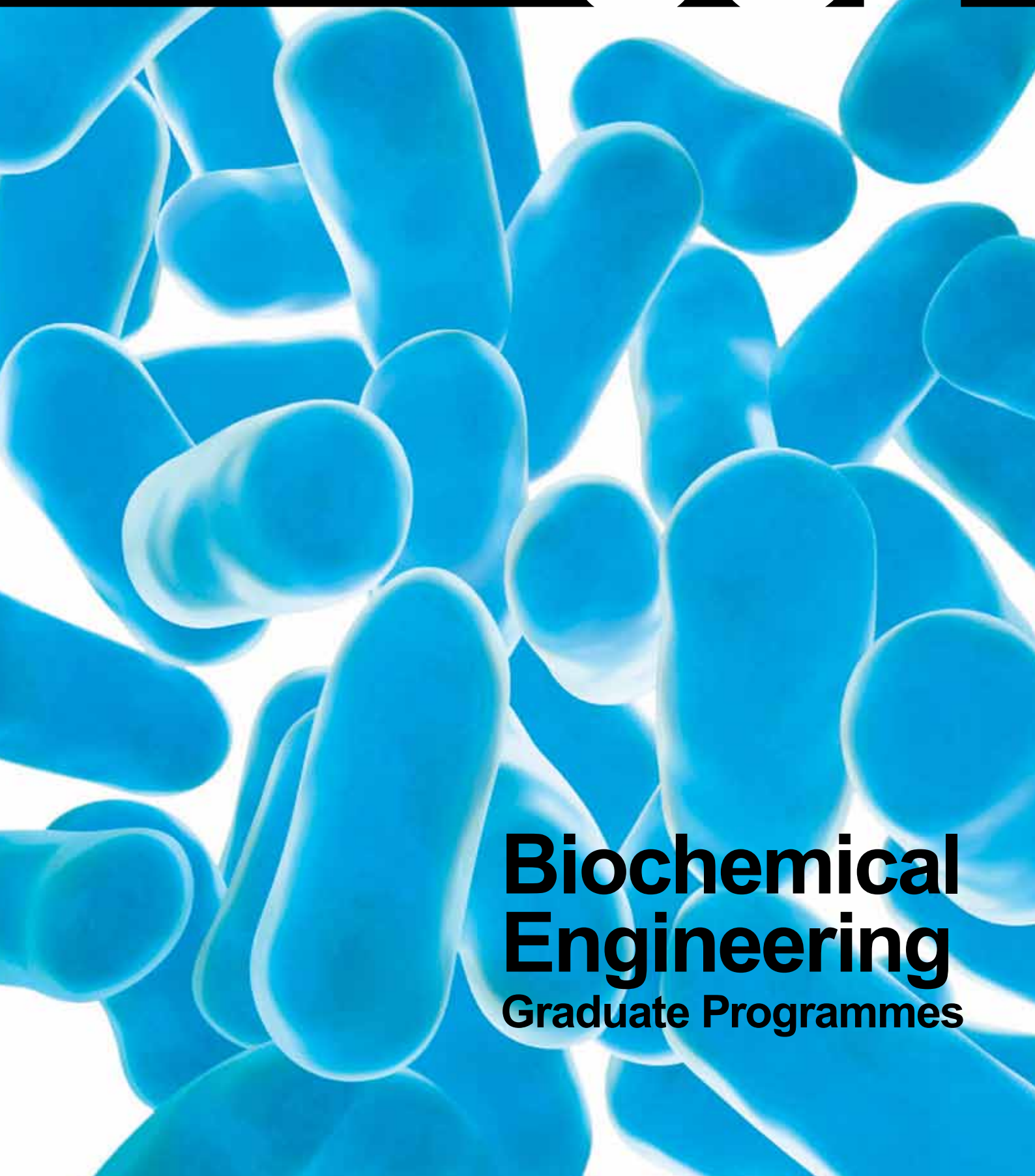
UCL ADVANCED CENTRE FOR
BIOCHEMICAL ENGINEERING

UCL



Biochemical Engineering

Graduate Programmes

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Graduate study at UCL

Graduate Study at UCL

UCL provides an outstanding and distinctive environment for graduate study. Guided by principles of excellence and innovation, UCL offers a range of programmes, resources and opportunities intended to help you make the most of your graduate study and to achieve your aspirations.

UCL's distinguishing features

- Research-led learning in which ground-breaking research at UCL informs the teaching and supervision of graduate students, providing opportunities to undertake or participate in such research.
- Exceptional research quality, with 85% of UCL's departments being awarded top ratings of 5 or 5* indicating research of international importance in the most recent (2001) UK Research Assessment Exercise.
- A global outlook which extends beyond welcoming over 6,600 students from outside the UK to prepare all our students to live and work in the global community. An international perspective is embedded in teaching and research at UCL, and co-operative links are fostered with governmental, educational, industrial and corporate organisations around the world.
- A welcoming, dynamic community in which collaboration and cross disciplinarity are promoted, and diversity is celebrated.

UCL's resources and support services

- The UCL Graduate School is dedicated to ensuring you are provided with high standards of teaching, supervision and support. It directs the provision of services and facilities for graduate students including: the Skills Development Programme; the Research Student Log; codes of good practice; research scholarships and funds; opportunities to present and display work in graduate competitions; social and networking events for graduate students and dedicated graduate computer and common room areas. www.ucl.ac.uk/gradschool
- The UCL Library provides a high-quality, integrated and innovative service, with support to help you access both printed and electronic resources. www.ucl.ac.uk/library
- Information technology facilities are provided in departments,workrooms, residences and through a wireless network across many parts of the main campus. www.ucl.ac.uk/is
- The UCL Language Centre supports language learning both for academic and personal interest. In addition to foreign languages, the centre also offers English language courses for international students. www.ucl.ac.uk/language-centre
- UCL's own museums and collections form a resource of international importance for academic research. They span art, archaeology, zoology, geology, science and ethnography. www.ucl.ac.uk/museums
- UCL Careers Service organises numerous events specifically for graduate students, including employer forums, networking events and employability skill-development workshops. Access to the careers library and vacancy information, together with personal consultations, are also available. www.ucl.ac.uk/careers
- A wealth of services and advisers provide both academic and pastoral support. In addition to your own supervisor or tutor, these include: the Dean of Students; a Health Centre; a Disability Centre; a Counselling Service, the Rights and Advice Centre and a Day Nursery. www.ucl.ac.uk/current-students
- Sporting and recreational interests are well catered for, with both a fitness centre and theatre on the main campus. In addition, the UCL Students' Union runs many clubs and societies as well as providing cafés, shops and social spaces located across UCL's premises. www.uclu.org

UCL's profile

- Founded in 1826. The first university in England to admit students irrespective of race, class or religion, and the first to admit women on equal terms with men.
- 20,170 students, of whom 8,000 are graduate students.
- 6,600 students from outside the UK.
- An overall staff to student ratio of 1:9 enabling a continued emphasis on small-group and one-to-one teaching.
- Currently ranked fourth in the 2010 QS World University Rankings (QS Quacquarelli Symonds Limited)

UCL in London

London affords an enormous range of academic, cultural and leisure opportunities. UCL is located in the Bloomsbury area of central London, famous for its intellectual and academic traditions.For those facilities not within walking distance of UCL, excellent transport links give access to resources across the capital.

- Internationally renowned establishments, such as the British Library, British Museum, Natural History Museum, Science Museum, National and Tate Galleries and National Archives, together with innumerable specialist organisations, provide a wealth of materials to support original research.
- Many professional institutions and bodies are located in London. This can enable UCL students, where applicable, to access specialist resources, and attend lectures, conferences and networking events.
- Theatres, cinemas and music venues abound in London, catering for every taste. Sporting facilities, for those who enjoy participating or spectating, are plentiful. There is a huge array of shops, restaurants and parks to enjoy. Numerous festivals and events celebrate the city's diverse and vibrant community.

Department of Biochemical Engineering

Biochemical Engineering at UCL

Biochemical Engineering at UCL is an interdisciplinary subject which has as its primary focus the fundamental issues that underpin the translation of biological discoveries, such as new kinds of advanced medicines, into practical outcomes. In this way biochemical engineers can contribute immensely to improving the quality of life. In the next decade and beyond, the contributions of biochemical engineers to the national and international community will be vital not only in the area of new medicines but also for more nutritious foods, novel materials from renewable sources and improved approaches to reducing and dealing with environmental pollution.

The Department of Biochemical Engineering at UCL is the largest university department of its kind in the UK; its graduate degree programmes lead to qualifications which are internationally recognised. Taught Master's programmes and research study programmes in the department draw on knowledge and methods derived from a range of disciplines, including biochemistry, microbiology and molecular biology as well as the core discipline of biochemical engineering in which the foundation subjects are applied and integrated.

There are close teaching and research links with scientists and engineers working in other departments and centres at UCL, including Structural and Molecular Biology, Computer Science, the Institute of Ophthalmology, Physiology, the Royal Free Hospital Oncology Dept, UCLH Haematology, Mechanical Engineering, Chemical Engineering and the London Centre for Nanotechnology, together with experts from other departments throughout the UK and overseas. A collaboration with the London Business School in the establishment of a Science Enterprise Centre now allows the integration of technical and business skills at all levels. Links with industry are exceptionally close, with leading industrialists contributing to teaching and research programmes.

These interactions with a range of disciplines and companies help to create a vibrant department at the forefront of the field, and create an exciting environment for graduate training and research Various independent assessments have confirmed the excellence and breadth of the department's taught programmes (IChemE Accreditation Exercise) and placed the research programmes at the forefront of international endeavours (Research Assessment Exercise 5* rating).

History of the department

In the 1930s Jack Drummond, the first UCL Professor of Biochemistry, succeeded in isolating pure vitamin A. To do this however, he needed large quantities of fish liver oils and later, wheat germ. Drummond was helped by Maxwell Donald, a young process engineer and lecturer in Chemical Engineering at UCL. So began the linkage of departments that created the Department of Biochemical Engineering. By the 1950s, Donald was a Professor and Head of Department. He worked with Ernest Baldwin, Head of Biochemistry, to establish a joint Diploma, later a Master's programme, in Biochemical Engineering at UCL. Donald also worked closely with visionary biologists Eric Crook and Pat Clark at UCL to scale up new biological discoveries. Crook and Donald helped launch Biotechnology and Bioengineering, the subject's first journal, in 1959, and a UCL staff member, Fife Webb, wrote one of the field's first monographs.

Malcolm Lilly, a student of Professor Clark, and Peter Dunnill, a student of Sir Lawrence Bragg (the father of molecular biology and hence of modern biotechnology) joined the department in the 1960s. At UCL, Lilly and Dunnill combined their interests and worked closely to isolate large quantities of commercially unavailable enzymes. An early outcome of their pioneering research, that shaped the future of biochemical engineering, was their work on penicillin acylase and its use for the production of the first semi-synthetic penicillins. Twenty years later Malcolm Lilly and Peter Dunnill became the first Professors of Biochemical Engineering in the UK.

In 1991 UCL was chosen as the UK's Interdisciplinary Research Centre (IRC) for Biochemical Engineering. This interdisciplinary role has been maintained with the creation of the Advanced Centre for Biochemical Engineering (ACBE). The establishment of the IRC and ACBE allowed the department to plan a unique set of pilot-scale capabilities embracing the 'whole bioprocess' concept with the B3 containment needed to allow the full range of 'genetically engineered' materials to be safely studied at scale. In 2002 UCL was selected as the UK's Innovative Manufacturing Research Centre (IMRC) for the bioprocessing industries which is now pioneering ultra-scale down techniques to speed the development of more cost-effective routes to new medicines. The 'whole bioprocess' approach represents the central theme of biochemical engineering at UCL within which all the teaching and training programmes are provided. As the central research theme of the department has developed, the study of whole bioprocesses has expanded to embrace related 'business processes' in collaboration with the London Business School.

