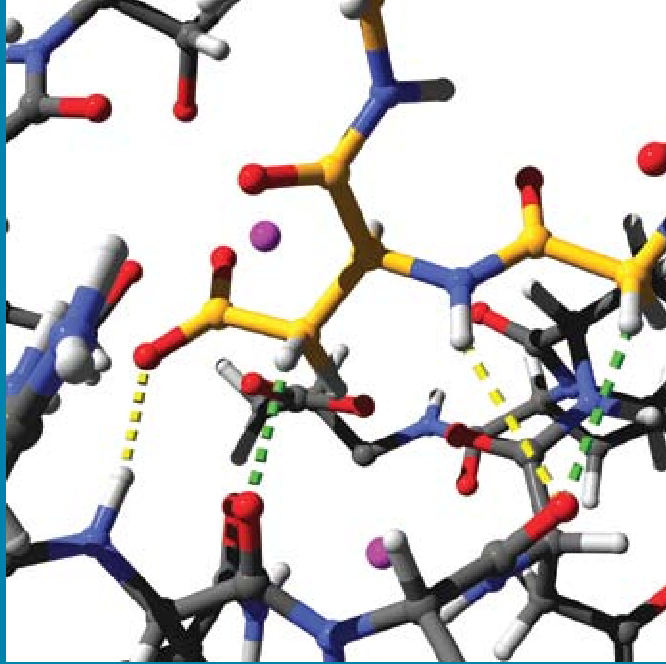

National Subject Profile for higher education programmes in:

Biochemistry

2008

The Higher Education Academy

CENTRE FOR bioscience

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1. Foreword

The National Subject Profiles are designed to provide contemporary characterisations of subjects and their provision in higher education. Informed by discipline communities and practitioners, the profiles have been initiated, compiled and written by the Higher Education Academy's Subject Centres.

Each profile establishes the contexts of current provision in relation to the historical development of the subject as a teaching discipline; the significance of the subject for employment; the current range of higher education (HE) programmes and curriculum content; the key teaching, learning and assessment patterns at subject level; trends in relation to staffing profiles; trends in relation to student entry profiles, student numbers and graduate destinations; and some baseline comparisons with other countries, including models of provision elsewhere and transferability of qualifications.

The profiles are core to the Academy's work in the mapping of trends in the student learning experience at a disciplinary level. They also meet a need across the sector for a contemporary baseline of trends within subjects, and provide a foundation that can be updated periodically so that the information they contain remains useful and relevant.

The Steering Group and the Academy are warmly appreciative of the vision, energy and creativity of the Subject Centres in instigating this major project, which the Academy believes will result in a landmark series of publications of particular significance to the higher education sector and its stakeholders.

Professor Bernard King CBE
Chair, National Subject Profiles Steering Group

Professor Robert Burgess
Chair, Higher Education Academy

2. Preface

I am very pleased to have the opportunity to write this preface to the National Subject Profile in Biochemistry. I congratulate Keith Elliott and his team for pulling together in one document a great deal of information to characterise the vibrant and diverse provision of Biochemistry programmes in higher education. These programmes are meeting the needs of students and providing graduates who make a major contribution to the economy. Some of this information has been available previously (and will continue to be provided so the Profile can be continuously updated), but the juxtaposition of previously separate data has enabled new insights and provided a necessary focus to highlight developing issues emerging from the Profile. Identification of these issues requires careful reading of the report, which reveals issues around:

- the amount and type of laboratory work carried out in programmes
- the nature and extent of the research project usually carried out in the final year
- the extent of funding per student provided for this laboratory intensive programme
- the competition between research and teaching and the recognition of teaching as a valid and realistic career path for academic staff
- the need for the curriculum to meet the needs of students who progress to discipline-based as well as non-discipline-based employment
- the expansion of knowledge and the blurring of boundaries between bioscience disciplines
- the balance between discipline specific knowledge and skills and discipline non-specific knowledge (for example, ethics) and generic skills.

As well as providing an important source of information I hope the availability of the Profile will stimulate discussion and change to ensure that higher education in Biochemistry best meets the needs of students. Against a background of major change in the discipline and the environment in which it is taught, students should graduate with the skills and knowledge required by employers and the economy in the future.

Professor Sir Philip Cohen FRS, FRSE
President of the Biochemical Society
Royal Society Research Professor
University of Dundee

3. Glossary of terms

Accepts. This term is taken from the terminology used by UCAS. The number of successful applicants for entry to a full-time, undergraduate subject programme. This may be close, but not necessarily identical, to the numbers who actually enrol in any one year. The ratio of applicants/accepts can be taken as an indicator of the extent to which demand from committed students is being met (if less than unity) or not met (if greater than unity).

Accredited programmes. Degree programmes which give rise to a qualification which is approved by the Institute of Biomedical Science for registration with the Health Professions Council.

All Biological Sciences. This term is taken from the classification used by HESA, and includes: broadly-based programmes within Biological Sciences; Biology; Botany; Zoology; Microbiology; Genetics; Sports Science; Molecular Biology, Biophysics & Biochemistry; Psychology; Others in Biological Sciences.

Applicants. This term is taken from the terminology used by UCAS. The number of prospective students who apply to UCAS for entry to full-time undergraduate programmes. Where applicants apply for more than one subject area they are counted as belonging to the subject area representing the majority of their choices (their preferred subject) as described by the JACS code. For some subjects this can give the impression that there are more accepts than applicants. This measure can be used as an indicator of the number of prospective students firmly committed to the discipline and the popularity of the discipline. The ratio of applicants/accepts can be taken as an indicator of the extent to which demand from committed students is being met (if less than unity) or not met (if greater than unity).

Applications. This term is taken from the terminology used by UCAS. Students are allowed to make up to five applications (six up to 2007) for programmes characterised by particular JACS codes. The total figure is the total number of applications as by 15 January of the respective year, which is the closing date for applications from UK and EU students.

Assessment. May be summative (carries marks which count towards an outcome), formative (does not carry marks but is there to help students assess their progress) or diagnostic (does not carry marks, but is designed to determine whether or not a student already has the required knowledge and/or skills or should be required to attend some particular learning exercise to achieve an appropriate standard).

Association of the British Pharmaceutical Industry (ABPI). The trade organisation of the pharmaceutical industry.

Biochemistry. Defined generally as the study of the molecular processes and transformations in living organisms.

Biosciences. Branches of natural science dealing with the structure, function and behaviour of living organisms. Comprises a large number of disciplines (from Plant Biology through Genetics and Psychology to Zoology).

Biosciences Benchmark Statement. Lists the generic and subject-specific attributes Bioscience graduates (Bachelors degree with Honours) should have acquired through their studies.

Bologna process. Started in 1999 with the aim of achieving greater convergence and mobility of students between European countries. Includes a framework of three cycles: first cycle: typically 180 to 240 ECTS credits, usually awarding a Bachelors degree. Second cycle: typically 90 to 120 ECTS credits (a minimum of 60 on second-cycle level) usually awarding a Masters degree. Third cycle: Doctoral degree. No ECTS range specified.

CETL. Centre for Excellence in Teaching and Learning. An initiative funded in England by the Higher Education Funding Council for England to provide, within an institution, a focus for development of a particular aspect of teaching and learning.

Clearing accepts. This term is taken from the terminology used by UCAS. This is the number of accepts deriving from the clearing process (in which students who have not been allocated a place on any of their five preference programmes can opt to take other programmes on which there are still vacancies). The clearing accepts as a percentage of all accepts can be taken as an indicator of the extent to which institutions were able to fill their places with applicants who applied for a particular programme and met the entry requirements they were given.

Combined degrees. Degrees combining one discipline with another discipline in a joint degree that splits the time between the two disciplines. The combination discipline is often a closely related discipline such as another bioscience, but combinations are available with more distantly related disciplines such as Forensic Science, Physical Geography, Management, Multimedia Applications/ Development or a modern language are available. The split between the two disciplines may have one as the major component (>60%), an equal component (60 to 40%) or a minor component (<40%). All Bioscience degrees will contain elements of other biosciences. It is the extent of the combination, especially in the final year, and the title of the degree which determines if it is a combined degree.

Contact hours. Direct face-to-face contact time between teaching staff and students as represented by hours of lectures, practicals, tutorials, seminars, etc. timetabled within a module. Contact hours (teaching) for a student may include time spent in activities partially supervised or supported by non-academic (technical and other support) staff, or activities being delivered by more than one teacher. Contact hours (workload) for a member of staff is the time during which they are directly teaching or facilitating student work, and does not normally include preparation or assessment time. Note that contact hours (teaching) for a student may be very different from contact hours (workload) for a member of staff since a one hour, one-to-one tutorial would represent one hour of student contact time (teaching) but would represent six hours of contact time (workload) if the member of staff was looking after six students.

Credits. Many UK universities operate the Credit Accumulation and Transfer Scheme (CATS) and all universities in Scotland use the Scottish Credit and Qualifications Framework (SCQF) enabling easier transfer between programmes and institutions. All higher education institutions (HEIs) in Wales use the Credit and Qualifications Framework for Wales (CQFW).

Under CATS at undergraduate level, 100 hours of student learning would typically, on successful completion, be worth ten CATS credits, at one of Levels 1 to 3. In many universities 360 credits need to be accumulated (120 credits at each level) to qualify for award of an Honours degree, but some universities operate this requirement flexibly. In Scotland 480 credits are normally required since Honours degrees are typically four years long.

The CATS measure of credits has been used in this Profile whenever values are given in terms of credits. Other countries in Europe use the European Credit Transfer and Accumulation System (ECTS) credits; 60 ECTS credits being broadly equivalent to 120 CATS credits.

C7 students. Students studying subject included in the JACS C7 subject coding. This includes Biochemistry and a variety of other subjects, as shown in Table 1.

European Union (EU). In the context of this report, with regard to the origin of students, EU students are taken to exclude those from the UK.

Foundation degrees. Designed and delivered in England and Wales in partnership with employers and higher/further education providers. Foundation degrees integrate academic and work-based learning and allow students already employed to undertake a programme of study while continuing to work. Programmes are delivered by colleges and universities and have flexible teaching arrangements including work-based, online and distance learning modes on a full-time or part-time basis. A full-time foundation degree programme will usually take two years to complete. After completing their foundation degree some students go on to study for an Honours degree (which usually takes one further year). There are no foundation degrees in Scotland but Higher National Certificates and Diplomas meet similar needs.

Health Professions Council (HPC). The regulator for professional biomedical scientists (for example, microbiologists and biochemists) working in a health/hospital laboratory context.

HESA. The Higher Education Statistics Agency. Central source of statistical information submitted by universities.

Industrial placement. A (usually) credit-bearing part of a degree programme spent in industry. A placement may or may not be paid, may last from a few weeks to a year and is usually supervised by an academic and an industrial supervisor. Sometimes called a sandwich placement.

Industrial year. A (usually) credit-bearing part of a degree programme spent in industry. A placement may or may not be paid and is usually supervised by an academic and an industrial supervisor. Sometimes called a sandwich year.

Institute of Biomedical Science. An organisation that accredits degree programmes as providing an appropriate qualification for registration with the Health Professions Council (HPC), which is the regulator for professional biomedical scientists working in analytical health laboratory contexts.

JACS (Joint Academic Coding System). The UK system for coding degrees in different subject areas. The JACS C700 programme code group (usually abbreviated to C7) is applicable to Biochemistry.

Laboratory classes. Can be "wet" (for example, "hands-on" laboratory work) or "dry" (for example, computer simulations and/or paper-based data interpretation exercises). May be associated with a formal schedule that students must follow or may use a more open-ended investigative approach. Often assessed on the basis of a write-up of the exercise rather than the actual performance of the student in the laboratory situation.

Lectures. Timetabled teaching, often of large numbers of students and usually lasting for about 50 minutes. The activities that take place in a "lecture" may often involve much more than listening and are increasingly involving interaction between the lecturer and the students and/or between students.

Microbiology. Defined as the study of micro-organisms (archaea, bacteria, fungi, protozoa, algae and viruses), the consequences of their interactions with other living organisms and the uses to which they can be put.

Postgraduate students. This term is taken from the terminology used by HESA. Students enrolled on programmes leading to higher degrees, diplomas and certificates, and professional qualifications, reported by the universities to HESA, including part-time and full-time students. Includes taught and research degree students.

Practicals. As laboratory classes.

Research project. A usually substantial piece of work, often part of the final year during which students work on a research question, sometimes as part of a research team. Research projects may be taken in a laboratory context and/or in a library context (researching published literature), or in other innovative contexts that may or may not be based on the discipline being studied (for example, producing teaching materials for schools). Usually carries a substantial number of credits and involves the writing of a 6,000 to 10,000 word dissertation.

Research student. Usually a student registered on an MPhil, MRes, PhD or DPhil programme involving mainly research work.

Seminars. Usually tutor-led, more participative for students than lectures and may involve a variety of activities (for example, oral presentation, debates, poster presentations).

SEMTA. The Sector Skills Council for Science, Engineering and Manufacturing Technologies in the UK.

Single subject degree. Usually a degree involving one specialism (for example, Biochemistry or Microbiology) though other subjects (for example, statistics, genetics) might be studied as a component.

SMEs. Small/medium sized enterprises. Usually considered as organisations employing fewer than 50 (small) or fewer than 250 (medium) people though different countries use different numbers. An SME can also be defined by its turnover.

Tariff. This term is taken from the terminology used by UCAS. The UCAS Tariff was introduced in 2002–03 and establishes agreed equivalences between different types of qualifications (for example, A-levels, Baccalaureates, Scottish Higher or other qualifications) and measures achievement for entry to higher education in a numerical format. This allows comparisons between applicants with different types and volumes of achievement. However, the tariff system does not include all qualifications.

Tariff points. This term is taken from the terminology used by UCAS.
A-level tariff:
Grade A=120; B=100; C=80; D=60; E=40.
Advanced Scottish Highers tariff:
Grade A=120; B=100; C=80; D=72.
Scottish Highers tariff:
Grade A=72; B=60; C=48; D=42.

Taught postgraduate programmes. Programmes containing substantial taught material, which is examined, and leading to Postgraduate Certificates, Postgraduate Diplomas, MSc and MRes degrees. Distinct from postgraduate programme by research (leading to MPhil, PhD, DPhil degrees) where the main component is research work and a thesis only is examined.

Tutorials. Usually involve a small group of students and are less formally structured than a lecture. Pastoral tutorials are concerned with a student's well-being rather than more academic learning outcomes. Tutorials may last 15 to 60 minutes.

UCAS. University Central Admissions Service. A central service through which prospective students apply for up to five choices (six to 2007 entry) of institution/programme.

UK education systems. The education systems in the four countries comprising the UK are diverging and features of one are not necessarily seen in others. For example, in Scotland the first degree is four years in length (England and Wales three years). The arrangement for tuition fees and student funding differ in each of the UK countries. National Teaching Fellowships and CETLs operate in England only. Prior to university, Scottish school pupils study Highers and Advanced Highers rather than A-levels.

Undergraduate students. This term is taken from the terminology used by HESA: all students registered on particular first-degree programmes reported by the universities, including part-time and full-time students.

4. Executive summary

1. The aim of this National Subject Profile is to present an overview of the provision of undergraduate and taught postgraduate Biochemistry programmes in higher education in the UK. This information will inform academic staff, parents, students, administrators, employers and planners about the nature of the provision and its diversity, and will form a baseline from which to map trends which may represent threats or opportunities for future developments in Biochemistry teaching.

2. Biochemistry can be defined as the study of the molecular processes and transformations in living organisms. Biochemistry provides the basis for specialised areas of chemistry, for example, protein, clinical or nutritional chemistry, and a basic understanding of biochemistry is essential for biosciences in general and for many other sciences, such as medicine, pharmacy and agriculture.

3. Biochemistry-based industries are thriving throughout the UK. The pharmaceutical industry for example, employs about 73,000 people and contributes £12.2 billion to exports. Another biochemistry-related industry is biotechnology, with hundreds of mainly small companies exploiting the new opportunities opened up by advances in biochemistry.

4. Over 300 undergraduate programmes involving biochemistry are provided by 70 institutions on a full-time or part-time basis. Undergraduate provision is very varied enabling students to choose a programme that meets their needs in terms of teaching and assessment methods used, support provided, options available and specialisms taught.

5. Student entry has been stable over the last four years with regard to numbers, the ratio of full-time to part-time students and the gender balance. The ratio of applications to admissions is more than six to one, and the average entry standard is 335 tariff points, which is higher than for biological sciences generally. An increasing number of overseas students are taking Biochemistry programmes in the UK.

6. Taught postgraduate programmes (188) leading to Postgraduate Certificates, Postgraduate Diplomas, MSc and MRes degrees involving biochemistry are readily available from more than 54 institutions for study on a full-time or a part-time basis. There is an impressive choice of specialisation in a wide range of biochemistry-related areas.

7. The evidence reviewed raises a number of key issues within the teaching of Biochemistry:

- the amount and type of laboratory work carried out in programmes and the engagement of students in practical work leading to employment
- the extent to which the laboratory skills of the graduates meet the needs of employers
- the nature and extent of the research project usually carried out in the final year
- the variability in the contact hours and amount of assessment per credit unit, and the extent to which this is justified by the philosophy of the programme and the teaching methods used
- the extent of funding per student provided for this laboratory intensive programme
- the available space in which to teach students

and its suitability
- the competition between research and teaching and the recognition of teaching as a valid and realistic career path for academic staff
- the need for the curriculum to meet the needs of students who progress to discipline-based as well as non-discipline-based employment
- the expansion of knowledge and the blurring of boundaries between bioscience disciplines
- the balance between discipline specific knowledge and skills and discipline non-specific knowledge (for example, ethics) and generic skills.

8. The industrial revolution and the age of the machine, which was followed by the electronic age, each changed the world. The biological age, with biochemistry at its centre, is happening now and will be as revolutionary for the lives of us all.

5. Background and context

5.1 Historical introduction to the development of biochemistry as a teaching discipline in the UK

5.1.1 Bioscience as a subject

Biosciences (branches of natural science dealing with the structure, function and behaviour of living organisms) comprise a large number of disciplines (from Plant Biology through Genetics and Psychology to Zoology). Biosciences can be studied at different levels of scale stretching from the biosphere and environment as a whole (the global level), through the populations of organisms that comprise the living biosphere, the individual organisms that make up the populations, the cells that make up organisms and the bio-molecular processes at molecular and atomic levels which function in cells.

