students felt that there should be greater efforts to integrate up to date research into A level courses. A number of them pleaded for better library resources for biology in schools.

One of the post-graduate groups, in which all of the students were engaged in biological research, emphasised the priority of critical thinking as opposed to the communication of a body of knowledge:

"You could allow greater specialisation where you could go for greater depth. The gaps can be put together at first year in university".

"You could do more investigative stuff – practical work would reinforce facts. People anyway tend to focus on what they are interested in. It's easier if you remember but the facts are all available so you don't need to…".

"Needs more enquiry and thought on the spot. You need to learn how to relate facts and ideas together.. There's too much emphasis on remembering..."

Critical thinking is "*the fundamental job of A level ….biology does impact on life. Students need to understand why people might disagree..they need to tackle these issues even if they don't fully understand the science. It should be seen as an application of science not just as an issue. This is also about issues of uncertainty and risk which are common to science – this should be part of science"*

4.5 The Response of Learned Societies

In order to extend the research outside of schools, colleges and biology departments in universities a wide range of learned societies, professional associations and interested bodies were contacted and offered the opportunity to contribute their views.

In total, 21 such bodies were sent a questionnaire of whom 7 responded. However, in some cases the response was itself the result of a wider consultation within the organisation and some organisations sent in a number of completed questionnaires or responses. The questionnaire is contained in Appendix 2.

4.5.1 Knowledge and Skills

Respondents were concerned that some skills and topics received insufficient attention within A level biology. This, they believed, might be due to lack of time, lack of teacher expertise or because these skills or topics were not prioritised in assessment.

Neglected skills mentioned were: research skills (including use of secondary as well as primary sources), practical skills such as accurate measurement, statistical skills and other mathematical skills, graphing, data handling, organisational skills, skills in handling equipment and materials, independent learning and thought, problem solving, basic biochemistry and work with animals including animal dissection.

"Skills look like they are being addressed, but students still struggle to draw conclusions from experimental data"

Areas of inadequate knowledge included animal behaviour, genetics and immunology, effects of drugs and pollutants on cells, animal biology, bioprocessing, covering the micro-organisms involved, the biology behind the production principles and the applications of products, biofilms, plants and whole organisms. Several respondents believed that the treatment of topics at A level was too superficial:

"A basic understanding of the genetic code and of genes and their promoters which switch on or off their expression. Currently this is not covered adequately and pupils learn that there is a genetic code but not exactly how proteins are built up using DNA and RNA information.

Pupils do not understand anything about how genes start and end nor how they are appropriately turned on and off. Some real examples of human gene sequence changes such as on the Sanger Centre human genome site should be covered in real depth. Also pupils need to know about amino-acids and about RNA polymerase and ribosomes and their roles in these processes."

One respondent believed that students without A level chemistry would be severely disadvantaged in their study of biological sciences at university.

Another respondent picked out two deficiencies:

1. *Ability to integrate information from across the different levels.*
2. *Some appreciation of the history of science, as a means of understanding the scientific method.*

Several respondents wanted more mathematical work:

"it would be useful to see more mathematics-based practical work, i.e. experiments that generate actual values that can then be used in calculations and to plot graphs"

One respondent wanted better laboratory skills*:*

"experience of employing school leavers with A levels, supervising A level students and sandwich students who are in the middle of their degree courses suggests there is not enough experience in using apparatus and materials in an appropriate or safe way. Use of basic laboratory equipment such as balances, pH meters, microscopes is poor and the ability to make up basic molar solutions or dilutions is also lacking."

4.5.2 Biology and Society

Some respondents were concerned that students did not develop:

1. *"Ability to structure a coherent argument from the facts.*
2. *Willingness to engage in debate, hold a position and also recognise the right of others to hold conflicting views.*
3. *Recognition of the limitations of science.*
4. *Willingness to keep abreast of current developments through background reading.*
5. *Ability to criticise and recognise the strengths and weaknesses of arguments."*

Another respondent thought that:

"They should learn how scientists have to apply for licences before they do lab work and how they have to take precautions for safety."

Another that they should learn*:*

"Concepts of probability, relative risk, the grading of information by source, vested interest…"

Another wrote:

"We would be very keen to see an 'ethics' topic, covering areas such as animal testing, cloning and genetic manipulations and therapy."

4.5.3 Research Priorities

The following research priorities were thought to be inadequately reflected in A level biology:

Whole genome and proteome analysis
Nanotechnology
Protein crystallography
RNAi
Forced evolution
Integrated projects involving chemistry, biology physics, maths, modelling and computing.
Stem cell work
Knockout and knock-in animals such as mice
Fluorescent tagging and detailed microscopy
Genetic engineering

One respondent thought:

"(Research) priorities are properly reflected in the current A level curriculum regarding genes and molecular biology, but perhaps not in the case of neuroscience…"

Another thought that:

"current research priorities were not properly reflected in current A level syllabuses and that A level specifications were slow to catch up. It was thought that existing coverage is uninspiring and limited."

