Faculty of Natural Sciences mission

- To make fundamental discoveries in the physical and life sciences
- To integrate research across these areas in a multidisciplinary manner
- To apply these discoveries to the benefit of humanity

Funders of research

We are grateful for the support of more than 200 organisations, which currently fund research within the Faculty of Natural Sciences (July 2009), including:

- UK Research Councils: Biotechnology and Biological Sciences Research Council, Economic and Social Research Council, Engineering and Physical Sciences Research Council, Medical Research Council, Natural Environment Research Council, and Science and Technology Facilities Council
- Over 100 UK and overseas industrial sponsors, including BP, GSK, Ineos, Invitrogen, LGC Ltd, Link Financial, Pfizer, Merck, QinetiQ, Sumitomo, Syngenta, Unilever, Yorkshire Water
- More than 20 UK and overseas charities, including Wellcome Trust, Leverhulme Trust, Cancer Research UK, British Heart Foundation, Grand Challenges in Global Health
- UK government departments
- UK national academies (Royal Society, Royal Academy of Engineering, British Academy) and other organisations (National Physical Laboratory, Big Lottery Fund)
- European Commission
- Other overseas organisations including World Health Organisation, US Government and United Nations
It gives me great pleasure to introduce this Research Outlook, which provides a flavour of the quality and breadth of research that we undertake in the Faculty of Natural Sciences at Imperial College London.

The College's critical mass of expertise across scientific disciplines enables us to take significant steps towards solutions to global problems, and thus offer exciting opportunities for collaboration and engagement.

In the two years since the Faculty was formed, research in departments, centres and multidisciplinary institutes has gone from strength to strength. We are delighted to have been rated the UK's second best natural sciences faculty during the 2008 Research Assessment Exercise, based on our proportion of world-leading and internationally excellent research.

As a biomedical scientist myself, I have experienced first-hand the advantages of working within Imperial's unique multidisciplinary research surroundings and of collaborating closely with researchers in other organisations. Within the Faculty, we strive to provide an environment where such collaborations can flourish, especially in areas that include energy and environment and the development of tools and technologies, as well as biomedical sciences.

I am delighted to acknowledge the long-term support of the funding bodies listed opposite. With their involvement, we are turning our discoveries into solutions for the benefit of everyone — an important part of Imperial's founding charter. Imperial's technology transfer company, Imperial Innovations, was the first majority university-owned technology transfer company to float in the UK, and our knowledge transfer activities continue to lead to substantial licensing, spin-out and industry-relevant opportunities.

Although this review is primarily about our research, we are also deeply committed to nurturing talent and developing the scientists, entrepreneurs and innovators of the future. The Faculty offers outstanding teaching and research opportunities for undergraduates and postgraduates. For example, this year, we welcome the first cohort of Imperial’s Junior Research Fellows, appointed through our new scheme to give top early-career researchers freedom to focus on research in our world class laboratories and facilities. We look forward to offering them the support they need to develop their ideas.

Whether you are interested in carrying out research, funding it, or collaborating with our outstanding researchers, we offer exceptional and compelling opportunities for engagement, and I look forward to talking with you.
The Faculty of Natural Sciences

Research strategy

Key Objectives:

- Support and sustain excellent science
- Strengthen the culture of collaboration and partnership with stakeholders in private and public sectors, both nationally and internationally
- Help to catalyse the translation of research into products and policies that benefit humanity
- Train future generations of scientists

Our research strategy aims to harness the strengths and breadth of our research to meet the changing needs of society, industry and healthcare, and to address the global challenges of climate change, energy, global health and security.

The expertise and knowledge of our academics help us to respond to natural science issues and deliver on the priorities of major funders. Our strategy is also to invest in the future by teaching and training the next generation of scientists, and by providing a supportive environment for knowledge transfer (pages 22–23).

This approach embeds us firmly within Imperial’s mission, guiding the development of our major research proposals, enhancing our multidisciplinary research, and helping us to allocate resources and support new initiatives as they arise.

The four core scientific disciplines (vertical boxes) form our main departments (pages 6–13) and the basis of our research strategy. They translate into three cross-cutting, multidisciplinary themes (horizontal boxes), which are important drivers for research across the Faculty and Imperial (pages 15–21), especially in our institutes and centres.
The Faculty of Natural Sciences of Imperial College London confirmed second best in the UK (2008 Research Assessment Exercise (RAE), based on the proportion of world-leading and internationally excellent research activity).

THES 2008 league tables placed our Faculty third in Europe and 14th in the world, and Life Sciences and Biomedicine third in Europe and 11th in world.