The complexity of the biosciences, which are intertwined with other subjects such as Medicine, Mathematics and Environmental Sciences, requires a particular mindset from students, researchers and teaching staff alike. The biosciences are subjects that combine uncertainty and chance with "scientific rigour and an acceptance of diversity and variability, thus providing a very good training for the complexities of life" [1].

The individual biosciences used to be regarded as separate disciplines in their own right, but this situation is in transition. They are changing from being discrete disciplines to having more blurred boundaries. The underlying fundamentals are moving away from reductionist ideas to a systems approach, represented, for example, in the new discipline of Systems Biology. This transition is reflected in the organisation of the subject within higher education where there has been a steady trend towards the merging of departments that were previously devoted to individual bioscience disciplines. This has facilitated research by making more manageable the "fuzzy edges" between disciplines where substantial research growth takes place. Separate departments (for example, Biochemistry, Physiology, Pharmacology and Immunology) have therefore merged into schools (for example, Biomedical Sciences), which in turn have merged with other schools (for example, Biology and Plant Sciences and of Biochemistry and Molecular Biology) to form larger units (for example, faculties of Life Sciences).

The merger of academic departments into larger units in order to enable closer co-operation has led to the formation of teaching units and programme teams responsible for the organisation of specific teaching provision within the larger administrative units. This has also enabled a greater availability of degree programmes that encompass in one programme several areas of bioscience and/or other sciences, for example: Forensic Science; Sport Science; Applied Bioscience and Technology.

Students successfully studying for a degree in the biosciences will acquire an understanding of multidisciplinarity, an enquiring attitude and an appreciation of complexity. They will develop competence in team and individual working and in numeracy (often including information technology and statistics and, increasingly, bioinformatics) as well as proficiency in preparing reports in a written format for many different purposes, and in delivering presentations. Many of the degree programmes enable the development of general skills and competencies suitable for the world of work where the focus is not biosciences. Indeed, current figures show that many bioscience graduates are successfully pursuing careers outside the world of molecules, cells and organisms.

Biosciences are also essentially practical and experimental subjects. Consequently, appropriate opportunities to participate in collecting data by undertaking experiments and practical investigations (for example, fieldwork for field biologists and laboratory studies for most other groups) are integral to any programme of study in this area. The appreciation of hypothesis formation and testing is also often developed by project work in the various sub-disciplines. Group work, problem-based learning exercises in practical situations, and (in some programmes) placements have important generic training benefits [1]. These particular qualities reflect what employers expect from bioscience graduates.

In 2005–06 there were 155,220 students studying a bioscience subject within higher education. In addition, the bioscience departments, schools and faculties provided significant service teaching to medical students (59,585), students in subjects allied to Medicine such as Pharmacy and Nursing (309,405), Agriculture and Food Science students (17,275), Veterinary Science students (4,465) and many others. These numbers compare with the total numbers of students within higher education of 2,336,110[2]. Provision of higher education in bioscience within further education colleges is patchy and is mainly concentrated in the land sciences (agriculture).

Other factors that have led and continue to lead to changes in teaching and the student experience in the biosciences are:

- realisation that about 50% of those studying bioscience may progress to employment in non-bioscience areas. This makes the explicit teaching and assessment of generic skills, knowledge and attitudes for all bioscience students even more important
- increased participation of students, leading to increasing numbers of students in the biosciences. As a consequence there is a greater diversity of students' ability, motivation and aspirations
- increased costs and health and safety issues associated with practical/field work
- diversity of final-year Honours projects (laboratory-based or literature-based, or a combination of both, or involving other innovations)
- increased discipline knowledge (and therefore time pressures on the curriculum)
- the fast pace of developments in fields such as Molecular Biology and medical research
- availability of information technology facilities and solutions
- greater availability of different learning techniques, such as e-learning and blended learning
- a diminishing unit of resource, funding differences across the UK and variable study fees
- an increasing proportion of overseas students
- competition between universities for students (particularly for excellent students).

A National Subject Profile over the whole range of the biosciences would be an enormous undertaking. In addition, if information is to inform and change the student learning experience, it must be available in discrete packages that match the granularity of the system through which it is administered and delivered, and through which discrete change can be informed and enacted. It is for these reasons that Profiles in selected parts of the bioscience provision have been undertaken since it is the discipline that is the cohesive influence for both the teacher and the student.

In 2007, the first two of these Profiles were commenced in Biochemistry and in Microbiology, both to benefit the disciplines and as pilots for further Profiles. We chose these two disciplines because:

- Biochemistry is a discipline in its own right and underpins many other biosciences. A knowledge of some biochemistry is required for most other biosciences in order to understand processes and systems. Biochemistry students at undergraduate and postgraduate levels form 6.4% of all bioscience students (i.e. 9940 students; 2005–06) [2]
- Microbiology has strong links to the public

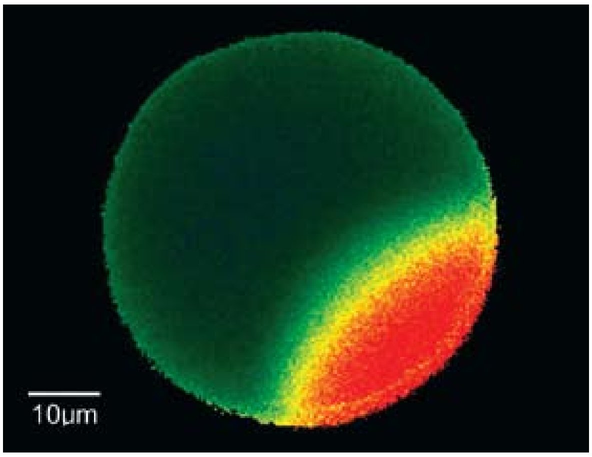


Figure 1. Calcium gradient in an oocyte. This image is of an oocyte injected with a furan dye viewed with a confocal microscope. Following fertilisation a wave of calcium spreads through the cell – and this is visualised by the orange and red colours against the general green cytoplasmic background.

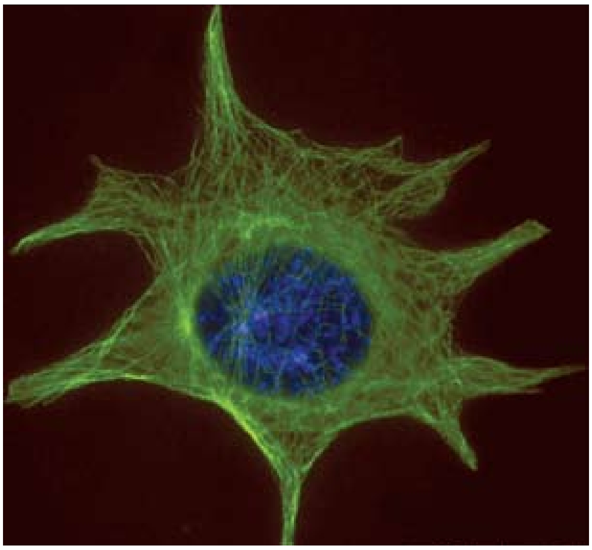


Figure 2. An immortalised mouse inner ear epithelial cell. The cell is labelled with an antibody to alpha-tubulin (microtubules) and stained with an Alexa-Fluor-488-conjugated secondary antibody (green). The cell's nucleus was counterstained with DAPI (blue).

health sector and to industry and underpins many strategically-important research areas in the biosciences. It is a slightly smaller subject area (2.8% of all bioscience students, 4370 students; 2005–06)[2].

Both disciplines encompass relatively well-defined areas with strong learned societies and make a significant contribution to the national economy. Both disciplines have been subject to changes recently because of the factors outlined above and the explosion of information available within biosciences generally.

5.1.2 Biochemistry as a bioscience

The term biochemistry was first defined in 1903 (for the study of enzymes and fermentation processes), although investigations of the nature and function of biomolecules had already begun in the 19th century. Today's biochemistry is often defined more generally as "the study of the molecular processes and transformations in living organisms".

From this definition it follows that biochemistry is intertwined with other disciplines involving the study of living organisms, such as Genetics, Cell Biology and Molecular Biology (Figures 1 and 2). Biochemistry also provides the basis for more specialised areas of biological chemistry, for example: protein chemistry, clinical chemistry or nutritional chemistry. A basic understanding of biochemistry is essential for many other sciences, such as medicine, pharmacy and agriculture, which is why biochemists provide a significant amount of service teaching to other academic disciplines. However, information about biochemistry on a broader level, in the way of providing general facts about living beings, also has a wide appeal across many more disciplines. It is also of wide interest to the general public, as judged by the regular occurrence of news themes directly or indirectly related to biochemistry in today's mass media, and including in television programmes such as Ever Wondered About Food and even CSI.

A Biochemistry programme will entail the study of all the complex interrelated chemical changes that occur within living beings, for example, those related to protein synthesis, the conversion of food to energy, the transmission of hereditary characteristics and the mechanisms by which body functions are performed such as muscle movement and neuronal transmission. Both the degradation of substances that release energy and the build-up of complex molecules that store energy or act as substrates or catalysts for biological chemical reactions are studied. Biochemistry also deals with the regulatory mechanisms, including hormones, within the body that govern these and other processes.

Over the last five to ten years the amount of available biochemical information has increased enormously. For example, the human genome, first published in the year 2000, holds the sequence of three thousand million "letters" of the DNA code, and the number of known DNA and protein sequences now runs into the hundreds of thousands and is increasing daily (Figure 3). Only computers can deal with this vast amount of information (stored on databases in various universities around the world) and the science of storing, searching and using this information is called "Bioinformatics". Students must have knowledge of this information and at least some information technology skills in order to be able to use it. Training in this area should now be part of all effective Biochemistry programmes.

5.2 Significance of biochemistry to the UK economy

Biochemistry-based industries are thriving throughout the UK and contribute hugely to our quality of life and the economy of the country, both internally and through exports. Biochemistry is involved directly in a huge range of industries including health care (medical and veterinary), agriculture (crops and animals) and food. One example is the UK pharmaceutical industry and in 2006 pharmaceuticals contributed about 6% of all UK exports, which made them number five in the top 30 of all externally traded commodities[3]. Britain's pharmaceutical industry employs 73,000 people directly and hundreds of thousands indirectly in support roles. The value of UK pharmaceutical exports in 2005 was £12.2 billion, or more than £166,000 per employee[4] (Figure 4).

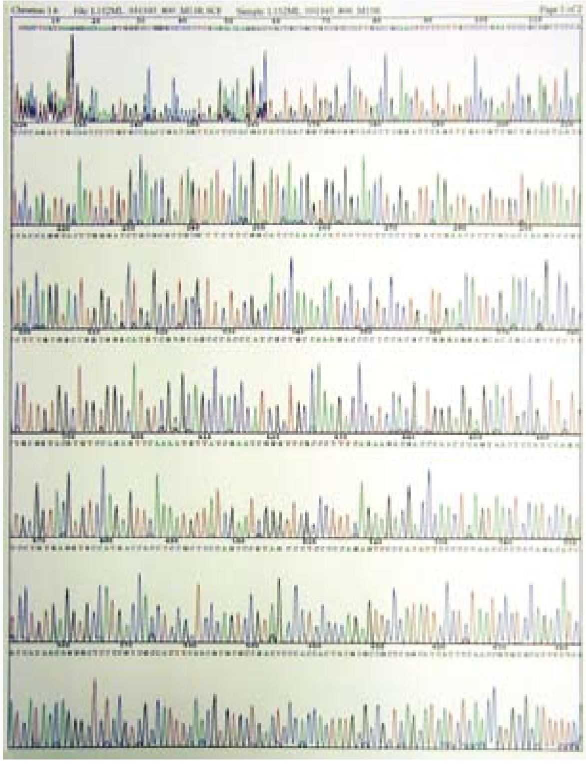


Figure 3. DNA sequencing gel printout. The development of methods for the rapid sequencing of DNA has allowed biochemists to sequence the human genome. This advance opens the door to the possibilities of identifying specific diseases and personalised medicine.

Figure 4. High throughput screening robot. Many analytical techniques that are developed on a small scale have now been modified to deal automatically with large numbers of compounds in screens for potential drugs that will contribute to pharmaceutical exports. This means that, for example, a million compounds may be screened for biological activity in just a few months.

Another biochemistry-related industry is biotechnology, with the UK being one of the main centres in the world for commercial biotechnology activity. In 2003, the UK was first in Europe with the foundation of 36 biotech companies. Biotechnology involves many biochemical activities and is one of the major contributors to the "new" economy. It is one of the economic sectors with the highest rates of growth in research and development investment worldwide[5]. The overall figures for UK patent applications can be taken as key indicators for the commercialisation of scientific innovation and are very positive. The UK ranked third for the number of patent applications to the European Patent Office in 2002, with 12% of all applications. Of these UK patents 18.4% were in the field of Human Necessities and 17.1% in Chemistry, both categories that incorporate patents in biochemistry[47]. On a regional level, three of the top ten regions for biotechnology patents in Europe are English: Berkshire, Buckinghamshire and Oxfordshire; Inner London; and East Anglia[5]. Biochemistry is involved indirectly in many other areas, such as teaching.

In terms of potential, the forthcoming age of biology, centred on biochemistry, could contribute as much to changes in lifestyles and the wealth of the country as did the Industrial Revolution.

5.3 Employer/practice environment

Any consideration of employer/practice environment must take into account the question of "who is the employer?". In this context it must be appreciated that 50% or more of those taking Biochemistry degrees may choose to take employment outside discipline-related jobs. Of those pursuing biochemical-related careers, most Biochemistry graduates find employment within pharmaceutical companies, biotech companies, research institutes and universities, contract research organisations and hospitals. A smaller percentage also find employment within companies that develop and manufacture food and drink and domestic products, forensic science laboratories, water treatment plants, agricultural companies and medical writing companies. Of those pursuing non-biochemical careers, the destination is widespread (section 6.2.5). Biochemistry degree programmes must therefore provide for those who intend to pursue biochemistry as a career as well as those who are taking it because it is a fascinating subject, but who intend to work outside biochemistry on graduation.

During their studies, Biochemistry graduates will acquire a mixture of knowledge and skills that are generic and subject-specific. These range from those that are intellectual through to communication skills and specific laboratory/practical skills. Appropriate attitudes are also developed. These are applicable to employment in any sector as is illustrated in the Employability Profiles from the Higher Education Academy[6].

The Biosciences Subject Benchmark Statement[1], written by the bioscience community for the Quality Assurance Agency, lists the generic and subject-specific attributes a bioscience graduate (Bachelors degree with honours) should have acquired through their studies. According to this statement a bioscience graduate will have:

- an appreciation of the complexity and diversity of life processes through the study of organisms, their molecular, cellular and physiological processes, their genetics and evolution, and the interrelationships between them and their environment
- the ability to read and use appropriate literature with a full and critical understanding, while addressing such questions as content, context, aims, objectives, quality of information, and its interpretation and application
- the capacity to give a clear and accurate account of a subject, marshal arguments in a mature way and engage in debate and dialogue both with specialists and non-specialists
- critical and analytical skills: a recognition that statements should be tested and that evidence is subject to assessment and critical evaluation
- the ability to employ a variety of methods of study in investigating, recording and analysing material
- the ability to think independently, set tasks and solve problems.

The same benchmark statement specifies that a Bioscience graduate's skills will include:

- intellectual skills
- practical skills
- numeracy skills
- communication, presentation and information technology skills
- interpersonal and teamwork skills
- self-management and professional development skills.

This catalogue of skills provides a good summary of employers' expectations whether they are in biochemical or non-biochemical areas[6].

According to a 2006 Sector Skills Council for Science, Engineering and Manufacturing Technologies (SEMTA) survey[7], 39% of employers in the pharmaceutical and bioscience industrial sector feel there are hard to fill vacancies, particularly in the bioscience and molecular bioscience (biochemistry) areas. Bioinformatics areas are particularly hard to fill. Some 22% feel there is a skills gap between their needs and the skills of their employees (five times that in other sectors). Overall, about half of the skills gaps were observed in scientific skills and the other half in generic skills.

A lack of skills and difficulties in recruiting suitably skilled individuals were also reported by the Association of the British Pharmaceutical Industry (ABPI)[8] and others[23]. Biochemistry, biotechnology and biopharmaceutics were particularly identified as medium priority areas for development with regard to numbers and quality of graduates. Identified weaknesses in core science graduate training included:

- lack of rigour in programmes
- insufficient knowledge of quantitative analytical techniques
- poor knowledge of statistics and mathematics
- lack of core graduate practical skills.

Our anecdotal evidence, gathered from biochemist contacts in industry, public sector and small/medium sized enterprises (SMEs), paints a slightly different picture. Although a few employers did note the varying levels of graduates' skills, this was generally attributed to the individual rather than to the state of university education.

In fact, our biochemist contacts in technical and operational departments in industry stated that they are relatively satisfied with graduates' skills in Biochemistry, such as gathering, evaluating and presenting information, the development of analytical protocols, problem solving, self-motivation and team skills. They did not expect any extensive experience in laboratory methods, with most of them being aware that on-site laboratory training at university is constrained by time and funding.

However, in previously unpublished work, all the Biochemistry graduates and students interviewed would have preferred more training in laboratory methods. As one of them said "we were shown the results of a Polymerase Chain Reaction (an important and widely used technique to amplify tiny amounts of DNA) but not the method. I would have liked to do the PCR myself." This is similar to the results of a 2003 survey[9] in which 21% of employed biosciences graduates said that they felt that their university practical training had not prepared them sufficiently well for their occupation. It may be there is a mismatch between students' expectations (that all laboratory work will be interesting and "cutting-edge") and the needs of industry (and science work generally) where repetition and routine are important and necessary, if tedious.

Some of our employer contacts also noted a lack of understanding of "the big picture", implying that Biochemistry graduates may not be aware of how to relate their own specific knowledge and experience to the life sciences in general. They may also be unaware of the applicable standards and regulations (such as Good Laboratory Practice) and business organisation. The apparent need for better training in standards and regulations has already been noted in a 2006 regional survey of operational staff in life science companies[10]. The extent to which this is or should be the responsibility of the universities is, however, debatable.