4.5.4 Structure

Several respondents expressed the view that there was simply too much testing. Formal assessment was thought to restrict and devalue other kinds of learning. April would be a better time for the first assessment and that the early June exam led to the wasting of July.

Several respondents, echoing a concern expressed by some post-graduates was concerned about excessive fragmentation:

'Students seem to be used small chunks of work i.e. a unit in physiology, a unit in genetics and so on. Therefore it is sometimes difficult for them to see the whole picture. This is a pattern of teaching that continues at undergraduate level. Maybe this is something to address, increasing the students' awareness of the "bigger picture".'

And again:

"In the Edexcel syllabus, genetics/molecular biology is taught across the 2 years. In year 1 pupils cover DNA structure and function, including the human genome project, whilst genetic engineering comes in year 2. There seems to be little attempt to relate these together, although clearly the ability to manipulate genes is closely related to the structure and properties of nucleic acids. The 'Gene Technology' component is comprised of a series of 'buzzwords' - PCR, reverse transcriptase, DNA fingerprinting. From the viewpoint of having something to build on when they come to university, I would prefer to have the basics of DNA biology and gene cloning well in place, rather than superficial knowledge of a few random topics. Currently we have to essentially re-teach most of what is done at A level in this area."

Several respondents addressed the transition between A level and degree level study:

"It was thought that universities/schools/colleges of further education and examining bodies should be more aware of one another's requirements. This would help universities better gear their early year courses to their talents of their students."

4.5.5 Assessment

Several respondents expressed concern about the dominance of assessment:

"Due to time pressure etc. it was also thought that students were only learning what was needed to pass exams and that the ability to think had been seriously eroded."

Several respondents were concerned about differences between assessment in schools and universities – though they differed about the remedy:

"What is becoming apparent is that universities need to consider more closely as to how students are assessed at school and to how they will be assessed as an undergraduate"

and

"Bringing back more discursive essay/ seminar topics would be of benefit as this is the type of assessment universities give out."

One respondent explicitly favoured more practical assessment:

"Taking into account the comments made earlier about lack of practical skills we suggest that it is important that the practical assessments should require candidates to apply their scientific knowledge…and make decisions independent of others."

Respondents were again concerned about fragmentation:

"A modular system inevitably tends towards 'packaged' learning. There needs to be more credit given for ability to think across modules. Emphasis on understanding rather than rote learning would prepare pupils better for higher education. Credit for 'extension activities' to encourage student-directed learning."

One respondent was very concerned that there should be no further changes and that a period of stability was long needed.

4.5.6 Content

Suggestions for additional content included:

Neuroscience
Use of animals in research
Support sciences e.g. chemistry etc. in a biological context.
Micro-biology

Neuroscience received significant backing:

"As far as I am concerned, I should like to make a plea for more neuroscience in the biology curriculum. In my experience (from giving talks in schools and at A-level conferences), 6th formers are fascinated by the brain and it is not difficult to teach neuroscience in an interesting and convincing way, without great technical detail.

I would suggest the following topics for the neuroscience content of A-level:

Action potentials
Synaptic transmission
Principles of information transmission in nerves
Sensory processing (exemplied by touch and vision)

Localization of function in the cerebral cortex
Memory"

One respondent advised that:

"More time needs to be spent on covering important topics and not trying to cover it all."

4.5.7 Teaching and Learning Activities

Several respondents advocated:

"Greater emphasis on directed self-study and project work, so that they can explore and expand their interests and not be completely constrained by the curriculum"

Another group of respondents recommended that topics *"relevant to human life"* should be to the fore. Others advocated more practical work.

.

4.6 Indicators of Priorities in Biological Science Research

One element of the research was to identify and suggest indicators which could provide a basis for tracking trends in research priorities in the biological sciences. A central challenge in this work was to formulate a relatively simple set of categories, based on A level biology course content which could be mapped against the extensive breadth and complexity of research areas in biological science. The QCA (Qualifications and Curriculum Authority) specifications for A Level biology, and their interpretation by the three Awarding Bodies (AQA, Edexcel and OCR) do not provide a common structure for organising the content of A level biology. In order to explore possible indicators, the research team decided to use the same set of categories which were selected for use within the questionnaire surveys

The complexity and overlap between areas of research in biological sciences do not lend themselves to simple classification and many research activities could fall into several broad categories. For example, a single piece of research could fall under cell biology, biochemistry, genetics and biotechnology.