These include issues of validation and regulatory requirements and also entrepreneurial activities which underpin the establishment of small, high-tech venture companies.

UCL pioneered biochemical engineering education in the UK and has provided the process industries with first-class future leaders. The department has a unique national and international network of industrial contacts and alumni which help it to maintain its position in the forefront of education and research. This enables the department to run the highly successful Modular Training for the Bioprocess Industries (MBI®) programme (over 1,000 modules have been taught to date, 700 international delegates have attended and 200 companies have participated). The MBI® modules are timed to dovetail with the MSc timetable and attendance at modules is a requirement for doctoral students.

Research and training facilities

The department is one of the largest global providers of training for the bioprocessing industry; it has one of the most modern biochemical engineering teaching facilities in the world. Constructed and first equipped in 1992 at a cost of approximately £20 million, the facility is able to attract leading industrial collaborators for the department's research and training programmes. The department's training facilities comprise superb pilot plant and instrument resources for scale-up studies of genetically engineered material. The facilities include a range of mechanically agitated fermenters up to 450 litre scale, linked via mass spectrometers and other instruments to a computer suite. These bioreactors are matched by a range of state-of-the-art, pilot-scale downstream processing equipment and analytical instruments which allow the staff in the department to provide training in the bioprocessing of genetically engineered materials.

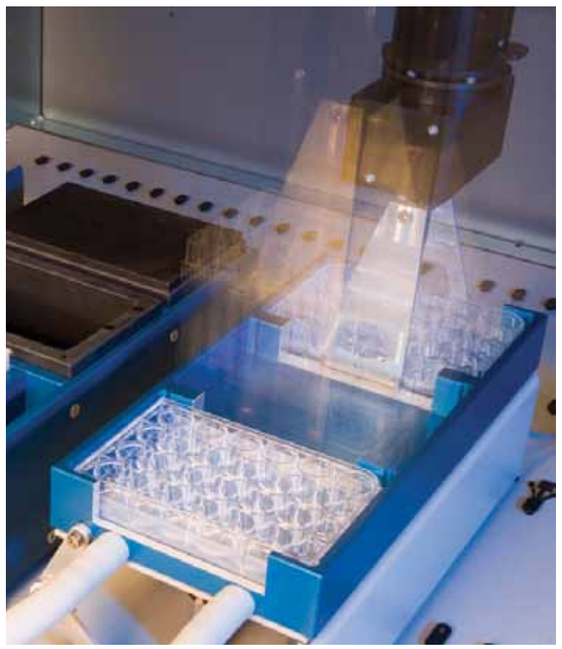
A further investment of £4 million was made in 2002 to establish the world's first Centre for Micro Biochemical Engineering. This is equipped with the latest automated robotic systems to enable more rapid process discovery and now allows process studies to be interfaced with the emerging fields of genomics and proteomics. Another £1 million investment has been made in the construction of a Regenerative Medicine Bioprocessing Unit for new research on human cell therapy products.

Funding

Details of sources of financial support for both UK/EU and overseas students are given on the internet at www.ucl.ac.uk/scholarships.

Details of tuition fees and estimated maintenance costs are given in UCL's Graduate Prospectus and fees may also be found at www.ucl.ac.uk/current-students/tuition-fees.

Typically 15-20 awards are made each year for graduate studies at PhD/EngD. Graduates with undergraduate or Master's degrees in a wide range of science and engineering disciplines are eligible for such awards. The department is a major recipient of funding for graduate training from the Engineering and Physical Sciences Research Council (EPSRC), and the Biotechnology and Biological Sciences Research Council (BBSRC).



Research Programmes

Research Programmes

The focus of research is the study of the whole bioprocess and the interaction between new biological discoveries and the novel engineering required for the formation, recovery, purification and formulation of biomaterials. Targets include 'small' and macro-molecules. Both are progressing to greater complexity; for example, metabolically engineered antibiotics and chiral drug intermediates, antibody fragments, plasmid genes and cellular therapies are the subject of current studies.

MPhil/PhD

The department offers a range of research degree opportunities; many supported by BBSRC awards, and by industrial sponsors. Typically eight to ten new PhD positions are offered each year. The projects draw upon the expertise within the department and the multidisciplinary research linkages of the Advanced Centre for Biochemical Engineering. Many of the PhD projects are collaborative with leading bioindustry companies. These external links, and close involvement with the Centre's research team, provide the foundation for producing much sought after doctoral graduates.

EngD

The department has been selected as the recipient of an annual EPSRC-supported allocation of ten Bioprocess Leadership Engineering Doctorates. Each EngD programme is of four calendar years' duration; with up to half of the time spent with the host company which also sponsors the researcher. This gives the researchers unprecedented opportunities to explore novel science and engineering in a process and business context relevant to future leadership roles in the bioindustry. Given the levels of company sponsorship negotiated by the department the stipends received by the EngD researchers are, in many cases, equivalent to graduate starting salaries in industry. Entry requirements Graduates with at least an upper second-class Honours degree or a graduate Master's qualification in a suitable science or engineering discipline are eligible to apply. Candidates offering relevant industrial experience in addition to, or partly in place of, academic qualifications are also welcome to apply.

Entry requirements

We are looking for graduates with at least a 2:1 honours degree from a UK university or the equivalent from an approved overseas institution, or postgraduates with a Master's qualification in a suitable science or engineering discipline. Candidates offering a relevant industrial experience in addition to, or partly in place of, academic qualifications are also welcome to apply.

Applications from graduate scientists are normally from candidates holding qualifications in applied biology, biochemistry, biotechnology, chemistry, microbiology, pharmacy or other related subjects. Applications from graduate engineers are normally from candidates holding qualifications in biochemical engineering, chemical engineering or other engineering disciplines.

Funding

The department is a major recipient of funding for graduate training from the Engineering and Physical Sciences Research Council (EPSRC), and the Biotechnology and Biological Sciences Research Council (BBSRC). There are typically up to 20-30 full-time places available each year.

Length of programme

The normal length of both the MPhil and PhD programmes is three years full-time. The EngD programme is of four years' duration. The research programmes normally begin in late September. Candidates wishing to start at a different date should contact the Admissions Tutor before applying.

Organisation

All MPhil/PhD research students are normally registered for the MPhil degree in the first instance, and, assuming that their work is satisfactory, will usually expect to transfer to PhD registration within 18 months of their arrival. All EngD students register for this programme at the outset, but progress is monitored at annual intervals.

On entering the department every student is assigned a main supervisor, who is responsible for giving guidance and advice on all aspects of the student's academic work throughout the period of registration. To ensure that students benefit from as much intellectual stimulus as possible, a second staff member (who may be from a collaborating department) is assigned to act as an adviser, with whom the student can discuss any aspect of his/her activities. For researchers collaborating with industry, an industrial supervisor will also be appointed. Students are expected to meet their supervisors regularly. Initially this will probably mean every week, but once a pattern of work and co-operation has been developed meetings may be less or more frequent. The department's policy on maintaining the quality of its teaching and training requires the students to record the minutes of all such meetings in their Graduate School E-log, including actions expected from the research team members. The Graduate School arranges a skills and development programme for all incoming research students which links into the department's formal training programme for graduate researchers.

In addition to the facilities described earlier, research students are offered shared office accommodation with access to computer terminals, and, where applicable, a PC for the duration of their study.

As part of their training, students have the opportunity to present their research plans to staff and students for feedback and comment. There are weekly research seminars given by staff and research students, and visiting speakers from the UK and abroad deliver 'Bioprocess Briefings', which all graduates are expected to attend.

Assessment

All research degrees are examined by thesis and viva voce examination. In the case of the EngD successful completion of all taught elements of the degree is also necessary.

Research areas

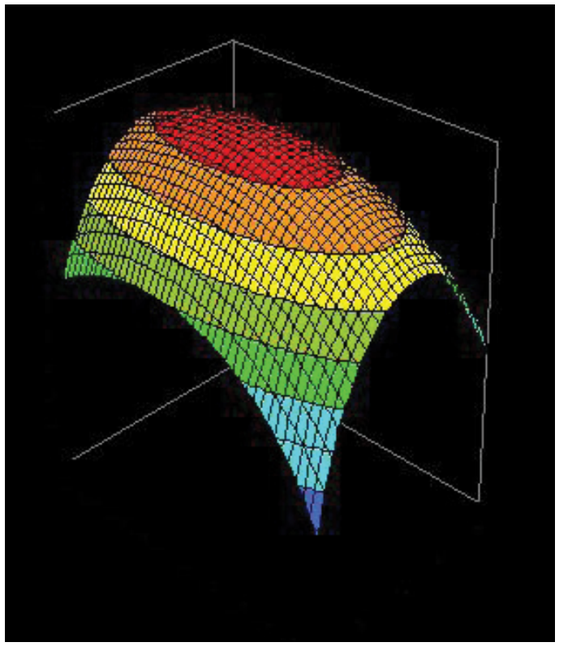
Biochemical engineering is at the heart of an immensely exciting revolution. Compared with older techniques of improving the performance of biological systems by mutation, new approaches are able to achieve exquisite precision. For the world to gain in terms of health and wealth these discoveries must be harnessed. Laying foundations for this demands biochemical engineering research which is as radical as the new biology and with which it must be fully integrated. Our research is described under five convenient headings though in practice there is a great deal of interaction between them.

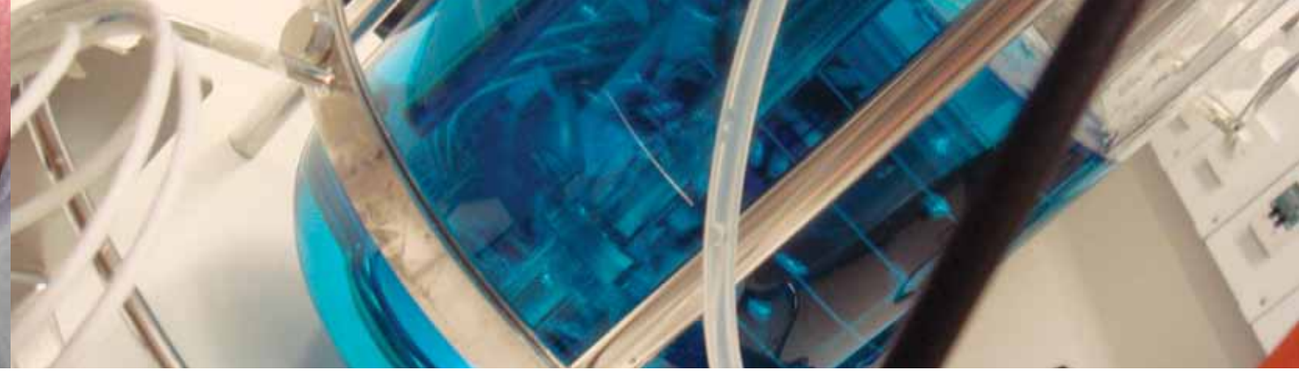
Achieving speed from discovery to benefit

At present it typically takes ten years to bring one potential major medicine from discovery to patient. Both patients and companies need faster routes and we are addressing a central aspect of achieving greater speed. Because so many new candidate medicines fail during trials of effectiveness and safety it has always been necessary to delay studies of large-scale production until a late stage of development. As medicines become more complex in order to address the need for greater selectivity, such large-scale trials are coming under severe time pressures and increasingly failing to yield efficient processes. This is especially true for recombinant human proteins and other complex biopharmaceuticals and for a new generation of more complicated small molecule pharmaceuticals. The UCL team has focused on solutions to this key challenge.