Within the large research and development (R&D) industries, graduates have the advantage of entering companies via graduate-training programmes. The 2006 SEMTA survey[7] reported that 15–23% of surveyed sites have graduate training schemes in place. This matches the 15.2% of all UK employees receiving job-related training in 2006 as stated by the Department of Education and Skills.[11]

The graduate training programme provided by one large company includes safety, information technology, personal effectiveness plus basic laboratory skills, for example, laboratory instruments, molecular biology, cell biology, protein purification and enzymology. It includes pipetting skills. ("Overview of the use of pipette types readily available. Topics will include the different types of pipette methods for reliable liquid handling, when to use different techniques (for example, reverse pipetting), pipetting a variety of liquids and accuracy of pipetting. Skills will be assessed by a short practical looking at precision of pipetting by the determination of unknown protein concentration and the masses of various liquids.") It is worthwhile noting the view of the Biochemistry Panel that the detailed content of the programme has evolved to equip graduates with the skills and knowledge which some of them have not acquired satisfactorily in their university programme.

Following completion of the initial company training, graduates tend to be placed with any of the R&D programmes to start their industrial career. Skills in data interpretation, critical analysis, experimental design and execution are therefore essential to enable the graduate to adapt quickly into any working environment. Despite there being a consensus on a skills gap with graduates, our contacts did comment that there were varying levels of graduate skills and this was attributable to the individual, and most likely affected by their student experience. In most cases higher levels of skills were found in graduates who had spent a year out in industry or had exposure to more practical experience through alternative placements (for example, summer, *ad-hoc* work experience) or their final-year projects. Due to this, practical and/or work experience is important within the selection criteria for assessing applications to the R&D industries.[23]

Although the provision by employers of a graduate training scheme could, as suggested by SEMTA, be due to a lack of suitably skilled candidates, it may also be part of a desire to provide an attractive workplace for newcomers and to inculcate new employees in the ethos of the company.

In contrast, SMEs, in most cases, find it difficult to absorb the costs of intensive training programmes and most vacancies are for specified jobs. As many graduates have limited previous work experience, applications for these specific-roles may be limited to those who have studied for a more focused degree dealing with, for example, *in vivo* pharmacology, enzymology or pure biochemistry, rather than general modular programmes and who therefore have more focused knowledge, skills and understanding applicable to the role.

Within the public sector, most graduates will enter non-science based roles where the generic skills they developed during their degree are of the most importance. For the minority that enter the limited scientific-based public sector roles, students will essentially have come from an accredited degree, such as Biomedical Sciences and enter a designated training career. These graduates are therefore "groomed" in their degree programme for the purposes of their chosen career.

SEMTA further reports[7] that 26% of employers recruit from overseas. According to the report, this could be one strategy to overcome the perceived skills gap. Anecdotal evidence from our contacts indicates that today's employers have moved to internet-based advertising, often on their own web sites, which is then open to being harvested by transnational job search engines. If appropriate, candidates will be accepted on skills and qualifications only, with their country of training bearing little or no importance for most positions.

It is evident that employment for Biochemistry graduates is very competitive. Places available on graduate training courses within large R&D companies have diminished over the years and, due to the focus on practical-experience, many graduates will delay entering a profession and pursue further education or contract positions to try to gain suitable experience or move away from a discipline-related career. For those who do wish to pursue scientific public sector roles requiring an accredited degree (i.e. one approved by the Institute of Biomedical Science as providing a qualification suitable for registration with the Health Professions Council for work in public sector health-related analytical laboratories), this choice must be made before beginning their degree as, once on an unaccredited degree, they will not have the option to pursue this career afterwards without considerable additional training. This can be an unfortunate realisation for a number of graduates who subsequently need to retrain at the expense of further cost and time.

All in all, the information available about employers' expectations may seem somewhat contradictory and may reflect a diverse requirement from different employers. It should be noted that parts of the SEMTA survey have attracted some criticism with regard to the validity of the data. The evidence gathered in compiling this Profile is factual as well as anecdotal, and may simply flag up the need for further collection and collation of robust data on this important aspect.

5.4 Impact of biochemistry on society

Modern biochemistry has long outgrown its earlier status as an applied science only and has acquired a place among the pure, or theoretical, sciences. Nevertheless, since biochemical research often deals with applied subjects, such as the chemical changes in disease, modes of drug action, nutrition, genetics or agriculture, research findings in these areas, or developments based on them, will often have an impact on humans, their environment and the economy.

Perhaps the most important concept to emerge from biochemistry research is that, at the biochemical level, there is surprising unity among the manifold forms of living matter. A chemical process studied in yeast culture may, for example, clarify a comparable series of reactions in mammalian muscle, or the study of the respiratory pigments of invertebrates may provide basic data that help to explain a general mechanism of biological oxidation.

This general applicability is reflected in the fact that the prestigious Nobel Prize is regularly awarded to biochemists and about half the prizes for Medicine and Physiology and about one third of the prizes for Chemistry have been awarded to people who would now be considered as biochemists or molecular biologists. Last year's (2006) prizes in Medicine and Chemistry were both won by Biochemistry research groups – for the discoveries of Ribonucleic Acid (RNA) interference and the molecular basis of eukaryotic transcription, respectively. Famous biochemists from the UK who are Nobel Prize winners include, among others, Frederick Sanger (twice!), Francis Crick, Hans Krebs and Paul Nurse, all of whom, in the words of Alfred Nobel's will, made discoveries which "have conferred the greatest benefit on mankind" [12].

The 2007 Nobel Prize in Medicine (there is no prize in Biochemistry specifically) was awarded to Drs Mario Capecchi and Oliver Smithies, and Sir Martin Evans. Dr Smithies was born in Britain, but now works in the US. Sir Martin Evans is from Cardiff University. A key part of their work on DNA was to develop a way of producing "knock-out" mice. By eliminating (knocking-out) a single gene, in other words a single stretch of DNA, it becomes possible to produce "mouse models" of human diseases on which new therapies can be tested. Sir Martin was the first person to isolate embryonic stem cells from mice thus founding stem cell technology, which has tremendous potential for treating disease.

The pervasiveness of biochemistry is illustrated by considering a short list of areas where biochemistry has made a major impact:

- understanding and treating disorders of human metabolism (diabetes and diseases such as phenylketonuria – currently newborn infants are screened for at least 20 so-called metabolic diseases)
- understanding disease processes (Parkinson's disease, hypercholesterolaemia)
- discovering and developing new medicines (antihypertensive therapies)

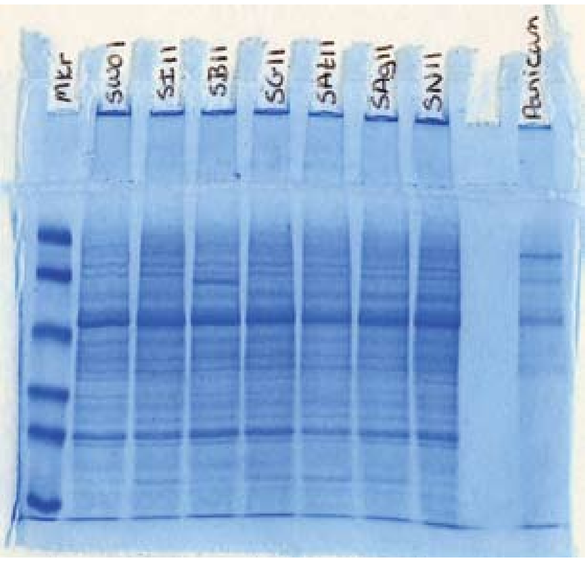


Figure 5. SDS-PAGE (sodium dodecyl sulphate polyacrylamide gel electrophoresis). This technique is often used to separate and analyse the proteins present in tissue samples. This gel shows the proteins present in the tissue of the plant *Sarracenia purpurea* (the purple pitcher – a carnivorous plant). The track on the left shows "marker" proteins of known molecular weight that are used to calibrate the gel.

- biotechnology and the use of cloned/ manipulated DNA to enable valuable proteins (Figure 5) to be produced in bacteria, yeasts and plants (for example, human insulin)
- understanding chromosome structure, identification of faulty genes in prenatal diagnosis (for example, of Down's syndrome and spina bifida) and the identification of disease susceptibility from analysis of the genome (for example, breast cancer)
- understanding of antibody structure and technology for producing monoclonal antibodies widely used in diagnosis (for example, pregnancy testing) but also possibly as "magic bullets" for targeting cancer cells
- knowledge of many 3D protein structures that can be manipulated on the screen to design potential therapeutic molecules
- biological washing powders and detergents
- cosmetics in all forms and "cosmeceuticals"
- use of enzymes in sensitive and easy diagnostic tests (for example, Clinistix®)
- genetically modified agricultural crops and biofuels
- use of enzymes in many processes to perform "difficult" chemical transformations or to carry out stereospecific conversions.

The full impact of biochemistry on society has yet to be felt. The mechanical age and the electronic age have both changed the world. The biological age, with biochemistry at its centre, is happening now and will change the world for all of us.

5.5 Generic background issues not specific to biochemistry

Between 2002–03 and 2004–05, typical figures for overall space per student in higher education went down by 3%, with reductions, particularly in teaching space, taking place in nearly 60% of higher education institutions. Support space and office provision for academic and support staff hardly changed. All in all, overall student numbers rose faster than space, and this has put pressures on teaching, especially of laboratory based subjects[19].

The Royal Society, in its 2006 report "A degree of concern?"[14] evidenced that there has been a reduction in the unit funding of students over a long period. This may have been offset somewhat by the introduction of tuition fees in 2006, but it is still too early to quantify the effects of fees on the resources for teaching and learning. An extensive data gathering exercise, the "Transparent Approach to Costing" will deliver more quantifiable information on costs by February 2008.

In its report[14] the Royal Society expresses the view (as it did in 2005 to the House of Commons Science and Technology Committee) that university degree-level teaching is under-funded and subsidised from research activities and, possibly, from lower-cost teaching activities. As stated, "Laboratory-based projects in the final years of BSc honours programmes are especially expensive, and laboratory-based subjects have been particularly badly hit when research income from the Funding Councils has been cut".

From 2007–08, the Higher Education Funding Council for England has allocated £75 million in additional funding for three years to support subjects (including Chemistry and Physics) that are very high cost, strategically important to the economy and society, but vulnerable due to low student demand. However, there has not been an equivalent allocation for bioscience programmes, despite the requirement for expensive specialist chemicals, equipment and facilities. It is also a misconception that the biosciences are not vulnerable to decline in student demand. Government figures for bioscience students include those studying subjects that would not be universally regarded as being within the "core" bioscience disciplines (for example, Psychology, Sports Science), but which are increasingly popular.

Space and resource issues are therefore, in biochemistry as in the rest of biosciences, sources of pressure on teaching, as is the relative importance of research as opposed to teaching in the career progression of academics. This latter pressure is easing somewhat with the introduction in some parts of the UK of national and local schemes that recognise excellence in teaching (National Teaching Fellowships, for example[15]). Furthermore, many local promotion criteria now make specific reference to contributions to teaching in all its aspects, including for promotion to professorial level, but it is vital that this is respected by the entire academic community.

Other initiatives such as the Higher Education Academy Subject Centres[48], particularly in the context of biochemistry, the Centre for Bioscience[49] and the Centres for Excellence in Teaching and Learning (CETLs)[50] are also functioning, where they are available, to support and to raise the profile of teaching.

Other increasingly important levers to effect changes in teaching are:

- the results from the National Student Survey[32], which have clearly identified issues that are important to students, such as feedback
- the introduction of Postgraduate Certificates in Teaching in Higher Education or similar qualifications
- the UK Professional Standards Framework for teaching and supporting learning in higher education[51].

These issues will continue to influence the provision and delivery of Biochemistry degrees. Academic staff, students and employers will need to respond to the changing environment in which higher education operates, the changing demands in the economy and the changing nature of the discipline. We need to appreciate that evolution does not only apply to organisms.

6. Teaching and learning of Biochemistry in 2007

6.1 Provision across the UK of Biochemistry undergraduate and taught postgraduate programmes

Biochemistry is a component of several types of degree programme within UK higher education at undergraduate and postgraduate levels. There are postgraduate research degrees and taught higher degrees (mainly Masters) and also undergraduate degrees such as single subject programmes (Honours BSc in Biochemistry) and combined degrees (joint honours), involving a combination of Biochemistry, in various proportions, with a range of other disciplines. These discipline-focussed programmes together involve 9,940 students (2005–06). There are currently 7,100 students studying Biochemistry at undergraduate level and 2,840 postgraduate students on taught programmes or doing research degrees. In addition, at least 500,000 students are registered on programmes in which taught biochemistry is an essential part of their degree (for example, many other biosciences, Medicine, Dentistry, Pharmacy, Nursing)[2].

This National Subject Profile has concentrated on the discipline-focussed programmes. In UK higher education all programmes of study are classified with a code from the JACS (Joint Academic Coding System). The JACS C700 "Principal Subject" code group (usually abbreviated to C7) denotes the discipline of Biochemistry and includes the sub-groups C710 to C790. A short description of each sub-group is given in Table 1[16].

A web search for all "Biochemistry" programmes at UK universities shows that 70 UK universities will admit students to such programmes in 2008[18]. Of these, 55 are in England, eight in Scotland, six in Wales and one in Northern Ireland. There are significant differences in the number of students admitted to each institution and in 1996–97 66 institutions admitted at least ten students and 41 at least 100; the corresponding figures in 2001–02 were 64 and 31, and in 2005–06 were 63 and 35[17]. There are no clear trends in these data to indicate substantial changes in the size of teaching units.

Across these providers there are 314 programmes offered. Of these programmes (Figure 6):

- 155 (50%) are single subject Honours programmes falling within the C7 JACS code
- 131 (42%) are degrees combining Biochemistry with another subject (combined degrees) provided at 40 universities. The combination discipline is often a closely related discipline such as Microbiology, Biotechnology, Cell Biology or Genetics, but combinations with more distantly related disciplines such as Forensic Science, Physical Geography, Management, Multimedia Applications/ Development or a modern language are also offered. The biochemistry component may be the major component (25, 8%), an equal component (81, 26%) or a minor component (10, 3%) as shown in Figure 6. There are also 15 (5%) that contain no C7 discipline within their title
- 28 (9%) are single subject Honours classified within non-C7 JACS code groups and are provided at 19 universities. These fall within the JACS group Biological Science C (for example, Biology C100/C110,

Table 1. Descriptions of the relevent JACS code "Principal Subject" second sub-groups (C700–C790)

JACS code	Discipline	Description
C700	Molecular Biology, Biophysics and Biochemistry	The scientific study of the chemical compounds and reactions occurring in the cells of living organisms including the molecular and biochemical analysis of life processes. Involves aspects of cellular organisation and specialisation and how the structure and function of DNA, RNA proteins, enzymes and membranes determine biological processes.
C710	Applied Molecular Biology, Biophysics and Biochemistry	Topics in Molecular Biology, Biophysics and Biochemistry of commercial or social importance.
C720	Biological Chemistry	The study of the molecules and compounds that make up cells and organisms, how they are formed and how they interact. Includes the study of Molecular Biology.
C730	Metabolic Biochemistry	Covers the biochemical aspects of metabolic processes.
C740	Medical and Veterinary Biochemistry	The study of the molecular basis of health and illness.
C741	Medical Biochemistry	Covers the biochemical aspects of metabolic processes in humans.
C742	Veterinary Biochemistry	Covers the biochemical aspects of metabolic processes in animals.
C750	Plant Biochemistry	Concerned with cellular processes in plants including the understanding of the expression of genetic information.
C760	Biomolecular Science	The study of the molecular processes in the life sciences.
C770	Biophysical Science	The use of the methods of physical science in the biological sciences.
C790	Molecular Biology, Biophysics and Biochemistry not elsewhere classified	Miscellaneous grouping for related subjects that do not fit into other Molecular Biology, Biophysics and Biochemistry categories. To be used sparingly.

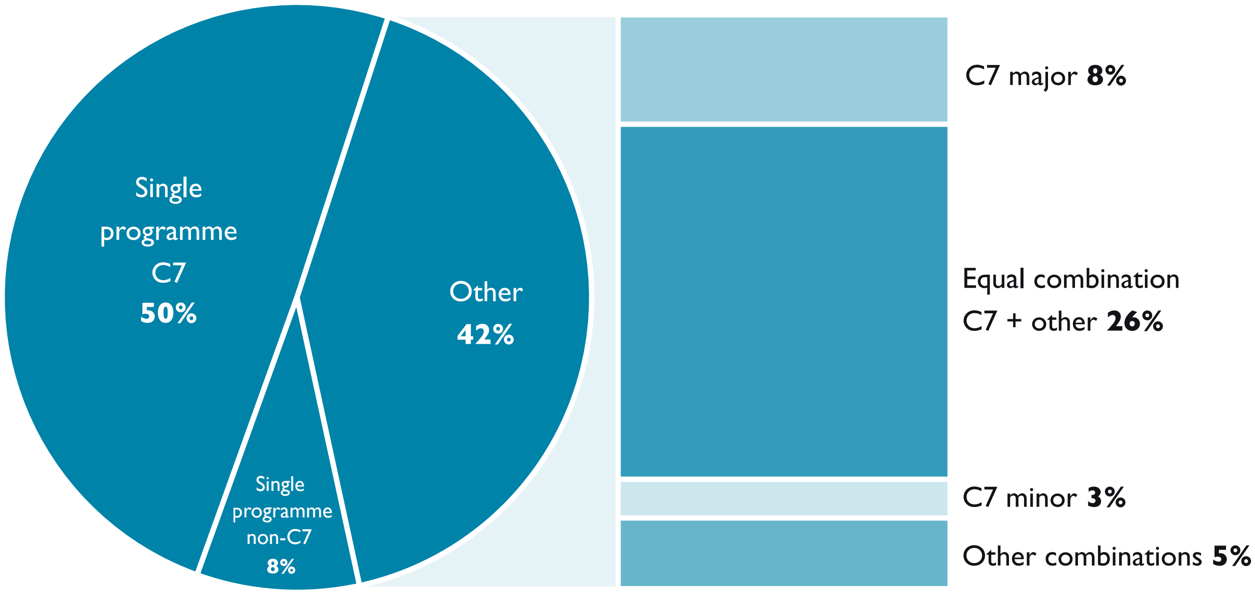
Exercise/Nutrition/Health Science C601, Immunology C550, Genetics C400), or an altogether different JACS group (for example, Biotechnology J700, Pharmaceutical Science B202, Food Science D610, Biochemical Engineering H811 and Biomedical Sciences B900/B901/B940/B990)
- 19 programmes in ten universities lead to an integrated Masters ("MSci") rather than a Bachelors degree.