From the exploration of this issue, it is suggested that indicators of research priorities could be based on four elements. A combination of these could provide an appropriate measure. The proposed elements can be summarized as answers to the questions:

- What topics are being written about in biological science?
- What topics are being read and referred to in biological science?
- What topics are being funded in biological science?
- What are the policy directions in biological science?

This research has made a start in exploring how these questions could be answered.

4.6.1 Using the Science Citation Index

A major source of information about published research, including the biological sciences, is the Science Citation Index (SCI). Work was done to investigate whether a relatively simple search of the SCI could be done using the set of categories identified for the questionnaires. After initial trials, advice was sought from CIBER (Centre for Information Behaviour and the Evaluation of Research) at City University, London. CIBER are specialists in conducting complex searches of large databases, including the SCI. CIBER used some of their existing search tools to interrogate the SCI using the fifteen categories identified. The search identified changes in levels of research paper publication for each of the fifteen categories, during the period from 1981 to 2001. The change was expressed by tracking articles for each of these categories, expressed as a percentage of all research articles in the SCI. This has produced some promising results, and the report produced by CIBER is shown at Appendix 3. The key findings include the following:

- There has been a considerable **increase** in published research in **cell biology and the structure of living organisms**
- There has been a considerable **increase** in published research in **genetics, DNA, inheritance and evolution**
- There has been a considerable **increase** in published research in **biotechnology**
- There has been a considerable **decrease** in published research in **food production, agriculture, and horticulture.**

It is important to note that this was a test search and these findings must be treated with a degree of caution. For six of the categories, CIBER was able to use existing 'filters' to help extract the information (including cell biology, genetics and biotechnology). For the other nine categories, no 'filter' was available, and the search was less refined. This applied to the finding on food, agriculture and horticulture. If this approach were to be adopted, two key developments would be necessary:

- Review and, if necessary, refine the set of categories to give optimum results.
- Design filters for the remaining categories to establish greater consistency and validity in the results.

4.6.2 Using other Literature Searches – the journal 'Nature'

The SCI represents the most comprehensive database of scientific research publications. There may, however be other options which could also yield valuable results. Nature is acknowledged as the world's leading scientific journal. Some exploratory discussions have taken place with editorial staff at Nature. This has identified potential to use some of the semantic matching tools (eg 'Autonomy') which the journal uses to allow editors to search content. Nature editors are willing to have more detailed discussions about how these could help the Wellcome research.

4.6.3 Essential Science Indicators

The ISI (www.isinet.com) website, through its 'Essential Science Indicators' provides a range of useful information about research trends. ISI publishes Science Watch, a subscription newsletter which quantitatively analyses scientific journal literature to provide concise overviews of key developments in scientific research.

Other facilities available through ISI include the 'In-Cites' component, and 'Sci-Bytes' which allows searching of sections on 'What's New in Research'. This includes information on 'Hot Papers' in biology. This shows which research papers are being cited most often in other research, and could be used as an indicator of the perceived importance and priority of the topic in question. This idea is linked to the notion of 'impact' as a measure of research priority. Those papers with most citations are regarded as 'high impact'. The ISI website does carry lists of the 'Top 25 'High Impact' papers in biosciences.

4.6.4 Funding Patterns

A further strategy for assessing priorities in biological research is to look at trends and levels of funding for research for different topic areas from the major research councils. This process is worthy of further investigation. There are complications which need to be dealt with, in that biological science research is funded by several research councils, and each research council has its own approach to categorising areas of research.

For this research, an exploratory test survey was carried out through the BBSRC (Biotechnology and Biological Science Research Council). As with all the research councils, a considerable amount of information is available about current and past funding for research. The BBSRC was able to provide information on research spending against seven areas, covered by their seven funding committees between 1997 and 2002. The results are shown in Table 5.

Table 5: Trends in BBSRC Funding (within 7 funding committees)

	Research Spending (£Millions)				
Scientific Area	**1997/8**	**1998/9**	**1999/2000**	**2000/1**	**2001/2**
Agri-Food	**34.2**	**33.6**	**33.1**	**38.9**	**37.4**
Animal Sciences	**25.0**	**21.3**	**21.5**	**23.6**	**30.2**
Biochemistry and Cell Biology	**18.3**	**19.4**	**20.4**	**23.0**	**25.6**
Biomolecular Sciences	**24.7**	**28.3**	**30.2**	**24.8**	**18.9**
Engineering and Biological Systems	**16.1**	**14.5**	**15.0**	**13.9**	**15.0**
Genes and Developmental Biology	**24.7**	**27.2**	**28.5**	**37.0**	**33.6**
Plant and Microbial Sciences	**26.3**	**26.9**	**28.0**	**29.2**	**32.2**

Data is also available for years preceding 1997, but the organization of funding categories and presentation of the data is different, making direct comparisons more difficult. However, if the current arrangement under the seven funding committees continues, this could provide another indicator of priorities.