Over the last ten years we have pioneered a 'whole bioprocess' approach to show how fermentation, bioconversion and downstream processing must be integrated. For the complex new materials that life science discoveries are bringing forward, it is necessary in the final analysis to conduct large-scale studies across this whole bioprocess. However, that is expensive and time consuming both for academic researchers and for industry. We need to minimise and focus such activity. By creating exceptionally small mimics of large-scale whole bioprocesses and combining these with detailed models for each interactive element of the process it is now proving possible to make good predictions of full scale performance (Titchener-Hooker et al. 2008). Future research in this field is being enhanced by a major programme involving a group of leading companies.

This ultra-scale down research represents a new paradigm for the creation of bioprocesses. Macromolecule studies are led by Mike Hoare and Daniel Bracewell, (e.g. Hutchinson et al. 2006). We have also examined the more complex small molecules required to enhance drug selectivity, led by Gary Lye (Micheletti and Lye, 2006). Small mimics of individual operations can quickly provide information to be used in models of the full-scale process (e.g. Berrill et al. 2008). By also simulating the interactions between operations Yuhong Zhou and Nigel Titchener-Hooker have established a portfolio of models for whole bioprocesses, (e.g. Zhou and Titchener-Hooker 1999). The success of the methods in several exemplars has been confirmed by large-scale studies, for which UCL is uniquely equipped with its £20 million pilot plant facility. Research on individual bioprocess operations will remain vital and we are pursuing new approaches such as the use of continuous countercurrent chromatography for purification of large macromolecules (e.g. Kendall et al. 2001).





For biocatalytic processes to synthesise small molecules we have created conceptual frameworks for systematically choosing the most appropriate bioreactor conditions (Burton et al. 2002) and have described methods of graphical representations which simplify the interpretation of this information (Woodley and Titchener-Hooker 1996). For small molecules our 'whole bioprocess' approach includes integration with chemistry through collaboration with colleagues in the UCL Chemistry Department and the Bioconversion-Chemistry-Engineering Interface Programme (BiCE).

A new £4 million Centre for Micro Biochemical Engineering is now providing a resource for this work and particularly for the automation of the small mimic studies using microwell robotics. Research on biocatalysis (Lye et al. 2003), fermentation and downstream processing (Titchener-Hooker et al. 2008) is underway. Current use of microwells for research entails simply the addition of one fluid to another, followed by analysis. The use of this approach for process studies demands a detailed analysis of the engineering transport processes within the wells (Doig et al. 2005). This research involves Gary Lye, Martina Micheletti (e.g. Micheletti et al. 2006) and Frank Baganz. In one example Frank Baganz led research to develop miniature scale processing approaches to the culture of microbial and mammalian cells in suspension cultures that have the potential for automation (Betts and Baganz 2006). This research also demonstrated the feasibility of predictive scale up from micro/mini reactors to lab scale reactors using established methods (e.g. Betts et al. 2006). An extension of this thinking is to use microfluidic systems to potentially further this area; this research is led by Nicolas Szita (Szita et al. 2006), who collaborates with the London Centre for Nanotechnology in this area.

The data obtained from these approaches is available in the form of computer-captured information and the experiments are susceptible to sophisticated experimental design. The large amount of data means that techniques such as principal component analysis will be vital (Edwards-Parton et al. 2008). Such analyses will further extend the capacity to organise, control and simulate cellular and macro processes. The robotic microwellsystems also represent a powerful interface to genomic and proteomic research.

Research related to achieving greater speed from discovery to outcome is enhanced by studies of the fast monitoring of bioprocesses. For small molecules, the techniques of multiparameter flow cytometry using fluorescent probes are used to study substrate and product toxicity to biocatalysts (Ammanullah et al. 2003). For macromolecules the use of an optical biosensor has been explored in detail for the first time in bioprocessing (e.g. Bracewell et al. 2004) together with infrared spectroscopy (e.g. Yeung et al. 1999). Methods to rapidly assess macromolecule stability in order to determine "processability" and conditions for formulation (e.g. Aucamp et al. 2005) are also active areas of research which relate to this topic.

Harnessing genomics

The sequencing of the human genome, and just as importantly of a number of key human pathogens, is a great achievement. Now the value of this information must be matched by biochemical engineering advances to yield outcomes for healthcare and wealth creation.

Many small molecule pharmaceuticals are chemically synthesised. To reduce side-effects these molecules are becoming increasingly complex, commonly involving several chiral centres. Enzymes can be highly efficient for synthesis but are not always sufficiently robust or capable of working in the solvents needed to dissolve intermediates. The techniques of directed molecular evolution are now capable of generating designed enzymes. In addition, the pathways of enzymes in biological cells represent a foundation for highly selective multi-step synthesis. However, until recently it has not been possible to control the action of sets of enzymes. The development of metabolic engineering addresses this issue by allowing the assessment of the controlling factors within cells and by defining how these may be altered by molecular genetics. UCL was the first UK centre to address metabolic engineering at both the discovery and process levels. The UCL team has addressed an 11-membered pathway transposed from a Pseudomonad to *E.coli* (e.g. Sheridan et al. 1998). We are now collaborating with industry on an in silico analysis of *E.coli* metabolic pathways and on experimental tests of the predictions.

UCL biochemical engineers work on this project with John Ward of the UCL Research Department of Structural and Molecular Biology. To an even greater extent than basic genomics, metabolic engineering rests on a bioinformatics approach and Yuhong Zhou addresses this aspect. Yuhong Zhou's research is complemented by that of Frank Baganz, an experienced engineer. He is interested in the engineering of metabolic pathways and biocatalytic processes and its linkage to modelling (Chen et al. 2007).

In addition to targeted manipulation of metabolic pathways the capacity to achieve directed evolution offers new opportunities. This can be applied to whole cells, as in metabolic engineering, or to individual molecules, particularly to proteins and enzymes. For example, the properties of therapeutic antibodies can be evolved to yield higher binding efficiencies and to produce characteristics which allow them to be processed more easily. The evolution of better enzyme catalysts will also be invaluable in reducing the cost of synthesis of the increasingly complex small-molecule medicines. Staff member Paul Dalby addresses biocatalyst evolution with company collaborators. His work is linked to that of those pursuing enhanced industrial biocatalysis (e.g. Hibbert et al. 2007), which include Gary Lye, Frank Baganz, Helen Hailes (Chemistry) and John Ward (Structural and Molecular Biology) within the framework of the Bioconversion-Chemistry-Engineering Interface Programme (BiCE).

In parallel, the potential of proteomics to enhance bioprocessing by defining the optimum conditions for expression of human recombinant proteins is being explored by Eli Keshavarz-Moore, John Ward, Yuhong Zhou and Frank Baganz. They are analysing the impact of growth conditions and nutrients on the levels of host protein versus human target proteins and applying metabolic engineering to ease product purification. Such developments will be important for future process design and manufacturing to achieve greater speed and cost reduction. They are also valuable for discovery research where quantities of hundreds of milligrams of human proteins must be quickly produced.

Making the outcome affordable

Because it costs over £1/2 billion to develop a new medicine, the price to the patient directly or via taxes will inherently be very high. As new generations of medicines are becoming more complex (in order to achieve greater selectivity) this cost is set to rise further unless a new manufacturing paradigm can be found. Already a therapeutic protein treatment for multiple sclerosis has put a strain on healthcare budgets. A promising antibody treatment for arthritis, a much more widespread condition, will present a greater dilemma. To define ways in which cost can be greatly reduced is as critical as the discovery of new medicines. Whereas the analysis of costs is well-established in traditional industries it has not been the subject of detailed study in the new industries based on the use of molecular genetics. At UCL we are conducting analyses of costs linked to the bioprocess research described above. We also have a research programme with a group of companies which is creating computer-based decisional tools. When a pharmaceutical company discovers several potential new medicines it faces very difficult decisions in prioritising how to develop them. It may not have the capacity to take them all forward in-house and must decide which to pursue and which to license out. Companies constantly reassess their process development and business priorities in the light of clinical data and global competition. Our computer-based tools are designed to help them make more systematic decisions embracing the process dimension. The research is led by Suzanne Farid (e.g. George et al. 2007).

One of the challenges to start-ups is that it is very hard for them to commit funds to capital installation to produce material for largescale clinical trials. The uncertainty of clinical outcome means that expensive facilities may be constructed only to find a lack of successful candidates with whom to work. One approach we are exploring which could ease the cost problem is the application of process scale disposable equipment. Use of such items could cut the high capital costs of stainless steel systems and also remove the expenditure on re-validating the cleaning of contact surfaces. The design and operation of disposable systems differs from that of conventional ones and raises fundamental engineering research issues. The approach led by Mike Hoare and Nigel Titchener- Hooker with Suzanne Farid (e.g. Novais et al. 2001; Farid et al. 2005) will be even more important as more personalised medicines become common in an effort to match treatment to individual human genomes.

Studies with colleagues at Newcastle University are examining the latest generation of software approaches for the rapid design and optimisation of manufacturing capacity. Led by Nigel Titchener- Hooker, this will bring together expertise in ultra scale-down, modelling and advanced multi-objective optimisation.

Addressing a new generation of complex materials

Many present-day medicines often have serious side effects. Indeed such effects are the fourth largest cause of death in developed countries. To achieve greater selectivity in medicines is generally demanding greater complexity. For macromolecules, such structural intricacy is inherent but, even here, progression from small proteins to ever more complex large ones, as well as to genes and artificial chromosomes is happening. In parallel, human cells and tissues are being prepared for therapy.

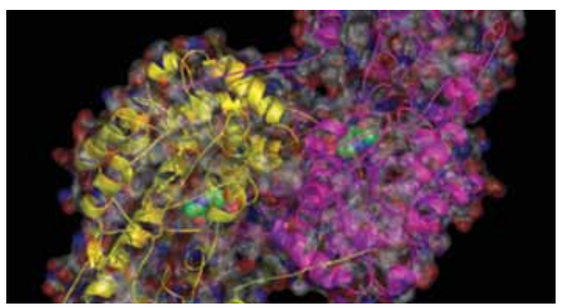
Our research on plasmid DNA processing for non-viral gene therapy and vaccines involves particularly Peter Dunnill, Eli Keshavarz-Moore, Tarit Mukhopadhyay and Gary Lye. It entails studies at each step of the whole bioprocess (see Levy et al. 2000) including cell/plasmid engineering (Cooke et al. 2004). Work on plasmid formulation is also crucial for effective delivery with gene therapy and DNA vaccines (e.g. Lee et al. 2001). The plasmid research is done in collaboration with John Ward (Structural and Molecular Biology, UCL), Steven Hart (Institute of Child Health, UCL) and Helen Hailes and Alethea Tabor (Chemistry, UCL) (Mukhopadhyay et al. 2005). Other projects which address complex macromolecules include: vaccines and antibodies from transgenic plants (Hassan et al. 2008) (Eli Keshavarz Moore); therapeutic proteins from transgenic animals (Pampel et al. 2007); and antibodies from immunised sheep (Thillaivinayagalingam et al. 2007). Stem cells have generated much excitement as they represent an unlimited supply of functional cells for the treatment of degenerative diseases such as Parkinson's and diabetes. Making these treatments a reality will require Biochemical Engineering approaches to ensure the consistency, functionality and safety of cellular therapies prior to their transplantation. Our research, led by Chris Mason and Farlan Veraitch, focuses on how the engineering environment affects the quality of cells from their initial derivation through to their expansion, differentiation, purification and implantation (Veraitch et al. 2008). Through collaboration with the UK's foremost stem cell scientists, such as Peter Andrews and Peter Braude, and clinicians attempting to translate stem cell discoveries into routine clinical practice we are laying the bioprocess foundations for the delivery of cost effective safe cellular therapies. There are important links between protein, gene and mammalian or human cell studies. We are, for example, examining the use of transient expression in mammalian cells to speed production of recombinant proteins.