The duration of programmes is not uniform. The CRAC (Careers Research and Advisory Centre) Programme Guide for 2006–07[20] identifies 187 programmes leading to degrees in Biochemistry:

- 57 had a fixed duration of three years
- 100 had a flexible length of three or four years
- 20 had a fixed duration of four years (of which 14 were Scottish universities)
- nine had a flexible length of four or five years (Scottish universities)
- one had a flexible length of three to five years
- 92 programmes offer the possibility of a foundation year at the same or a franchised institution (of which 22 allow entry to the programme at Year Two; Scottish universities only).

The differences in duration hinge round the compulsory, optional or absence of provision

Figure 6. Types of Biochemistry BSc honours programmes on offer 2008–09



Source: UCAS.

of an industrial placement year, the location in Scotland or the provision of a foundation year.

A search of the UCAS website[18] under foundation degrees showed only one foundation degree specifically in Biochemistry, though some more generic bioscience, biomedical science or biology programmes are offered in 15 of the 314 degree programmes returned by the search. In 2005–06 no students graduated with foundation degrees in Biochemistry[13].

6.2 Undergraduate Biochemistry programmes

6.2.1 Prior education at school/college

Most undergraduates entering Biochemistry programmes will do so with a strong background in science having studied a variety of science subjects at school. At A-level the number of candidates in science subjects has reduced over the last seven years (2000 to 2007), Biology by 0.3%, Chemistry by 1.4% and Physics by 14.3%, although there is some variability year to year. This effectively means that only Physics has fallen significantly in absolute terms. These data must be set in the context of the numbers sitting all A-level subjects, which showed a rise of 4.4% over the same period[22]. The number of pupils opting into science has therefore decreased and is likely to decrease further with the projected demographic contraction of the 16 to 18 year old age group[21].

Admission requirements for Biochemistry programmes are detailed in section 6.2.2.1, but it is noteworthy that the Joint Council for General Qualifications[22] reports improvements in learners' achievement and a significant rise in pupils achieving higher grades, A and B at A-level. Since 2000, Biology has increased from 37.5% to 47.5% – a rise of 26%; Chemistry has increased from 47.7% to 56.6% – a rise of 18%, and Physics has increased from 44.7% to 51.8% – a rise of 15.8%. The overall change including all subjects was from 37.0% (2000) to 49.7% (2007), a rise of 34.3%. Anecdotally there is a view in universities that this improvement has not been reflected in the ability of first-year students to cope with the standard or rate of provision in many science programmes.

There is some evidence that teaching at school by specialist science teachers can influence pupils' choices of degree subject. In science, the proportion of non-specialist teachers is relatively small, as reported by the Department for Education and Skills (DfES) in an enquiry about deployment of Mathematics and Science teachers[24]. In this report, 93% of Science teachers were found to be "specialists", meaning that they had a Maths/Science-related degree or had specialised in Maths/Science at initial teacher training. 44% of these teachers had a specialism (i.e. holding a degree in the subject or specialising in initial teacher training) in Biology, compared with 25% who were Chemistry specialists and 19% who were Physics specialists. It is noteworthy that only 3% of Biochemistry undergraduates and 0.6% of taught postgraduates in Biochemistry progress to a Postgraduate Certificate in Higher Education (PGCE).

The issues in Scotland are very similar, as highlighted in a report by the Scottish Science Advisory Committee[25].

6.2.2 Current student numbers and trends

6.2.2.1 Applications, applicants and accepts; undergraduates

The "UCAS Tariff" [26] was introduced for entries to the academic year 2002–03. The tariff establishes agreed equivalences between different types of qualifications (for example, A-levels, Baccalaureates, "Scottish Higher" or other qualifications) and measures achievement for entry to higher education in a numerical format. This allows comparisons between applicants with different types and volumes of achievement. However, the tariff system does not include all qualifications and 6% of students entered with a tariff score of 0, i.e. with qualifications not based on tariff points. Data must be interpreted with this in mind.

The actual UCAS tariff points of entrants to BSc Biochemistry programmes (C7) have been relatively consistent from 2003–04 to 2005–06 as is shown in Table 2. The average tariff points for these years is 335, which is higher than the average tariff points for all Biological Sciences (group C) of 253.

The majority of universities expressing a requirement state that an A-level in Chemistry is compulsory, while Biology is generally preferred, but not necessarily compulsory (Table 3).

With regard to published university requirements for entry to BSc Honours single-subject C7 programmes in 2006–07 (Table 4), the most prevalent requirement was BBB (tariff equivalent 300) for A-levels and BBBC (tariff equivalent 228) for SCQF Highers.

The distribution of tariff points with age is shown in Figure 7 and indicates that many of the students admitted on zero tariff points (6.2%) are mature students (over 21 years). In comparison with Microbiology (12.6%), Biochemistry admits a smaller proportion of mature students.

With regard to numbers of applicants, it should be noted that the main data source for national information, HESA, changed the way it allocated students to subject divisions in 2002–03 by

Table 2. UCAS Tariff Score

Subject	2003–04	2004–05	2005–06
Group C Biological Sciences	248	256	256
C7 – Biochemistry	327	342	335

Source: UCAS.

Table 3. A-level Chemistry and Biology requirements

A-level subject	Stated by university to be preferred	Stated by university to be compulsory
Chemistry	15	41
Biology	42	8

Source: CRAC Degree Course Guide 2006–07.

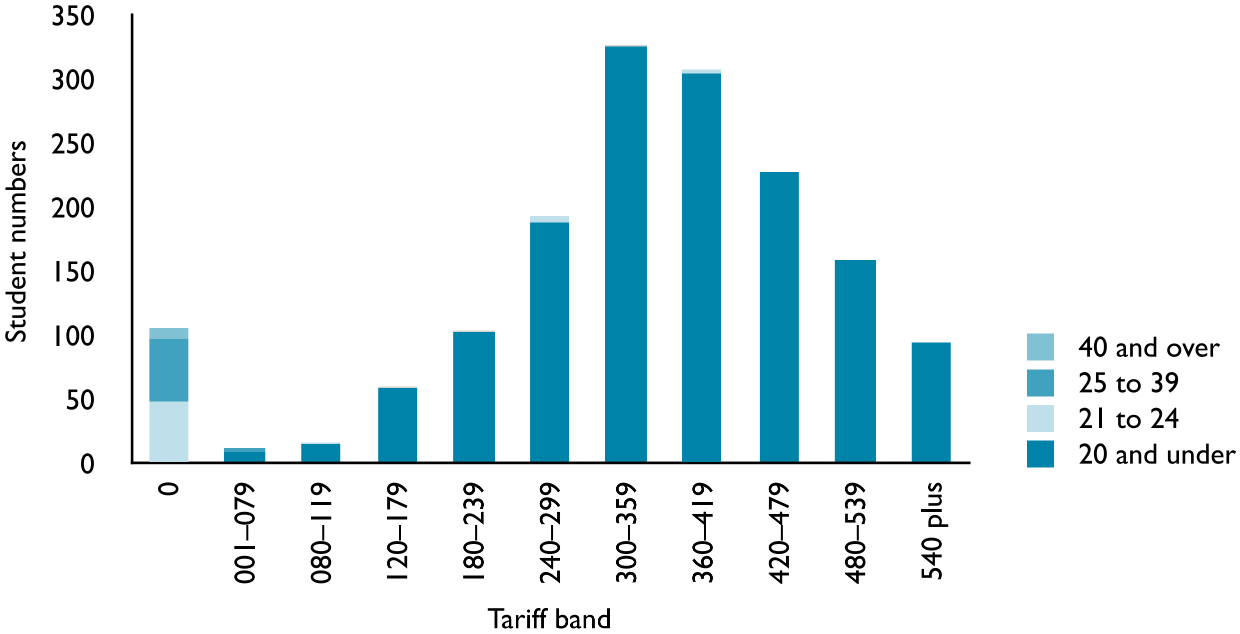
Table 4. Requirements, stated by universities, as necessary for entry

A-level grades (tariff)	Stated by how many universities?	SCQF Higher grades (tariff)	Stated by how many universities?
AAA (360)	1	AAAAA (360)	1
AAB (340)	7	AAABB (336)	2
ABB (320)	3	AAAB (276)	2
BBB (300)	10	AABBB (324)	4
BBC (280)	4	ABBBB (312)	4
BCC (260)	7	BBBBB (300)	3
CCC (240)	3	BBBB (240)	3
CCD (220)	2	BBBC (228)	9
CC (160)	3	BBB (180)	6
CDD (200)	1	BBCC (216)	2
DDD (180)	3	CCCCC (240)	1
		CCC (144)	3

(Not all universities apply the above criteria)

Source: CRAC Degree Course Guide 2006–07.
A-level tariff: Grade A=120; B=100; C=80; D=60; E=40.
Advanced Scottish Highers tariff: Grade A=120; B=100; C=80; D=72.
Scottish Highers tariff: Grade A=72; B=60; C=48; D=42.

Figure 7. Accepts per tariff band and age



Tariff band 0: 'tariff band unknown', for example in the case of overseas qualifications. Source: UCAS.

adoption of the JACS code system and also altered the way students on joint programmes were split between subjects. Subject-based data are therefore not comparable across the 2001–02 and the 2002–03 divide[27].

Table 5 shows that between 2002–03 and 2006–07, the total number of applicants for C7 programmes has decreased by 16%, while the number of applications (see legend to Table 5 for definition of these terms) has increased by 1%, with variable rates of change over the intervening years (Figure 8). However, in April 2007 it was reported by UCAS[28] that there had been a rise in applications for C7 programmes of 6.6% (i.e. 12,817 applications) for the academic year 2007–08, compared with 12,023 for the same stage in 2006–07. If this increase is reflected in increased admissions it will reverse the decline shown over the last few years. The number of students enrolled in C7 undergraduate programmes between 2002–03 and 2005–06 has increased slightly by 1.5%[2].

Two important features of these data are the rising proportion of accepts through clearing and the falling ratio of applicants:accepts possibly indicating that fewer pupils develop a commitment to biochemistry while at school.

6.2.2.2 Full-time and part-time students

The data (Table 6A) show the number of full-time and part-time undergraduate students studying C7 subjects up to 2005–06. There has been little change in the ratio of FT:PT over the four years. Biochemistry has a smaller proportion of part-time undergraduate students than biological sciences as a whole, but is within the range of the variation between other biological science disciplines (Table 6B).

6.2.2.3 Age distribution

As can be seen from Figure 7, in 2005–06 most (i.e. 92%) of the students accepted onto a C7 programme were 20 years old or younger. The age group of 21 to 24 years comprised 59 (3.7%) of the accepts, the group 25 to 39 years comprised 50 (3.1%) and six students were in the group of 40 years and older. It is noteworthy that all the student entry at 0 tariff (i.e. with non-standard qualifications) were 21 or over.

6.2.2.4 Origin of C7 students

Data from both HESA and UCAS have applicability regarding the origin of C7 students. The HESA data deal with *all* students (undergraduate and postgraduate) and are based on location of normal residence. Table 7A shows that there was an increasing proportion of students from outside the UK taking C7 programmes (20.2% in 2005–06 up from 15.0% in 2002–3) (Figure 9). Biochemistry was well above the average for biological sciences as a whole (9.3% in 2005–06). With regard to individual bioscience disciplines, there appear to be two groups, those with a high proportion of non-UK students (including biochemistry) and those with a low proportion of non-UK students (Table 7B).

The data from UCAS are based on the domicile of the degree accepts (number of successful undergraduate applicants) notified to UCAS. The data show (Table 8A) an increasing proportion of non-UK students commencing Biochemistry programmes, but with considerable variation from year to year. In order to smooth this variability, the average non-UK degree accepts has been calculated for the years 2004–05 to 2006–07 (17.3%) and for 1996–97 to 1998–99 (9.9%) and demonstrates the substantial increase in the proportion of non-UK students commencing C7 programmes. Comparison with other biosciences (Table 8B) shows, in confirmation of the conclusions from the HESA data, that there are two groups of biosciences. Biochemistry is in the group with the high proportion of non-UK students.

Both data sets show that a substantial increase in the proportion of non-UK students taking C7 programmes has occurred in recent years.

6.2.2.5 Gender of first-degree students registered on C7 programmes

There are more women than men taking first degrees in Biochemistry (taking all years of a programme together), and there has been only a small decrease in the gender ratio over the last four years (Table 9A). Biochemistry has a smaller proportion of women than biological sciences taken overall, but is close to the ratios for the other biological science disciplines (except Sports Science) (Table 9B).

Table 5. Numbers of Biochemistry (C7) undergraduate (UG) students enrolled, undergraduate applicants, applications and accepts

Academic year	Students enrolled in Biochemistry programmes UG	All applications (UCAS)	All applicants (UCAS)	All accepts (UCAS)	Ratio applicants to accepts	Clearing accepts (UCAS)	Clearing accepts as percentage of all accepts
	footnote [1]	footnote [2]	footnote [3]	footnote [4]	footnote [5]	footnote [6]	footnote [7]
2006–07	not available	12658	1703	2017	0.84 : 1	389	19.3
2005–06	7100	13828	1920	2291	0.84 : 1	414	18.1
2004–05	6935	13157	1904	2104	0.90 : 1	407	19.3
2003–04	7065	12764	1986	2021	0.98 : 1	362	17.9
2002–03	6995	12511	2030	1943	1.04 : 1	295	15.1
2001–02	5540		2008	1887	1.06 : 1		
2000–01	6085						
1999–00	6400						
1998–99	6479						
1997–98	6386						
1996–97	6610		1953	2070	0.94 : 1		

Source: HESA and UCAS.

[1] **UG Students enrolled in Biochemistry programmes (HESA)** are the total number of UG students in all years on Biochemistry programmes (C7 JACS codes) reported by the universities to HESA, including part-time and full-time students.

[2] **All applications (UCAS):** Sum of all C7 applications (applicants' choices). Figures as by 15 January of the respective year, which is the closing date for applications from UK and EU students. Excludes clearing and extra applications.

[3] **All applicants (UCAS):** Applicants who apply at UCAS for entry to full-time undergraduate C7 subject programmes are allocated to the subject area (JACS code) represented by the majority of their allowed choices (up to five; six were allowed up to 2007 entry). In some subjects this can give the appearance of there being more accepts than applicants. This measure can be used as an indicator of the number of prospective students firmly committed to the discipline and the popularity of the discipline.

[4] **All accepts (UCAS):** The number of successful applicants for entry to a full-time, undergraduate C7 subject programme. This may be close, but not necessary identical, to the numbers who actually enrol in this year.

[5] **Ratio applicants/accepts:** This can be taken as an indicator of the extent to which demand from committed students is being met (if less than unity) or not met (if greater than unity). The average for the last five years is 0.92 (corresponding figure for microbiology is 0.78).

[6] **Clearing accepts (UCAS):** This is the number of accepts deriving from the clearing process.

[7] **Clearing accepts as percentage of all accepts:** A number of factors can have a major influence on this figure, but it can be taken as an indicator of the extent to which institutions were unable to fill their places with applicants whose first choice is Biochemistry and who met the published entry requirements. The average for the five years is 17.9%, and the comparable figure for microbiology is 16.0%.

Figure 8a. Applicants and accepts for C7 degrees

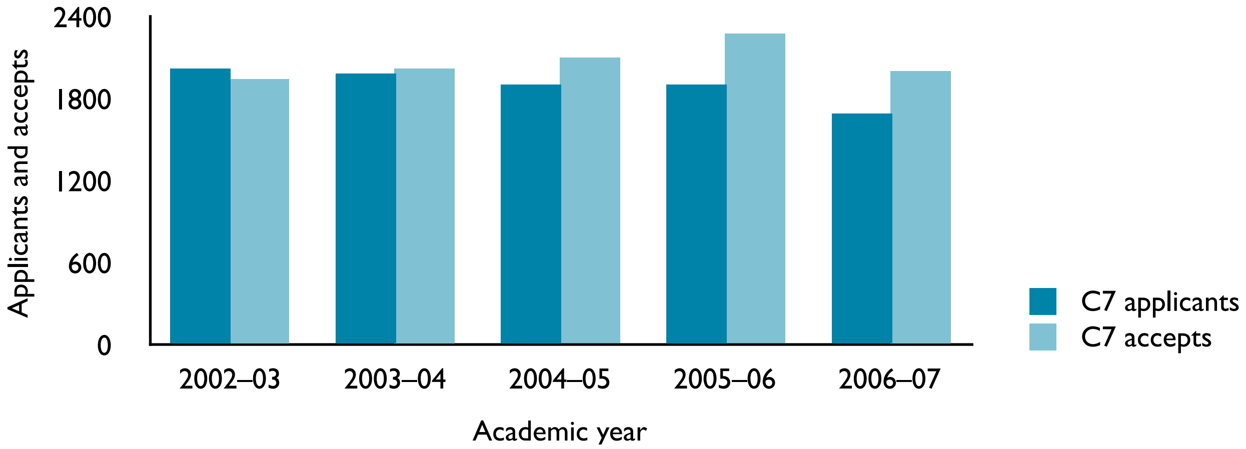
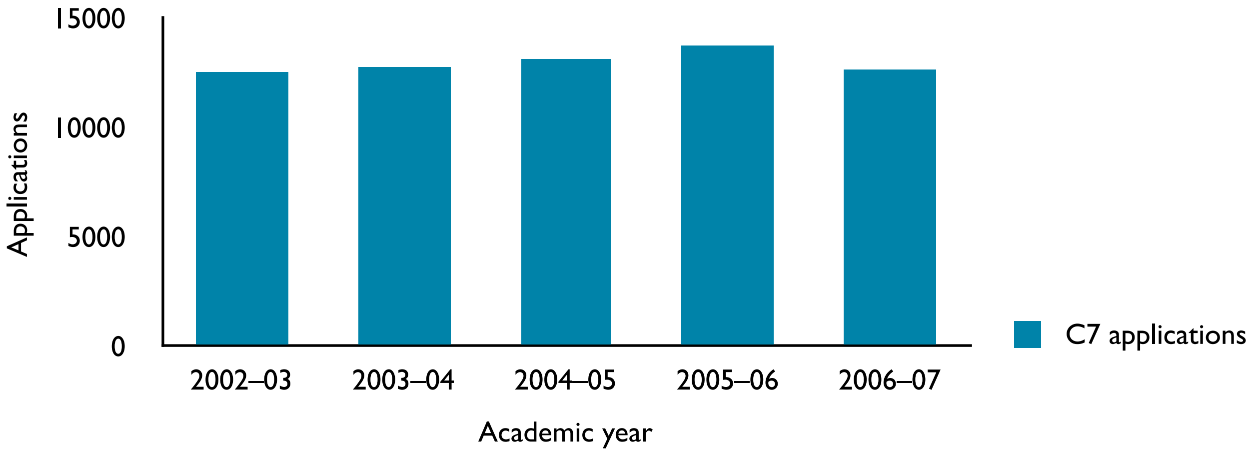


Figure 8b. Applications for C7 degrees



In some subjects the way UCAS allocates students between JACS codes according to the majority of their allowed choices can give the appearance of there being more accepts than applicants. The footnotes to Table 5 should be read in conjunction with this figure.