Imperial is at the forefront of European universities in natural sciences, and one of the top four European universities for postgraduate research in biology, chemistry, mathematics and physics, according to the Centre for Higher Education Development, Germany. All departments are ranked highest (in terms of coverage of overall achievement) in number of publications, number of citations relative to international subject standard and number of highly cited authors.

The Faculty of Natural Sciences collaborates with seven of the top 10 global pharmaceutical and chemical companies (MedAdNews 2007, ICIS 2008).

The Faculty of Natural Sciences collaborates with the world’s top 10 educational institutions (THES 2008).

Of the 19 Imperial staff identified as highly cited by ISIhighlycited.com, 11 are from the Faculty of Natural Sciences.

Euro stars
In 2008, the European Research Council awarded seven of its prestigious and highly competitive Advanced Grants to Imperial researchers, with two awards going to staff in the Faculty of Natural Sciences.

**CASE STUDY**
**Origin of species**
Dr Vincent Savolainen, Department of Life Sciences, is investigating how new plant species arise on remote oceanic islands, to solve the mystery of how speciation occurs when there are few differences in the natural environment. In a twenty-first century continuation of Charles Darwin’s work, Dr Savolainen and his team are using field work, DNA sequencing techniques, genomics tools and computer modelling to analyse the genes responsible for the evolution of new species.

**CASE STUDY**
**Designer solvents**
Professor Tom Welton, Department of Chemistry, is developing new, environmentally friendly solvents by mixing different ionic liquids. Reactions in solvents play a key role for mass-producing everyday products such as drugs, plastics, dyes and materials. The aim is to produce solvents that perform more effectively than those currently used in industry, and that are easier to recycle and create less waste.
Department of Chemistry

Research overview

The Department of Chemistry has an outstanding reputation, and is at the forefront of modern research, both in core disciplines and at interfaces with other subjects. Chemistry staff collaborate widely throughout Imperial, nationally and internationally, and have strong links with industry. Facilities are extensive, with well-equipped research laboratories and workshops for the construction of mechanical and electronic instruments. The Department is organised into five research groups:

- Biological and Biophysical Chemistry Group
- Catalysis and Advanced Materials Group
- Nanostructured Materials and Devices Group
- Synthesis Group
- Theoretical and Experimental Physical Chemistry

We are one of the largest chemistry departments in the UK and are recognised as world class for both research and teaching. We are a diverse community who come from all around the world and have interests across the full range of the chemical sciences.”

Professor Tom Welton, Head of Department

RAE 2008 • 3RD BEST IN THE UK
based on proportion of world-leading and internationally excellent research activity

Measure of impact • Imperial’s research in chemistry came top in the UK and third in Europe based on citations per paper (Essential Science Indicators database, 1 Jan 1999 – 28 Feb 2009)
CASE STUDY

Synthesising innovation

Synthesising bioactive natural products such as antibiotics, antifungal agents and antiviral compounds has implications for pharmaceutical innovation. Professor Tony Barrett’s research has resulted in the concise preparation of antibiotics including resorcylates and other natural products, and to simplify synthesis by introducing novel multi-component benzyne coupling and late-stage aromatisation.

Professor Barrett’s group is also carrying out research into the total synthesis of heterocyclic compounds, organometallic compounds, macrocyclic ethers and lactones.

The researchers have designed new catalysts for chemical transformations that include applying alkene metathesis in natural product and medicinal chemistry, and alkaline earth catalysts for hydroaminations and hydrophosphinations. In collaboration with Northwestern University, USA, they have synthesised new classes of porphyrazines and seco-porphyrazines. Their unusual coordination chemistry makes them useful as novel magnetic and optical materials and imaging agents for detecting cancer in its early stages.

Professor Barrett FRS, FMedSci is co-Founder and Director of Science for Argenta Discovery in England, which focuses on respiratory diseases, and iThemba Pharmaceuticals in South Africa, which focuses on infection.

CASE STUDY

Single cell reactions

More sensitive ways of analysing cellular and sub-cellular proteomes could improve our understanding of fundamental biology by helping us observe differences in protein expression between individual cells. The Single Cell Proteomics (SCP) group, chaired by Professor David Klug, was set up to reveal new levels of information about how a cell responds to its environment.

The group is a collaboration between between the Faculty’s Departments of Chemistry and Physics, the Cancer Research UK London Research Institute and the Institute of Cancer Research.

The SCP group uses innovative spectroscopies, such as two-dimensional infrared spectroscopy (2DIR) and fluorescence labelling with microfluidic technologies, to identify which proteins interact and how they interact. The group has developed a new technique — coherent 2DIR — to identify and quantify proteins in human cells.

Infrared laser light causes a vibration in one part of the protein molecule, which can be tracked as it moves through the protein, building up a specific energy flow map that identifies the protein. The technique has implications for new drugs and biomarkers, diagnostics and basic biology.