Environment and sustainability

The department addresses research which minimises environmental problems, rather than research which examines the clean-up of waste. This is now being called Industrial Biotechnology and for example uses biocatalysis to avoid the use of toxic and environmentally damaging reagents in the synthesis of intermediates for new medicines. The department pioneered the use of two liquid phase biocatalysis in a classic study (Buckland et al. 1975) – the aqueous phase to dissolve the biocatalyst, the immiscible organic phase to dissolve the chemical intermediate. More recently Gary Lye has pioneered the use of ionic liquids as a replacement for conventional organic solvents in biocatalysis (Cull et al. 2000). Such solvents are not volatile or flammable and offer the potential to enhance the velocity or stability of enzyme catalysis (Roberts et al. 2004).

An exciting research community

You will see from this description that the Department of Biochemical Engineering, with colleagues in other disciplines, is addressing major challenges which will allow the full potential of biological systems to be tapped. The department is distinctive in addressing whole bioprocesses so that there will be the full knowledge necessary for carrying the science right through to real outcomes such as new generations of medicines.



Master's Programmes

Taught MSc degree programmes

Three distinct MSc degree programmes are offered:

- Biochemical Engineering MSc – for graduate scientists
- Biochemical Engineering MSc – for graduate engineers.
- Biochemical Engineering MSc – for graduate biochemical engineers.

The programmes provide students with the opportunity to understand how advances in the life sciences can most effectively be translated into real outcomes of benefit to all. Close linkage of the Master's programmes with the research activities of the Advanced Centre for Biochemical Engineering (ACBE) ensures that lecture and case study examples are built around the very latest biological discoveries and bioprocessing technologies. Examples include the production, processing and formulation of plasmid DNA for applications in gene therapy and the rational engineering of bacterial metabolic pathways for the production of novel antibiotics to overcome the growing problem of microbial resistance. Further research examples are given under Research Areas on pages 5-8 of this booklet.

The MSc programmes include material on the financing and management of bioprocess business ventures. The aim here is to generate an entrepreneurial spirit in all the students of the department. It also recognises the fact that the discovery of new products and processes is increasingly driven by small, high-tech companies. The training provided in this area is centred on the generation of a bioprocess business plan and is strengthened by collaboration with the London Business School. Another recent innovation is the delivery of material on the validation of bioprocesses. This is a vital area for the bioindustry since companies need to show that their processes are safe and reproducible if they are to be granted licences for the production of human therapeutic materials. The programme has also developed to cover new treatments in the rapidly evolving area of cellular therapies with a module on mammalian cell culture and stem cell processing.

The content of the MSc programmes is closely linked to, and benefits considerably from, the department's post-experience MBI® Training Programme. Scientists and engineers already working in the bioindustry participate in the MBI® programme to update their knowledge on particular aspects of biochemical engineering, or to work towards a Master's qualification. Industrialists engaged upon MBI® training activities come from all over the world and sit alongside the full-time Master's students for a number of the programme elements. Delegates from nearly 200 companies have benefited from such training while over 50 leading industrialists contribute to the teaching activities.

Entry requirements

Normal entry requirements are at least a second-class Honours degree from a UK university or the equivalent from an approved overseas institution. Candidates offering recent industrial experience in place of academic qualifications are encouraged to apply.

As with any engineering discipline numeracy skills are important for the quantitative description of biological and physical phenomena. Evidence of numerical ability is requested as either an A level in Mathematics (or in exceptional cases, in Physics) or some mathematics studied at university. The department provides mathematics tutoring for Master's students throughout the year adjusted to a candidate's ability.

Applications from graduate scientists are normally from candidates holding qualifications in applied biology, biochemistry, biotechnology, chemistry, microbiology, pharmacy or other related subjects. Applications from graduate engineers are normally from candidates holding qualifications in biochemical engineering, chemical engineering, process engineering or other related subjects.

There are typically up to 30 full-time places available each year. Both degree programmes are 12 months in length and begin in late September.

Master's Programmes

Funding

UCL offers a range of financial awards aimed at assisting both prospective and current students with their funding. Details can be found at http://www.ucl.ac.uk/prospective.students/scholarships

Career options for UCL MSc graduates

The first destinations of those who graduate from the Master's programmes in Biochemical Engineering reflect the highly relevant nature of the training delivered. UCL biochemical engineers are in demand, and are likely to stay in demand, due to their breadth of expertise, numerical ability and problem-solving skills.

Approximately three-quarters of candidates elect to take up employment in the relevant biotechnology industries while the remainder follow careers in the management, financial or engineering design sectors. Approximately half of those who choose the bioindustry sector will undertake PhD or EngD programmes in biochemical engineering either at UCL or other universities, before commencing their industrial careers. Brief career profiles of some of the former graduates of the department are presented on page 16 of this booklet.

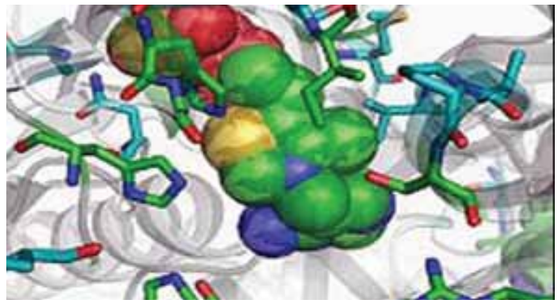
Assessment

The conversion and biochemical engineering elements of both streams of the MSc programme are assessed by written examinations in May/June. The bioprocess management and pilot plant studies are assessed by a combination of case study reports, oral and poster presentations throughout the year.

The bioprocess research projects (for graduate engineers) and design projects (for graduate scientists) are assessed by written theses and oral examinations in September. The MSc Examination Board meeting is held in mid-September to provide the final programme assessment.

Accreditation

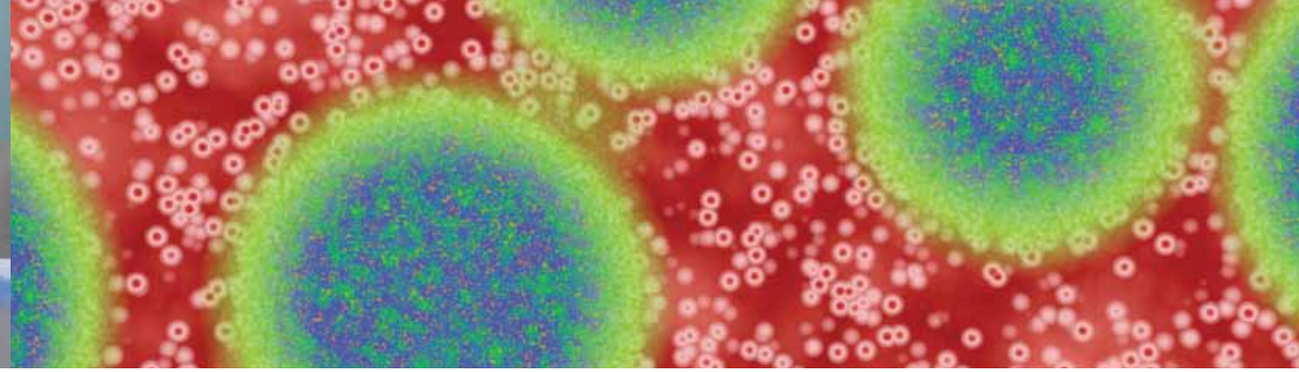
The Institution of Chemical Engineers (IChemE) www.icheme.org, is the body which represents the biochemical engineering profession in the UK. All Master's programmes in the department are accredited by the IChemE. The accreditation allows graduates to join the institution and obtain admission to the professional grade 'Chartered Engineer – CEng' after appropriate additional experience.



UCL MSc in Biochemical Engineering

Modular structure reflecting the different entry points to the programme

Biochemical Eng. Graduates	Engineering Graduates	Science Graduates
Taught courses		
Emerging Bioprocess Sectors & Applications • Industrial synthetic biology • Biorefineries & sustainability • Cell therapy bioprocessing *Vaccines or Bioprocess microfluidics*	**Advanced Life Sciences** • Microbial metabolism & engineering • Structural biology & protein design • Cell biochemistry: gene to metabolisis • Applied molecular biology	**Emerging Bioprocess Sectors & Applications** • Bioprocess synthesis and mapping • Heat & mass transfer in bioprocesses • Fluid flow & mixing in bioprocesses • Process analysis & mass balancing
Advanced Bioprocess Engineering • Bioprocess systems engineering • Validation & quality control (QbD) *Options: e.g. Project management Process dynamics / Advanced safety*	**Advanced Biochemical Engineering** • Bioreactor design & fermentation • Integrated downstream processing • Vaccine and stem cell processing • Validation & quality control (QbD)	
Project based courses		
Advanced Bioprocess Research • Bioprocess research dissertation: Projects range from biopharmaceuticals to chiral biotransformations with both experimental and modelling themes	**Whole Bioprocess Management & Implementation** • Whole bioporcess practical studies • Bioprocess analysis & presentation • Bioprocess commercialisation • Business planning for bioventures	
	Advanced Bioprocess Research • Bioprocess research dissertation: Projects range from biopharmaceuticals to chiral biotransformations with both experimental and modelling themes	**Advanced Bioprocess Design** • Bioprocess creation & analysis • Bioprocess design and economics • Safety appraisal (HAZOP studies) Validation & regulatory approval



Biochemical Engineering MSc – for Biochemical Engineers

This course is specifically designed to allow first degree biological scientists and biotechnologists to achieve recognised status in biochemical engineering. The course is recognised by the Institution of Chemical Engineers (IChemE) such that after a suitable period of relevant training the successful graduates may become Chartered Engineers (CEng) and Members of the Institution (MIChemE). It comprises a conversion element in addition to biochemical engineering and pilot plant studies and an advanced design project.

Course Structure

The flow chart on Page 11 shows the structure of this degree programme and the individual topics studied. The numbers in parenthesis indicate the credit hours associated with each element of the course. 180 credits are required in order to be considered for the award of the MSc degree. The programme is divided into four distinct but integrated parts:

Advanced Biochemical Engineering (BENGG022, BENGG023, BENGG024, BENGG025: 60 credits)

These 4 compulsory modules focus on the latest areas research activity:
Sustainable Industrial Bioprocesses and Biorefineries - process integration including energy supply and waste treatment, design, operation and control of complex plants and life cycle assessment.
Bioprocess Systems Engineering - advanced modelling, optimisation and statistical techniques related to evaluating the cost-effectiveness and robustness of bioprocess design strategies.
Cell Therapy Biology, Bioprocessing and Clinical Translation - understanding the critical pathways to clinic and considerations for commercialisation of advanced therapies.
Industrial Synthetic Biology - linkage of information from different biological contexts to build and design new elements, pathways, cells and systems.

Dissertation: Bioprocess Research Project (BENGG098: 60 credits)

Each candidate usually carries out an original research project, of their choice, under the supervision of a member of academic staff. During this time the Master's students are fully integrated into the activities of one of the multidisciplinary research teams within the Advanced Centre. Research projects are often co-supervised by staff in associated UCL departments such as Biochemistry and Molecular Biology, Chemistry, or Electrical Engineering and, on occasion, are linked to on-going industrial collaborations. Students complete a written thesis and undergo an oral examination. Engineering graduates may opt to take part in the bioprocess design project activity (BENGGD99) in place of the research project. The project is supported by a series of experiments on individual unit operations which are complemented by a week-long course in the department's pilot-plant, and a two week bio-business planning course.