From the results shown in Table 5, it can be suggested that, since 1997, increased priority has been given to biochemistry and cell biology, genes and developmental biology, and to plant and microbial sciences. However, the data would need to be extended for further years to assess trends in most of the other scientific areas.

One point worthy of note, is the spending pattern in the agri-food area. Whilst the pattern is not clear, funding has been maintained at a high level, and the data does not appear to support the finding from the SCI search which suggested a significant decrease research publications in the area of food production, agriculture and horticulture. This tends to support the need for further refinement of the SCI search, and the use of more than one indicator in assessing priorities.

4.6.5 Policy Directions

A further way to assess priorities in biological science can be based on tracking of science policy through Government departments and key agencies. Key Government departments include the DfES, DTI, and DEFRA. The Office for Science and Technology would be a valuable source of information and advice. The Wellcome bulletin 'SPIN' could provide a vehicle for tracking policy trends.

SECTION 5: CONCLUSIONS

1. Most stakeholders agreed that A level biology should provide a broad foundation for progression to higher level studies and careers in the biological sciences. However, some university tutors identified significant imbalance (eg deficiency in plant biology and in understanding of whole organisms) and some learned societies identified other areas of neglect, e.g. neuroscience.

2. Stakeholders were divided in their evaluation of AS and A2 biology. Most valued the extensive descriptive and traditional content, while a minority of respondents were critical of the burden of knowledge and the way this impacts upon learning and assessment. The descriptive nature of the subject was seen as a factor in the subject's "general", rather than its "scientific" appeal. However, a number of university tutors expressed the view that some students achieving a good grade in biology A level can struggle with the 'harder' scientific content at degree level.

3. A majority of stakeholders supported the principle that biology A level should provide a broad foundation in the subject, and support the notion of greater choice through, for example, the inclusion of specialist options, an increase in topical scientific issues and more attention to social and ethical issues.

4. Biology A level is effective in maintaining and developing the interest of students intending to continue their studies in biological sciences and also attracts significant numbers of students who do not intend to continue studies in the subject. However, a variety of stakeholders voiced concerns about how well existing courses inform choices about progression into the full range of bioscience courses.

5. Most stakeholders were broadly content with the A level biology course. However, a majority of university tutors and some teachers and learned societies perceived that current biology A level courses appear to be less effective in developing practical skills, numerical skills and the ability to produce extended writing than in the past. However, stakeholders reported that students tend to be more confident in group work, discussions and the use of IT.

6. Coursework investigations were considered by many teachers and some sixth formers as mechanical, time consuming and unreliable as an assessment of investigative skills. Some university tutors believe that students have not gained sufficient understanding of the true nature of scientific enquiry

7. The current assessment regime, including the introduction of AS examinations, has imposed time pressures which limit the scope for scientific reflection and investigation. Representatives of all stakeholders expressed concern about the volume, timing and impact of assessment. Just over half of the teachers surveyed expressed dissatisfaction with recent changes in the assessment of coursework.

8. There was a close correlation in the relative interest shown by A level teachers, students, undergraduates and postgraduates in different topics in biological sciences. This correlation suggests that preferences for human and medical biology, and some other topics (eg genetics) are likely to be

reinforced. Plant biology and, to a lesser degree, ecology are relatively less popular.

9. Teachers felt that their opportunities for professional development are limited and inadequate. Professional development is focused on specific course delivery and assessment issues, with little opportunity for the development of new subject knowledge, including recent advances in bioscience.

10. All groups generally agreed that A level biology should reflect current research priorities, while maintaining reasonable balance with the provision of a broad foundation in the subject. Most A level teachers and university tutors felt that A level biology has responded to recent developments in the subject. Most students welcomed opportunities to find out more about current research and to learn about controversial issues in the biological sciences. The challenge is to find a balance which takes account of the diverse 'claims' of priority in rapidly advancing biosciences, and the widely held support for a 'broad foundation' in biology A level.

11. The changing nature of bioscience research is also significant. More research is based on interdisciplinary approaches, which require physical sciences, information technology and mathematics in addition to traditional biology. The evidence suggested that biology A level has made progress in responding to some of the major development areas in research (eg cell biology, biochemistry, genetics) in terms of basic content. However, current A level courses are still provided as separate sciences, in a way which does not lend itself easily to an inter-disciplinary approach. Also, a significant number of students choosing AS or A level could find the subject more difficult, and less attractive, if there was an increase in the physical science and mathematics content.

12. The introduction of option choices and modular structures in A level biology has led to variations in the topics covered by students. This has meant that universities cannot assume all students have covered the same work and has contributed to the introduction of foundation work in the first year of degrees. This may lead to repetition or issues about "pace" for some students.