Source: UCAS.

6.2.2.6 Number and class of degree for C7 students

The grade and number of degrees awarded to C7 students for 2002–03 to 2005–06 are in Table 10A. The total number of graduates remained constant and on average 1800.7 students graduated. 60.7% C7 graduates obtained first- or upper second-class Honours degrees and 1.8% of students' degrees were unclassified (Figure 10). The concept of a fraction of a student graduating may seem bizarre, but this arises from the distribution of whole students between constituent disciplines for joint degrees.

Of the students graduating in 2004–05, 56% were from a Russell Group university, 32% were from other pre-92 universities and only 11% were from post-92 universities[14]. Earlier data are not available because of the change in the way

Table 6A. Full-time and part-time students studying C7 subjects

Academic year	Undergraduate (UG)		Total UG	Ratio FT:PT UG
	FT	PT		
2005–06	6780	320	7100	21.2 : 1
2004–05	6595	340	6935	19.4 : 1
2003–04	6420	645[1]	7065	9.9 : 1[1]
2002–03	6685	310	6995	21.6 : 1
2001–02	5335	205	5540	26.0 : 1
2000–01	5895	190	6085	31.0 : 1
1999–2000	6190	210	6400	29.4 : 1
1998–99	6259	220	6479	23.2 : 1
1997–98	6175	211	6386	29.3 : 1
1996–97	6404	206	6610	31.1 : 1

Table 6B. Full-time and part-time students studying other bioscience disciplines (2005–06)

Discipline	UG FT:PT ratio
All biological sciences[2]	4.84 : 1
Biology	4.40 : 1
Botany	1.29 : 1
Zoology	17.83 : 1
Genetics	62.40 : 1
Microbiology	12.05 :1
Sports Science	13.68 : 1
Molecular Biology, Biophysics and Biochemistry	21.18 : 1

[1] This might appear to be a spurious figure, but it is correct from the HESA data, which in themselves are internally consistent.

[2] This is the classification used by HESA and includes: broadly-based programmes within biological sciences; Biology; Botany; Zoology; Microbiology; Genetics; Sports Science; Molecular Biology, Biophysics & Biochemistry; Psychology; others in biological sciences.

PT = Part-time and other
FT = Full-time and placement
Source: HESA.

HESA collected the data[27]. However, the Royal Society has recalculated the HESA data for UK domiciled students. This shows that the number of Biochemistry (C7) degrees awarded increased slightly from 1994–95 to 2000–01 and thereafter fell by about 15% to 2004–05[14].

The percentage of first-class degrees in Biochemistry shows a small rise over the four-year period and is above the average for biological sciences as a whole. Table 10B also shows that the percentage of firsts awarded taking biological sciences as a whole rose considerably over the 12-year period, although the HESA data are not strictly comparable over the whole period[27].

6.2.3 Curriculum content of Biochemistry undergraduate degrees

The Bioscience Subject Benchmark Statement[1] defines broad-brush outcomes for bioscience degrees as a whole and does not define a curriculum as such. Providers are therefore free to play to their research strengths and mission statements, which encourages a beneficial variety of specialities. Particularly in the final year, there are significant differences in the *content* of the curricula at different institutions although the *outcomes* in broad terms will be the same. Furthermore, the nature of many programmes encourages students to choose optional modules, which allows for different interests and, especially in the final year, for the development of different specialisations.

In summary the Bioscience Subject Benchmark[1] guides all programmes towards the provision of appropriate:

- subject knowledge
- generic skills
- graduate and key skills
- intellectual skills
- practical skills
- numeracy, communication and information technology skills
- interpersonal and teamwork skills
- self-management and professional development skills.

Table 7A. Origin of C7 students (undergraduate and postgraduate)

Academic year	UK		EU[1]		Non-EU	
	number	% of total	number	% of total	number	% of total
2005–06	7935	79.8	700	7.0	1310	13.2
2004–05	7727	80.5	655	6.8	1217	12.7
2003–04	8098	82.6	607	6.2	1100	11.2
2002–03	7890	85.1	600	6.5	785	8.5

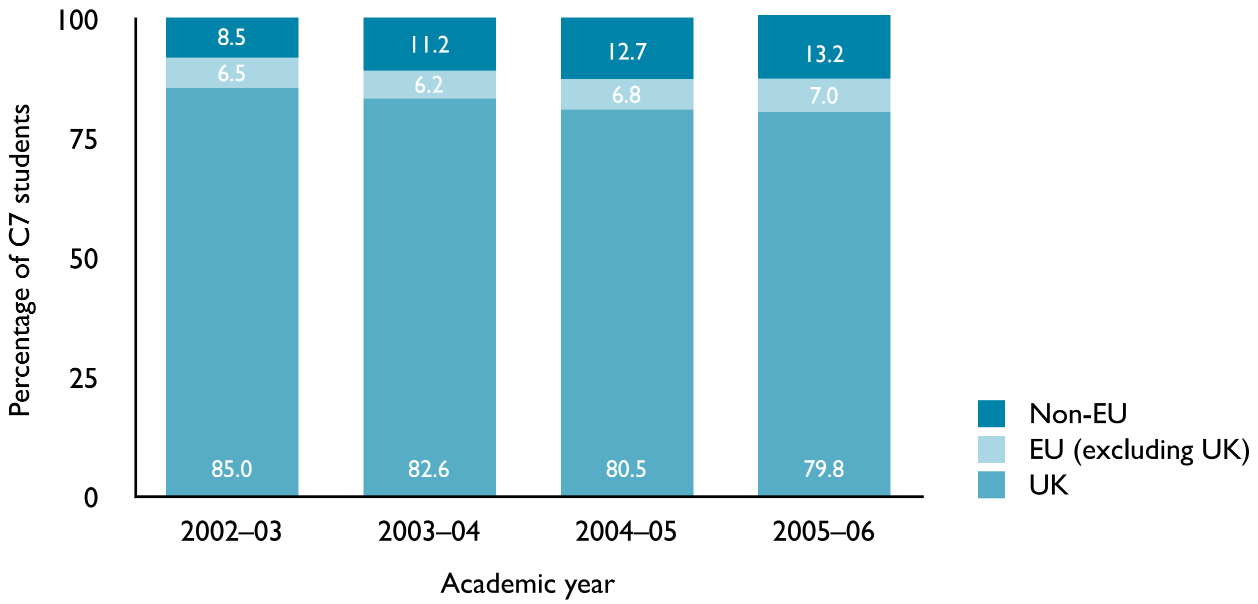
Table 7B. Origin of students in other biological sciences (2005–06) (undergraduate and postgraduate)

Discipline	UK	EU[1]	Non-EU	UK%	EU%	Non-EU%
All biological sciences	140720	6665	7835	90.6	4.3	5.0
Biology	24085	1305	1685	88.9	4.8	6.2
Botany	540	70	140	72.0	9.3	18.6
Zoology	3510	160	140	92.1	4.2	3.7
Genetics	1705	175	410	74.4	7.6	17.9
Microbiology	3195	320	855	73.1	7.3	19.6
Sports Science	27820	485	745	95.8	2.6	1.7
Molecular Biology, Biophysics and Biochemistry	7935	700	1310	79.8	7.0	13.2

[1] Excludes UK students.

Source: HESA.

Figure 9. Origin of C7 students (undergraduate and postgraduate)



Source: HESA.

Table 8A. Origin of C7 students commencing first-degree programmes of study

Academic year	UK		EU[1]		Non-EU	
	number	% of total	number	% of total	number	% of total
2006–07	1685	83.5	136	6.7	196	9.7
2005–06	1916	83.8	107	4.7	262	11.5
2004–05	1701	80.8	107	5.1	296	14.1
2003–04	1704	84.4	74	3.7	241	11.9
2002–03	1683	86.6	75	3.9	185	9.5
2001–02[2]	1653	88.1	95	5.1	129	6.9
2000–01	1761	90.9	87	4.5	90	4.6
1999–2000	1766	90.9	110	5.7	66	3.4
1998–99	1931	89.6	131	6.1	93	4.3
1997–98	2009	91.4	112	5.1	78	3.5
1996–97	1853	89.7	129	6.2	83	4.0

Table 8B. Origin of students commencing programmes of study in other bioscience disciplines (2006–07)

Discipline	UK	EU[1]	Non-EU	UK%	EU%	Non-EU%
All biological sciences	28654	1292	970	92.7	4.2	3.1
Biology	3952	215	164	91.2	8.0	3.8
Botany	28	1	1	93.3	3.3	3.3
Zoology	987	43	12	94.7	4.1	1.2
Genetics	357	50	61	76.3	10.7	13.0
Microbiology	2823	35	43	78.3	9.7	11.9
Sports Science	8378	154	66	97.4	1.8	0.8
Molecular Biology, Biophysics and Biochemistry	1685	136	196	83.5	6.7	9.7

[1] Excludes UK students.

[2] UCAS changed their classification system and adopted the JACS codes for 2002 and later data, while previous data were classified according to SCAS (Standard Classification of Academic Subjects). In the SCAS system Biochemistry (C7) and Molecular Biology and Biophysics (C6) were separately identified, but have been added together for the data above to enable some comparison to be made with the JACS grouped data where Molecular Biology, Biophysics and Biochemistry (C7) are recorded together.

Source: UCAS.

Table 9A. Gender of first-degree C7 students

Year	Females (F)	Males (M)	Total	Ratio F:M
2005–06	3842	3157	6999	1.22 : 1
2004–05	3769	3035	6804	1.24 : 1
2003–04	3911	3002	6913	1.30 : 1
2002–03	3930	2951	6881	1.33 : 1

Table 9B. Gender of first-degree students in other bioscience disciplines (2005–06)

Discipline	Females (F)	Males (M)	Total	Ratio F:M
All biological sciences	75746	41468	117214	1.83 : 1
Biology	12421	7796	20217	1.59 : 1
Botany	77	69	146	1.12 : 1
Zoology	2057	1143	3200	1.78 : 1
Genetics	889	697	1586	1.27 : 1
Microbiology	1350	1060	2410	1.27 : 1
Sports Science	9249	14972	24221	0.62 : 1
Molecular Biology, Biophysics and Biochemistry	3842	3157	6999	1.22 : 1

Source: HESA.

In addition, core curricula are devised, updated and have been published by the Biochemical Society[29] following consultation with institutions. Some programmes involving Biochemistry (though not C7 programmes) are accredited by the Institute of Biomedical Science[30], which maintains a close control over curriculum content (particularly content of laboratory work) and programme delivery methods.

The curriculum taught at any institution may reflect, in the detail of its content, the research expertise of that university in biochemistry. Further details on programme content can be obtained from the CRAC Degree Course Guides[20].

6.2.4 Delivery and assessment – snapshot of current undergraduate provision

Some details of delivery methods and current provision were obtained from a survey of a representative sample of universities. Processing the data returned by teaching units in response to the questionnaire on current teaching practices (Appendix 2) was challenging for several reasons:

- not all units responded to all questions
- the data obtained by the Centre for Bioscience from the surveyed universities was provided by individual members of staff at those universities and was not subject to any independent check for accuracy. It will also reflect the teaching philosophy underlying the provision. For example, a

Table 10A. Number and class of degrees for C7 students

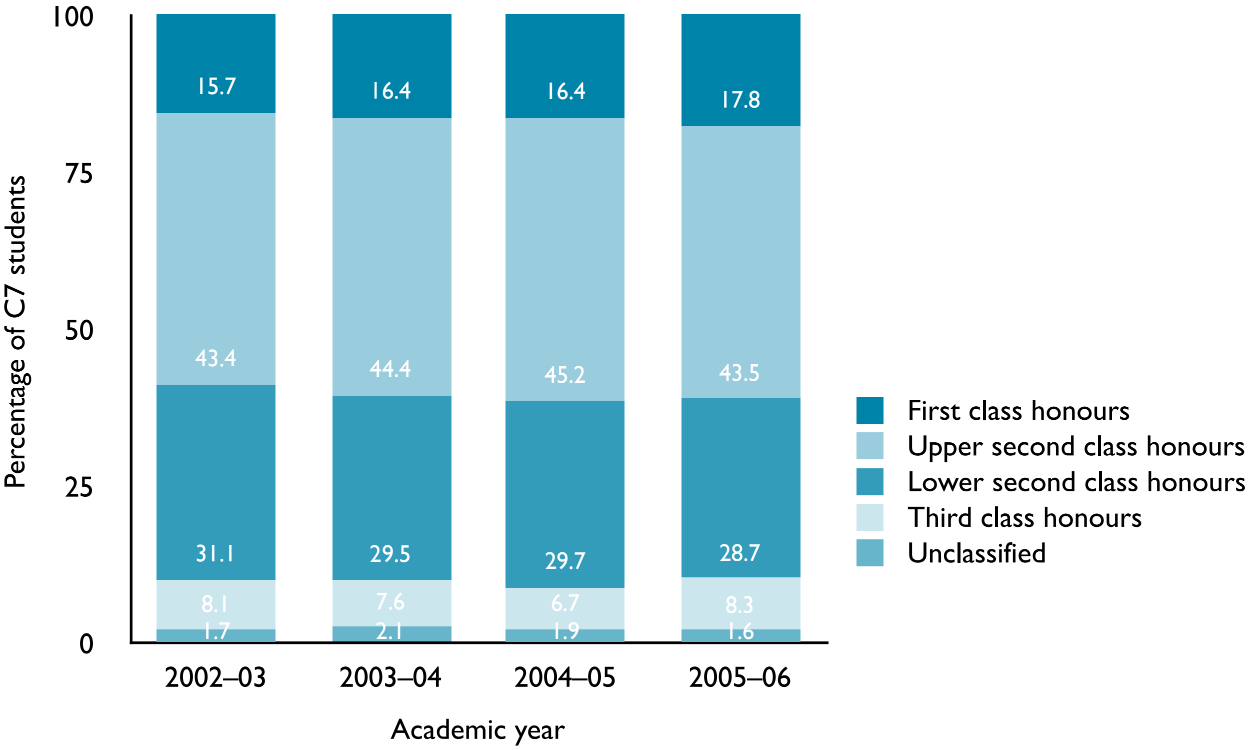
Academic year	First-class Honours	Upper second-class Honours	Lower second-class Honours	Third-class Honours	Unclassified	Total
2005–06	320.0 17.8%	780.6 43.5%	515.3 28.7%	149.7 8.3%	29.5 1.6%	1795.1
2004–05	301.0 16.4%	828.8 45.2%	544.8 29.7%	123.7 6.7%	34.0 1.9%	1832.3
2003–04	293.3 16.4%	791.5 44.4%	526.8 29.5%	135.3 7.6%	37.2 2.1%	1784.2
2002–03	307.5 15.7%	850.5 43.4%	609.8 31.1%	157.7 8.1%	33.2 1.7%	1958.8

Table 10B. Percentage of degree classes awarded for biological sciences as a whole

Academic year	First-class Honours	Upper second-class Honours	Lower second-class Honours	Third-class Honours	Unclassified
2005–06	11.2%	48.5%	31.2%	6.3%	2.9%
2002–03	10.0%	*Data not available*			
1999–2000	8.7%				
1994–95	8.0%				

Source: HESA.

Figure 10. Degree class, percentage of students graduating



Source: HESA.

module taught exclusively by problem-based methods may involve very little staff contact time or none at all and would therefore return a very small value for contact hours per credit. Similarly, a short (say five credit) practical-intensive module might involve a large number of hours in the laboratory, all of which would be supervised, and would therefore return a very high value for contact hours per credit

- units reported on the programmes they provided that had major biochemistry content. These were not all C7 programmes, but included non-C7 programmes such as B900 (Other subjects allied to medicine) and J700 (Biotechnology). All the reported programmes have been included in the data analysis below
- some institutions taught several programmes that involved different teaching practices. This made analysis by institution difficult. However, analysis by programme would have distorted the data by overrepresentation of institutions with multiple programmes all of which may be based on a similar teaching philosophy, thus swamping the contribution of a provider of a single programme
- since degree programmes may be of three, four or five years' duration (mostly depending on whether an industrial year is incorporated or the provision is located in Scotland) the term *Year One* is used to denote the first year of a BSc (provided outside Scotland), *Year Two* is used to denote the second year of a BSc programme outside Scotland and *Final Year* is used, unsurprisingly, to denote the last year of a BSc programme (which may in fact be the third, fourth or fifth year of student participation). The data from Scottish universities (which run four-year duration programmes) were not markedly different from the rest of the UK. Years One and Two for Scotland have been averaged and included in Year One data for the UK. Year Three data from Scotland have been included with Year Two from the rest of the UK
- as expected there is considerable diversity between providers and, where appropriate, mean values and the range have been given.

Across the ten institutions sampled a total of 34 programmes were reported of which 27 fell into the C7 group. Institutions provided between one and nine programmes. Not all institutions provided all the requested data.

6.2.4.1 Student numbers

Data from the nine sampled universities providing data in this section indicated that the numbers of students in each year studying C7 subjects at undergraduate level are as shown in Table 11.

It should be noted that none of these data necessarily indicate the size of the groups in which the students will be taught. This is because the teaching unit is generally the module and students from other programmes may participate in modules taken by Biochemistry students. Especially in the final year, where modules are less likely to be taken by other students, students may be taught in small groups. As far as the student experience is concerned it is therefore important to appreciate that Biochemistry students, like other bioscience students, are not necessarily taught in isolation from other students or as a single cohort.

The data obtained from the sampled universities provide some further information, but it should be noted that three universities returned no data in this section and others only provided a partial return which will affect the robustness of the data. At these seven universities the average staff:student ratio with respect to academic staff, demonstrators and support staff in laboratory classes is shown in Table 12. The variability between universities was considerable.