Professor David Klug

 Protein imaging hotspot: The light source used in the 2DIR imaging technique for identifying proteins.

Coordination complexes: Useful for detecting and treating early cancers.

Professor Tony Barrett FRS, FMedSci
Department of Life Sciences

KEY STATS

- 99 Academic staff
- 223 Research staff
- 221 Postgraduate Research (PhD)
- 175 Postgraduate Taught (Master’s)
- 1045 Undergraduate students

RAE 2008 • 3RD BEST IN THE UK
based on volume of world-leading research activity

Research overview

The Department of Life Sciences, formed in 2007, is one of the largest life science groups in Europe. Research and teaching are funded by a wide variety of research councils, charities and industries. The Department comprises three divisions:

- Molecular Biosciences
- Cell and Molecular Biology
- Biology

"Our Department embraces the full breadth of modern life sciences, from atomic biology to global biosphere models. We combine world class research with innovative training programmes, and have a particularly strong record in applying novel interdisciplinary approaches to tackle high-profile questions."

Professor Ian Owens, Head of Department

Protecting biodiversity • Taxonomy PhD student Michelle Taylor is studying deep sea corals from South Georgia to help predict species-rich areas in other parts of the world.
CASE STUDY
Structure and function of membrane proteins

Membrane proteins are important for respiration, signal transduction and molecular transport. More than half of commercially available drugs, such as antihistamines, beta blockers and morphine, interact with membrane proteins. Despite their importance, less than 20 independent structures for mammalian integral membrane proteins have been reported so far. A more fundamental understanding of the link between structure and function for these proteins would make invaluable contributions to structural biology, pharmacology and medicine.

Professor So Iwata leads an international team of scientists in Imperial’s Membrane Protein Laboratory at the Diamond Light Source national synchrotron facility in Oxfordshire, and has recently been awarded the inaugural Diamond Professorial Fellowship by the Biotechnology and Biological Sciences Research Council. The team has so far determined structures including cytochrome c oxidase, photosystem II and the membrane transporter lactose permease. More recently, the researchers have revealed for the first time how a transporter protein opens and closes for molecules to pass across the membrane and into the cell, by analysing the molecular structure of Microbacterium hydantoin permease (Mhp1). Hundreds of similar transporters are found in human cell membranes, so understanding the structure of Mhp1 could help design new drugs that are more effective at targeting and entering specific cells.

CASE STUDY
Fields of the future

Research into how ecosystems may be affected by future changes to climate and biodiversity is underway at Imperial’s Silwood Park Campus in Berkshire. The experiment is simulating the prediction from the Intergovernmental Panel on Climate Change that southern England will experience up to 30 per cent less summer rain and 15 per cent more winter rain by 2100.

Drs Pete Manning and Sally Power are leading the study to explore how ecosystem functions such as water processing, nutrient cycling and carbon storage are affected by the significant changes predicted for rainfall patterns. The research is being carried out by a team of students, led by Ellen Fry whose PhD is funded by Imperial’s Grantham Institute for Climate Change. She is looking at how differing levels of plant biodiversity in an ecosystem can modify the climate-driven effects on key ecosystem functions. Plant biodiversity is likely to decrease during this century due to climate change, pollution, changing patterns of land use and other human impacts, which may increase ecosystem sensitivity to climate stress.

“...This experiment promises one of the most realistic pictures to date of how UK ecosystems may react to the environmental changes caused by human emissions of greenhouse gases.”

Professor Sir Brian Hoskins FRS, Director, Grantham Institute for Climate Change
Department of Mathematics

Research overview

The principal aim of this Department is to train professional mathematicians to pursue the study of scientific and technological problems using mathematical methods, and to undertake world class research in various branches of the subject, some examples of which are described below. The Department of Mathematics is organised into four research sections:

- Applied Mathematics and Mathematical Physics
- Pure Mathematics
- Mathematical Finance
- Statistics

“...Our Department flourishes at the cutting edge of mathematical research across the spectrum and I am delighted with our recent outstanding RAE results. We have established a vibrant and dynamic research environment that informs and underpins much of the other research within the Faculty and across College.”

Professor Ari Laptev, Head of Department
**Case Study**

**Tied up in knots**

Dr Dorothy Buck applies modern mathematics to biomedical problems, such as using topological techniques to illuminate structural and mechanical features of DNA — protein interactions. Her current research focuses on the knots and links (or catenanes) arising during DNA recombination.

Recombinase enzymes cleave DNA and mediate the removal, addition or inversion of DNA pieces, as part of processes such as DNA repair or when viral DNA integrates itself into a host genome. Such site-specific recombination can occur on tightly coiled (supercoiled) DNA, which causes extensive and complex knots and links.