13. Contact and communication between A level biology teachers and university tutors (who are not admissions tutors) was limited. This is likely to make preparation of students for degree courses less effective, and also may reduce the quality of advice about bioscience specialisms.

14. Detailed consideration should be given to teaching and learning styles in biology A level. Many stakeholders were concerned about excessive reliance on factual recall, and insufficient emphasis on developing scientific understanding. Many felt that practical work and field work is inadequate. It is important to acknowledge that the evidence showed a wide diversity of views. The evaluation of different A level courses offering a choice of styles and approaches could make a valuable contribution to the debate about these issues.

SECTION 6: RECOMMENDATIONS

1. The development of the A level biology curriculum should remain responsive to the changing nature and the range of voices within contemporary biological science. If it does not, A level biology will lose credibility with some biologists, and communication and progression between higher and tertiary phases will suffer.

2. There should be a review of what is genuinely foundational in A level biology, and what is not. This may help to clarify and define the essential core, which every A level biology student should study, and at the same time map out the space that remains for free or restricted option choices that might satisfy the appetite for flexibility. Such a review should consider to what extent this "foundation" consists of factual or conceptual knowledge and to what extent it is defined by a distinctive type of questioning and researching. Furthermore this review needs to take account of actual and possible changes in other courses that post 16 students are likely to be following.

3. Wherever possible, contemporary science issues and examples should be integrated into the subject core, rather than added on as option choices.

4. Providers of bioscience courses in higher education should be closely involved in discussions about the essential core and options structure of biology A level. The outcome of these discussions should inform decisions on the extent to which all bioscience degree courses should include a first year foundation programme.

5. There should be a review of the coursework component of A level biology. This should aim to encourage a broader range of practical investigations, designed to support understanding through the development of investigative and practical skills. The review could examine the usefulness and practicability of producing a set of cost-effective, practical investigations which could be delivered by any school or college, subject to compatibility with particular assessment requirements, and which could be disseminated to teachers through professional development.

6. There should be investment in continuing professional development to support the teaching of existing topics, such as ecology, and newer topics, such as biotechnology, so that teachers and students from all centres are able to tackle learning in these areas with confidence, enthusiasm and enjoyment. In the same way there is a need for good learning resources and CPD to support teaching and learning in the area of ethical and social issues in biology. There is a particular need to produce innovative and motivating materials and activities to support plant biology, which might be linked with teacher professional development to rebuild confidence and generate enthusiasm for this part of biology.

7. There should be better understanding and more collaboration between students and staff in secondary and higher education with a view to improving progression. One strategy to achieve this might be the dissemination of good practice in links between biologists in schools and higher education.

8. Assessment in A level biology should be monitored and re-evaluated. Evaluation should include the following questions:

    - Does the assessment regime test a sufficient range of biological and scientific skills?
    - Does the assessment add value to the learning of students in biological science?
    - How well matched are the styles of learning emphasised in delivery and the demands of assessment – particularly the higher order demands of the synoptic papers?
    - Is there too much A level biology assessment?

9. Teachers need to deploy teaching strategies to support and develop a wider range of learning styles over and beyond "memorization". This might be brought about through continuing professional development for teachers of A level biology. However, opportunities for teachers to build their subject knowledge and understanding are currently lacking or difficult to access. In some cases the development of teachers' subject understanding may provide a way of extending learning styles for students. The Science Learning Centres being established by the DfES and the Wellcome Trust could make a major contribution in this area.

10. Further research could be undertaken to explore more thoroughly the extent to which evidence supports the provisional finding that research priorities in the biological sciences have permanently shifted, to explain these changes, and to evaluate their significance for the A level biology curriculum. As part of this research it would be valuable to analyse the several changes that the A Level Biology curriculum has undergone over the same period in order to evaluate the extent to which this curriculum may have responded to messages from the research community.

REFERENCES

Chen S-Y, Raffin (1999) *Biotechnology: a student's knowledge and attitudes in the UK and Taiwan* Journal of Biol Education 34 (1) 17-23

Lewis J, Leach J, Wood-Robinson C (2000) *All in the genes?: Young people's understanding of the nature of genes.* Journal of Biol Education 34(2) 74-79

Hodgson A and Spours K *"Curriculum, Learning and Qualifications 14-19"* - a paper presented at the Nuffield Foundation Seminar Series (Dec 2001-Jan 2002)

House of Lords, Select Committee on Science and Technology 1st Report (1991-92) *Systematic Biology Research.* HL Paper 22-1 (The Dainton Report)

House of Lords, Select Committee on Science and Technology 4th Report (2001-02) *What on Earth? The Threat to the Science Underpinning Conservation* HL Paper 118(i)

House of Lords, Select Committee on Science and Technology 3rd Report (2002-03) *What on Earth? The Threat to the Science Underpinning Conservation: The Governement's response and the Committee's Commentary* HL Paper 130