6.2.4.2 Teaching provision

The basic teaching unit is the module, which is often taught and assessed as a free-standing unit, although in later years some modules may require that certain earlier modules be taken as pre-requisites to ensure students have the background knowledge necessary. Modules may vary in size, in this sample from 10 to 40 credits. In this survey, data from all universities have been normalised to 120 credits/year, i.e. 360 for a three year degree (section 7.2). Each module will contain an appropriate balance of teaching to achieve its learning outcomes, but, in general, modules contain:

- lectures – given by academic staff (very rarely did postgraduate teaching assistants give lectures)
- tutorials – sometimes associated with modules and/or were free-standing as personal pastoral tutorials outside the module system. The numbers in a tutorial class may vary considerably and the tutor may be academic staff or a postgraduate
- practical classes – most programmes ran "wet" i.e. real laboratory practicals and a varying mixture of "dry" practicals that might involve computer simulations and/or paper-based data interpretation exercises. Academic staff were involved in laboratory classes, but considerable additional input was provided by postgraduates, teaching assistants, demonstrators and technicians.

Because many programmes enable extensive choice from a range of modules and each module may be taught and assessed differently it is difficult to derive a fully correct "average student experience" of teaching methods or assessment. From the survey however, as a rough guide: 30 hours of teaching, as lectures, tutorials or laboratory work in some combination equals ten credits the remaining 70 hours involving preparation, the performance of set exercises and self-directed learning.

Data deriving from Scottish universities were of a similar order to that for the rest of the UK (except of course the four-year duration of the programme). The hours per week spent in lectures, tutorials and practicals in each year of the programme are shown in Table 13. It should be noted that students will additionally spend a variable number of hours in preparation and self-directed learning. The number of lectures and tutorials will be significantly influenced by the extent to which parts of the curriculum are delivered by self-directed learning or problem-based learning. In a completely problem-based learning module there may be no lectures at all.

6.2.4.2.a Year One

Out of the ten sampled institutions only two provided a fixed set of modules with students unable to exercise any choice. All institutions required students to attempt a normalised 120 credits during Year One, and the easiest way to express choice is through the number of credits that are associated with compulsory modules. This averaged 85 over the eight institutions with programmes where choice was permitted (range 40 to 110). For the optional modules, choice was often limited to a set of permitted options, but in some programmes any module that could be timetabled was permitted. The hours of timetabled formal teaching per ten credits was not uniform across all institutions and varied from 14 to 60 hours per ten credits although most provisions fell within the range 20 to 36 hours per ten credits. Tutorials to deliver pastoral care were provided on an "as necessary" basis by all seven institutions that returned data.

6.2.4.2.b Year Two

Out of the ten sampled institutions only one provided a fixed set of modules with students unable to exercise any choice. The number of compulsory credits (out of a normalised 120) was 90 averaged over the nine institutions with programmes where choice was permitted (range 30 to 110). The hours of timetabled formal teaching per ten credits was not uniform across all institutions and varied from 14 to 102 hours per ten credits. This upper figure may seem very high, but was associated with a module that provided only laboratory work. Most modules fell within the range 20 to 40 hours per ten credits. Tutorials to deliver pastoral care were provided on an "as necessary" basis by all seven institutions that returned data.

6.2.4.2.c Final Year

Out of the ten sampled institutions only three provided a fixed set of modules with students unable to exercise any choice. The number of compulsory credits averaged 69 over the seven institutions with programmes where choice was permitted (range 40 to 100). The hours of timetabled formal teaching per ten credits (excluding any research project) was not uniform across all institutions and varied from 7.5 to 39 hours per ten credits although most provisions

Table 11. Number of students in each year studying C7 subjects at undergraduate level

Year	Total students (nine institutions)	Mean per institution	Complete range	Range including 80% of programmes
One	317	35.2	7–83	10–66
Two	278	30.9	2–90	10–49
Final	303	33.7	1–85	10–64

Table 12. Staff to student ratio (average)

Year	Average academic staff: student ratio	Range	Average demonstrator: student ratio	Range	Average support staff: student ratio	Range
One	1 : 62	15–175	1 : 17	1–40	1 : 20	1–48
Two	1 : 35	15–60	1 : 17	1–40	1 : 22	1–60
Final	1 : 21	5–60	1 : 9	1–40	1 : 18	1–60

Table 13. Student hours per week spent in lectures, tutorials and practicals

Year	Lectures average hours/week (range)	Tutorials average hours/week (range)	Average tutorial group size (range)	Practicals average hours/week (range)
One	8.9 (3–13)	2.4 (0–6)	22.6 (4–56)[1]	3.4 (0–9)
Two	7.3 (0–10)	3.4 (0–16)	18.7 (4–41)[1]	3.3 (1–7.5)
Final	5.0 (0–9)	1.6 (0–6)	16.2 (4–25)[2]	5.3 (0–16)[3]

[1] Based on seven survey returns.
[2] Based on five survey returns.
[3] This excludes project work which averaged 9.4 hours per week (not necessarily evenly distributed throughout the year).

fell within the range 15 to 25. Tutorials to deliver pastoral care were provided on an "as necessary" basis by all seven institutions that returned data.

The final year contained a compulsory research project, which could be taken in a laboratory context or, in most institutions, in a non-laboratory context. Although the project was allocated a credit rating and was often associated with a number of hours of work it was clear that these were assigned on a different basis to other teaching as the hours per ten credits varied widely and bore little relationship to the hours per ten credits expected in all other forms of teaching. There was considerable variation between institutions as shown in Table 14.

6.2.4.2.d Industrial Year

In five of the eight institutions that supplied data it was possible to take a year in industry on placement as part of the programme, almost without exception between Years Two and Three in England (Three and Four in Scotland). In one institution it was a compulsory part of the programme, while in the others it was optional. Between 5% and 50% of students took up the option. This year is often highly valued by students as it greatly improves their employability[23] and on the UCAS website 68 out of 309 programmes returned from a "Biochemistry" search offered an industrial placement/sandwich year (22%)[18].

6.2.4.2.e Assessment

Each module is assessed in an appropriate manner and formative (carrying no marks), summative (carrying marks) and diagnostic (used to determine if a student has adequate prior knowledge/skills or needs a particular learning experience) assessment may be used. A variety of assessment methods are used including:

- multiple-choice and extended matching set questions
- essays
- short answer questions
- assessment of practical work mainly in the form of the write-up, rarely through assessment of manipulative skills
- assessed talks and oral presentations
- assessed posters and/or web pages
- dissertations
- problem-solving exercises
- data interpretation exercises
- literature search exercises
- other innovative assessment methods are also used such as assessed debates and writing in different styles.

Group assessment (of individual performance within a group and of collective group performance) is used as is peer- and self-assessment (to develop students' critical skills).

Detailed information on assessment methods and the time involved in assessment is difficult to find, but such information as there is indicated that there are major differences between institutions both in the type of assessment used and the time spent on assessment[31]. Detailed information from a single university (shown in Table 15) re-enforces the point about variability in the amount of time spent on assessment by students. Two other points emerged from this study:

Table 14. Hours worked per credit ratings of final year projects

Project average credit rating (range)	Average hours worked per 10 credits (range)	Average duration of projects (hours) (range)
35 (24–40)	68 (50–130)	235 (150–520)

Table 15. Student time spent on assessments (at one university)

Modules in subject area	Time spent on assessments per 10 credits (mean hours)	Standard deviation	Range	Number of modules
All bioscience	44	15	13–90	141
Microbiology	36	15	17–63	25
Biochemistry	36	10	24–53	14
Biology	54	17	28–90	29
Biomedical Sciences	41	14	15–90	47
Sports Science	41	12	13–65	26

Calculated by assigning to all summatively assessed items in a module the amount of time likely to be spent by students in preparing for and performing the assessed tasks as described by Crook and Park[33].

1. Ten credit modules have more assessment (33%) per credit than 20 credit modules

2. Year Two modules have the greatest amount of time associated with assessment (Year One = 34 hours; Year Two = 47 hours; and Year Three = 40 hours per ten credits).

The extent to which these data are qualitatively representative of the situation in other universities is unknown and their quantitative accuracy depends on the reasonableness of the time associated with particular assessments as defined by Crook and Park[33].

6.2.4.2.f Questions for prospective students

In making choices between institutional programmes, prospective students will have some difficulty in defining the crucial differences between programmes. Below, therefore, is a set of questions which students may wish to pursue with the institutions they are considering in order to compare critical features of degree programmes:

- what proportion of teaching in each year consists of compulsory modules and what proportion can be chosen by the student?
- are the optional modules chosen from a pre-defined list or can any module be taken?
- what is the range of options? For example, the options may differ in an institution with a medical school compared with one without a medical school but with provision in agriculture.
- can I change programmes at the end of Year One without having to start again in Year One?
- how is pastoral support provided in all three years of the programme?
- how much laboratory work must/can I do in each year?
- how many students take an industrial year during the programme?
- what is the range (subject, type of organisation, geographical) of the placements?
- how are the placements allocated? Do students have to find their own or does the university do it for them?
- how long is the research project in the final year, what choice of projects do I get and is there provision for laboratory and non-laboratory based research projects?
- what methods of assessment are used in each year?
- what is the balance between in-module assessment and formal examinations in each year/module?
- how many students enter the programme each year and how big are the classes in the first and other years?

6.2.5 First destinations of Biochemistry graduates

Universities supply information to HESA about the destinations of their graduates, and this information is aggregated by HESA on a national basis. Although 7370.4 students graduated in Biochemistry (2002–03 to 2005–06) HESA only holds complete data on 6494.1 students of which 2893.8 were inappropriate to classify (presumably because they were travelling, not wishing to be employed, or, if an overseas student, had returned to their own country). There are therefore records applying to 3600.3 employed students and these can be classified by two methods:

- the Standard Industrial Classification (denoting types of work activity; for example, collection, purification and distribution of water; Table 16 and Figure 11)
- the Standard Occupational Classification (for example, science and technology professionals; Table 17 and Figure 12).

It should be noted that this information is supplied by universities from student contact six months after graduation and therefore may or may not represent the occupation or work areas in which a student finally may choose to make a career.

It is clear that education, health and social work, manufacturing and research and development, which could be regarded as discipline-related work, involve 56.3% of graduates. The “other classified areas of work” include 45 other defined areas such as: manufacture of motor vehicles, trailers and semi-trailers; agriculture and related activities; air transport; computer-related activities.

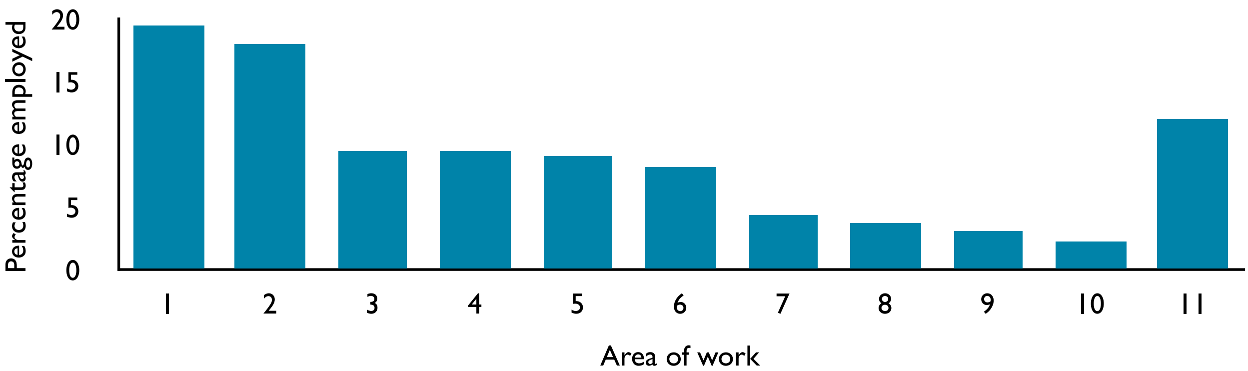
Science and technology, together with teaching and research, which could involve discipline-based work, involved 49.2% of graduates, while

Table 16. Percentage of employed Biochemistry (C7) graduates entering the ten most popular Standard Industrial Classification areas of work (2002–03 to 2005–06)

Industrial classification code number	Classification descriptor	Number of graduates[1]	Percentage of those employed
80	Education	703.5	19.5%
85	Health and social work	650.6	18.1%
24	Manufacture of chemicals and chemical products	347.6	9.6%
74	Other business activities	343.8	9.5%
73	Research and development	326.5	9.1%
52	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	298.7	8.3%
75	Public administration and defence; social security	159.5	4.4%
65	Financial activities, except insurance and pension funding	136.7	3.8%
55	Hotels and restaurants	114.4	3.2%
92	Recreational, cultural and sporting activities	82.7	2.3%
Various	45 other classified areas of work	436.3	12.1%

[1] Fractions of graduates (which may seem a bizarre concept) arise because of the split of graduates taking joint or combined degrees into the component subjects on a proportionate basis.

Figure 11. Percentage of employed Biochemistry (C7) graduates entering the ten most popular Standard Industrial Classification areas of work (2002–03 to 2005–06)



The areas of work correspond to the following Standard Industrial Classification areas of work groups:

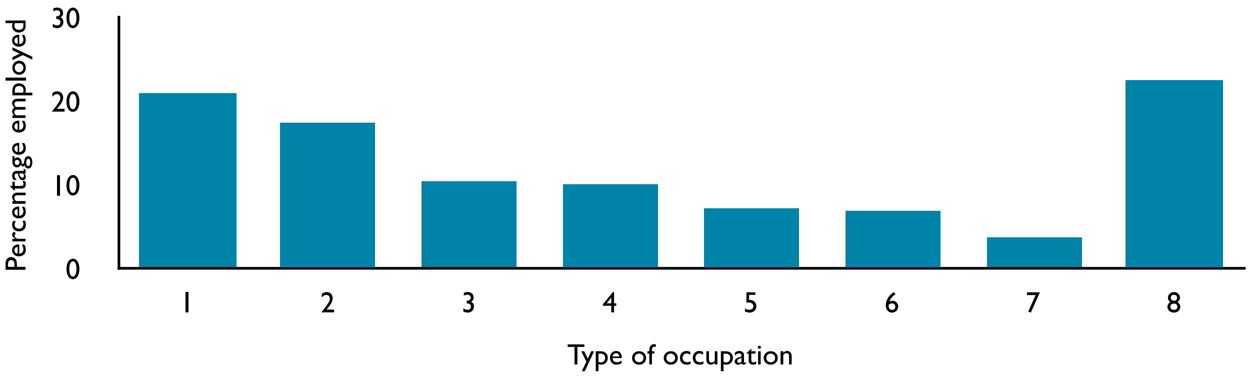
1. Education (group 80)
2. Health and social work (group 85)
3. Manufacture of chemicals and chemical products (group 24)
4. Other business activities (group 74)
5. Research and development (group 73)
6. Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (group 52)
7. Public administration and defence; social security (group 75)
8. Financial activities, except insurance and pension funding (group 65)
9. Hotels and restaurants (group 55)
10. Recreational, cultural and sporting activities (group 92)
11. Combined 45 other classified areas of work in which Biochemistry graduates are employed.

Source: HESA.

Table 17. Percentage of employed Biochemistry (C7) graduates entering the seven most popular types of occupation classified by the Standard Occupational Classification (2002–03 to 2005–06)

Occupational classification code number	Classification descriptor	Number of graduates	Percentage of those employed
21	Science and technology professionals	762.2	21.2%
23	Teaching and research professionals	633.1	17.6%
31	Science and technology associate professionals	373.3	10.4%
41	Administrative occupations	362.5	10.1%
35	Business and public service associate professionals	260.4	7.2%
71	Sales occupations	248.0	6.9%
11	Corporate managers	139.1	3.9%
Various	Other classified groups	821.6	22.8%

Figure 12. Percentage of employed Biochemistry (C7) graduates entering the seven most popular types of occupation classified by the Standard Occupational Classification (2002–03 to 2005–06)



The types of occupation correspond to the following Standard Occupational Classification groups:

1. Science and technology professionals (group 21)
2. Teaching and research professionals (group 23)
3. Science and technology associate professionals (group 31)
4. Administrative occupations (group 41)
5. Business and public service associate professionals (group 35)
6. Sales occupations (group 71)
7. Corporate managers (group 11)
8. Combined 19 other Occupational Classification groups in which Biochemistry graduates are employed.

Source: HESA.

the remainder were involved in what might be non-discipline-related work. This distinction is difficult, however, as within sales occupations the work might involve selling biochemistry-related products. The "other classified groups" comprise 19 other job descriptions including, for example: skilled agricultural trades; skilled metal and electrical trades; skilled construction and building trades; textiles, printing and other skilled trades; caring personal service occupations; leisure and other personal service occupations. These illustrate the great variety of occupations taken by Biochemistry graduates.

The main impression from consideration of the above data is of the diversity of occupation taken by biochemists and the probability that about one-half will be using the skills and knowledge they acquired on Biochemistry programmes in a discipline-related occupation.

According to a labour market survey carried out in 2006 by SEMTA[7], only a relatively small proportion of science graduates enter the bioscience sector, but the survey did cover all types of science graduate.

In the SEMTA survey, individual professions matched the areas mentioned in the Higher Education Academy employability profile for biosciences graduates, which states that "biosciences graduates are employed in a range of posts which may, or may not, be related to the discipline they studied. They include accountancy and other related financial professions, forensic scientist, higher education lecturer, immunologist, scientist, industrial research scientist, process development, research scientist (medical), toxicologist and commercial, industrial and public sector management"[6].

The Biochemical Society has surveyed Biochemistry graduates as to their employment destinations[34] and these data are shown in Table 18 for the average of the two cohorts 2001–02 and 2002–03 graduates. Note that 14% of graduates were uncontacted. While the Biochemical Society's graduate employment survey provides the only national data for the employment destinations of Biochemistry graduates that pre-date those collected in recent years by HESA, it should be remembered that the patterns of employment recorded will be influenced by a slightly varying pool of responding universities.

The Biochemical Society[34] report in its 2003 graduate employment survey: a decrease of graduates going into industrial research; a slight fall in the proporation of first graduates remaining in Biochemistry (51.5%); a lower proportion of Class 1 Honours graduates (53.5%) and higher proporation of Class 2.2 graduates (13.3%) going on to do research degrees and low unemployment levels (3.5%) compared with national figures for biological sciences graduates (6.5%). These data must be interpreted in the light of the sample used and the nearly 16% of first graduates whose destination is not known.