Dr Buck has recently predicted a topological model of the knots that can be formed as a result of this process. As all products of site-specific recombination fall within a single knot family, Dr Buck’s work will help researchers determine what faulty DNA repair mechanisms lie behind genetic disorders and conditions such as a predisposition to cancer.

**DNA knots from site-specific recombination:** Topological techniques have classified the DNA links formed during recombination into a single knot family.

---

**Case Study**

**Theory of numbers**

Professor Kevin Buzzard’s research examines symmetries in algebra and apparently similar symmetries in analysis. His research is looking for links between these two fields to explain why the symmetries match up. This area of mathematics, known as the Langlands Programme, has made huge advances in recent years.

Much progress was kick-started by the proof of Fermat’s Last Theorem by Andrew Wiles and Richard Taylor, deemed by many to be one of the greatest achievements of the past 300 years in number theory. Buzzard was a former PhD student of Taylor and a ‘grand-student’ of Wiles, and some of his most acclaimed work has involved extending techniques that they discovered.

The theoretical research has practical applications in areas including cryptology and security, for example, by creating algorithms for keeping credit card details secure on the internet. Professor Buzzard won the 2002 Whitehead Prize from the London Mathematical Society for his work in number theory, and the 2008 Senior Berwick Prize. *Times Higher Education* recently named him a ‘rising star’ and a ‘young academic who is tipped to go places’.

“Individuals, communities, businesses and governments are facing new security challenges in many aspects of everyday life due to advances in technology, globalisation and living in a more interconnected world, as well as from environmental threats and civil emergency. Imperial has a large number of world-leading researchers whose work can be applied to these challenges. The Institute for Security Science and Technology will harness multidisciplinary teams to identify new ways of applying research to problems faced across defence and homeland security.”

*Professor Sir Keith O’Nions FRS, Director, Institute for Security Science and Technology*
Research overview

The Department of Physics is one of the largest physics departments in the UK, with researchers collaborating across academic communities at national and international levels, as well as with industry. Research within the Department of Physics covers a comprehensive range of important experimental and theoretical research fields and is organised into nine research groups:

- Astrophysics
- Condensed Matter Theory
- Experimental Solid State Physics
- High Energy Physics
- Photonics
- Plasma Physics
- Quantum Optics and Laser Science
- Space and Atmospheric Physics
- Theoretical Physics

We are one of the largest and most prestigious physics departments in the UK with an outstanding reputation for excellence in research, postgraduate training and undergraduate education. We have a vibrant and internationally leading research programme that provides broad coverage of fundamental and applied physics, strongly supports multidisciplinary collaborations, and actively fosters the development of new fields. We are committed to providing a positive environment that supports everyone in reaching their potential.”

Professor Joanna Haigh, Head of Department

“Peering into the early universe • Imperial physicists based at CERN in Geneva are working with colleagues from around the world to recreate conditions similar to those that existed a split second after the Big Bang.”
Case study

Professor Russell Cowburn’s nanotechnology research focuses on tailoring the magnetic properties of miniscule structures (100nm or smaller) to create new functionality that is not possible in larger scale versions of the same material. His research has practical uses for computer memory technology, which stores data as nanometre-sized magnetised regions on the hard disk drive, and his research group holds patents on a new three-dimensional memory device that could make large volumes of data storage available in portable electronic devices such as mobile phones. This revolutionary new device won the coveted Degussa Science to Business Award in 2006.

Cowburn’s group is also seeking to understand how laser light behaves when shone on nanostructures, and what the details of the reflected light can tell us about the nanostructures. This work has led to new laser scanning technology — laser surface authentication — which can be used to detect and prevent forgeries by identifying naturally occurring, unique identifying features on material surfaces, from pharmaceutical packages to valuable documents. The technology is being sold to brand owners and government authorities around the world through the spin-out company Ingenia Technology Ltd (www.ingeniatechnology.com). Professor Cowburn has won a string of international prizes, including the 2007 Hermes Award and the 2008 Institute of Physics Paterson Medal and Prize.

Case study

Metamaterials and the perfect lens

Naturally occurring materials show a limited range of electrical and magnetic properties. But the research of Professor Sir John Pendry FRS and his group has generated a new series of ‘metamaterials’, whose properties owe more to their carefully designed internal structure rather than their chemical composition. These properties are not found in nature, and include negative electrical permittivity, negative magnetic permeability, and negative refractive index, leading to the demonstration of remarkable effects for the first time.