Jenkins E (2000) *"The Impact of the National Curriculum in Secondary School Science teaching in England and Wales"* International Journal of Science Education 22: pp325-36

Joint Council for General Qualifications (2002) *Response to the report of the House of Commons Science and Technology Committee on Science Education from 14-19*

Miller R and Osborne J (1998) *"Beyond 2000: Science Education for the Future"* A report of the Nuffield Foundation seminar series

National Academy of Science (2002) *BIO2010: Transforming Undergraduate Education for Future Research Biologists*

Osborne J and Collins S (1999) *"Pupils, Teachers and Parents Views on the School Science Curriculum"* Kings College London

QAA (2002) Biosciences Subject Benchmark Statements - Quality Assurance Agency for Higher Education: Gloucester

QCA (2001) GCE Advanced Subsidiary and Advanced A Level Specifications subject criteria for Biology Qualifications and Curriculum Authority: London

Roberts Sir Gareth (April 2002) *"SET for Success – The supply of people with science, technology, engineering, and mathematics skills"* The Roberts Review

Select Committee on Science and Technology (Third Report) (July 2002) *"Science Education from 14-19"*

The Wellcome Trust (2001) *"Valuable Lessons"* - based on Levinson R and Turner S *" The teaching of social and ethical issues in the school curriculum, arising from developments on biomedical research: a research study of teachers"* London Institute of Education

APPENDIX 1

RESEARCH INSTRUMENTS

Questionnaires:

- A level students
- A level teachers
- Bioscience undergraduates
- Bioscience postgraduates

Interview Schedules:

- A level teachers
- Higher education tutors, research supervisors and admissions tutors

Focus Group Schedules:

- A level students
- Undergraduate bioscience students
- Postgraduate bioscience students

Full copies of these research instruments are available from:
Peter Stagg, Centre for Education and Industry, University of Warwick, Westwood, Coventry CV4 7AL

They can also be accessed from this site

APPENDIX 2

SURVEY OF LEARNED SOCIETIES

Letter to Professional Bodies/Learned Societies/Subject Associations

Date

Dear

Biology 'A' Level Courses - An Investigation on behalf of the Wellcome Trust

We are writing to request your participation in an investigation being carried out by the Centre for Education and Industry at the University of Warwick on behalf of the Wellcome Trust, to identify the extent to which current biology A level courses prepare students for degree courses and careers in the biological sciences and develop in young people the ability to understand the impact of biology upon society. This is a relatively small scale research project designed to inform the Welcome Trust. Its longer term purpose is to contribute to future development and improvement of Biology courses. The main aims of the project are:

- To identify the skills and knowledge deemed essential at A level, to ensure progression to contemporary undergraduate and postgraduate life sciences;
- To identify the components of existing courses that enthuse and excite young people, including those who study the subject for intrinsic interest rather than career aspiration;
- To analyse the current research priorities in biological science research in relation to the content of A level biology courses;
- To research the views of stakeholders (teachers, students, researchers, employers, societies and associations) about the adequacy of A level biology courses and about the desirability of changes designed to improve the adequacy of biology A level.

Apart from conducting a range of interviews, questionnaires and focus groups with various students and teachers in schools, colleges and universities we are keen to gather views from professional associations, learned societies and subject associations. In January 2003 we plan to circulate a list of questions or issues arising from the research that we will have carried out by that point in time. We would value your views on these issues, and would like to invite you to send any comments to us at that time. If you would like to be included within this informal process please would you complete the slip below and return it by post or email.

If your organisation has already developed a position upon the role or future development of A level biology, or if your organisation would like to contribute immediately any ideas or evidence relevant to this research, please send what you can to us or contact me.

Yours sincerely

Julian Stanley

Please return this form to Julian Stanley at CEI, University of Warwick, COVENTRY, CV4 7AL or Fax 024 765 23617 or email julian.Stanley@ntlworld.com for an electronic copy.

Name	
Role in Organisation	
Organisation Name	

QUESTIONS

A LEVEL AND HIGHER EDUCATION
What skills or knowledge should be learnt in A Level Biology to prepare young people for the possibility of undergraduate study of biological sciences or post-graduate research?
So far as you know are these skills or types of knowledge properly represented in the current A Level Biology curriculum?

BIOLOGY AND SOCIETY
What skills or knowledge should be learnt in A Level Biology to permit young people to understand the implications of developments in biological science and technology and to participate in debate and decision making about the use and control thereof?
Do you believe that these skills and knowledge adequately represented within the existing A Level Biology curriculum?

What are the current research priorities across the various biological sciences?
Have there been any significant changes in research priorities over the last 20 years?
Are these priorities properly reflected in the current A Level curriculum?