6.2.6 Views of current Biochemistry students and graduates

While most of the data from the National Student Survey[32] is grouped by institution or by large subject group (for example, all biological sciences), some information is available on a discipline basis. The survey is completed (post, telephone or online) by graduates from selected institutions on a voluntary basis. The students participating in the survey (participation rate about 58%) may or may not be a representative sample of the relevant Biochemistry student body. The students score a number of statements (for example, "Staff are good at explaining things.") about their student experience on a 1 to 5 scale (1=definitely disagree; 2=mostly disagree; 3=neither; 4=mostly agree; 5=definitely agree). The 21 scored questions are converted into six aspects (shown in Table 19), and there is a 22nd question concerning overall satisfaction, which is shown as aspect seven. The numbers in the table represent difference in the satisfaction (rated on a 1 to 5 scale) between the students on the listed disciplines (8410 replies involving 58 institutions in 2006) as compared with the standard comparator, the Law student. Absolute values for the scores given by the comparator (Law) students are shown in parentheses after the aspect title below the table. Thus, with

Table 18. Occupations of Biochemistry graduates (2001–02 and 2002–03)[34]

Occupation	Number	Percentage
Further biochemical study or training	522	27
Teacher training	66	3
Non-biochemical study and training	110	6
Intercalating medical students	19	1
Research in industry	158	8
Research in higher education	52	3
Hospital laboratories	73	4
Civil service/public laboratories	38	2
Non-laboratory based scientific work	75	4
Teaching in higher education	6	0.3
Other employment	322	17
UK students employed abroad	15	0.8
UK students studying abroad	7	0.4
Overseas students return home	28	1
Unplaced but not seeking work	88	5
Unplaced and seeking work	61	3
Unknown	273	14
Total	1916	

Table 19. Differences in student satisfaction with experience, by discipline as compared with standard comparator

Discipline	Aspect						
	1	2	3	4	5	6	7
Biology	0.04	0.06	0.19		0.10		0.10
Zoology			0.23				
Genetics			0.26		0.18	-0.16	
Microbiology	0.11	0.18	0.41		0.13		0.22
Molecular Biology, Biophysics and Biochemistry		0.10	0.24		0.12		0.07

1 = teaching and learning (4.0)
2 = assessment and feedback (3.5)
3 = academic support (3.7)
4 = organisation and management (3.9)
5 = learning resources (4.1)
6 = personal development (4.0)
7 = overall satisfaction (4.1).

Source: Paula Surridge as cited on the HEFCE website.

respect to academic support (aspect three) the comparator, the average Law student scored this aspect 3.7. Biology students scored this aspect 0.19 higher, thus being more satisfied than were Law students. A blank in the table indicates that the level of satisfaction was not statistically significantly different from that of the comparator, the Law student.

Overall, Biochemistry provided a better experience (totalling +0.53 points) for students than did Law in four of the seven aspects and was worse than Law in no aspect. While the size of the difference might look small it must be remembered that this refers to a difference between values measured on a 1 to 5 scale and did represent a statistically significant difference in each case.

Other data are available to throw light on the student experience. A survey of first-year students' views on the laboratory classes they have undertaken was carried out in 2007[35]. While this survey involved all bioscience disciplines it has been possible to isolate the data for the 27 students (from three institutions) in the first year of Biochemistry BSc degrees. These students were asked to rate (0=not at all applicable, 10=highly applicable) their experience of first-year laboratory work with respect to each of the following words (mean values, n>22 in every case):

- Stimulating: 6.6
- Repetitive: 7.1
- Waste of time: 2.9
- Repeat of school work: 1.7

Bearing in mind that a neutral score is 5 it is clear that students found laboratory classes stimulating and that the classes were not regarded as a waste of time or a repeat of school work. The high score for "repetitive" may well reflect the fact that it does take time and repetition to develop skills and may also reflect the nature of research science.

Some comments on their laboratory work were:

"It's quite sociable working in groups"

"You receive lots of help inside the practical class"

"Do work myself and see the results"

"Independence was great"

In order to obtain more representative student views on Biochemistry programmes, 350 questionnaires (Appendix 3) were sent to tutors for distribution to final-year students and 70 (20%) were returned. This low return rate may have provided a non-representative range of replies. Not all students answered all questions. Of the students who provided returns:

- 65 (93%) were aged below 25 and five (7%) were aged over 25 years
- 32 were males (46%) and 38 females (54%)
- 69 (98%) were full-time students (one no response)
- 60 (90%) were UK students, three (4%) from the EU and four (6%) from overseas (three no response).

6.2.6.1 Scored questions

Not all students providing the 70 returns responded to all questions. Questions (Table 20) were scored as follows: 5=strongly agree, 4=agree, 3=don't know, 2=disagree, 1=strongly disagree. The mean and standard error of the score for each question is shown. Consideration of the distribution of scores for each question did not generally suggest there was more than one population in the answers to each question as the scores were distributed on a smooth curve. However, with regard to question one the distribution (5=13, 4=33, 3=8, 2=15, 1=0) showed some indication that views were polarised into two groups (in the survey of Microbiology students, data suggestive of two populations (23, 73, 15, 23, 6) were also obtained for this question).

Since a numerical value of 3 represents a neutral view it is notable that all the questions returned positive responses well above neutrality. The lowest score was question 15 and clearly some improvement can be made in the preparation universities provide for their placement students. Scores over 4 are particularly noteworthy and it was pleasing to see that students would recommend their degree programme to others (Q14), that lecturers were enthusiastic and made

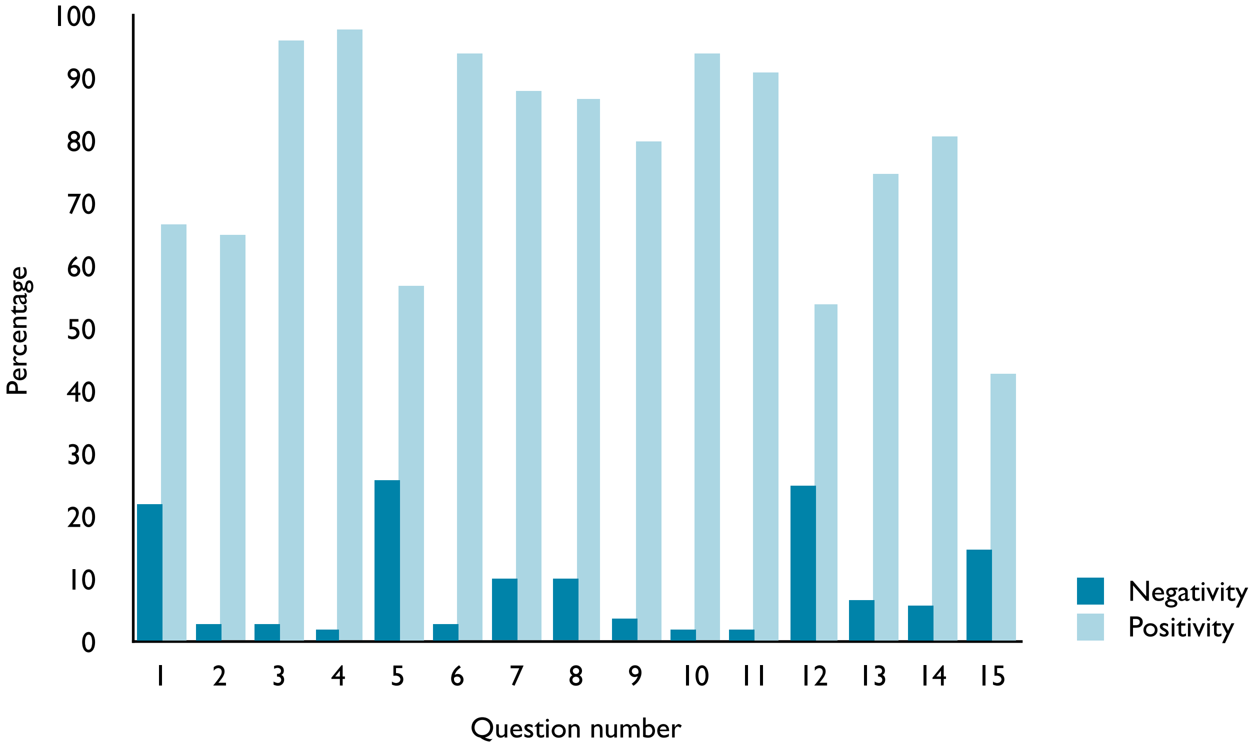
Table 20. Centre for Bioscience student survey questions and results (see also Appendix 3)

Question number	Text of question	Mean	Standard error	Number contributing
1	I have been encouraged to think about the range of career opportunities that will be available to me when I graduate.	3.64	0.12	69
2	My department/school has shown concern for my overall well-being.	3.76	0.10	68
3	There have been adequate opportunities available for me to develop my practical skills in Biochemistry.	4.23	0.08	68
4	My experience has helped me to develop a range of transferable (generic) skills, such as communication, group work and IT skills.	4.39	0.07	69
5	My lecturers have provided helpful feedback on my progress.	3.41	0.14	68
6	As a result of my experience I have improved my ability to learn independently.	4.35	0.08	69
7	There has been adequate provision of library facilities.	4.04	0.12	68
8	There has been adequate provision of IT facilities.	4.03	0.13	69
9	I have been given adequate support and guidance for my learning.	3.88	0.08	69
10	Lecturers are enthusiastic about what they teach. They made the subject of Biochemistry interesting/relevant.	4.25	0.07	69
11	Lecturers made effective use of technology in their teaching (for example, Blackboard/WebCT; personal response systems; online assessments and discussion boards).	4.28	0.08	69
12	I have had adequate opportunities during my degree to gain work experience relevant to Biochemistry.	3.41	0.13	69
13	My overall experience during my degree programme met with my expectations.	3.83	0.09	69
14	I would recommend the degree programme that I have followed to other students.	4.01	0.11	68
15	My university has prepared me well for my industrial placement (if applicable).	3.17	0.13	46

good use of information technology facilities (Q10, Q11), and that practical and generic skills were developed (Q3, Q4).

For each question, indices of positivity (percentage of responses >3) and of negativity (percentage of responses <3) have been calculated and are shown in Figure 13 (page 44). Clearly the student experience in these programmes was overwhelmingly positive although it is interesting to note that lower positivity was seen with aspects flagged nationally as concerns in the National Student Survey and other surveys[9] (feedback, support, career guidance and work-placements) (for example, Q15).

Figure 13. Student positivity (percentage of respondents scoring >3) and negativity (percentage of respondents scoring <3) to each of the 15 questions listed in Table 20.



6.2.6.2 Free text responses

From the 70 returns 32 students made comments, sometimes several, on the programme they had experienced. Overall the comments were classified as very positive (10, 31%), positive (11, 35%), neutral (6, 19%), negative (5, 16%) and very negative (0) again showing the generally positive experience of the students with 21 positive views contrasting with five negative ones.

There was only a small number of free text responses, and these were quite varied in their nature. The most consistent positive themes were that the programme was "enjoyable" (6), that the laboratory work and project were very interesting (6) and staff generally (though not always) helpful and friendly. On the negative side, students were critical of the facilities (laboratory equipment, library, social facilities and information technology (7)).

"The practical aspect of the degree has been really good, and the lecturers are really enthusiastic and helpful in their various departments."

"Generally the course is well structured. The course leader and lecturers have been very supportive and helpful. The facilities can be improved but overall I have enjoyed my course. The course has allowed me to gain many skills and attributes."

"I've had a great time, I would have liked to have more work experience opportunities in the labs over the summer and next summer."

"I think the course was varied and interesting in parts, most lecturers were on hand for questions."

"Not enough computers in the library for everyone. As a whole the lecturers are hard working and enthusiastic and up to date on biochemical research."

6.3 Postgraduate taught programmes

A search for taught Biochemistry programmes at Postgraduate Certificate, Postgraduate

Diploma, MSc and MRes levels on the British Council website[36] yielded the data shown in Table 21.

A search for Biochemistry postgraduate programmes on the "Prospects" website[37] yielded 188 programmes at 69 institutions. Of these, 119, provided at 54 institutions, led to PhD/MPhil degrees by research and 69, provided at 34 institutions, were taught programmes leading to MSc of MRes degrees. Of these 69, sufficient details were available from 39 for further analysis regarding their title, numbers of students, delivery and assessment.

Overall the picture emerges of a very active provision of taught programmes, very variable in their nature, delivery and assessment with a huge range of choice for students to construct a personalised programme that will meet their needs.

6.3.1 Title of programme

Although these programmes were classified as "Biochemistry" by their home university presumably on the basis of their actual content, and the term "Biochemistry" was in the programme description, the titles of the programmes were very diverse as is illustrated below:

- Applied Toxicology
- Biochemical Engineering
- Biochemical Research
- Biomedical Engineering
- Biomedical Science
- Biomedicine
- Bioscience with Ion Channels in Health and Disease
- Bioscience with Plant Science
- Biosciences
- Biotechnology
- Cancer Therapeutics
- Cellular and Molecular Neuroscience
- Chemical Biology
- Clinical Biochemistry
- Clinical Biochemistry with Molecular Biology
- Clinical Drug Development
- Clinical Microbiology
- Clinical Nutrition and Health
- Computational Biology for Genomics and Proteomics
- Drug Discovery
- Drug Discovery and Translational Biology
- Food Biotechnology
- Food Safety
- Forensic Genetics
- Genetic Manipulation and Molecular Cell Biology
- Genomics Research
- Healthcare Research Methods
- Instrumental Analytical Sciences
- DNA Analysis, Proteomics and Metabolics
- Instrumental and Analytical Methods in Biological and Environmental Chemistry
- Intelligent Textiles and Clothing Systems
- Life Science and Technology
- Mathematical Biology and Biophysical Chemistry
- Medical Microbiology
- Medical Molecular Genetics
- Molecular Biology with Bioinformatics
- Molecular Pathology and Genomics
- Pharmaceutical Synthesis
- Polymer Engineering and Science
- Sports Science (Fitness and Health)
- Toxicological Studies
- Toxicology.

Source: www.prospects.ac.uk.

6.3.2 Full-time and part-time programmes

Most programmes could be taken by full-time or part-time study, and all except three of the 35 programmes available by full-time study lasted 12 months (range 10–24 months). Regarding part-time study, 24 programmes were available, 18 lasting 24 months (from a range of 22 to 60 months). Only three programmes were available by distance learning.

6.3.3 Student numbers and gender

Postgraduate students are those enrolled in Biochemistry programmes leading to higher degrees, diplomas and certificates, (including PGCE) and professional qualifications, reported by the universities to HESA, including part-time and full-time students. Taught programmes (usually leading the MSc or MRes degrees and lasting usually one year) and research-based

Table 21. British Council website search results for taught Biochemistry programmes

Search criteria	No. of institutions	No. of programmes
Biochemistry in programme description, full-time	45	127
Biochemistry in programme title, full-time	14	35
Biochemistry in programme description, part-time	33	75
Biochemistry in programme title, part-time	10	17
Biochemistry in programme description, distance learning	1	2
Biochemistry in programme title, distance learning	0	0

programmes (leading to MPhil, PhD and DPhil degrees examined by thesis alone and usually lasting two to four years) are shown separately in Table 22. Note that the numbers represent enrolled students and therefore the research student numbers will include students in all years of the programme.

The number of students on a taught programme at an institution will vary from year to year, but the most common target admission was 20 students (from a range of 5 to 20). Overall, over the four-year period, the total number of postgraduates on taught programmes has increased substantially (52% for females; 39% for males; 47% overall). This differential increase is reflected in the gender ratio, which has increased from 1.27 : 1 to 1.40 : 1. Research student numbers have also increased, but only by 18% and the gender ratio is effectively unchanged.

In 2005–06 the comparable figures for other biological sciences are shown in Table 23, as are the number of undergraduates and the ratio of undergraduates to postgraduates on taught programmes. Biochemistry has a relatively high number of taught postgraduates relative to the number of undergraduates, but the difference from other biological sciences is not large although they do cover a considerable range. The gender balance of students taking taught programmes is similar in Biochemistry to those in other biological sciences.

6.3.4 Delivery

The programmes were very diverse in the way in which they were delivered. Most involved a mixture of lectures, tutorials, seminars and laboratory work though there were major differences in the balance between these components as is illustrated in Table 24.

6.3.5 Assessment

As with delivery, assessment of the programmes was also very variable, with average percentages of overall assessment methods shown in Table 25.

6.3.6 Destination post-qualification

The Biochemical Society has surveyed Biochemistry graduates obtaining an MSc as to their employment destinations[38] and these data are shown in Table 26 for the average of the two cohorts graduating in 2001–02 and 2002–03. The data are subject to reservation regarding the variability of the response rate between years and universities. At least 64% of graduates continued their career in research Biochemistry.

Table 22. Numbers of students enrolled on postgraduate Biochemistry programmes

Academic year	Postgraduate taught programmes			Gender ratio F : M	Postgraduate research			Gender ratio F : M
	Female	Male	Total		Female	Male	Total	
2005–06	403	288	691	1.40 : 1	1150	999	2149	1.15 : 1
2004–05	308	235	543	1.31 : 1	1121	996	2117	1.12 : 1
2003–04	284	251	535	1.31 : 1	1144	1058	2202	1.08 : 1
2002–03	264	207	471	1.27 : 1	947	866	1813	1.09 : 1

Source: HESA.

Table 23. Numbers of biological science students and gender ratios

Discipline	Postgraduate taught programmes			Gender ratio F : M	Undergraduate numbers (UG)	Ratio UG : PG
	Female	Male	Total			
All biological sciences	10886	4873	15759	2.23 : 1	117214	7.4 : 1
Biology	930	644	1574	1.44 : 1	20217	12.8 : 1
Botany	58	48	106	1.21 : 1	146	1.4 : 1
Zoology	50	21	71	2.38 : 1	3200	45.1 : 1
Genetics	122	105	227	1.16 : 1	1586	7.0 : 1
Microbiology	637	535	1172	1.19 : 1	2410	2.1 : 1
Sports Science	571	838	1409	0.68 : 1	24221	17.2 : 1
Molecular Biology, Biophysics and Biochemistry	403	288	691	1.40 : 1	6999	10.1 : 1

Source: HESA.

Table 24. Diversification of Biochemistry postgraduate programmes' delivery methods

	Lectures	Tutorials	Seminars	Laboratory work (percentage laboratory; percentage placement) [2]
Average percentage of overall provision	31.1% [1]	7.3%	7.0%	35.9%, 17.4% Total 53.3%
Range across programmes	0–100%	0–100%	0–100%	20–90%

[1] The most frequent extent was 25% lectures (ten programmes).
[2] Some programmes provide for some laboratory work to be undertaken in industry.