Sir John has collaborated closely with Professor David R. Smith of Duke University, USA, who used the theoretical description of metamaterials to produce the first working prototype cloaking device in 2006. This rendered objects invisible to microwaves, by making them flow smoothly around an object, instead of striking and reflecting off it, so that they behave as if there is no object present, giving the illusion of perfect transparency.

The research has also generated the revolutionary theory of the perfect lens, which overturns conventional laws of physics governing the smallest object visible with light. Prior to the theory, it was thought impossible to use light for imaging objects smaller than the wavelength of light. Researchers at the University of California at Berkeley are working on producing a functioning device that uses light to produce images of smaller objects than ever before.

Sir John has been awarded the 2006 Royal Medal from the Royal Society and the 2009 UNESCO Niels-Bohr gold medal based on his groundbreaking contributions to meta-materials.

Sharper focus: perfect lenses have better resolutions than conventional optic lenses.

Demonstrator chip: portable electronic devices such as mobile phones and MP3 players could store larger volumes of data using nano-data storage elements.
Research overview

The Centre for Environmental Policy (CEP) provides a unique interface between science and technology, and the economic and policy contexts in which they are developed and applied. The Centre focuses on environmental and development issues including energy, pollution, natural resources, food security and poverty. By integrating Imperial’s outstanding science and technology research with a leading team of social and policy scientists, it has created innovative, interdisciplinary research programmes based around four themes:

- **Energy Policy**
- **Environmental Quality**
- **Biosecurity Policy**
- **Sustainable Transitions**

**CASE STUDY**

Is the UK prepared for Sudden Oak Death?

CEP researchers are carrying out a DEFRA-commissioned review of our ability to stop the spread of so-called Sudden Oak Death, a disease threatening the country’s trees, woods and heathland.

Despite its name, Sudden Oak Death affects not only oak trees, but also a range of trees and shrubs including beech, ash and heathers. The two pathogens that cause the disease — *Phytophthora ramorum* and *Phytophthora kernoviae* — create cankers around the trunk or stem and reduce uptake of water. Since the 1990s, Sudden Oak Death has wiped out millions of trees in the USA. Experts fear that if the disease took hold in the UK, the impact on ecosystems, biodiversity and the national landscape could be severe.

The researchers, led by Dr Clive Potter, are evaluating the effectiveness of measures to control recent outbreaks in Cornwall and will recommend improvements for a new control programme. They are also analysing the science and policy of tree disease epidemics as part of the UK Research Council’s Rural Economy and Land Use Programme to investigate how lessons learnt during the 1970s Dutch Elm Disease epidemic can be applied to the new threat of Sudden Oak Death.

**Dr Clive Potter**

Healthy trees • Improving policies for managing tree disease epidemics.
Harnessing and developing our expertise at the interfaces with other disciplines is vitally important to the Faculty of Natural Sciences.

We work closely with Imperial's Business School and other Faculties, and have established a series of multidisciplinary research institutes and centres in key areas to carry out research in support of our strategic translational themes and priorities.

**Institutes**
- Energy Futures Lab
  www.imperial.ac.uk/energyfutureslab
- Grantham Institute for Climate Change
  www.imperial.ac.uk/climatechange
- Institute of Biomedical Engineering
  www.imperial.ac.uk/biomedeng
- Institute for Global Health
  www.imperial.ac.uk/globalhealth
- Institute for Mathematical Sciences
  www.imperial.ac.uk/mathsinstitute
- Institute for Security Science and Technology
  www.imperial.ac.uk/securityinstitute
- Institute for Shock Physics
  www.imperial.ac.uk/shockphysics
- Institute of Systems and Synthetic Biology
  www.imperial.ac.uk/systemsbiology
- Porter Institute
  www.imperial.ac.uk/porterinstitute

**Centres**
- Centre for Bioinformatics
  www.bioinformatics.imperial.ac.uk
- Centre for Integrative Systems Biology at Imperial College
  www.imperial.ac.uk/cisbic
- Centre for Molecular Microbiology and Infection
  www.imperial.ac.uk/cmmi
- Centre for Plastic Electronics
  www.imperial.ac.uk/plasticelectronics
- Centre for Structural Biology
  www.imperial.ac.uk/structuralbiology
- Centre for Synthetic Biology and Innovation
  www.imperial.ac.uk/syntheticbiology
- Chemical Biology Centre
  www.imperial.ac.uk/chemicalbiologycentre
- London Centre for Nanotechnology
  www.imperial.ac.uk/nanoscienceandnanotechnology
- Thomas Young Centre
  www.thomasyoungcentre.org
Case study

Flying lower

Aviation is the fastest growing contributor to global emissions of carbon dioxide. An interfaculty collaboration between the Department of Physics and Imperial’s Centre for Transport Studies has assessed the impact of aircraft condensation trails, known as contrails, on climate.