Optional Modules (45 credits)

Students select 3 of the modules listed below:

- BENGG027 - Bioprocess Microfluidics
- BENGG007 - Business Implementation for Life Sciences
- CENGG018 - Fluid Particle Systems
- CENGG020 - Energy Systems and Sustainability
- CENGG019 - Advanced Safety and Loss Prevention
- CENGG006 - Process Dynamics and Control
- MSING001 - Project Management
- BENG2028 - Vaccines Bioprocess Development

Bioprocess Validation and Quality Control (BENGG026: 15 Credits)

The course addresses the challenge of the safe delivery to patients of biopharmaceuticals and in particular injectables. The aim of the course is to familiarise students with current validation methodology using leading edge developments with expert speakers in a workshop format.

Biochemical Engineering MSc – for Graduate Scientists

Course Structure

The flow chart on Page 11 shows the structure of this degree programme and the individual topics studied. The numbers in parenthesis indicate the credit hours associated with each element of the course. 180 credits are required in order to be considered for the award of the MSc degree. The programme is divided into five distinct but integrated parts:

Conversion Elements: Biochemical Engineering Fundamentals and Bioprocess Challenges (BENGG001, BENGG016, BENGG017: 45 credits)

The material here is designed to provide science graduates with the fundamentals of process engineering relevant to the handling of biological materials. Students learn, for example, the principles of how to calculate nutrient requirements for industrial scale microbial conversion processes and how to predict and control the environment in which cells have to survive and grow. We also build upon the students' knowledge of the structures of biological polymers and show how this can be used to predict the stress damage which may occur when delicate biological materials are processed at scale.

Advanced Biochemical Engineering (BENGG004, BENG005, BENGG024: 45 credits)

These core elements of the course cover the detailed design of biological conversion processes, i.e. fermentation and biotransformation, and the subsequent recovery, purification and formulation of therapeutic products. Here students make use of all the Centre's facilities to learn how to plan and execute whole sequences of complex operations. The material in this element of the course is designed to provide students with the ability to take the results of new life sciences, such as gene therapy, tissue engineering, metabolic pathway engineering, and translate them into real process outcomes.

Dissertation on Bioprocess Design (BENGGD99: 60 credits)

The design module involves the application of the skills and information gained in the above elements to a group design project. For graduate scientists who wish to proceed towards Chartered Engineer (CEng) status this is a vital part of the course. The project involves the complete design of a bioprocess, together with economic and safety analyses, and the establishment of process validation methodologies. The choice of target products are closely linked to the research activities of the Advanced Centre and, in recent years, have included the manufacture of plasmid DNA, a hepatitis B vaccine, novel polyketide antibiotics and chiral pharmaceuticals. Lecture and case study material is supported by a series of experiments on individual unit operations which are complemented by a week-long course in the department's pilot-plant, and a two week bio-business planning course.

Commercialisation of Bioprocess Research (BENGG006: 15 credits)

This element of the MSc programme reflects the growing need for qualified biochemical engineers to be equally aware of the issues involved in the establishment and management of small, high-tech Biotechnology companies. The material covered here is based around a number of real industrial case studies and culminates in the production and presentation of a business plan for the translation of a life science discovery into a real outcome.

Bioprocess Validation and Quality Control (BENGG026: 15 Credits)

The course addresses the challenge of the safe delivery to patients of biopharmaceuticals and in particular injectables. The aim of the course is to familiarise students with current validation methodology using leading edge developments with expert speakers in a workshop format.

Biochemical Engineering MSc – for Graduate Engineers

Course Structure

The flow chart on Page 11 shows the structure of this degree programme and the individual topics studied. The numbers in parenthesis indicate the credit hours associated with each element of the course. 180 credits are required in order to be considered for the award of the MSc degree for assessment purposes the Bioprocess Research Project and Bioprocess Implementation are combined in a 60 credit dissertation. The programme is divided into five distinct but integrated parts:

Conversion elements: Appraisal and Application of Advanced Life Sciences (BIOCG008, BENGG029, BENGGB03: 45 credits)

The material here is designed to provide engineering graduates with fundamental knowledge of standard molecular biology techniques, applied cell biology and the biology of stem cells, all within the context of today's biochemical engineering-led industries. Students also learn how to use molecular biology to rationally engineer changes to the properties of biocatalysts, biopharmaceutical host cells and whole-cell therapeutics in order to bring about process improvements. Lecture materials are supported by tutorials and practical classes in which key concepts are explored, explained and put into practice.

Advanced Biochemical Engineering (BENGG004, BENGG005, BENGG024: 45 credits)

These core elements of the course cover the detailed design of biological conversion processes, i.e. fermentation and biotransformation, and the subsequent recovery, purification and formulation of therapeutic products. Here students make use of all the Centre's facilities to learn how to plan and execute whole sequences of complex operations. The material in these elements of the course is designed to provide students with the ability to take the results of new life sciences, such as gene therapy, tissue engineering, metabolic pathway engineering, and translate them into real process outcomes.

Dissertation: Bioprocess Research Project and Bioprocess Implementation (BENGGR99: 60 credits)

Each candidate usually carries out an original research project, of their choice, under the supervision of a member of academic staff. During this time the Master's students are fully integrated into the activities of one of the multidisciplinary research teams within the Advanced Centre. Research projects are often co-supervised by staff in associated UCL departments such as Biochemistry and Molecular Biology, Chemistry, or Electrical Engineering and, on occasion, are linked to ongoing industrial collaborations. Students complete a written thesis and undergo an oral examination.
Engineering graduates may opt to take part in the bioprocess design project activity (BENGGD99) in place of the research project. The project is supported by a series of experiments on individual unit operations which are complemented by a week-long course in the department's pilot-plant, and a two week bio-business planning course.

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Academic Staff

Academic staff and their areas of research

Nigel Titchener-Hooker

Professor, Head of Department, Director of the Innovative Manufacturing Research Centre for Bioprocessing (IMRC), Fellow of the Royal Academy of Engineering and the Institution of Chemical Engineers, Member of the American Institute of Chemical Engineers
Accelerated design of new bioprocesses using computer-based and experimental methods. Integrated design of process sequences, including the use of novel unit operations. Linkage of business and process models to improve the rate of development of new biopharmaceuticals.

Frank Baganz

Senior Lecturer, Society of Chemical Industry, Biotechnology Subject Group Committee Member, Member of Society of General Microbiology
Engineering and modelling of metabolic pathways and biocatalytic processes especially with whole cells. Fermentation and cell culture processes and its integration with downstream processing. Bioreactor design and scale-down focusing on engineering characterisation of novel miniaturised devices and microwellbasedsystems.

Daniel Bracewell

Reader, Chair of the Royal Society of Chemistry Analytical Biosciences Group, Associate Member of the Institution of Chemical Engineers
Ultra scale-down of downstream processing operations particularly chromatography. Rapid bioprocess monitoring, in particular of protein product and heteroforms together with key contaminants. The application of novel analytical techniques in terms of real-time process definition and control.

Paul Dalby

Reader, Royal Society of Chemistry, Biotechnology Group Committee Chairman, Member of the American Chemical Society
Protein engineering of biocatalysts in real bioprocess environments and linkage to metabolic pathway engineering. Understanding the principles of protein refolding, stability and formulation.

Suzanne Farid

Reader, Member of the Institution of Chemical Engineers
Rapid evaluation of bioprocessing alternatives using decisionsupport simulation tools that link bioprocess and business models. Risk analysis for the selection of competing bioprocess options under financial and operational uncertainty. Development of computer-aided techniques to determine the impact of manufacturing decisions on the management of R&D drug portfolios. Technical and economical evaluation of the production of tissue engineering products.

Mike Hoare

Professor, Director of the Advanced Centre for Biochemical Engineering (ACBE) and Chairman to the Innovative Manufacturing Research Centre for Bioprocessing (IMRC), Fellow of the Royal Academy of Engineering and the Institution of Chemical Engineers
Downstream processing, especially centrifugation, flocculation, precipitation, crystallisation, and the formulation and drying of biopharmaceuticals. Biomacromolecules and biomaterials from formation to formulated product: the enhanced creation and operation of bioprocesses using ultra scale-down experimentation and predictive design methods.

Eli Keshavarz-Moore

Professor, Member of the Institution of Chemical Engineers, Programme Leader in Enterprise Training for Bioprocessing and Life Sciences
Bioprocess synthesis for recombinant macromolecules with emphasis on the impact of DNA technology on bioprocessing. Containment and safety of bioprocesses and the processing of materials produced by transgenic organisms.

Gary Lye

Professor, Deputy Head of Department, Member of the Institution of Chemical Engineers, Director of MSc Programme, Director of Industrial Doctoral Training Programme, Chair IChemE Biochemical Engineering Subject Group
Automated microscale processing techniques for the rapid design of bioconversion process sequences and the expansion and differentiation of stem cells. Whole-process evaluation of novel separation technologies, and the design and scale-up of integrated reaction-separation systems.

Chris Mason

Professor, Fellow of Royal College of Surgeons
Regenerative medicine bioprocessing – translation of tissue engineering and stem cell discoveries into routine clinical practice.

Martina Micheletti

Lecturer, Associate Member of the Institution of Chemical Engineers
Microscale bioprocessing and fundamental engineering - development of automated microscale techniques for upstream and downstream operations, mixing in multi-phase flows and scale-up.

Tarit K. Mukhopadhyay

Lecturer, Associate Member of the Institute of Chemical Engineers, Member of Society of Chemical Industry
Vaccine bioprocess development. Creating innovative platforms for the rapid determination of the process route of vaccines. Aggregation phenomena and its impact on downstream processing of virus like particle vaccines. Bioprocessing of RNA/DNA vaccines.

Darren Nesbeth

Lecturer in Synthetic and Molecular Biology
Applying engineering principles to the re-design of living cells for both improved functionality in biosynthesis of small molecules, and improved bioprocessing of biopharmaceuticals.

Nicolas Szita

Senior Lecturer
Bioprocess Microfluidics - application of micro and nanotechnology for novel microbioreactors, small-scale cultivation and downstream processing. Integrated microfluidic systems for stem cell derivation, expansion and differentiation.

Karen Smith

Director of Bioprocess Leadership, Director of External Relations EPSRC Industrial Doctoral Training Centre in Bioprocess Engineering Leadership, FRSA, RTTP
Knowledge Transfer, University Technology Transfer, Entrepreneurship and Public Understanding of Science.

Ajoy Velayudhan

Principal Research Fellow, EPSRC Manufacturing Fellow, Member of the American Chemical Society
Rational design of flexible and cost-effective bioprocesses for the next generation of medicines. Development and validation of whole-bioprocess models, from cell culture and fermentation through purification sequences to formulation and freeze-drying. Integrated experimental, computational, and mathematical approach to the identification of robust operating conditions in bioprocesses.

Farlan Veraitch

Lecturer, Member of the Institution of Chemical Engineers, Biochemical Engineering Subject Group Committee Member, Member of the European Society for Animal Cell Technology
Development of robust, reproducible, high-yield processes for embryonic stem cell production. Dynamic control of the microenvironment during embryonic stem cell expansion and differentiation. Automated control of harvesting and inoculation for cell therapy production.

Ivan Wall

Lecturer in Cell Therapy Bioprocessing, Associate Member IChemE, Member Society of Biology
Regenerative potential of stem cells for treating age-related degenerative disorders.