Source: www.prospects.ac.uk.

6.4 Academic staff teaching Biochemistry

The increasing trend towards the aggregation of departmental units in institutions into larger administrative units (for example, schools and faculties) means that academic and other staff are, in many institutions, no longer associated formally with a discipline. Indeed there is an increasing trend to develop teaching units wholly responsible for the organisation and administration of teaching matters and partly responsible for its delivery – the latter in conjunction with research-active staff assigned to research groups.

Therefore the concept of defining Biochemistry staff as "those in the Department of Biochemistry" is no longer applicable. Other methods of definition are also less than practical since, for example, staff with a Biochemistry first degree may or may not be involved in Biochemistry teaching. The same is applicable to staff members belonging to, for example, the Biochemical Society. It is

Table 25. Postgraduate programme average percentages of overall assessment methods

	Written formal examinations	Coursework	Dissertation[1]
Average percent of overall assessment	31.8%	26.9%	39.8%
Range across programmes	0–100%	0–100%	0–100%

[1] The length of the dissertation was also variable and ranged from 6,000 to 20,000 words.

Source: www.prospects.ac.uk.

Table 26. Employment destinations of Biochemistry graduates obtaining an MSc

Occupation	Number	Percentage
Further biochemical study or training	60	38
Teacher training	1	0.6
Research in industry	15	10
Research in higher education	15	10
Hospital laboratories	4	3
Civil service/public laboratories	5	3
Non-laboratory based scientific work	10	6
Other employment	8	5
UK students employed abroad	12	8
UK students studying abroad	1	0.6
Overseas students return home	10	6
Unplaced but not seeking work	2	1
Unplaced and seeking work	2	1
Unknown	18	12
Total	156	

Source: The Biochemical Society[38].

therefore effectively impossible to distinguish Biochemistry staff from other biological science staff or to calculate any meaningful overall national staff:student ratio, age profile or national trends for Biochemistry teaching staff.

The best national data are derived from HESA[39] and apply to biological sciences as a whole. The student to staff ratio for the biosciences cost centre has changed very little over the last three years: from 15.6 in the academic year 2003–04 to 15.1 in 2004–05 and 15.4 in 2005–06. This is below the UK average of 16.8 (2005–06). However, it should also be noted that Biochemistry staff may have very significant input to teaching in non-C7 programmes.

According to Universities UK[40] the number of academic staff full-time equivalents within the cost centre for Biochemistry with qualification in C7 subjects was 4650 in 1996–97 and 4320 in 2005–06 (-7%). The change in staff numbers of academic staff in the cost centre for Biosciences as a whole over the same period is +34.4% (7370 to 9896). With respect to the availability of academic staff for teaching duties, it is difficult to draw any conclusions from these data since the involvement of staff in teaching may be anywhere from 0% to 100% and the blurring of discipline boundaries means that staff not formally qualified in Biochemistry may be involved in teaching it.

In response to an enquiry by the Centre for Bioscience about staffing of Biochemistry units, we received responses from one large, one medium-sized and one small department. A common feature of the comments was that there were few individuals who described themselves generically as "biochemists" especially among the newly recruited, and that this had consequences for the subjects taught by teachers with an appropriate background. They were more likely to style themselves more specifically as "Structural Biologists", "Molecular Biologists" or "Cell Biologists", etc. This may be an illustration of how wide the remit of biochemistry has become, or alternatively an expression of the fact that people in practically all areas of bioscience are using the techniques of biochemistry and molecular biology. The consequences for teaching are felt especially in a small department trying to teach the whole of modern biochemistry. Larger departments are at an advantage in this respect – there will be more individuals to cover the range.

A factor causing recruitment to departments of individuals who are not basic biochemists is the pressure to appoint people with a good research record and potential (for the sake of the RAE and funding). In many institutions it is the research agenda rather than the teaching agenda that is controlling staff appointments. Part of the problem is also what should be taught as "Biochemistry" in a course of that name. The overall view is that it is probably too difficult to teach it all coupled with the difficulty of knowing what "all" represents these days. However, correspondents report that it has been difficult to recruit into the areas of enzymology, immunology, protein chemistry and medical biochemistry.

Another comment was that some of the older members of departments have a wider view of Biochemistry and its relationship to Biology generally, and also have a better knowledge of chemistry. When these members retire there will be a gap.

Respondents indicated that their departments had teaching-only appointments. Some of these are temporary and some permanent with the possibility of promotion to more senior levels. Such individuals are regarded as "very useful" and have appropriate backgrounds. However, not being research active as time goes on they may be less able to teach against a background of research.

Departments appear to be aware of their teaching deficiencies and do aim to do something about them in as much as the research agenda and priorities with respect to the RAE allow. Most said that they aimed to improve their teaching in areas such as medical biochemistry and bioinformatics.

7. Comparison with other countries

7.1 Models of Biochemistry provision elsewhere in world

Higher education is increasingly international, especially at research intensive universities. Although some universities in the UK are at the top end of the ranking lists[41], education providers in other countries are increasingly competitive. Higher education is important to the economic activity, innovation and success of a country and increasingly is seen as a product of that country that may make, overall depending on student immigration and emigration, a positive contribution to exports. Marketability of higher education has therefore become important, and there is considerable change in national provisions.

In Europe, the Bologna process, which started in 1999, was a major educational reform created with the aim of achieving greater convergence and transferability between European countries. For most UK higher education institutions this has not involved any major change in programme organisation[42]. Other countries have made more significant changes; for example, Germany has now introduced a Bachelors degree (which did not exist before) and France has merged the *Diplôme Universitaire d'Etudes Générales* (DEUG) and "Licence" degrees into the equivalent of a Bachelors degree.

It is thus increasingly possible to study for a Bachelor of Science in Biochemistry in any European country, and the three-year programme will often have a title with the English term "Bachelor" in it. The classifications of the individual sciences and the programme content will, however, vary considerably and the JACS code classification, standard in the UK, is not applied elsewhere in Europe.

Bachelors degrees in the United States (US) typically require four years of full-time study, but some universities and colleges allow particularly able students to complete them in less time. Some US institutions have a separate academic track known as an "honors" or "scholars" program, generally meant for the "top" students of the school and offering more challenging programmes or more individually-directed seminars or research projects in lieu of the standard core curriculum. In 2004–05, 4729 students graduated from a US university with a Bachelors degree in Biochemistry, corresponding to 7.3% of all biological and biomedical science graduates[43] The US classification of individual sciences does, however, differ from the UCAS classification system and does not use the UK JACS code system, which makes comparisons uncertain.

7.2 Transferability/recognition of qualifications

There is no formal regulatory body that registers all qualified biochemists (as the General Medical Council does for doctors, for example) and biochemists will work within biochemistry and other fields on the merits of the particular qualifications they have. Some may be registered with the Health Professions Council through an accredited qualification (though not C7 programmes) from the Institute of Biomedical Science[30].

With regard to movement of students between degree programmes there are at least three issues:

- does the student have sufficient credits to enter an appropriate year of the programme (see below)?
- has the student covered an appropriate curriculum to be able to cope with the material presented in the year to be entered? This is affected by the sequencing of information within an individual programme structure and would have to be judged on an individual programme basis
- are there language problems? While many European students have fluency in English, the lack of language skills of many UK Biochemistry students makes it impossible for them to consider taking part of their programme abroad when teaching is not in English, even if the credits and curriculum are appropriate.

With regard to credits, many UK universities operate the Credit Accumulation and Transfer Scheme (CATS)[44] and all universities in Scotland use the Scottish Credit and Qualifications Framework (SCQF)[45] enabling easier transfer between programmes and institutions. All HEIs in Wales use the Credit and Qualification Framework for Wales (CQFW). Under this scheme, a university programme involving 100 or 200 student learning hours would typically, on successful completion, be worth 10 or 20 CATS credits, at one of Levels 1 to 3. In many universities 360 credits need to be accumulated (often 120 credits at each level although some universities operate lower limits) to qualify for award of an Honours degree. In Scotland, 480 credits are normally required since Honours degrees are typically four years long. It is this measure of credits that has been used in this Profile whenever values are given in terms of credits.

In response to the Bologna agreement, most European countries have made changes to their respective first degrees so that qualifications throughout Europe are standardised in terms of three cycles of higher education qualification. These are defined in terms of qualifications and European Credit Transfer and Accumulation System (ECTS) credits (60 ECTS are broadly equivalent to 120 CATS[46]):

- first cycle: typically 180 to 240 ECTS credits, usually awarding a Bachelors degree
- second cycle: typically 90 to 120 ECTS credits (a minimum of 60 on second-cycle level). Usually awarding a Masters degree
- third cycle: Doctoral degree. No ECTS range specified.

The naming of the cycles may vary from country to country. In most cases, the cycles will take three, two and three years respectively to complete. A Bachelor of Science in Biochemistry would in most European countries involve three years of study and 180 to 240 ECTS credits (equivalent to 360 CATS credits).

While in formal terms there is no direct relationship between time spent studying and credits, nevertheless, the ECTS is based on the principle that 60 credits measure the workload of a full-time student during one academic year. The student workload of a full-time study programme in Europe, taking formal teaching as well as preparation and expected self-directed learning, amounts in most cases to around 1500 hours per year and therefore one credit stands for around 25 working hours.

Scottish and Welsh higher education institutions have credit systems in place that are compatible with the ECTS (European Credit Transfer and Accumulation System).

With regard to the US, the US Department of Education does not accredit institutions in foreign countries. The accreditation of a university programme for an individual science student, moving from a UK to a US university (or vice versa) during the course of a programme, depends on the specific institution that will examine the transcripts of curricula and standards achieved to determine the level of the student's qualifications.

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Appendices

APPENDIX 1

Methods

Data sources and acquisition

Three main sources of data have been used:

1. Global databases (for example, UCAS, HESA)

It should be noted that there are a number of problems with global databases, especially those that rely on data being reported to them by other organisations. In addition, the HESA database changed the way it allocated students to subject divisions in 2002–2003 by adoption of the JACS code system and also altered the way students on joint programmes were split between subjects. Subject-based data are therefore not comparable across the 2001–02 and the 2002–03 divide.

The UCAS database provides data that are not easy to reconcile with that in HESA and that are known to vary from data reported by individual teaching units. In part this may be due to the fact that when applicants apply for more than one subject group, only the subject group listed most frequently (the preferred subject) is counted. For some subjects this can create the impression that more students accepted offers than applied.

In addition, UCAS changed its classification system and adopted the JACS codes for 2002 and later data, while previous data were classified according to SCAS (Standard Classification of Academic Subjects). In the SCAS system Biochemistry (C7) and Molecular Biology and Biophysics (C6) were separately identified. The data for C7 and C6 classified under the SCAS system have been added together to make them more comparable with JACS grouped data where Molecular Biology, Biophysics and Biochemistry (C7) are recorded together.

It is noteworthy that the Royal Society has recently commissioned HESA to re-analyse some of its statistical data on Maths and Biology graduates to account for differing trends within the disciplines[27]. HESA data also rely entirely on the returns from the individual universities. This is one of the reasons why UCAS and HESA data are not necessarily the same.

2. Responses to questionnaires sent to academic staff contacts at representative universities

Responses to questionnaires (Appendix 2) sent to academic staff were incomplete in some aspects and therefore a full set of data was not obtained in every case. Also, because of the large number of universities with Biochemistry programmes, it was impossible to survey each one and therefore a representative sample of ten (approximately 20% of universities providing programmes) was surveyed. In order to produce this representative sample, the HUBS (Heads of University Biological Sciences) selection criteria were applied, ensuring that the final sample represented, as closely as possible, the major university groups, UK countries and English regions, RAE score distribution, plus the variety of student populations and programmes in Biochemistry.

Our final sample consisted of three "old" universities (pre-1992), three "new" universities (post-1992), and four Russell group universities.

3. Responses to questionnaires sent to final-year students on Biochemistry programmes

Student views were sampled in the same representative group of universities as used for 2, above. The return rate on 390 questionnaires was 20%. See also Appendix 3.

APPENDIX 2

Departmental contacts questionnaire

Course

How many students are registered in each year of your course(s)?

Degree	JACS code (C7xx)	Sandwich Yes/No Length of placement	1st	2nd	3rd	4th

Modules Year One

Please give us some more details about the individual modules:

Module name	Compulsory or optional from named list	Credit points	Lecture (hours)	Tutorial (hours)	Practical (hours)

How many modules (credits) per year, if any, can the students pick as free choice from other departments or programmes?

Modules Year Two

Please give us some more details about the individual modules:

Module name	Compulsory or optional from named list	Credit points	Lecture (hours)	Tutorial (hours)	Practical (hours)

How many modules (credits) per year, if any, can the students pick as free choice from other departments or programmes?

Modules Year Three

Please give us some more details about the individual modules:

Module name	Compulsory or optional from named list	Credit points	Lecture (hours)	Tutorial (hours)	Practical (hours)

How many modules (credits) per year, if any, can the students pick as free choice from other departments or programmes?

Modules Year Four

Please give us some more details about the individual modules:

Module name	Compulsory or optional from named list	Credit points	Lecture (hours)	Tutorial (hours)	Practical (hours)

How many modules (credits) per year, if any, can the students pick as free choice from other departments or programmes?

Lectures

How many hours of lectures (on average) do students have in each year?
How many are given by post-doc researchers or postgraduate students?

	Total hours/week	Given by post-docs (average number of hours)?	Given by postgraduate students (average number of hours)?	Assessment method
Ist Year				
2nd Year				
3rd Year				
4th Year				

Tutorials

How many hours of tutorials do students receive? Would the tutor be a lecturer, post-doc, postgraduate student, or other? What would be the average size (or size range) of a tutorial group?

	Hours/week	Tutor position	Group size	Assessment method
Ist Year				
2nd Year				
3rd Year				
4th Year				

Are tutorials associated with specific modules or are they free-standing?

Practicals

Is the practical "wet" or "dry"? Are the practicals delivered over a period of several weeks or over a block of consecutive days? How many students per staff?

	Hours/ week	Assessment method	Wet/dry, block	Number of students per:		
				Academic staff	Demonstrators	Support staff
Ist Year						
2nd Year						
3rd Year						
4th Year						

In case of a student not getting a place at a desired practical:
What are the alternatives (waiting list, replacement with other learning opportunity, other)?

Projects

Are they individual or group projects? If group project: what is the average size of a group? What would be the type of a project (laboratory practical, analytical work, literature presentation, other)?

	Individual project (total hours or days)	Group project (total hours or days)	Group size	Project type
Ist Year				
2nd Year				
3rd Year				
4th Year				

If not all students carry out final-year laboratory-based ("wet") practical projects: how many students (average or range) carry out a "wet" final year project? What would be the criteria for a student being assigned a "wet" or "dry" final-year practical project?

Placement year (if part of course)

How many students take up an industrial placement? In which year of their studies?

	Uptake (percentage or range)
Ist Year	
2nd Year	
3rd Year	
4th Year	

Departmental pastoral care

What type of pastoral care is offered by the department? How many hours per week are provided?

	Type of pastoral care	Hours/week
Ist Year		
2nd Year		
3rd Year		
4th Year		

Other

How many students do you estimate to be in paid employment (not course-related) during their studies? If no estimate can be given, please leave blank.

	Percentage of students being in paid employment (estimate)
Ist Year	
2nd Year	
3rd Year	
4th Year	

Thank you very much for your help!

APPENDIX 3

Student survey

Survey of the student learning experience

Your university has agreed to take part in this short survey run by the Centre for Bioscience of the Higher Education Academy as part of a UK-wide review of the learning experience for students following BSc Biochemistry and related degree programmes.

There are three sections:

Section 1 asks for your course code and general comments.

Section 2 asks for some demographic information to enable us to check whether our sample is representative and to compare between different groups of students. This will be evaluated completely anonymously. It will not be used to identify individuals or their universities.

Section 3 asks about what you think of specific aspects of your degree programme.

Section 1

Please state the title and UCAS code (if known) of your degree programme

Please make any further comments that you wish about your experience as an undergraduate Biochemistry/Biochemistry student. For example, which aspects did you think were particularly good and which could have been improved?

Section 2 (please circle your answers)

1. I am: 25 years old or younger 26 years old or older

2. I am: Male Female

3. I am registered as studying: Full-time Part-time

4. For fees purposes, my normal place of residence is registered as: Home Other EU Non EU

Section 3 (please circle your answers)

For each statement, please rate the extent of your agreement or disagreement (A = strongly agree, B = agree, C = neutral, D = disagree, and E = strongly disagree).

1	I have been encouraged to think about the range of career opportunities that will be available to me when I graduate.	A	B	C	D	E
2	My department/school has shown concern for my overall well-being.	A	B	C	D	E
3	There have been adequate opportunities available for me to develop my practical skills in Biochemistry.	A	B	C	D	E
4	My experience has helped me to develop a range of transferable (generic) skills, such as communication, group work, and IT skills.	A	B	C	D	E
5	My lecturers have provided helpful feedback on my progress.	A	B	C	D	E
6	As a result of my experience I have improved my ability to learn independently.	A	B	C	D	E
7	There has been adequate provision of library facilities.	A	B	C	D	E
8	There has been adequate provision of IT facilities.	A	B	C	D	E
9	I have been given adequate support and guidance for my learning.	A	B	C	D	E
10	Lecturers are enthusiastic about what they teach and they made the subject of Biochemistry interesting and relevant.	A	B	C	D	E
11	Lecturers made effective use of technology in their teaching (for example, Blackboard/webCT; personal response systems; online assessments and discussion boards).	A	B	C	D	E
12	I have had adequate opportunities during my degree to gain work experience relevant to Biochemistry.	A	B	C	D	E
13	My overall experience during my degree programme met with my expectations.	A	B	C	D	E
14	I would recommend the degree programme that I have followed to other students.	A	B	C	D	E
15	My university has prepared me well for my industrial placement (if applicable).	A	B	C	D	E

Thank you very much for completing the questionnaire! Please hand it back to your tutor. We wish you well in the future.

Appendix 4

More information about Biochemistry

The Biochemical Society
www.biochemsoc.org.uk

American Chemical Society, Division of Biological Chemistry
www.biochemdivision.org

"Yay Biochemistry". A general introduction to biochemistry
www.queenoflub.com/biochem/

Open access Biochemistry research journal
www.biomedcentral.com/bmcbiochem

Job descriptions and options for biochemists
www.prospects.ac.uk/cms/showpage/home_page/options_with_your_subject/your_degree_in_biochemistry/p!ebfadpk

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