Contrails are thin ice clouds created in the exhaust from aircraft. At high altitudes, they scatter back some solar radiation, which cools the Earth. But they also warm the planet by trapping infrared radiation in the same way as greenhouse gases. The net effect is thought to be a warming of the climate, similar in magnitude to the warming caused by carbon dioxide emitted from aircraft.

Ice clouds occur much less frequently at lower flight levels because it is often too warm for them to form. If aircraft flew lower, this could potentially eliminate contrails. However, the additional drag on the aircraft at lower altitudes increases fuel consumption leading to more carbon dioxide emissions.

By combining Imperial’s expertise in contrail formation with knowledge in aircraft routing, our researchers found that the contrail warming effect dominates, so there could be a potential net benefit to reducing aircraft cruise altitudes.

In a further investigation, Professor Ralf Toumi and colleagues estimated the contribution of aviation to carbon dioxide emissions by calculating emissions from 3,600 flights. The annual average carbon dioxide emission was in line with earlier estimates using other methods. However, the method adopted by the Imperial team identified key contributors to the total. Nearly half the carbon emissions are accounted for by only six per cent of aircraft routes, which turn out to be the long haul routes. This discovery raises issues about long haul flights for policy makers to consider.

“Energy remains a critical global challenge, which Imperial is uniquely placed to address. At the Energy Futures Lab, we provide a focus for College’s research on a wide range of energy issues, including nuclear power, renewable energy, carbon capture and storage, transport, electric and hybrid vehicles, fuel cells, smart networks, bio-energy, future fuels, and energy policy.”

Professor Nigel Brandon, Executive Director, Energy Futures Lab
**CASE STUDY**

**Biomass to biofuels**

Researchers at the Porter Institute are developing systems to convert biomass into energy, liquid fuel, chemicals and materials. To make such systems sustainable, they are looking for ways to maximise biomass yield from crops including willow, giant grasses and poplar. Dr Richard Murphy and colleagues are using fungi to increase ease of access to cellulose and other parts of plant cell walls so that biofuel conversion processes for lignocellulose can become much more efficient.

This research was originally intended to improve the preservation of wood-based structures. This new application represents a major breakthrough in the sustainable production of biofuels and biomaterials. The researchers have filed a patent and are seeking follow-on funding to exploit their discovery.

**Most influential biofuels paper**

A research paper by Drs Charlotte Williams, Richard Murphy and David Leak, and Professor Richard Templer, on mapping the way forward for sustainable biofuel production has been named as one of the most influential studies of the last 10 years in its field. The paper was intended as a manifesto for the sustainable production of fuel, power, chemicals and materials in integrated biorefineries of the future. The path forward for biofuels and biomaterials was published in *Science* in 2006, and has been cited in over 150 subsequent academic studies, according to Thomson Sciencewatch’s *Essential Science Indicators*.

**CASE STUDY**

**Catching rays**

The first briefing paper from the Grantham Institute for Climate Change sets out options for harnessing solar energy for hot water and electrical power, to provide an overview of current technological options, the policy context and the research agenda for key decision makers.
Controlling malaria

Malaria now threatens half the global population. While much of the effort in preventing and controlling the disease has traditionally focused on clinical research, there is now a global initiative to reconsider the elimination and even eradication of the parasites.

To achieve this, Imperial scientists have emphasised that it is essential to focus on understanding what controls the transmission of the malarial parasites *Plasmodium falciparum* and *P. vivax*. What happens to the parasite when it is in the mosquito? And how can you block transmission between mosquitoes and humans?

Our staff are working with colleagues in the Faculty of Medicine, the Institute for Global Health and the Institute of Systems and Synthetic Biology to find multidisciplinary solutions.

For example, researchers in Professor Robert Sinden’s group are tackling the spread of malaria by reducing development of malaria parasites inside the mosquito host. Professor Austin Burt’s group is developing genetic strategies to block the spread of malaria by mosquitoes.

**Case study**

**Lifetime achievement**

Professor Fotis Kafatos was awarded a special lifetime achievement prize in 2008 from the Louis-Jeantet Foundation for his exceptional research into the biology of the mosquito that carries the malarial parasite. The Swiss Foundation provides funding and major prizes for biomedical research. Professor Kafatos was also recognised for his major contributions to the development of European biomedical research on the world stage. In 2007 he became the first President of the European Research Council, the first cross-European funding agency.

“After a lifetime of working in public health, I’m deeply convinced that global health problems will not be solved by focusing on medicine alone. We need to redefine public health, and demand action from business, engineers, environmental experts and scientific innovators, all working together. The willingness of Imperial College to break down barriers between disciplines is exactly what we need to fulfill our vision of an Institute for Global Health.”