John Ward

Professor of Synthetic Biology for Bioprocessing, Director of the MRes in Synthetic Biology, Member of the Society for General Microbiology, Member of the Society for Applied Microbiology, Member of the Biochemical Society.
Synthetic Biology, Biocatalysis, Functional metagenomics, Pathway engineering, Cell engineering for enhanced bioprocessing, Enhancing DNA, Protein and Phage manufacture, Novel microbial genetic systems.

Yuhong Zhou

Lecturer, Associate Member of the Institution of Chemical Engineers
Accelerated design of bioprocess sequences and business processes. Application of numerical and computing techniques to metabolic pathway modelling and bioinformatics.

Careers Information

Careers Information

Planning your career

The department places great emphasis on its ability to assist its graduates in taking up challenging careers. UCL alumni, together with the department's links with industrial groups, provide an excellent source of leads for graduates.

At the end of January each year the department circulates, to a wide number of companies both in the UK and abroad, the CVs of Master's students interested in obtaining full-time employment within the biological industries (including the pharmaceuticals, food, antibiotics, waste treatment and biotechnology sectors). This is a major exercise and one of the main routes by which recent students in biochemical engineering at UCL have gained employment. Additionally, students are strongly encouraged to make direct applications to companies and are given considerable help and advice in preparing their CVs. Each year a large number of industrialists visit the department and many hold their initial interviews with Master's students at UCL.

Career profiles of some former graduate students

Nearly 1,000 students have graduated from UCL with graduate qualifications in biochemical engineering at Master's or doctoral levels. Many have gone on to distinguished and senior positions in the international bioindustry. Others have followed independent academic careers in universities around the world. A few examples are given below to show the breadth of interests and the extent of feedback to the department from its alumni in areas such as career advice and training input.

Mr Neil Bingham studied for his MSc in 1995. On completion he took a position with Lonza Biologics UK working on mammalian cell filtration. In 2003, he joined Amgen in Thousand Oaks, California.

Dr Paul Bird completed the MSc in 1998 and then joined Lonza Biologics where he was involved in the manufacture of therapeutic antibodies. In 1999 he returned to the department to undertake PhD research, which he completed in 2003, and subsequently joined Avecia in Billingham.

Mr Charles Boit completed a first degree in pharmacology before undertaking the MSc in Biochemical Engineering for graduate scientists. He graduated in 2001 with a distinction and is now a principal engineer with Unilever in Kenya.

Dr George Bou-Habib began his PhD in the department in 1994. On finishing his doctorate he took a research position at the Nestle Research Centre near Lausanne, Switzerland. In 2002, he moved to a small company in Zurich MMS AG Membrane Systems as a senior process engineer.

Dr Natalie Boulding completed an MSc in 1996 and a PhD in 2001. For five years she was the MBI® Training Programme manager for the Department of Biochemical Engineering at UCL. She then took a position as a Research Scientist at the Bioprocess Technology Institute of Singapore.

Professor Barry Buckland is Vice-President of Bioprocess Research at Merck, USA, one of the largest biopharmaceutical companies in the world. His links with the department include his MSc in 1971 and his PhD in 1974. He has been a regular lecturer on industrial courses at UCL and is an Honorary Professor and a Fellow of UCL.

Dr Jim Davies, originally an applied biologist, completed the MSc in 1997 and a PhD in 2000. He initially worked for GlaxoSmithKline, Beckenham, on the production of DNA vaccines before moving to Lonza Biologics, Slough, in 2003.

Dr Andrew Dorward graduated as a chemical engineer from UMIST before joining the department in 1998 to work on large scale protein crystallisation in collaboration with Novo Nordisk, Denmark. He joined Eli Lilly, Speke, in 2003 where he is now involved in large-scale antibiotic fermentation.

Dr Joanna Harrison completed an MSc in Biochemical Engineering at UCL in 1991 and a PhD in 1996. She was then involved in the establishment of the department's MBI® Training Programme before joining the business development group at the University of Cambridge in 2001.

Dr Katie Lander completed a Natural Sciences degree at Cambridge before graduating with a UCL Master's degree in 1998 and a PhD in Biochemical Engineering in 2002. She now works for Eli Lilly alongside a number of former UCL graduates.

Dr Tim Lee completed a UCL Master's degree in 1996 and a PhD in Biochemical Engineering in 1999. Since completing his PhD he has worked for Sanofi Pasteur in Canada but spends a considerable amount of time liaising with other Sanofi Pasteur sites around the world, particularly in France, in his role as a senior developmental scientist.

Dr Ihsan Marzouqi completed his Masters in 2002 and PhD in 2005 before returning to the United Arab Emirates to join Dubai Biotechnology and Research Park (DuBiotech). As Director of Business Development he works on developing the necessary regulatory framework and environment to attract biotech/pharma companies.

Dr Matt Osborne completed the MSc in 1996 and a PhD in collaboration with Pfizer, Sandwich, in 2000. He subsequently worked for Cambridge Antibody Technology, Cambridge, for two years before joining Pfizer as a full-time employee in 2003.

Dr Jon Postlethwaite completed a UCL Master's degree in 1999 and a PhD in collaboration with Pall Filtration in 2003. Upon graduation he took up a position with Codexis, California, a company involved in the engineering of advanced industrial biocatalysts.

Dr Jo Rumpus took her BEng degree in 1989 and completed her PhD in 1997. Jo worked in a consultancy role at Glaxo Wellcome (now GSK) before joining Jacobs Engineering in 1998. She is now employed as a pharmaceutical engineer with Cantab Pharmaceuticals in Cambridge.

Dr Somaiya Siddiqi graduated with a BEng in 1988 and a PhD in 1997. Between her two degrees she worked as an accountant. She joined Jacobs Engineering in 1996 and most recently moved to Kleinwort Benson Bank as an IT specialist in the Far East trading section.

Dr Martin Smith was awarded his degree in Biochemical Engineering in 1994, undertook collaborative research with Pharmacia (Sweden) and achieved his PhD in 1997. After graduation, Martin joined Merck, USA, where he worked as a research engineer. He is now a senior engineer with Lonza Biologics, UK.

Dr Karen Wilson was awarded her first degree in 1989. After a year in the City she returned to UCL to study for her PhD. Following graduation, Karen went to the University of Sydney, Australia, where she is working as a lecturer in biochemical engineering.

Dr John Young joined the department to study for his MSc in 1995 and remained to work towards his PhD which he completed in 1999. He initially worked as a process engineer with Foster Wheeler, a large engineering contractor with offices throughout the world, before becoming an independent consultant in 2003.

Application Information

How to apply

To make an application please visit www.ucl.ac.uk/prospective-students/graduate-study and select How to Apply, where you can choose between the options of applying online, downloading the application materials, or requesting an application pack to be sent by post.

Alternatively you may telephone the UCL Study Information Centre to request an application pack (contact details are given on the inside front cover). Your completed application should be submitted to UCL Admissions.

Some advisory notes on the completion of the application form are listed below. You may have already submitted a detailed CV and this form will request duplicate information. If preferred, you are welcome to cross-refer to your CV.

Research subject area/name of taught programme

For research subject areas 'Biochemical Engineering/ Bioprocessing' will suffice as an entry but applicants who do have specific research areas of interest should note these in the personal statement.

Education

For students with a biological science background wishing to apply for a place on the MSc in Biochemical Engineering, it would be helpful if they could, in addition, provide details of mathematics courses taken at A level (or equivalent) standard and at university.

Transcripts are required for all qualifications that are relevant to the application that is being submitted. All documents must be in English. Any translation of documents must be certified as true and original.

Referees

Both referees should be able to comment on your recent higher education studies. For applicants with relevant industrial experience one of these referees may be a scientist or engineer with whom you have recently worked. Current UCL students need not supply references.

International students

The department welcomes applications from overseas students for both its taught Master's degree programmes and research degrees. Over recent years students have come from Argentina, Australia, Canada, China, Denmark, Finland, France, Germany, Greece, Hong Kong, India, Iran, Italy, Malaysia, Mexico, Portugal, Singapore, Spain, Sweden, Taiwan, United Arab Emirates and the United States.

Before beginning a programme of study all students whose first language is not English are required to provide recent evidence of their ability to understand and use English to a standard that will ensure that language problems do not substantially impede their academic progress. UCL accepts a number of English Language qualifications including the International English Language Testing System (IELTS) at a minimum overall grade of 6.5 with no less than 6.0 in each of the sub-tests. A list of acceptable English Language qualifications is included in UCL's Graduate Applications Pack and in the How To Apply section of UCL's website at www.ucl.ac.uk/prospective-students/graduate-study

UCL's Language Centre offers both a one-year full-time Diploma in English for Academic Purposes and a range of pre-sessional English language courses for those who do not meet UCL's minimum standard.

The International Office is a centre of expertise and advice for overseas students, who are welcome to seek help or guidance in many areas such as immigration, housing, finance, English language tuition and fees. Research in biochemical engineering can be expensive, especially when using recombinant materials or operating at pilot-plant scale. For overseas students we must request a contribution towards the cost of the research in the form of additional research expenses. Typically these will range from £2,000 to £10,000 per year and will be agreed before the research programme begins.

Advice on a variety of matters, including the level of additional research expenses required, can also be obtained within the department from the Admissions Tutor or the Departmental Administrator (non-academic matters only).

Fees and funding

For a full list of our Tuition fees, please refer to our website www.ucl.ac.uk/current-students/money

Details of tuition fees and estimated maintenance costs are also given in UCL's Graduate Prospectus.

Tuition fees are subject to an annual increase.

Details of sources of financial support for both UK/EU and overseas students are given on the internet at www.ucl.ac.uk/scholarships.

References

Bioconversion Bioprocessing Research

One-pot synthesis of amino diols using a *de-novo* transketolase and ß-alanine:pyruvate transaminase pathway in *Escherichia coli.*
Ingram CU, Bommer M, Smith MEB, Dalby PA, Ward JM, Hailes H, Lye GJ Biotech Bioeng 2006 96 559-569. DOI 10.1002/bit.21125

Directed evolution of transketolase activity on non-phosphorylated substrates.
Hibbert EG, Senussi T, Costelloe SJ, Lei W, Smith MEB, Ward JM, Hailes HC, Dalby PA
J Biotech 2007 131 425-432. DOI 10.1016/j.jbiotec.2007.07.949

Structural stability of *E. coli* transketolase to urea denaturation.
Martinez-Torres RJ, Aucamp JP, George R, Dalby PA Enzyme Microb Technol 2007 41 653-662. DOI 10.1016/j.enzmmictec.2007.05.019

Distributions of enzyme residues yielding mutants with improved substrate specificities from two different directed evolution strategies.
Paramesvaran J, Hibbert EG, Russell AJ, Dalby PA Protein Eng Design and Selection 2009 22 401-411. DOI 10.1093/protein/gzp020

Hydrodynamic and oxygen mass transfer studies in a three-phase (air-water-ionic liquid) stirred tank bioreactor.
Torres-Martinez D, Melgarejo-Torres R, Gutierrez-Rojas M, Aguilera-Vazquez L, Micheletti M, Lye GJ, Huerta-Ochoa S Biochem Eng J 2009 45 209-217. DOI 10.1016/j.bej.2009.03.014

Fermentation/Cell Culture Bioprocessing Research

Characterization and application of a miniature 10 mL stirred-tank bioreactor, showing scale-down equivalence with a conventional 7 L reactor.
Betts JI, Doig SD, Baganz F Biotech Prog 2006 22 681-688. DOI 10.1021/bp050369y