STRUCTURE
Should there be any changes in the structure and organisation of the AS or the A2 Biology courses? Are there the right number and sequence of units? Are they correctly designed?

ASSESSMENT
Should there be any changes in the system, type, timing, manner or criteria of assessment in A Level Biology courses?

CONTENT
Should there be any changes in content such as the addition or removal of topics or modification the level of difficulty or detail of material?

TEACHING AND LEARNING ACTIVITIES

Should there be any changes in type and balance of teaching and learning activities that typically go on within A Level Biology? How would such changes relate to the design and structure of the existing qualification?

EXCITING INTEREST

What aspects or parts of the A Level course are most exciting and motivating to young people?

Is there a need to develop or extend these parts of the A Level course?

OTHER COMMENTS

Have you any other comments which you believe are relevant to this research?

APPENDIX 3

SURVEY OF BIOSCIENCE RESEARCH

BY

CITY UNIVERSITY, LONDON

SCHOOL OF INFORMATICS

City University School of
London Informatics

World and UK bioscience outputs, 1981-2001

for the Wellcome Trust
28 February 2003
by Grant Lewison
Project no. W0307 26 February 2003

1 INTRODUCTION

1.1 Origins of study

This study arose from an enquiry by Mr Julian Stanley, Regional Director of the Centre for Education and Industry at the University of Warwick, on Tuesday 11 February 2003. They have been commissioned by the Wellcome Trust to investigate whether the current A-level biology syllabus reflects the current balance of bioscience research.
Following initial discussions, the Trust agreed to accept a short study (3 days) as part of its allocation of free consultancy days in 2003 at the Bibliometrics Research Group at City University on 26 February 2003.

1.2 Objectives

The study was intended to show the numbers of research papers (articles only) in the Science Citation Index (SCI), © The Institute for Scientific Information, in each of 15 sub-fields of biology, expressed as percentages of all scientific output, in the five years 1981, 1986, 1991, 1996 and 2001. Outputs both of the world and of the UK were to be considered.
For six of the sub-fields, City University has "filters" that will selectively identify and extract papers in the SCI on the basis of their being in specialist journals or having one or more selected keywords in their titles. For the other nine sub-fields, papers would be taken purely on the basis of journal, using the categorization system developed by CHI Research Inc. for the US National Science Foundation.
The list of biological sub-fields, and the filters, or journal sub-fields, used to extract papers is shown in Table 1.

Table 1. List of biological sub-fields to be investigated, with the filters or journal sub-field sets used to define them, and codes used to designate them.

Topic	*Code*	*Filters or sub-fields used to define*
Molecules, biochemistry and the chemical basis of life	BIOCH	Biochem & Molec Biol
Cell biology and the structure of living organisms	CYTHI	CYTHI filter
The variety of living organisms – their characteristics and classification	GENBI	General Biology
Human biology, structure, and physiology,	ANMPH	Anatomy & Morphology Physiology
Animal biology, structure and physiology	GENMZ	General Zoology Miscellaneous Zoology
Brain, nervous system, and behaviour	NEUSC	NEURO filter
Growth, development and reproduction and fertility	DEVEL	DEVEL filter
Medical aspects of biology – health, fitness, disease, combating disease, immunology	IMM/INF	IMMAL and INFEC filters (in combination)
Microbiology	MICRO	Microbiology
Genetics, genetic research (eg GM foods), DNA, inheritance and evolution	GENET	GENET filter
Ecology – relationship between organisms and their environment	ECOLO	Ecology
Plant biology, structure and physiology	BOTAN	Botany
Food production, agriculture, horticulture	AFGDA	Agricult & Food Sci Dairy & Animal Sci
Environmental biology and the impact of humans on the environment	ENVIR	Environmental Sci
Biotechnology (e.g., use of micro-organisms for large scale production of insulin)	BIENG	BIENG filter

2 METHODOLOGY

2.1 Identification of papers

The filters were run against the SCI for each of the five years and the numbers of world and UK articles noted. For the medical aspects of biology sub-field, papers identified by either the IMMAL (immunology and allergology) or the INFEC (infectious diseases) filter were counted.

For each year, the bibliographic full sources of all world and UK articles were also downloaded. MS Access was used to list the journals in which the papers were published, and the numbers in each. These were then exported to an MS Excel file and compared with a file of journal sub-fields recently received from the US National Science Foundation. This gave the field and sub-field for each journal (in practice, about 3% of the journals from 1981-1991 could not be identified with a sub-field, and about 1% of journals in 1996 and 2001). It was then a simple matter to filter this column for each required sub-field (or pair of them) in turn to show how many articles had been published in each biological sub-field.