Professor Baron Peter Piot, Director, Institute for Global Health
CASE STUDY

The effect of mosquito genes on human malaria

Drs Dina Vlachou and George Christophides have identified mosquito genes that control the number of malaria parasites that can successfully develop inside the body of the mosquito.

In a field study in Cameroon, Dr Vlachou and her colleagues showed, for the first time, that deactivation of particular mosquito genes drastically reduces the number of malaria parasites that can successfully grow and multiply in the mosquito. One gene plays a role in moving fats around the mosquito’s body; another is involved in remodelling the mosquito cell scaffolds. This study has given us a much better insight into the complex relationship between malaria parasite and mosquito host.

CASE STUDY

Proteins, not genes, define complexity

Professor Michael Stumpf has recently shown that proteins in humans interact in many more ways than proteins in species such as fruit flies, suggesting that the network of protein interactions in a species could be a better indicator of relative biological complexity than the genome.

The research estimates the total number of protein-protein interactions in the body, called the human interactome. Human proteins interact in approximately 650,000 ways — 10 times more interactions than in a fruit fly, even though the two species have relatively similar numbers of genes (24,000 in humans and 14,000 in the fruit fly).

Professor Stumpf and his colleagues from the Max-Planck-Institute for Molecular Biology and the University of Århus used mathematical tools to analyse incomplete network sets to help them predict the size of the interactome.

Research is now focused on making more detailed predictions based on careful comparisons between species. This will be crucial in order to understand, for example, why some fungal species, such as baker’s yeast, are important for producing bread and beer, while other closely related species cause fungal infections with high mortality rates.
Imaging is everything

Research across our faculty covers all major forms of imaging. These are crucial to our strategy, because the technology underpins our translational themes of energy and environment, and biomedical science. Combining outstanding strengths in chemistry, physics and the life sciences enables us to compete effectively in developing and translating new imaging technologies.

New optical imaging techniques are enhancing the efficiency of drug discovery. Advances in spectroscopy are providing real-time optical molecular contrast for clinical imaging, to improve our ability to diagnose diseases and understand their onset and progression. Scaling optical technologies demonstrated in the information and communication technology sector can provide low-cost, portable, point-of-care instrumentation that could benefit people in developing countries as well as the increasingly aged populations of the developed world.

Collaborations with the Faculty of Medicine help our imaging researchers to translate new optical technologies into clinical applications. Other work includes developing photonics technology for use in fundamental cell biology and immunology. A major goal is to translate existing optical microscopy techniques from in vitro to in vivo imaging, to improve our biological understanding of fundamental mechanisms. For example, Professor Dan Davis uses multidimensional fluorescence imaging to observe directly how the immune system functions. Imperial houses many wide-field, confocal and multiphoton microscopes, offering unparalleled functionality and world class expertise in the synthesising, developing and applying novel fluorescent probes, including small molecules, fusion proteins and quantum dots.

"My experience in developing plastic semiconductors for solar energy, communications and medical diagnostics has taught me that Imperial’s community of talented students, postdocs, academics and industrial collaborators is a perfect melting pot for generating new tools and technologies.”

Professor Donal Bradley FRS, Deputy Principal of the Faculty of Natural Sciences, and Director of the Centre for Plastic Electronics
The group collaborates extensively with industry: for example, with Corus Chemicals to integrate solar cells into strip steel roofing products, and with BP to develop polymer-based solar cells. The researchers are now extending their photochemical studies to explore solar hydrogen generation by the photolysis of water, working with colleagues from the Faculty of Engineering to incorporate research on innovative materials synthesis, theoretical modelling, and practical device development and commercialisation.

CASE STUDY

Molecular materials for converting solar energy

Developing renewable, low-cost energy technologies is a key challenge for twenty-first century research. Professor James Durrant is working with his group and colleagues from across Imperial to develop molecular approaches for converting solar energy. The research combines fundamental scientific studies of new materials with developing new devices and technologies for converting solar energy.

The research uses transient laser spectroscopies to study electron and energy transfer reactions driven by light. In parallel, researchers are using a wide range of molecular, polymeric and inorganic materials for developing the new devices.
As a centre of education, training and innovation, we actively seek new ways to stimulate economic recovery in the UK. Encouraging a culture that recognises the economic and social impact of our work, by driving knowledge exchange and translation of our research to meet the needs of industry and society, is integral to Imperial’s mission.

Our supportive knowledge transfer environment includes Imperial Innovations to support our spin-outs and licensing (interim profit £1.3 million in April 2009) and Imperial Consultants for inventive technology-related services.

"The output of highly educated people rather than research results is widely regarded as the most effective knowledge transfer mechanism.”