Fluid mixing in shaken bioreactors: Implications for scale-up predictions from microlitre scale microbial and mammalian cell cultures.
Micheletti M, Barrett T, Doig SD, Baganz F, Levy MS, Woodley JM, Lye GJ Chem Eng Sci 2006 61 2939-2949. DOI 10.1016/j.ces.2005.11.028

Characterisation of mechanical properties of transgenic tobacco roots expressing a recombinant monoclonal antibody against tooth decay.
Hassan S, Liu W, Ma, JK C, Thomas CR, Keshavarz-Moore E Biotech Bioeng 2008 100 803-809. DOI 10.1002/bit.21819

Host strain influences on supercoiled plasmid DNA production in *E.coli*; implications for efficient design of large scale processes.
Yau SY, Keshavarz-Moore E, Ward JM Biotech Bioeng 2008 101 529-544. DOI 10.1002/bit.21915

Thermal profiling for parallel on-line monitoring of biomass growth in miniature stirred bioreactors.
Gill NK, Appleton M, Lye GJ Biotech Letters 2008 3 1571-1575. DOI 10.1007/s10529-008-9719-0

Faster Creation of Bioconversion, Fermentation and Cell Culture Bioprocesses

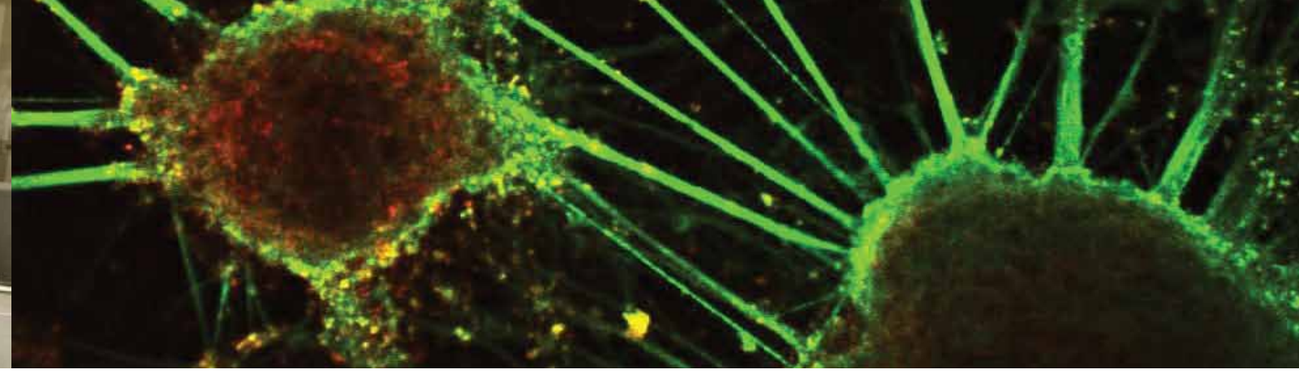
Quantification and prediction of jet macro-mixing times in static microwell plates.
Nealon AJ, O'Kennedy RD, Titchener-Hooker NJ, Lye GJ Chem Eng Sci 2006 61 4860-4870. DOI 10.1016/j.ces.2006.02.001

Scale-up of *E. coli* growth and recombinant protein expression conditions from microwell to laboratory and pilot scale based on matched k_La.
Islam RS, Tisi D, Levy MS, Lye GJ Biotech Bioeng 2008 99 1128-1139. DOI 10.1002/bit.21697

Quantification of power consumption and oxygen transfer characteristics of a stirred miniature bioreactor for predictive fermentation scale-up.
Gill NK, Appleton M, Baganz F, Lye GJ Biotech Bioeng 2008 100 1144-1155. DOI 10.1002/bit.21852

Design and characterisation of a prototype enzyme microreactor: Quantification of immobilised transketolase kinetics.
Matosevic S, Lye GJ, Baganz F Biotech Prog 2010 26 118-126. DOI 10.1002/btpr.319

Microwell evaluation of mammalian cell lines for large scale culture.
Barrett T, Zhang H, Wu A, Levy MS, Lye GJ Biotech Bioeng 2010 105 260-275. DOI 10.1002/bit.22531



Rapid whole monoclonal antibody analysis by mass spectrometry: an ultra scale-down study of the effect of harvesting by centrifugation on the post-translational modification profile.
Reid CQ, Tait A, Baldascini H, Mohindra A, Racher A, Bilsborough S, Smales CM, Hoare M Biotech Bioeng 2010 pub online. DOI 10.1002/bit.22790

Primary Recovery Bioprocessing Research

A methodology for centrifuge selection for the separation of high solids density cell broths by visualisation of performance using Windows of Operation.
Salte H, King J, Baganz F, Hoare M, Titchener-Hooker NJ Biotech Bioeng 2006 95 1218-1227. DOI 10.1002/bit.21102

Shear stress analysis of mammalian cell suspensions for prediction of industrial centrifugation and its verification.
Hutchinson N, Bingham N, Murrell N, Farid S, Hoare M Biotech Bioeng 2006 95 483-491. DOI 10.1002/bit.21029

Degradation of supercoiled plasmid DNA within a capillary device.
Meacle FJ, Zhang H, Papantoniou I, Ward JM, Titchener-Hooker NJ, Hoare M Biotech Bioeng 2007 97 1148-1157. DOI 10.1002/bit.21275

Factors affecting protein refolding yields in a fed-batch and batch-refolding system.
Mannall GJ, Titchener-Hooker NJ, Dalby PA Biotech Bioeng 2007 97 1523-1534. DOI 10.1002/bit.21377

Prediction of shear damage of plasmid DNA in pump and centrifuge operations using an ultra scale-down device.
Zhang H, Kong, S, Booth A, Boushaba R, Levy MS, Hoare M Biotech Prog 2007 23 858-865. DOI 10.1021/bp0700666z

Impact of clarification strategy on chromatographic separations: Pre-processing of cell homogenates.
Bracewell DG, Boychyn M, Baldascini H, Storey SA, Bulmer M, More J, Hoare M Biotech Bioeng 2008 100 941-949. DOI 10.1002/bit.21823

Evaluation of cell disruption effects on primary recovery of antibody fragments using microscale bioprocessing techniques.
Rayat ACME, Micheletti M, Lye GJ Biotech Prog 2010 pub online. DOI 10.1002/btpr.450

Purification and Formulation Bioprocessing Research

Visualising fouling of a chromatographic matrix using confocal scanning laser microscopy.
Siu SC, Boushaba R, Topoyassakul V, Graham A, Choudhury S, Moss G, Titchener-Hooker NJ Biotech Bioeng 2006 95 714-723. DOI 10.1002/bit.21028

A framework for the prediction of scale-up when using compressible chromatographic packings.
Joseph JR, Tran R, Bracewell DG, Zhou Y, Titchener-Hooker NJ Biotech Prog 2007 23 413-422. DOI 10.1021/bp060303i

Studies on aerosol delivery of plasmid DNA using a mesh nebuliser.
Arulmuthu ER, Williams DJ, Baldascini H, Versteeg HK, Hoare M Biotech Bioeng 2007 98 939-955. DOI 10.1002/bit.21493

A microscale approach for predicting the performance of chromatography columns used to recover therapeutic polyclonal antibodies. Chhatre S, Bracewell DG, Titchener-Hooker NJ J Chromatog A 2009 1216 7806-7815. DOI 10.1016/j.chroma.2009.09.038

Design and characterization of a microfluidic packed bed system for protein breakthrough and dynamic binding capacity determination.
Shapiro M S, Haswell SJ, Lye G J, Bracewell DG Biotech Prog 2009 25 277-285. DOI 10.1002/btpr.99

Factors influencing antibody stability at solid-liquid interfaces in a high shear environment.
Biddlecombe JG, Smith G, Uddin S, Mulot S, Spencer D, Gee C, Fish BC, Bracewell DG Biotech Prog 2009 25 1499-1507. DOI 10.1002/btpr.211

Faster Creation of Primary Recovery, Purification and Formulation Bioprocesses

An automated microscale technique for the quantitive and parallel analysis of microfiltration operations.
Jackson NB, Liddell JM, Lye GJ J Membrane Sci 2006 276 31-34.DOI 10.1016/j.memsci.2005.09.028

Adapted ultra scale-down approach for predicting the centrifugal separation behaviour of high cell density cultures.
Tustian AD, Salte H, Willoughby NA, Hassan I, Rose MH, Baganz F, Hoare M, Titchener-Hooker NJ Biotech Prog 2007 23 1404-1410. DOI 10.1021/bp070175d

A microscale yeast cell disruption technique for integrated process development strategies.
Wenger MD, DePhillips P, Price C, and Bracewell DG, Biotech Prog 2008 24 606-614. DOI 10.1021/bp070359s

Micro biochemical engineering to accelerate the design of industrial-scale downstream processes for biopharmaceutical proteins.
Titchener-Hooker NJ, Dunnill P, Hoare M Biotech Bioeng 2008 100 473-487. DOI 10.1002/bit.21788.

Rapid optimisation of protein freeze-drying formulations using ultra scale-down and factorial design of experiment in microplates.
Grant, Y, Matejtschuk P, Dalby PA Biotech Bioeng 2009 104 957-964.DOI 10.1002/bit.22448

Mimic of a large-scale diafiltration process by using an ultra scale-down rotating disc filter.
Ma G, Aucamp J, Eardly-Patel R, Craig A, Hoare M, Zhou Y Biotech Prog 2010 26 466-476. DOI 10.1002/btpr.327

Regenerative Medicine Bioprocessing

Behaviour of adult human mesenchymal stem cells entrapped in alginate-RGD.
Markusen JF, Mason C, Hull DA, Town MA, Tabor AB, Clements M, Boshoff CH, Dunnill P Tissue Eng 2006 12 821-830. DOI 10.1089/ten.2006.12.821

The impact of manual processing on the expansion and directed differentiation of embryonic stem cells.
Veraitch FS, Scott R, Wong J-W, Lye GJ, Mason C Biotech Bioeng 2008 99 1216-1229. DOI 10.1002/bit.21673

Lowering oxygen tension enhances the differentiation of mouse embryonic stem cells into neuronal cells.
Mondragon-Teran P, Lye GJ Veraitch FS Biotech Prog 2009 25 1480-1488. DOI 10.1002/btpr.248

Mechanical dynamics of single cells during early apoptosis.
Pelling A E, Veraitch FS, Chu CP, Mason C, Horton MA Cell Motil Cytoskeleton 2009 66 409-422. DOI 10.1002/cm.20391

Regenerative medicine bioprocessing: concentration and behaviour of adherent cell suspensions and pastes.
Zoro BJH, Owen S, Drake RAL, Mason C, Hoare M Biotech Bioeng 2009 103 1236-1247. DOI 10.1002/bit.22356

Sub-population analysis of human cancer vaccine cells – ultra scale-down characterisation of response to shear.
McCoy R, Ward S, Hoare M Biotech Bioeng 2010 106 584-597.DOI 10.1002/bit.22716

Decisional Tools To Capture The Bioprocess-Business Interface

A computer-aided approach to compare the production economics of fed-batch versus perfusion culture.
Lim AC, Washbrook J, Titchener-Hooker N J, Farid SS Biotech Bioeng 2006 93 687-697. DOI 10.1002/bit.20757

Regenerative medicine bioprocessing: The need to learn from the experience of other fields.
Mason C, Hoare M Regen Med 2006 1 615-623. DOI 10.2217/17460751.1.5.615

Process economics of industrial monoclonal antibody manufacture.
Farid SS J Chromatog B 2007 848 8-18. DOI 10.1016/j.jchromb.2006.07.037

Strategic biopharmaceutical portfolio development: an analysis of constraint-induced implications.
George ED, Farid SS Biotech Prog 2008 24 698-713. DOI 10.1021/bp070410s