2.2 Categorization of the papers

It should be noted that the allocation of journals to sub-fields does not correspond exactly to the biological sub-fields listed in Table 1. Moreover, for many of the sub-fields, there will be additional papers in general journals. One sub-field (the characteristics and classification of living organisms) is not at all well characterised by papers in journals classified as "general biology", but no other classification was available.

3 RESULTS

3.1 List of outputs for each biological sub-field

Table 2 shows the numbers of papers in each of the 15 sub-fields listed in Table 1 as a percentage of the total numbers of articles in the SCI. The results are given for the world, but the right-hand column gives the corresponding mean percentages for the UK. The column heading "Trend" shows whether the percentage of papers in each sub-field has been increasing a lot (++), moderately (+), staying approximately constant (~), decreasing moderately (-) or decreasing a lot (--) over the 20-year period.

Table 2. Outputs of SCI papers in 15 biological sub-fields, 1981-2001, as percentages of all science.

Topic	*Code*	*1981*	*1986*	*1991*	*1996*	*2001*	***Mean***	*Trend*	*UK*
Molecules, biochemistry and the chemical basis of life	BIOCH	5.4	5.3	5.8	6.1	5.4	***5.6***	~	*5.8*
Cell biology and the structure of living organisms	CYTHI	1.2	1.4	1.5	1.9	2.0	***1.6***	++	*1.6*
The variety of living organisms - characteristics and classification	GENBI	0.2	0.1	0.1	0.2	0.2	***0.2***	~	*0.2*
Human biology, structure and physiology	ANMPH	1.1	1.3	1.3	1.2	1.1	***1.2***	~	*1.3*
Animal biology, structure and physiology	GENMZ	0.8	0.7	0.7	0.6	0.6	***0.7***	-	*0.7*
Brain, nervous system and behaviour	NEUSC	3.9	4.5	4.9	5.1	4.5	***4.6***	+	*4.7*
Growth, development and reproduction and fertility	DEVEL	1.0	1.1	1.2	1.3	1.2	***1.2***	+	*1.2*
Medical aspects of biology - health fitness disease and immunology	IMM/INF	8.5	9.4	10.1	10.8	9.6	***9.8***	+	*11.4*
Microbiology	MICRO	1.1	1.2	1.3	1.3	1.3	***1.3***	+	*1.4*
Genetics, genetic research DNA inheritance and evolution	GENET	3.1	3.7	4.9	6.4	6.2	***5.1***	++	*5.5*
Ecology - relationship between organisms and their environment	ECOLO	0.6	0.6	0.6	0.7	0.8	***0.7***	+	*0.7*
Plant biology, structure and physiology	BOTAN	2.3	2.3	2.2	2.2	1.9	***2.2***	-	*2.5*
Food production, agriculture and horticulture	AFGDA	3.1	2.5	2.5	2.3	2.2	***2.5***	--	*2.0*
Environmental biology, impact of humans on the environment	ENVIR	0.9	1.0	1.0	1.2	1.5	***1.2***	+	*1.1*
Biotechnology	BIENG	0.4	0.5	0.5	0.7	0.8	***0.6***	++	*0.6*
	Sum biol	**33.5**	**35.8**	**38.7**	**42.1**	**39.4**	***38.3***	**+**	***40.9***

4 DISCUSSION

4.1 Time trends

Table 2 shows that biology, as here defined, now occupies rather more of the SCI than it did 20 years ago, the percentage of papers in these 15 sub-fields having increased from about 33% to 40%. (These totals include some double-counting as the filter-

defined sub-fields may overlap with each other and with the journal-defined ones.) However there are also many areas of biomedicine that are not covered by these sub-fields. In fact, the percentage of SCI articles in journals classed as "biology", "biomedical research", "clinical medicine" or "health sciences" has declined from 57% in 1981 to 53% in 2001.
Within the areas of biosciences studied here, there are clearly some that have expanded, notably genetics (GENET), cell biology (CYTHI) and biotechnology (BIENG = biomedical engineering), all of which have doubled their percentage share of SCI articles, or nearly so. The latter might be held also to include some of the work in microbiology journals, which have also expanded although by not so much. On the other hand, food production/agriculture has apparently declined, as have the classical disciplines of botany and zoology. These sub-fields, however, have been defined only by means of specialist journals and there may be an increasing tendency for scientists in these areas to publish their papers in more general journals in order to attract a wider readership. It may not therefore be safe to conclude that interest in these subjects has waned relative to all science.
If it is important to discover the trends more accurately, then it would be necessary to create filters for the sub-fields not so defined at present so as better to reflect their content.

4.2 UK biological output

Table 2 shows that UK outputs parallel those of the world quite well but there are a few differences:

- the UK is relatively strong in botany, the medical aspects of biology, and genetics, relative to its overall presence in the SCI
- it is somewhat weak in food and agriculture.

It may be thought useful to take account of these differences.