Warry Report 2006: Increasing the economic impact of Research Councils

Nurturing talent

The Faculty is committed to educating its future scientists through Master’s courses and postgraduate research programmes.

Doctoral training

The next generation of scientists to make world-changing breakthroughs will have their talents nurtured by Engineering and Physical Sciences Research Council Centres for Doctoral Training (CDTs), which aim to develop interdisciplinary skills and expertise to tackle the major challenges facing the world today. Imperial is involved with seven CDTs, four of which sit within the Faculty of Natural Sciences. (www.imperial.ac.uk/centresfordoctoraltraining)

Taught courses

The Faculty currently offers 29 postgraduate MSc and MRes courses. Individual departments also run short postgraduate taught courses. We provide transferable skills training for postgraduate students through a programme run by the Graduate Schools for Engineering and Physical Sciences, and Life Sciences and Medicine, which won the Times Higher Award for outstanding support for early career researchers in 2006 and 2008.
Exchanging knowledge and supporting the UK economy

Commercialisation

Our Faculty actively encourages a culture of knowledge transfer and commercial exploitation, and has spun out over 15 companies in the past 10 years. These include:

- **deltaDot Ltd**: Harnesses high energy physics technologies to separate and analyse biomolecules, leading to higher quality, faster and cheaper separations. These separations have applications in pharmaceutical, biotechnology, biodefence, food and drink quality, forensic science, diagnostic and academic markets.

- **Molecular Vision Ltd**: Develops low-cost diagnostic ‘lab on a chip’ devices for use in the doctor’s surgery and at home. The devices combine microfluidic chips with organic semiconductor light sources and photodetectors to provide lab-quality, easy-to-use diagnostic tests in a disposable format.

- **QuantaSol Ltd**: Pioneers the application of nanostructures such as quantum wells and quantum dots to develop photovoltaic cell technology that delivers greater conversion efficiency, better spectral performance and longer cell lifetimes than competing cells. QuantaSol regularly features in the UK’s top 100 best new companies in the clean tech industry.

Industry partnerships

Collaborations between the Faculty of Natural Sciences and industry totalled £6 million in 2008–09. Partners include BP, GSK, Merck, QinetiQ, Sumitomo, Syngenta and Unilever. For example, BP has funded research and consultancy projects that include organic solar cell research, climate change risk management, and the development of new catalysts for polymers.

Flexible light: The combination of research into plastic electronics by Professor Donal Bradley FRS and Dr John de Mello with research into microfluidics by Professor Andrew de Mello has led to the formation of the spin-out company Molecular Vision Ltd.

Strategic partnerships

The Faculty of Natural Sciences welcomes strategic partnerships with a wide range of organisations. For example, the ABACUS partnership with Merck has enabled an exchange programme and research projects to combine fundamental human biology and pathology research with clinical expertise, offering huge potential for radical new disease treatments. In another example, Imperial has signed a memorandum of understanding with the National Physical Laboratory to increase research collaboration.

“Researchers must be encouraged to become more aware of the benefits, to both the economy and society, that their research could generate.”

*Research Council Support for Knowledge Transfer, House of Commons Science and Technology Committee Report, 2006*

Advising and developing policy

Much of our research informs and improves the efficiency of evidence-based policy development. For example, Professor Georgina Mace’s research on biodiversity indicators has had a direct impact on European Parliament and international policy development. Many of our staff hold high-profile advisory positions, including Professor John Beddington FRS as the government’s Chief Scientific Advisor and Professor Sir Brian Hoskins FRS as a member of the government’s Climate Change Committee. They also make significant contributions to national reviews such as the Wakeham Review of UK Physics (Professor Donal Bradley FRS).
Consistently rated as one of the world's best universities, Imperial College London is a science-based institution with a reputation for excellence in teaching and research.

Key people

Principal — Professor Maggie Dallman
Deputy Principal — Professor Donal Bradley FRS
Head of Chemistry — Professor Tom Welton
Head of Life Sciences — Professor Ian Owens
Head of Mathematics — Professor Ari Laptev
Head of Physics — Professor Joanna Haigh
Head of Centre for Environmental Policy — Professor John Mumford
Director, Graduate School for Engineering and Physical Sciences — Professor Richard Kitney OBE FREng
Director, Graduate School for Life Sciences and Medicine — Professor Bernard Morley
Faculty Operating Officer — Mr Bob Cummins
Strategic Research Officer — Dr Rebecca Wilson
Business Development Manager — Mr Rafat Malik

For more information
Faculty of Natural Sciences
Level 3, Faculty Building
Imperial College London
South Kensington Campus
London SW7 2AZ
UK
Tel: +44 (0)20 7589 5111
www.imperial.ac.uk/naturalsciences