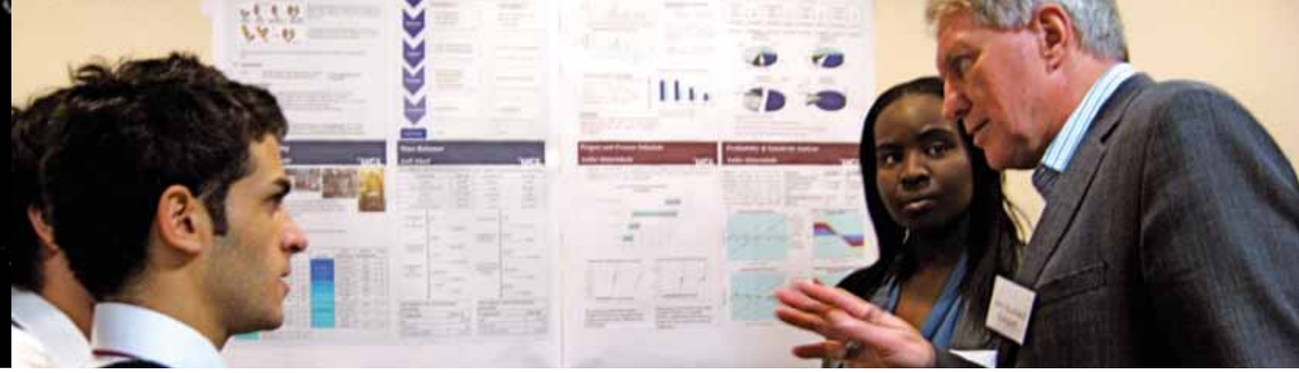
Assessing the value of autologous and allogeneic cells for regenerative medicine.
Mason C, Dunnill P Regen Med 2009 4 835-853. DOI 10.2217/rme.09.64

Process economic drivers in industrial monoclonal antibody manufacture.
Farid SS In Gottschalk, U. (ed.) Process Scale Purification of Antibodies 2009 New Jersey: John Wiley & Sons. Ch 12 239-261. DOI 10.1002/9780470444894

Quantities of cells used for regenerative medicine and some implications for clinicians and bioprocessors.
Mason C, Dunnill P Regen Med 2009 4 153-157. DOI 10.2217/17460751.4.2.153

Application of agent-based system for bioprocess description and process improvement.
Gao Y, Kipling K, Glassey J, Willis M, Montague G, Zhou Y, Titchener-Hooker NJ Biotech Prog 2010 26 706-716. DOI 10.1002/btpr.361

Appendix: Text References



Measurement of straw-dependant toxicity in the indene bioconversion using multiparameter flow cytometry.
Ammannullah, A., Hewitt, C.J., Nienow, A.W., Lee, C., Chartrain, M., Buckland, B.C., Drew, S.W. and Woodley, J.M. Biotechnol. Bioeng 2003 81: 405-420.

Highthroughput measurement of protein stability in microtitre plates.
Aucamp. J.P., Cosme, A.A., Lye, G.J. and Dalby, P.A. Biotechnol. Bioeng 2005 89: 599-607.

Ultra scale-down to define and improve the relationship between flocculation and discstack centrifugation.
Berrill, A., Ho, S.V., Bracewell, D.G. Biotechnol. Prog 2008 24: 426-431.

Miniature bioreactors: current practices and future opportunities.
Betts, J.I. and Baganz, F. Microbial Cell Factories 2006 5: 21.

Characterization and application of a miniature 10mL stirred-tank bioreactor, showing scale-down equivalence with a conventional 7 L reactor.
Betts, J.I., Doig, S.D. and Baganz, F. (2006). Biotechnol. Prog 22: 681-688.

Addressing a whole bioprocess in real-time using an optical biosensor – formation and purification of antibody fragments from a recombinant *E. coli* host.
Bracewell, D.G., Brown R.A. and Hoare, M. Bioproc. Biosys 2004 Eng., 26: 271-282.

The enzymatic transformation of water-insoluble reactants in nonaqueous solvents. Conversion of cholesterol to cholest-4-ene-3-one by a Nocardia sp.
Buckland, B.C., Dunnill, P. and Lilly, M.D. Biotechnol. Bioeng 1975 17: 815-826.

The search for the ideal biocatalyst.
Burton, S.G., Cowan, D.A. and Woodley, J.M. Nat. Biotechnol 2002 20: 37-45.

Modelling and optimisation of a transketolase mediated carbon-carbon bond formation reaction.
Chen, B., Baganz, F. and Woodley, J. Chem. Eng. Sci. 2007 62: 3178-3184.

Impact of intrinsic DNA structure on processing of plasmids for gene therapy and DNA vaccines.
Cooke, J.R., McKie, E.A., Ward, J.M., Keshavarz-Moore. E. J. Biotechnol 2004 114: 239-254.

Room temperature ionic liquids as replacements for organic solvents in multiphase bioprocess operations.
Cull, S.G., Holbery, J.D., Vargas-Mora, V., Seddon, K.R. and Lye, G.J. Biotechnol. Bioeng 2000 69: 227-233.

Modelling surface aeration rates in shaken microtitre plates using dimensionless groups.
Doig, S.D., Pickering, S.C.R., Lye, G.J. and Baganz, F. Chem. Eng. Sci 2005 60: 2741-2750.

Principal Component Score Modeling for the Rapid Description of Chromatographic Separations.
Edwards-Parton, S., Thornhill, N.F., Bracewell, D.G., Liddell, J.M., and Titchener Hooker, N.J. Biotechnol. Prog 2008 24: 202-208.

A tool for modelling strategic decisions in cell culture manufacturing.
Farid, S., Novais, J.L., Karri, S., Washbrook.J. and Titchener-Hooker, N.J. Biotechnol. Prog 2000 16: 829-836.

Decision-support tool for assessing bio-manufacturing strategies under uncertainty: Stainless steel versus disposable equipment for clinical trial material preparation.
Farid, S.S., Washbrook, J. and Titchener-Hooker, N.J. Biotechnol. Prog 2005 21: 486-497.

A multi-criteria decision-making framework for the selection of strategies for acquiring biopharmaceutical manufacturing capacity.
George, E.D., Titchener-Hooker, N.J. and Farid, S.S. Comput. Chem. Eng 2007 31: 889-901

Considerations for extraction of monoclonal antibodies targeted to different subcellular compartments in transgenic tobacco plants.
Hassan, S., van Dolleweerd, C.J., Ioakeimidis, F., Keshavarz-Moore, E., Ma, J.K. Plant Biotechnol J 2008 6: 733-748.

Directed evolution of transketolase activity on non-phosphorylated substrates.
Hibbert, E.G., Senussi, T., Costelloe, S.J., Lei, W., Smith, M.E.B., Ward, J.M., Hailes, H.C., and Dalby, P.A. J. Biotechnol 2007 131: 425-432.

Bioprocess engineering issues that would be faced in producing a DNA vaccine at up to 100m3 fermentatation scale for an influenza pandemic.
Hoare, M., Levy, M.S., Bracewell, D.G., D. Doig, S.D., Kong, S., Titchener-Hooker, N., Ward, J.M. and Dunhill, P. Biotechnol. Prog 2005 21: 1577-1592.

Shear stress analysis of mammalian cell suspensions for prediction of industrial centrifugation and its verification.
Hutchinson, N., Bingham, N., Murrell, N., Farid, S. and Hoare, M. Biotechnol. and Bioeng 2006 95: 483-491.

Separation of supercoiled and open-circular plasmid DNA by liquid-liquid counter-current chromatography.
Kendall, D., Booth, A.J., Levy, M.S. and Lye, G.J. Lett. Biotechnol 2001 23: 613-619.

Characterisation of the physical stability of colloidal polycation-DNA complexes for gene therapy and DNA vaccines.
Lee, L.K., Mount, C.N. and Ayazi Shamlou, P. Chem. Eng. Sci 2001 56: 3163-3172.

Accelerated design of biotransformation processes using automated microscale processing techniques.
Lye, G.J., Ayazi-Shamlou, P., Baganz, F., Dalby, P.A. and Woodley, J.M. Trends Biotechnol 2003 21: 29-37.

Fluid mixing in shaken bioreactors: Implications for scale-up predictions from microlitre scale microbial and mammalian cell cultures.
Micheletti, M., Barrett, T., Doig, S.D., Baganz, F., Levy, M.S., Woodley, J.M., Lye, G.J. Chem. Eng. Sci 2006 61: 2939-2949.

Microscale bioprocess optimisation
Micheletti, M., Lye, G.J. Curr. Opin. Biotechol 2006 17: 611-618.

Rapid characterization of outer membrane proteins in N.lactamica by SELDI- TOF mass spectroscopy for use in a meningococcal vaccine
Mukhopadhyay, T.K., Halliwell, D., O'Dwyer, C., Shamlou, P.A., Levy, M.S., Allison, N., Gorringe, A., Reddin, K.M. Biotechnol. Appl. Biochem 2005 41: 175-82.

Economic comparison between conventional and disposablesbased technology for the production of biopharmaceuticals
Novais, J.L., Titchener-Hooker, N.J. and Hoare, M. Biotechnol. Bioeng 2001 75: 143-153.

The influence of major components on the direct chromatographic recovery of a protein from transgenic milk
Pampel, L., Boushaba, R., Udell, M., Turner, M.K., Titchener-Hooker, N.J. J. Chrom. A 2007 1142: 137-147.

Lipase catalysed resolution of the Lotrafiban intermediate 2,3,4,5-tetrehydro-4-methyl-3-oxo-1H-1,4-benzodiazepine-2-acetic acid methyl ester in ionic liquids: Comparison to the industrial t-butanol Process.
Roberts, N.J., Seago, A., Carey, J.S., Freer, R., Preston, C. and Lye, G.J. Green Chem 2004 6: 475-482.

Rational engineering of the TOL meta-cleavage pathway
Sheridan, R., Jackson, G.A., Regan, L., Ward, J.M. and Dunnill, P. Biotechnol. Bioeng 1998 58: 240-249.

Development of a multiplexed microbioreactor system for high-throughput bioprocessing
Szita, N., Boccazzi, P., Zhang, Z., Boyle, P., Sinskey, A.J. and Jensen, K.F. Lab. Chip 2005 5: 819-826.

Characterisation of an industrial affinity process used in the manufacturing of digoxin-specific polyclonal Fab fragments
Thillaivinayagalingam, P., O'Donovan, K., Newcombe, A.R., Keshavarz-Moore, E. J. Chrom. B 2007 848: 88-96.

Micro biochemical engineering to accelerate the design of industrialscale downstream processes for biopharmaceutical proteins
Titchener-Hooker, N.J., Dunnill, P., Hoare, M. Biotechnol. Bioeng 2008 100: 473-487.

The impact of manual processing on the expansion and directed differentiation of embryonic stem cells
Veraitch, F.S., Scott, R., Wong, J., Lye, G.J. Mason, C. Biotech Bioeng 2008 99: 1216-1229.

The use of windows of operation as a bioprocess design tool
Woodley, J.M. and Titchener-Hooker, N.J. Bioprocess Eng 1996 14: 263-268.

Near infrared spectroscopy for bioprocess monitoring and control.
Yeung, K.S.Y., Hoare, M., Thornhill, N.F., Williams, T. and Vaghjiani, J. Biotechnol. Bioeng 1999 63: 684-693.

Visualising integrated bioprocess designs through "Windows of Operation".
Zhou, Y.H. and Titchener-Hooker, N.J. Biotechnol. Bioeng 1999 65: 550-557.

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